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REVOLUTIONIZING THE APPLICATION OF AUTOMATIC INSPECTION SYSTEM FOR INDUSTRIAL PARTS USING AI MACHINE VISION TECHNOLOGY

BAOJUN WANG *AND YULAN LV †

Abstract. This paper addresses the challenges of large data management, prolonged operation times, and low detection efficiency encountered in automatic detection systems. To overcome these issues, we propose a novel research and application method utilizing AI machine vision technology. The methodology employs the Pulse-Coupled Neural Network (PCNN) algorithm for analyzing machine control points, enhancing system reliability and detection efficiency. Furthermore, a three-stage sliding table mechanism is implemented to facilitate seamless operation restarts. Notably, our approach significantly reduces the time required for key operations, such as feeding, imaging, decision-making, on-site inspection, and re-inspection, all within 5 seconds and 1 meter distance. It supports high-precision dynamic identification, detection, and correction of errors during high-speed movement, thereby enhancing overall system performance. The experimental results demonstrate exceptional accuracy, particularly in detecting small parts measuring 28.87 mm in length and 12.36 mm in width, achieving an impressive precision of 0.04 mm. Additionally, our system boasts meticulous hardware selection, robust software stability, and high-performance capabilities, culminating in improved detection efficiency and accuracy. This research not only contributes novel ideas and results but also holds significant commercial value in industrial applications. Overall, our proposed methodology represents a noteworthy advancement in automatic inspection systems, offering superior performance and reliability compared to existing approaches.

Key words: Pulse-Coupled Neural Network; decision-making; on-site inspection; re-inspection; high-precision dynamic identification.

1. Introduction. In recent years, with the continuous deepening of industrial restructuring and transformation and upgrading of modern manufacturing industries, more and more enterprises have begun to implement "machine substitution". The combination of robotics and machine vision technology has become a disruptive force in the ever-changing field of modern manufacturing, transforming industries around the world. The need for industrial restructuring and the constant search for efficiency and innovation have led to exceptional adoption of these technologies in recent years. The era of "machine substitution" has arrived, as companies in the aerospace and automotive industries gradually integrate robots into their operations. Robots have become essential tools driving innovation in many industries, from automating complex production lines to speeding up logistics procedures [1]. Figure 1.1 vividly illustrates the growing scope of robotics, which is penetrating various sectors and driving supporting industries. At the heart of this revolution is the very essence of robotics: the magic of engineering power and intelligence. As shown in Figure 1.2, the emphasis on the advancement of robotics technology has been increased, highlighting its strategic importance in the fields of modern technology and industry. Making robots in automobiles, logistics, aerospace, ships and even food, and other fields have been more and more widely used, and led to the development of related industries. Robot is a kind of automation equipment or device that integrates various advanced technologies such as machinery, sensing, recognition, decision-making and control, and has some intelligent capabilities; the emphasis on development is increasing day by day. Robot technology and its application have become a "must fight" for today's technology and industrial development, and have important strategic significance.

As the "eye" of the robot, the machine vision system is a device that obtains the characteristic image of the detected object with the help of optical devices and non-contact sensors, and extracts information from the image through a computer for analysis and processing, thereby realizing detection and control. Machine vision system has the advantages of good real-time performance and high positioning accuracy, which can effectively increase the flexibility and intelligence of robots, and is one of the important means to realize industrial

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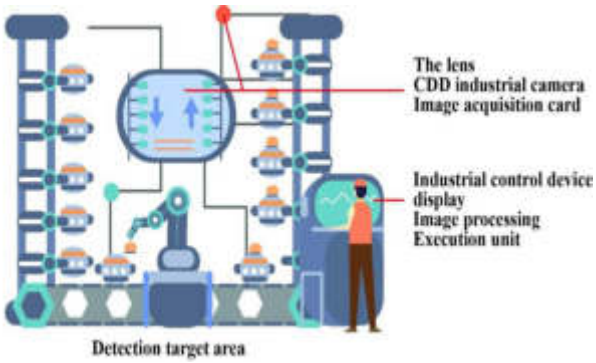

Fig. 1.1: Automatic recognition and detection based on machine vision

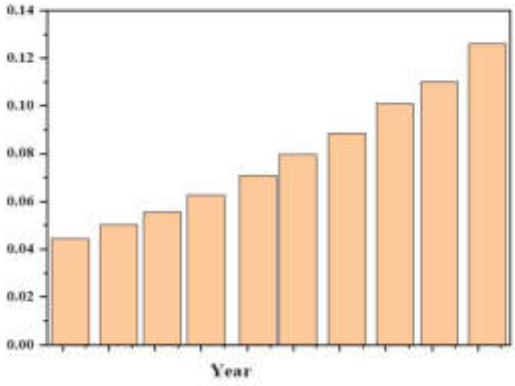

Fig. 1.2: Scale of the global machine vision industry from 2008 to 2018

automation and intelligence [1]. With the continuous improvement of various technologies and the increasing demand for high-quality products in the manufacturing industry, machine vision has been mainly used for defect detection in industrial electronic assemblies from the beginning, and has been gradually applied to automobile manufacturing, food monitoring, visual navigation, transportation, military, textile processing and other fields, the market scale continues to expand [2]. The vision system is connected with the mechanical servo mechanism to form an open-loop control visual servo mechanism. The introduction of visual servo system can improve the degree of automation of product inspection, but there are still shortcomings in acquisition accuracy, detection speed and algorithm robustness [3]. Therefore, it is of great significance to study machine vision related technologies to improve the industrial development of industrial intelligent robots. The author mainly summarizes and analyzes the development history, research status, related core technologies and automatic identification and detection system of machine vision, taking the research progress of machine vision technology as the breakthrough point, and makes an outlook on the future development trend [4].

In industrial production, the pursuit of precision, efficiency, and quality assurance are essential requirements. As the industry evolves and consumer demands increase, the need for reliable and efficient test systems becomes increasingly important. To meet this need, the integration of artificial intelligence (AI) and machine vision technology is emerging as a revolutionary force that is expected to redefine the flexible inspection system landscape. Traditionally, manual inspection processes are labor-intensive, time-consuming, and prone to human error, creating major challenges for manufacturers seeking to ensure consistency and quality. However, recent

advances in AI and machine vision technology have brought about a paradigm shift, providing unprecedented opportunities for automated testing and quality control. The combination of AI algorithms and vision systems gives these inspection machines the cognitive capabilities to distinguish complex details, detect errors, and classify anomalies. It often provides superior accuracy and efficiency. This combination of technologies not only streamlines the testing process, but also increases accuracy and reliability, minimizing the risk of errors and optimizing production efficiency. Additionally, AI-based vision systems have the ability to continuously learn and adapt, allowing them to adapt to changing production needs and changing environments. Through iterative feedback loops and improvements, these systems continually improve their performance and strengthen their position as essential assets in modern industrial environments. This article explores the transformative potential of AI machine vision technology to revolutionize automated industrial part inspection systems. Explore the applications, benefits, and various future prospects of this breakthrough technology based on recent advances, case studies, and industry insights. From automotive assembly lines to precision engineering systems, the integration of AI-driven image processing promises to open new frontiers in quality assurance, productivity, and innovation.

1.1. Contribution. Automated sensor systems play a central role in modern industrial environments, ensuring the quality and accuracy of manufactured parts. However, these systems often encounter challenges such as handling large data sets, long operating times, and low detection efficiency. In response, our paper proposes a new research and application method that leverages AI machine vision technology to overcome these obstacles and improve the performance of automated inspection systems. The methodology of our method is the use of the PCNN (Pulse Coupled Neural Network) algorithm, a powerful tool for analyzing machine checkpoints. By integrating PCNN into our system, we improve detection reliability and efficiency, allowing for more accurate and faster error identification. In addition, we are introducing a three-stage sliding table mechanism designed to support smooth restart of operations, meeting the need for uninterrupted workflow in industrial environment. This mechanism ensures that key operations, including feeding, imaging, decision-making, spot checking and rechecking, are completed in just 5 seconds and at a distance of 1 meter, maximizing efficiency and performance. A notable feature of our method is its support for highly accurate dynamic error identification, detection, and correction during high-speed motion. This capability significantly improves overall system performance, allowing for real-time adjustments and minimizing production disruptions.

The rest of this article is arranged as literature review in section 2, methods in section 3, results and discussion in section 4 followed by conclusion in section 5.

2. Literature Review. The literature review provided covers a wide range of research efforts that advance object detection and segmentation techniques in various fields. Each study brings unique insights and methods to address the complex challenges inherent in detecting objects in complex backgrounds or dynamic environments. Let us discuss each contribution: Lee, E. proposed extended object detection in complex backgrounds based on fractal features [5]. This approach can explore the fractal characteristics of objects to improve detection accuracy, especially in situations where objects are embedded in cluttered or irregular backgrounds. Nguyen, N.H. presented a pulse-coupled neural network for detecting aerial and bridge targets [6]. This neural network architecture excels at detecting targets in complex contexts, leveraging principles inspired by the synchronization of biological neurons. Binh, K. proposed morphologically enhanced relative connectivity entropy for automatic object detection [7]. This method can use morphological operations and entropy calculations to improve the robustness of object detection, especially in situations with different object sizes or shapes. Jeong, H.G. presented a multi-motion object segmentation algorithm based on the level set method [8]. This algorithm can use the level setting method to delineate the boundaries of moving objects in dynamic scenes, thereby providing accurate segmentation regardless of object motion. Zhao, W. proposed a method for fast division of level sets [9]. This method is capable of optimizing the computational efficiency of level set-based segmentation, allowing for rapid and accurate identification of objects in real-time applications. Roos, M. H. proposed a moving object detection algorithm based on gradient direction information [10]. This algorithm can take advantage of gradient direction signals to identify moving objects in video sequences, thereby providing robust detection performance under different environmental and lighting conditions. Ma, C. introduce automatic target detection based on watershed transformation combined with genetic algorithm [11]. This approach can use genetic algorithms and watershed transformations to identify targets in images, providing strong noise and

clutter resistance. Krebs, J. proposed an improved level setting method for multiple object detection and tracking [12]. This method can improve traditional level set algorithms to facilitate accurate detection and tracking of multiple objects in complex scenes. Vuong, Z. conducted extensive research on multi-object detection and image sequence tracking [13]. This research can explore advanced algorithms and techniques to simultaneously detect and track multiple objects in dynamic environments. Li, R. presented a target segmentation method that involves subsample extraction and correlation calculation [14]. This method can use pattern matching and clustering techniques to accurately segment targets from background clutter, thereby providing robustness in object recognition. Wu, S. proposed a target detection method using random decision trees and statistical matching subwindows [15]. This approach can use statistical and machine learning methods to detect targets in images, providing scalability and adaptability to a variety of scenarios. Wieduwilt, E. introduces gradient direction histogram detection operator for target detection [16]. This operator can take advantage of gradient information to distinguish between positive and negative samples, thereby improving the accuracy of target detection in harsh environments. Overall, these contributions highlight the breadth and depth of research efforts aimed at advancing automatic object detection and segmentation techniques. By leveraging innovative methods and interdisciplinary approaches, researchers aim to meet the changing needs of object detection in various application areas.

2.1. Research gaps. Based on the comprehensive literature review provided, several research gaps and opportunities for further investigation can be identified: Some studies address the detection of objects in complex backgrounds, such as Lee's discovery of fractal features [5], and Bin's proposal for improved entropy calculation [7], methods are still needed. It can reliably detect objects in the middle of very cluttered or irregular backgrounds. Developing robust algorithms capable of accurately distinguishing objects from complex environmental contexts remains a significant research gap. Jeong's work on multi-motion object segmentation [8] and Roos' algorithm for moving object detection [10] highlight efforts to address segmentation objects in dynamic scenes. However, there is still much room for improvement in algorithms that can effectively segment objects subject to complex motions, such as occlusions, deformations, or rapid changes in appearance. Despite Zhao's proposal of a fast level set segmentation method to improve computational efficiency [9], achieving real-time performance is still a challenge for many object detection algorithms, especially in applications that require fast, high-performance processing. resolution image or video stream. Research focuses on speeding up algorithms without compromising guaranteed accuracy. Several studies, including Krebs's improved level setting method [12] and Wang's research on multiple object detection and tracking [13], consider detecting and tracking multiple objects at the same time. However, there is a need to further explore algorithms that can robustly handle occlusions, object interactions, and scale variations, especially in cluttered or dynamic environments. Adaptability to varying conditions: Although Wu's approach using stochastic decision trees is promising for target detection [15], achieving robust performance under Varying environmental conditions, such as changes in lighting, weather or viewing angles, remain a challenge. Research focused on developing algorithms that are adaptable and flexible to such variations is essential for real-world implementation. Most of the reviewed research focuses on image-based object detection; However, there is growing interest in integrating multiple methods, such as LiDAR, radar or depth sensors, to improve detection performance, especially in challenging situations such as low visibility. Research on fusion techniques and multimodal approaches can lead to significant advances in object detection. Evaluation metrics and benchmark datasets: Although the experimental results presented in the reviewed studies demonstrate the effectiveness of the proposed methods, evaluation metrics are lacking standardized and benchmark datasets to compare the performance of different algorithms. Developing comprehensive evaluation frameworks and datasets tailored to specific application areas can facilitate fair comparisons and reproducibility of research results.

Filling these research gaps will be the main goal of this research work. This not only involves advancing the state-of-the-art in automated object detection and segmentation, but also contributes to the development of more robust, efficient and adaptable systems for various industrial and practical applications.

3. Methods.

3.1. The basic working principle of PCNN and its algorithm improvement. PCNN has a multi-neuron model, which is a bionic machine for animal visual recognition, where each neuron is a layer of a neural

network capable of recognizing the results of the network without training[17]. It also includes: spatio-temporal summation characteristics, dynamic pulse emission characteristics, and vibration and oscillation characteristics due to synchronous pulse emission. In image processing, PCNN can be widely used in digital image segmentation, edge detection, detection, enhancement, fusion, pattern recognition, target classification, intrusion prevention, etc. It can be used in wavelet theory, mathematical morphology, and fuzzy processing, and together with other signal processing technology, it is widely used in graphics and other operations. The wiring process of the neuron can be approximated as the transfer process of the integration loss, which is the linear output [18-19]. PCNN is a feedback mechanism built by connecting many neurons, each neuron usually has three parts: a receiver, a network (multiple transformations) and a machine electric pulse [20-21]. In real-world imaging, the neural network's connectivity corresponds to the pixels in the image one-to-one, that is, the number of pixels in the image corresponds to the neurons in the network, more. it will be. This corresponds to many neurons.When used for edge detection, the performance of the algorithm changes with the number of iterations, and so does the detection result. Each iteration corresponds to a binary image output showing the details of the target and the background, but the results of each iteration are not ideal. According to the maximum data entropy rule, as the number of iterations increases, the maximum data entropy is often used to determine the quality of the image, because the highest value The amount of image information entropy indicates that the image contains important information. the number of iterations.It is not possible to determine which results are better before testing, which is one of the shortcomings of PCNN, that is, its results cannot be objectively evaluated. Considering the shortcomings of the traditional PCNN edge detection algorithm, the author wrote a PCNN algorithm program based on the average maximum information entropy detection of objects, stationary objects, and images, and improved the traditional PCNN algorithm. , reducing unnecessary repetition, speeding up the algorithm, capturing the joint target in time, and obtaining target information.The author detects the edges of the image lena.png by using the advanced PCNN algorithm and traditional edge detection algorithms such as Sobel operator, Roberts operator, Prewitt operator, LOG operator, and Canny operator as complete and with good continuity, but there are many spurious ones. edge in the extracted result.The edge removal by improving PCNN is very successful, and the target edge can be extracted more in areas with complex backgrounds.

3.2. The network model of PCNN. The PCNN model consists of basic neurons, and each neuron is mainly composed of two functional units: the feedback input domain and the connection input domain, which are connected to its neighboring neurons through the synaptic connection weights M and W, respectively.

3.3. Visual inspection and recognition automation system design. The author developed a PCNN-based recognition and detection system by combining LabVIEW software and Matlab software.The system has two parts: the vision system and the control system. The vision sees and sees the incoming objects, and after receiving large data, converts it into a control signal, and sends the control signal to the control card to control the corresponding functions;Additionally, the control has a XYZ three-degree-of-freedom slide table. First, the workpiece is moved to the camera and the focal length is adjusted to place the part in the best measurement position, while the vision system records the image of the part and precisely defines the edges of the part. PCNN algorithm, then the edge of the part is processed by the Vision Assistant module, and the control signal is generated according to the measurement, identification and recognition of the car size, and the control signal is converted into energy control card using the control of the control parts of the mechanism. The specific process is shown in Figure 3.1.

3.3.1. Experimental platform construction. The equipment of the final chair is composed of upper computer (production computer), lower computer (Leisai four-axis motion control card and image capture card), servo motor , driver, CCM three-axis sliding table and shadowless space and DC power supply. These include: The upper computer is used to send motor control instructions, receive graphic and operating instructions, display information, and human interaction- computer; The four-axis control card of the downstream computer receives instructions from the upstream computer, generates voice control signals, and sends the signals to the servo motor drive. digital I/O port and the driver completes the speed and direction. . monitoring, signal amplification, engine operation; After the motor receives the driver's control signal, it is used as an actuator to perform the corresponding function, and the CCM three-axis sliding table mechanism can move three levels of movement: left, right, front and rear. freedom and education; The optical card receives signals from the

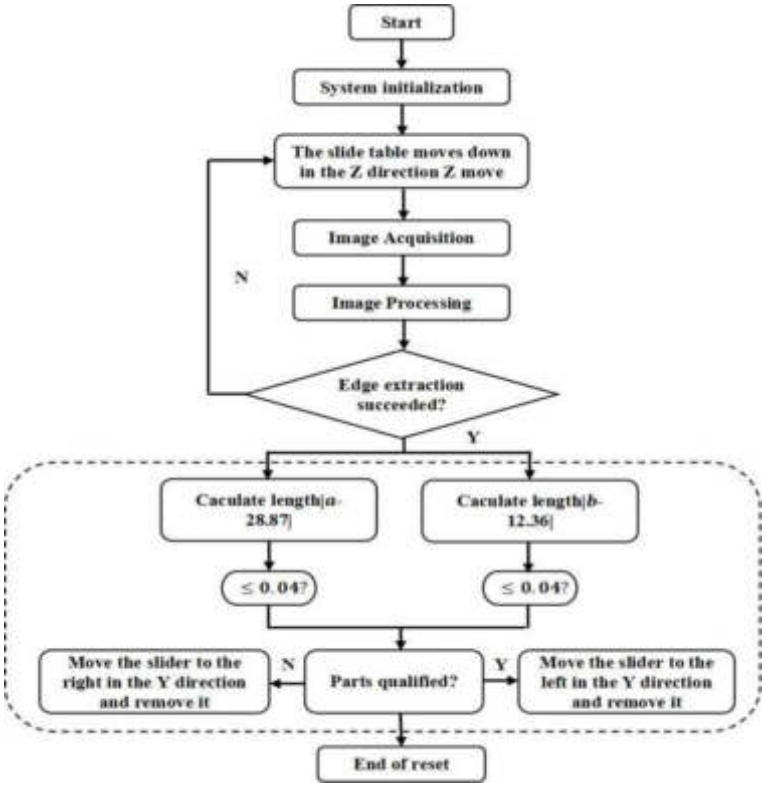

Fig. 3.1: Program running process

control computer, collects an image of the area, and then sends the image data back to the supercomputer for processing. done through the digital I/O port.

3.3.2. Software development. In the professional development of LabVIEW2011, the author uses the MatlabScript node to call the Matlab program, and the controller is connected to LabVIEW to realize and control the automatic equipment, as shown in Figure 3.2. After the program starts running. , the first control card sends the control signal to move the slide in the Z direction, send the part, run the camera with LabVIEW's VisionAcqusition module, collect the image of the part, and bite it with the values , and then call him. In order to run the PCNN edge search on a node, Matlab converts the edges to digital images after processing, and then LabVIEW's VisionAssistant module measures the length, width, and end of the ratio. measure the measured value with the standard value, determine the quality of the part, and make a motion control diagram to understand the movement of the Y-table three-level slider. No need to wait for another time to complete the orientation, location measurement, reset after completion, or explain the measurement.

The integration of LabVIEW and MATLAB application in the evolution of PCNN-based detection and recognition systems represents a holistic approach that leverages the strengths of both platforms for effectual and effective implementation. This system further consists of the two main components: the vision system and the control system, each of which carry out separate but interrelated functions.

3.3.3. Visual System. The visual system is incorporated as the "eyes" of the system and is accountable for capturing images of incoming objects and processing them for analysis. First, use the camera carriage with 3 degrees of freedom to position the part within the field of view of the camera. This ensures precise alignment and optimal measurement conditions. After positioning, the camera captures images of the part, which are processed using the PCNN algorithm. PCNN's edge detection feature allows the system to accurately identify the edges of a part. This is important for subsequent analysis. The processed edge information is further refined with the Vision Assistant module, which can integrate another image processing techniques to improve

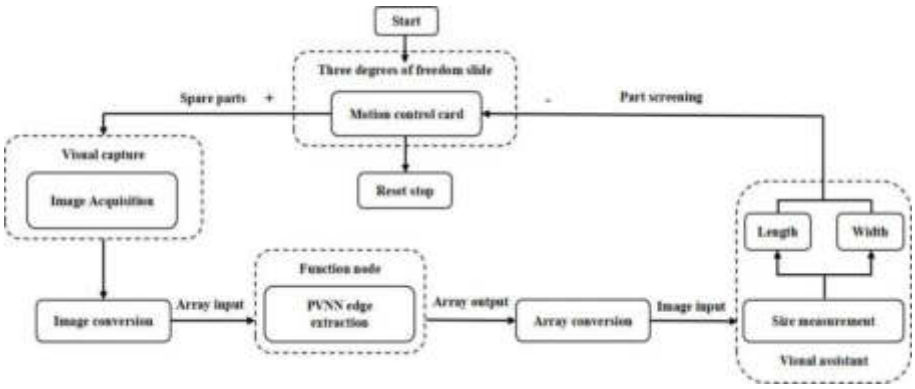

Fig. 3.2: Flowchart of the control system

edge sharpness and remove noise and artifacts. The vision system then performs measurement, identification, and recognition tasks based on the features extracted from the parts, such as size, shape, and specific features. The results of these analyzes are converted into control signals that provide instructions for further action by the control system.

3.3.4. Control System. A control system converts the output of a vision system into executable commands to control mechanical components or devices. The control signals generated by the vision system contain information about the measurement results and object properties and are received by the control system. Using LabVIEW software, the control system processes these signals and converts them into commands suitable for controlling the 3 degrees of freedom carriage and other related mechanisms. The control system communicates with the power control board or other hardware components to perform specific actions. Adjust part positions or activate specific tools based on analysis. Analysis is performed by a visual system.

In summary, LabVIEW and MATLAB integration facilitates seamless communication and coordination between vision and control systems, allowing PCNN-based detection and recognition systems to detect, analyze, and accurately detect incoming objects in real time. This multidisciplinary approach leverages the strengths of both software platforms to create important and adaptable solutions for a wide range of industrial applications.

4. Results and Discussion. The main characteristics of field detection and analysis automation systems are the ability to guarantee accurate measurements, robust algorithms, and stable system operation. The authors began a thorough investigation to determine these important aspects and began collecting images with different backgrounds under uniform illumination. Using traditional edge detection methods and an improved pulse-coupled neural network (PCNN) algorithm, the authors carefully analyzed and identified the edges of the object. A comparative analysis of edge extraction using traditional methods and his PCNN algorithm enhanced in the background yielded convincing results. Images processed using the PCNN algorithm had more detail and improved sharpness than images processed using traditional methods. It is noteworthy that the ability of the PCNN algorithm to improve accuracy on difficult backgrounds and enable robust edge and object detection even in difficult scenarios. The evaluation was then extended to repeated measurements using both the LabVIEW algorithm and the improved PCNN algorithm as shown in Figure 4.1. A standard model with known dimensions (length 28.87 mm, width 12.36 mm) serves as a benchmark, and measurements are performed under constant illumination conditions and indirect position guidance. As the position of the scale changes continuously, the length and width measurements also change. In particular, measurements performed using the improved PCNN algorithm had smaller deviations from the sample values compared to those obtained with the LabVIEW algorithm. This result highlights the excellent stability and accuracy of the PCNN algorithm,

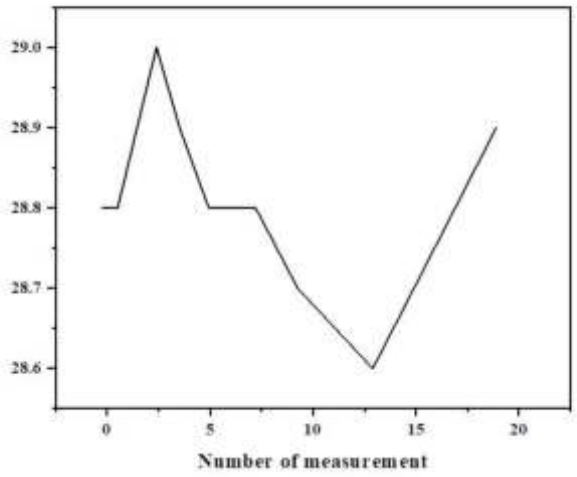

Fig. 4.1: Detection results of arbitrary parts in position and direction under the same illumination

Table 4.1: Experimental results

	length/mm	width/mm	Parts display
Right	28.84	12.34	Qualified
left	28.92	12.40	Failed

which facilitates accurate measurements even under fluctuating conditions.

Additionally, the system's ability to accurately detect position during high-speed movement (1 m/s) was evaluated, providing an outstanding detection accuracy of ±0.04 mm. Extensive testing on 20 production batches confirmed the system's effectiveness in establishing appropriate product dimensions (length [28.83 mm, 28.91 mm] and width [12.32 mm, 12.40 mm]), thus ensuring consistent and reliable analysis results as shown in Table 4.1. Comprehensive evaluation shows that when system accuracy is maintained at 0.04mm, objects can be clearly separated, with the entire analysis process achievable in a fast timeframe of 5 seconds. Notably, discrepancies between measured and actual dimensions were quickly identified, highlighting the system's ability to accurately detect potential differences and defects. Essentially, the systematic evaluation highlighted the robustness, reliability, and effectiveness of the field detection and analysis automation system. By leveraging advanced algorithms and precise measurement techniques, the system delivers excellent accuracy and stability, facilitating seamless and reliable analysis of objects in a variety of environments, conditions and different activities.

The detection machine has a stable, high precision and good working time, and during the detection and confirmation, the three-axis sliding table is working parallel, which improves the level of automation the system [22-24].

A runtime comparison of traditional edge detection methods and an improved PCNN (Pulse Coupled Neural Network) algorithm provides valuable insights to improve accuracy and increase computational efficiency. This result clearly shows that using the improved PCNN algorithm significantly reduces the execution time, from 256 seconds for the traditional method to just 100 seconds for the PCNN algorithm. This significant reduction in processing time highlights the superior computational efficiency of the PCNN algorithm in edge detection tasks. Notably, the PCNN algorithm still maintains or improves accuracy despite its increased processing speed

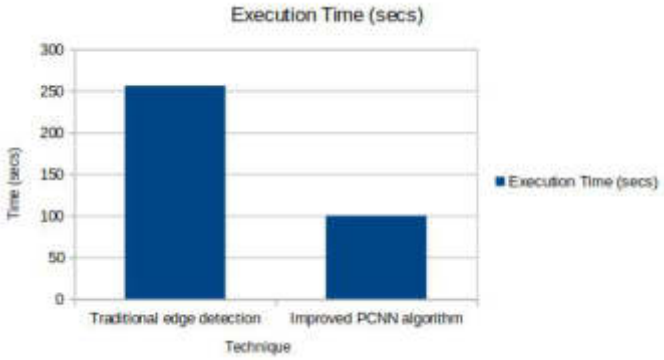

Fig. 4.2: Execution Time

compared to traditional methods. This efficiency increase not only improves the overall performance of the detection system, but also enables rapid image analysis and facilitates rapid decision-making in a variety of applications. In summary, the observed runtime differences highlight the significant computational advantages offered by the PCNN algorithm, making it an attractive choice for edge detection in automated analysis systems.

5. Conclusion. The author presents an innovative automatic search and authentication control system, underpinned by a vision-based detection and recognition automation package developed through the integration of LabVIEW and MATLAB software. Employing the refined PCNN edge extraction algorithm, experiments conducted on a fixed platform in a garden setting yielded promising results. The observational analysis underscores the system's adaptability to dynamic measurement scenarios, wherein fluctuations in measurement position induce corresponding changes in length and width values. Notably, the integration of the vision system with a servo mechanism establishes an open-loop optical servo mechanism, elevating product control automation capabilities. This enhancement addresses deficiencies inherent in conventional control systems, such as low control precision, inadequate automation efficiency, and lack of trust, while facilitating comprehensive analysis and defect detection across diverse tasks including food inspection, size analysis, and partial analysis. The system achieves remarkable efficiency, with tasks such as photographing, size analysis, partial analysis, and table reset completed within a mere 5 seconds. Moreover, the system demonstrates robustness in detecting and analyzing objects in motion, showcasing its potential for real-time applications even at speeds of up to 1m/s. The developed system represents a significant advancement in automation and control technology, offering unparalleled accuracy, efficiency, and adaptability. By seamlessly integrating cutting-edge software tools and innovative algorithms, it promises to revolutionize various industrial processes and elevate the standards of product inspection and control automation.

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RESEARCH AND APPLICATION OF BIG DATA CLUSTERING ALGORITHM BASED ON AI TECHNOLOGY IN CLOUD ENVIRONMENT

DAN HUANG *AND DAWEI ZHANG †

Abstract. Traditional big data filling algorithms often give inaccurate results due to vulnerabilities to different data types. To solve this problem, this study presents a new big data clustering algorithm powered by AI technology in a cloud environment. The study proposes an advanced Big Data clustering algorithm that leverages AI technology in a cloud environment. It optimizes clustering based on predicted strength using parallel processing. The research focuses on optimizing the clustering algorithm based on the predicted intensity through parallel processing. Experimental results demonstrate that image clustering stability is achieved when the number of clusters exceeds 4, indicating reduced sensitivity to random factors. Although it was not possible to precisely determine the optimal number of clusters, the use of an optimization algorithm showed that at four clusters the prediction intensity reached its peak, ensuring more accurate cluster identification. Through rigorous testing, the optimal number of clusters was determined to be 4. Clustering results show that visitors characterized by certain attributes show higher interest in most columns. This algorithm makes it easier to cluster incomplete large data, improves clustering speed, and improves the accuracy of filling in missing data. Compared to existing methods, this algorithm leverages AI technology in the cloud environment to optimize clustering based on prediction intensity, providing improved accuracy and efficiency during processing in big data management.

Key words: Distributed Computing; Prediction Strength; Algorithm Research; Cloud Environment; Clustering Algorithm.

1. Introduction. In today's data-driven landscape, the growing amount of information has brought data to the forefront as a key strategic asset alongside natural resources and human capital. This paradigm shift, driven by the rapid development and widespread adoption of computer technology, internet connectivity, mobile devices, and cloud computing, has ushered in an era of data ubiquity across many different industries. Moreover, the challenge is not only to manage its size, but also its complexity, which is characterized by different data types, pervasive noise, and high-dimensional structures. Effectively harnessing the hidden potential of this vast amount of data requires advanced analytical techniques. Clustering algorithms, in particular, are essential tools for identifying meaningful patterns and deriving actionable insights from large datasets. However, given the complexity of big data, traditional clustering techniques often fail and yield inaccurate results, especially in situations where data integrity is compromised. To address these challenges, this study attempts to present an innovative solution in the form of an improved big data clustering algorithm based on artificial intelligence (AI) technology in electronic environments. By leveraging the power of cloud infrastructure and AI, the algorithm aims to overcome the limitations of traditional methods by optimizing the clustering process, improving prediction accuracy, and increasing computational speed. Through a comprehensive study on the use of advanced clustering techniques and parallel processing techniques, this research aims to not only improve the accuracy of clustering results but also streamline the processing of incomplete and noisy datasets. This section highlights the importance of addressing the challenges posed by big data clustering, highlighting the integration of AI and cloud computing as essential elements for achieving advanced clustering capabilities, and the proposed It paves the way to highlighting the rationale of the approach.

Data, as a quantitative representation of information, constitutes a strategic asset like natural and human resources, representing important economic and scientific value. The advent of computing and information technology, especially the widespread adoption of internet technology, digital platforms, mobile devices and cloud computing, has fueled explosive growth in Generate data in many different fields. This increase in data production manifests itself in many different types, characterized by extensive noise and high complexity [1].

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For example, Baidu processes 10 to 100 PB of website data daily, while Taobao accumulates transaction data volumes of up to 100 PB. Meanwhile, Sina Weibo generates 80 million messages per day, and a provincial branch of China Mobile registers phone communications at prices ranging from 0.5 PB to 1 PB per month. In addition, a provincial police office accumulated 20 billion pieces of road vehicle monitoring data over three years, a total of 120 TB. Forecasts from IDC, a leading computer information analysis and consulting company, predict that the global annual volume of data will reach 35 ZB by 2020 [1]. The term "big data" has emerged to summarize the nature of such large, unstructured, digitized data sets. In 2008, recognizing the emerging challenges and opportunities inherent in handling big data, the journal Nature devoted a special issue to technical obstacles and officially introduced the concept of "Big Data" [2,3].Therefore, these large unstructured data sets, characterized by their digital and high-dimensional nature, are now often referred to as big data.

1.1. Article Contribution. This research contributes to the field of big data management by presenting a new big data clustering algorithm supported by AI technology in a cloud computing environment. Leveraging advanced clustering techniques and parallel processing, the algorithm optimizes clustering based on predicted strength. Experimental results demonstrate that clustering stability is achieved when the number of clusters exceeds four, indicating reduced sensitivity to random factors. Using an optimization algorithm, the study identifies four clusters as optimal, thereby improving the accuracy of cluster identification. The algorithm significantly improves clustering speed, missing data filling accuracy, and allows clustering of large incomplete data sets. Compared to existing methods, this algorithm delivers higher accuracy and efficiency by leveraging AI technology in the cloud environment. The results highlight the practical benefits of optimized clustering algorithms, showing a significant reduction in the influence of random factors on clustering results. Additionally, the study highlights distinct visitor behavior patterns, which have implications for improving user engagement. Overall, the proposed optimization algorithm shows significant application value across industries, promising to reduce the time complexity and economic costs associated with data clustering analysis. Further research efforts are needed to refine and apply advanced clustering algorithms to effectively meet changing business needs and user preferences.

2. Literature Review. In order to optimize network resources and improve user experience, Paknejad, P proposed a large-scale network traffic monitoring and analysis system based on Hadoop, which is an open source distributed computing platform established to process large amounts of data on hard disks. The system has been deployed to run on the core network of large cellular networks, and the system works well and has been widely praised [4]. Banerjee, A In order to solve the problem that the processing efficiency of frequent subgraph mining decreases when the amount of data increases, a frequent subgraph mining algorithm FSM-Ho FSM-H based on the MapReduce framework is proposed, which is suitable for all the latest FSM algorithms [5]. Through experiments, we verify that the parallel frequent subgraph FSM-H is effective with a large comprehensive dataset. Qin, X conducted in-depth research on the development status of MapReduce at home and abroad, pointed out the advantages and disadvantages of domestic and foreign MapReduce research results, and at the same time, deeply analyzed the development status and trends of key MapReduce technologies [6]. Finally, he expressed his views on the future development direction of the MapReduce distributed framework. Li, C decomposes noisy data into clean data, Gaussian noise and sparse error matrix, and then performs low-rank subspace clustering, which can improve the robustness of the model [7]. Wen, L. H combined sparsity and low rank to give a multi-subspace representation model; In the LRR model, the column representation coefficient matrix and the row representation coefficient matrix are simultaneously low-rank constraints, so that the row and column information can complement each other and de-noise each other, and a hidden low-rank representation model is proposed [8].

The applications of big data clustering algorithms are mainly concentrated in the fields of graph processing, pattern matching, and market analysis. There are various difficulties in cluster analysis research of big data, and these difficulties are determined by the characteristics of big data itself [9]. After entering the era of big data, the amount of data that needs to be processed has increased dramatically, and the traditional clustering method using serial data analysis has been difficult to adapt to the data processing requirements in the current cloud computing network environment, the author adopts a parallel method to study and optimize the big data clustering algorithm with the prediction strength as the starting point. Starting from one or several attributes of a specified data set, this process of classifying it is called clustering, and the process of clustering does not

require a full knowledge of all the properties of the dataset. Generally, each of the divided categories is called a cluster, and the similarity of the data on one or several specific attributes, as a standard for the division between different clusters. Therefore, in the process of clustering, it is not necessary to set classification criteria in advance, but the classification is performed automatically based on the specific attributes of the data itself.

2.1. Research gaps in existing literature. Despite significant progress in big data clustering algorithms and their applications in various fields such as graph processing, pattern matching, and market analytics, several research gaps still exist, requiring deeper inquiry and innovation.

1. Scale network traffic analysis: Although Paknejad's Hadoop-based system proves its effectiveness in monitoring large-scale network traffic, there is still a need to optimize scalability, especially in The mobile network landscape is expanding rapidly. Further research could focus on improving the system's ability to efficiently process and analyze network traffic data while accommodating growing data volumes.
2. Improving the efficiency of frequent subgraph mining: Banerjee's FSM-Ho algorithm offers a promising solution to improve the efficiency of frequent subgraph mining using Using the Map-reduce framework. However, there is a need to explore additional techniques to further improve the scalability and performance of the algorithm, especially with regard to handling larger data sets and complex graph structures.
3. Meeting the challenges of big data clustering research: Qin's comprehensive analysis of Map-reduce technology highlights both its advantages and limitations in meeting the challenges of data processing big material. Future research efforts could delve deeper into addressing specific barriers encountered in big data clustering, such as handling different data types, scalability issues Scaling and optimizing algorithm performance in distributed computing environments.
4. Improving robustness and handling noise in data clustering: Li and Wen's study of low-level subspace clustering models and multi-subspace representations provides valuable insights value in improving the robustness of clustering algorithms. However, further research is needed to develop techniques that can effectively handle noisy data and improve the accuracy and reliability of clustering results, especially in situations where large data are available data is heterogeneous and has many dimensions.
5. Automating cluster analysis in cloud computing environments: Despite advances in parallel big data clustering methods, there are still gaps in automating the cluster analysis process in networks cloud computing.

Future research could focus on developing intelligent clustering algorithms that are able to dynamically adapt to changing data patterns and network conditions, thereby optimizing resource utilization and improving performance. Improve user experience in cloud-based applications. Addressing these research gaps will help advance modern big data clustering algorithms, allowing more efficient analysis of large-scale datasets in various application domains.

3. Research Methods.

3.1. Data fusion in cloud environment. With the rapid development of network technology, especially the Internet, the amount of unstructured or semi-structured data is increasing day by day. Among them, the IDC survey report shows that: The amount of unstructured data in the enterprise accounts for 80 percent and is growing exponentially by 60 percent every year [10]. If the structured data in the enterprise records the development and transaction activities of the enterprise meticulously and intuitively, then the unstructured data is the key lifeline of the enterprise development and the method to improve the competitiveness of the enterprise. Therefore, in order to make the enterprise develop rapidly and steadily and improve the core competitiveness of the enterprise, the research on unstructured data is imminent.

Therefore, in order to make full use of unstructured data, grasp the lifeline of enterprise development, and improve the core competitiveness of enterprises, enterprises must process unstructured data to realize data fusion and provide high-quality data guidance for future enterprise decision-making. However, due to the huge amount of unstructured data, it is difficult to quantitatively analyze it, its manifestations are diverse, which makes the integration results inefficient and inaccurate, which has a great impact on the results of future data analysis and may bring unpredictable losses to enterprises [11]. Therefore, how to carry out data fusion

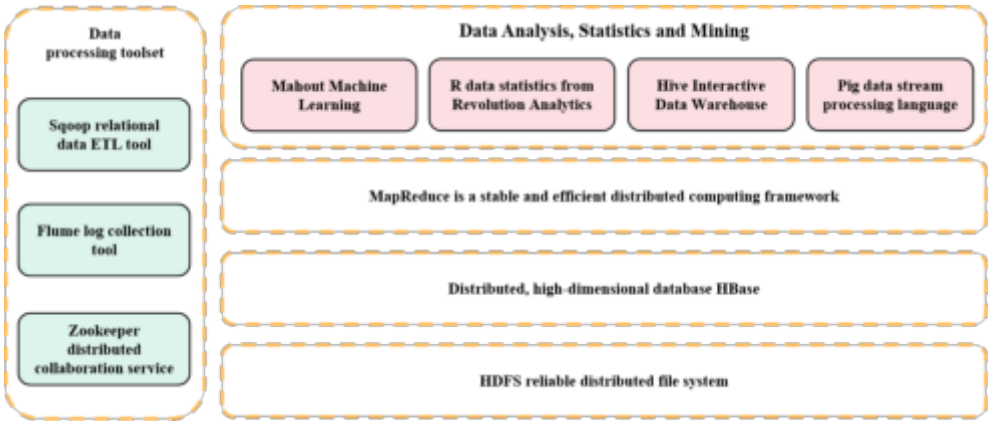

Fig. 3.1: Hadoop ecosystem structure diagram

efficiently and quickly, and provide reliable data guarantee for later data analysis and data mining, is a very challenging task.

The concept of data fusion originated from sensor data fusion, which is a series of processing of data from multiple sensors, in order to obtain unknown, useful information. Sensor data fusion has existed for a long time and was proposed around the 1970s, at the same time, it is widely used in military, biomedical and transportation [12]. The concept of data fusion also exists in the field of information retrieval. Data fusion in information retrieval mainly refers to merging the retrieval results of each independent data set into a unified result, so that the combined effect is as close as possible to the retrieval effect on a centralized data set.

3.1.1. Data Analysis System. There are two main directions of the current big data analysis and processing system: Batch processing systems represented by Hadoop; Stream Processing systems developed for specific applications. The main difference is that batch processing systems need to store and then process, while stream processing systems process directly [13]. A single data analysis and processing system is difficult to adapt to the rapid increase in data volume in the current cloud computing network environment, a hybrid data analysis system that mixes application architecture with underlying design languages and high-level computing modes for big data processing is more suitable for current application needs.

The Hadoop ecosystem structure is shown in Figure 3.1.

The core of Hadoop is Distributed File System (HDFS) and MapReduce. HDFS has high fault tolerance and high throughput data access, suitable for applications deployed on cheap machines and large datasets [14]. MapReduce is a mature programming model for parallel computing of large data sets. HBase is a column-oriented data database, it runs on HDFS. The main goal of HBase is to quickly locate and access the required data for billions of rows of data that exist on the host. HBase can also be used in combination with Hive and Pig, with their high-level language support, HBase can easily and quickly perform statistics on data.

The core of the Hadoop framework is HDFS and MapReduce. Here is mainly to explain the composition of HDFS, as shown in Figure 3.2.

Next, we describe the relationship between NameNode, DataNode and Client from three operations: file writing, file reading, and file block copying [15].

(1) File writing: First, the Client makes a request to write a file to the NameNode, after the NameNode receives the request, according to the size and configuration of the file, it feeds back the DataNode information under its jurisdiction to the Client, after receiving the DataNode address information returned by the NameNode, the Client divides the file into blocks and writes them to the DataNode in sequence [16].

(2) File reading: First, the Client sends a request to the NameNode to read the file, the NameNode responds after receiving the request, and feeds back the DataNode information of the stored file to the Client, the Client receives the DataNode information sent by the NameNode and performs a read operation on the file.

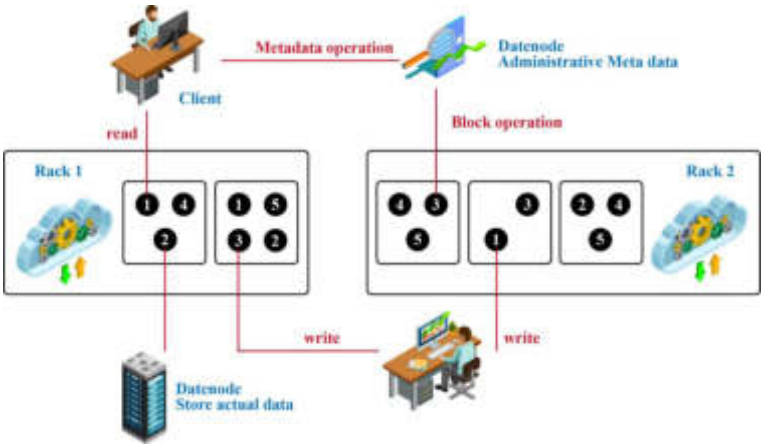

Fig. 3.2: HDFS structure diagram

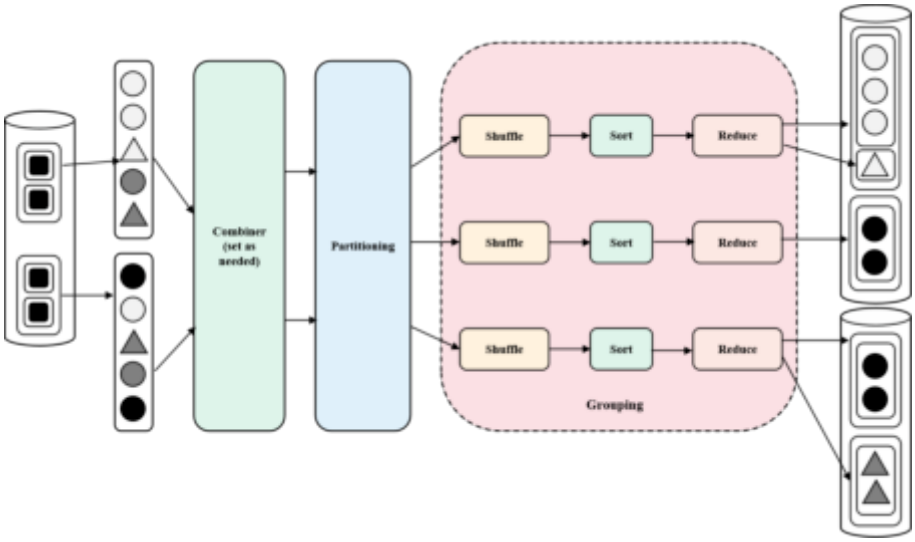

Fig. 3.3: MapReduce flowchart

(3) File block copy: When the NameNode finds that the number of file blocks has not reached the minimum number of replications, and detects that some DataNodes have failed, the NameNode will issue commands to the DataNodes under its jurisdiction to copy file blocks with each other, and these DataNodes will perform block copy operations with each other after receiving the NameNode instructions.

In addition to the map and reduce functions, a mature MR model also contains three functions: Part, comp, group, the following author will introduce the relationship between them [17]. First, the part function divides the data output by the map and distributes it to the available reduce tasks; Then all the keys will be sorted under the comparison function comp; Finally, the data is grouped by group for the convenience of reduce calls. It is important to note here that functional operations are performed on keys in key-value pairs without involving values, and the keys here are any kind of data that are comparable [18]. Proper selection of part, comp, and group functions can realize the division and grouping of complex tasks, which is particularly important when using mixed keys. The following is a detailed description through the flow chart of MapReduce, as shown in Figure 3.3.

As can be seen from Figure 3.3, MapReduce can be generally divided into two processes: Map and reduce. In Figure 3.3, it can be seen that the MapReduce instance in the figure contains 2 map tasks and 3 reduce tasks. The map function is called once for each block of input data (the four light gray squares in the Figure). When the map stage is completed, it generates 10 sets of intermediate key-value pairs and outputs them for further processing. Each set of intermediate keys corresponds to a shape (triangle and circle) and a color (light gray, dark gray, and black). These key-value pairs are assigned to 3 reduce tasks through the Partition function based on a part of the key (like color) (and of course also by shape). You can also formulate a Combiner class for the map function as needed to combine the output composite key-value pairs. Finally, the group function groups the entire key-value pair, so that the reduce function completes the classification of the five key-value pairs [19].

The actual execution of MR programs (that is, what we call jobs) is implemented through an MR architecture, such as Hadoop. An MR cluster consists of a series of nodes running on a fixed number of map and reduce processes. It's worth noting that the partition function is partially dependent on the number of reduce tasks, because it sends key-value pairs to the available reduce tasks. If the MapReuduce instance program in Figure 3.3 is running in a Hadoop cluster, and it contains 1 map process and 2 reduce processes, that is to say, 1 map task and 2 reduce tasks can run at the same time; Therefore, this 1 map task will be processed in this 1 map process, and these 3 reduce tasks will need these 2 reduce tasks to be processed.

3.2. Clustering Algorithm for Prediction Strength Optimization. The number of clusters expected to be divided into clusters is an important parameter in the clustering process, and the authors used the prediction strength-based method proposed by Tibshirani in 2001 to calculate the number of clusters. The prediction strength is defined as formula (1):

$$pk(s) = \min_{1\le j\le k} 1/(n_{kj}(n_{kj}-1)) \sum_{i\neq i'@i,i^*\in A_{kj}} I(D[C(A,k),B]_{ii'}=1) \tag{3.1}$$

The specific calculation steps are:

1. Divide the current data set into test set A and test set B by random division;
2. Using k as the current number of clusters, cluster the two subsets and record the results;
3. Distinguish the clustering results of the two subsets;
4. Count the classification errors of all samples in set A in set B, and calculate the correct rate of allocation;
5. The prediction strength with k as the number of clusters is the minimum value among all the correct rates.

In the prediction strength definition, $C(A,k)$ indicates that the set A is clustered into k categories, A_{kj} indicates the jth category that the set B is clustered into, n_{kj} indicates the number of elements in A_{kj}, $D[C(A,k),B]_{ii'}$ is the element value of the i row and i' column in the discriminant matrix of the clustering result. It can be seen that the predicted strength value $pk(s) \in [0,1]$ is affected by the number of clusters. The larger the prediction strength value, the stronger the prediction ability of the current clustering algorithm to classify new data elements into correct clusters. The random division of the data between the prediction set and the test set will cause the prediction strength to be seriously disturbed by accidental factors [20]. The author proposes to divide the data into multiple random classes first, and use them as the test set to calculate the prediction strength, and take the average of multiple prediction strengths as the final prediction strength under the current number of clusters, so as to reduce the interference of accidental factors on the prediction strength, function as an optimization algorithm.

The number of clusters k is determined by the prediction strength, and the corresponding algorithm for clustering is as follows:

Input: dataset D= $d_1, d_2, \ldots, d_i, \ldots, d_n$, the current optimal number of clusters k

1. Select k data points $d'_1, \ldots d'_k$belonging to D from the D set as the centroids of the clustered clusters;
2. For $\forall d_i \in D$, its corresponding cone should be N_j=arg $\min_j \|d_i - d'_j\|$;
3. Modify the centroid position $d'_i = (\sum_{i=1}^{n} \text{sign}(N_j = j)d_i)/(\sum_{i=1}^{n} \text{sign}(N_j = j))$ of each cluster
4. Take the sum of squares of errors between the centroid of each cluster and the data points in the cluster as the criterion function $G(N, d') = \sum_{i=1}^{n} \|d_i - d'_j\|$;

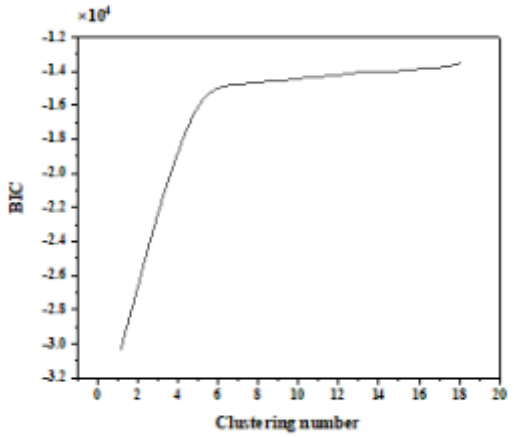

Fig. 4.1: BIC criterion model function curve

5. Repeat steps (2) and (3) until the value of (4) no longer changes, obviously, the value of the criterion function is shrinking.

Output: The cluster $N_1, \ldots, N_k$ where the centroid $d'_1, \ldots, d'_k$ is located

Among them, N_j should be the cluster where the centroid d'_j closest to the data d_i is located, sign$(N_j = j)$ indicates that its value is 1 when $N_j = j$, and its value is 0 in all other cases [21].

4. Analysis of results.

4.1. System Composition. To understand visitor behavior on live streaming platforms, visitor engagement duration data was analyzed in different columns. The analysis involved importing data from three columns and using a model built using the Bayesian Information Criterion (BIC). This criterion serves as the main measure for determining the optimal number of clusters and sets the number of anchor points for the analysis to her three variables.

4.1.1. Model Optimization and Prediction Strength. Figures 4.1 and 4.2 show function curves showing the relationship between the number of variables and the number of clusters. Note that the BIC criterion alone does not have a significant impact on determining the number of clusters when the number of variables is the same. As shown in Figures 4.1 and 4.2, when the number of clusters exceeds 4, the cluster images tend to become stable, indicating reduced sensitivity to random factors. Although it is clear that the optimal number of clusters should exceed 4, it is still difficult to determine the exact value [22].

4.1.2. Optimized algorithm and improved cluster identification. We find that using the optimized algorithm, the prediction strength reaches its maximum value at four clusters. This finding indicates that the number of clusters can be determined more accurately using an optimization algorithm. Based on the test strength, it was concluded that the optimal number of clusters is actually 4. The resulting curve after cluster analysis is shown in Figure 4.3.

4.1.3. Visitor Attribute Analysis. Analysis Figure 4.3 shows the different behavior patterns of visitors based on the categories assigned to them. Visitors characterized by the first attribute type have increased interest in most columns, which is very much in line with the content focus of the platform. This idea suggests opportunities for customized services to improve user engagement. In contrast, the fourth category of users shows little interest in the platform's current content, and there is no potential for targeted or strategic content adjustments to re-target that segment of users.

This result highlights the importance of using advanced clustering algorithms, such as the BIC criterion and algorithms using predictive strength optimization, to derive valuable and actionable insights from big

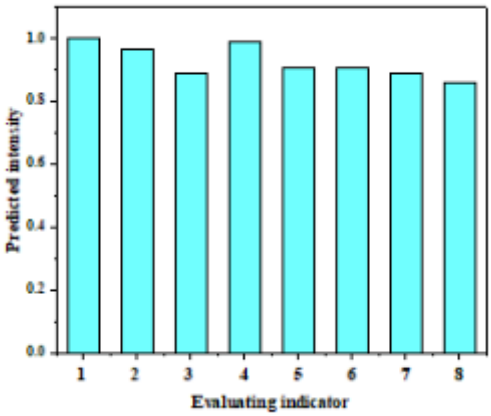

Fig. 4.2: The function curve of the optimized prediction strength model

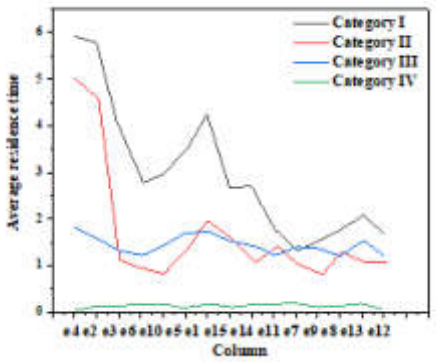

Fig. 4.3: The average stay time of different types of visitors on all columns

data. Understanding visitor behavior patterns allows platform operators to refine content strategies, improve user experience, and optimize resource allocation. Future research efforts may focus on improving clustering methods and exploring real-time adaptation strategies to respond to changes in user preferences.

5. Conclusion. The results of the performed experiments highlight the tangible benefits of using optimized clustering algorithms in real applications. By improving traditional clustering methods and optimizing the determination of specific cluster numbers, our study shows a significant reduction in the influence of random factors on clustering results. Our results reveal that when the number of clusters exceeds four, a stable trend emerges, suggesting a reduced susceptibility to random influences. Although the exact value of the optimal number of clusters remains elusive, our optimization algorithm facilitates a more precise determination, with maximum prediction strength observed for four clusters. Our analysis highlights distinct visitor behavior patterns, with a particular focus on increasing visitor interest with attributes that align with the platform's content focus. The use of this optimization algorithm promises significant practical benefits, including reduced time complexity and economic costs associated with large-scale data clustering analysis. By streamlining clustering processes and improving accuracy, our approach has significant application value in various industries. Further refinement and adoption of advanced clustering algorithms are warranted to continuously improve the efficiency and effectiveness of data analytics to meet growing business needs and user preferences.

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A STUDY ON THE PREDICTION METHOD OF ENGLISH PERFORMANCE IN UNIVERSITIES BASED ON THE STACKING INTEGRATED MODEL

TONGSHENG SI*

Abstract. Students' performance in higher education reflects their overall quality in higher education. By predicting the performance, students with greater learning problems can be screened out early and given appropriate guidance. To predict students' performance in English, the knowledge information of courses, examination papers, and historical examination records are used to build a feature project of students' examinations. Meanwhile, the features strongly correlated with their performance are filtered out. Then the next step of performance prediction is carried out. The results showed that a neural network long and short-term memory performance prediction model incorporating an attention mechanism was more effective than other models in predicting English performance in higher education. Further experiments found that the model reduced the error by 1.04% on the MAE metric, 0.53% on the RMSE metric, and increased its value by 4.12% on the R2 metric. Adding the new feature dataset led to better forecasting by the Att-LSTM model in all metrics. This indicated that the enhanced dataset temporality could improve the effectiveness of the Att-LSTM model in predicting English grades in higher education. The stacked integrated prediction model, by integrating multiple strong regressors, can avoid poor prediction and excessive overall bias due to one regressor and increase the soundness and prediction precision of the mode.

Key words: Stacking, Achievement Prediction, Integrated Learning, Attention Mechanism, English in higher education

1. Introduction. With the fast growth of national education computerization, a large amount of data on education has been generated in the education management system[15]. Data mining has been a new power in these sectors [5]. However, the application of this technology in student performance prediction is still underdeveloped and still being explored [12]. Big data has made a huge difference in how people work, live and think, and its impact on the education sector cannot be ignored [9]. Big data is becoming a huge force for progress and change in the education system [2]. Education is undergoing a dramatic change due to the influence of big data. The education sector continuously generates and accumulates a large amount of data, which constitutes big data in agriculture [10]. Big data's importance in education and its huge value is gaining more attention. With the construction of information systems on campus, there is a hardware basis for collecting and processing the various data generated by students on campus [6]. Therefore, this study uses the Stacking integrated model to study English performance prediction in colleges. A multi-model overlay prediction model based on the integrated learning stacking method is proposed for college students' English grades. The algorithm takes the prediction results of XGBoost, LightGBM and Att-LSTM models as input and then uses multiple regressors to integrate the prediction results to obtain the students' grade prediction results.

2. Related Works. Under the influence of big data, the education sector is undergoing a dramatic change. It constantly generates and accumulates large amounts of data, which constitute a large amount of energy in agriculture. The importance of big data in education and its huge value is becoming increasingly visible. With the continuous construction of information systems on campuses, there is a hardware basis for collecting and processing the various data generated by students on campus. So that college English can be promoted and students can achieve better grades. Achievement prediction has become an important topic and has been thoroughly studied by many scientists. Mubarak et al. proposed a supermodel of deconvolutional networks and long-term and short-term memory, dubbed CONV-LSTM, to extract features automatically from the raw MOOC dataset and to forecast each student to drop or finish the course. The proposed model showed an

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improved performance [11]. Wu L proposed a spatial recurrent mould grounded in deep attention, which learnt to focus on key target components and encoded those into space expression characterization. The method was experimentally demonstrated to outperform two typical fine-grained recognition tasks [13]. Thanh et al. proposed a profound study using classroom data conversion and factorial data over time to predict the pupils' grades. The experiment was built on 16 statistical collections relevant to various fields of study, collected from about 4 million samples from the student message board of a large-scale discipline network in Vietnam. The outcomes indicated that the presented approach offered excellent forecasting results, particularly when transforming the data and applied to practical cases [4].

Liu et al. proposed a new framework for student performance prediction using machine learning to capture features and fused attention mechanism-based recurrent neural networks. Experiments demonstrated the effectiveness and practicality of the method with an accuracy of 98% [7]. Baruah et al. presented a deeply neuro-fuzzy web based on the MapReduce framework for multiple universe optimization of grade competition-based student performance prediction. The values of the proposed method in terms of mean square error, root mean square error and mean absolute error were 0.3383, 0.5817, and 0.3915, respectively [3]. Abdollahi et al. presented a depth study-based multi-step algorithm to predict trip times using 5-fold cross-validation to detect the ability of the prediction mode. The proposed algorithm performed on a mean of 4 minutes outperforming a deep neo-network applied to the original eigenspace [1]. Meng et al. presented a deep feedforward forecasting model of neighbourhood neural networks to implement a suitable software system for employment forecasting and guidance of college and high school students, and the results showed some applicability [8]. Zhang et al. presented a method for predicting exploits using a multi-step N-gram characteristic selection and hierarchical integrated study. The results showed that the presented approach was validated on the server exploit buffer spill exploit and resource management exploit datasets with the lowest false positive and false negativity rates of 1.58% and 4.06%, respectively [16]. Xie et al. proposed a model for predicting grades through an attentive multilayer LSTM that combined students' demographic and clickstream datasets for integrated analysis. The results showed higher prediction accuracy and could provide timely interventions [14].

Currently, the research on student performance prediction is less concerned with the association between course knowledge data and performance. Its applicability and extensibility are narrow, which is not conducive to the practical application of relevant research findings. Meanwhile, existing studies have also paid little attention to the effect of time-series factors on predicting pupil achievement. Thus, this study proposes a neural network long- and short-term memory performance prediction mode incorporating an attention mechanism and a multi-model overlay of university students' English performance prediction mode. The algorithm takes the prediction results of XGBoost, LightGBM and Att-LSTM models as input, and then uses multiple regressors to integrate the prediction results. Finally, the prediction results of students' performance are obtained, and a new idea is proposed for the comprehensive research of English education in colleges.

3. A Stacking Integrated Multi-Model Overlay Based Approach for Predicting English Performance in Higher Education.

3.1. A neural network long and short-term memory performance prediction model incorporating attention mechanism. The first step for predicting English grades in higher education is pre-processing students' English grade data. The pre-processing allows richer information to be obtained on language test data and makes it easier to access questions. The data set records all knowledge points besides the student's English grades, with classification, sectioning, numbering and complexity information. Also, for each English test, the dataset records the points in the question paper, and the scores accounted for by those points. They are pre-processed through cleaning, feature engineering, and the generation of training datasets to investigate the intrinsic correlation between the data. These data provide a view of the overall distribution of student performance and also enable an understanding of whether there are any anomalies in the examination performance. Student performance is plotted according to a range of statistics per 10 points while being able to draw a box plot of student performance, as shown in Figure 3.1. Figure 3.1 shows that most students in this English course are within 60-100. Among them, the median score of students is more than 80, and a few students score under 60, indicating the good overall performance of college students. However, a small number of students have a score of 0 and might miss exams. The exam score of 0 is low, so this part of the anomaly is removed. In the construction of feature engineering, a computer program is usually used to record data, which is convenient,

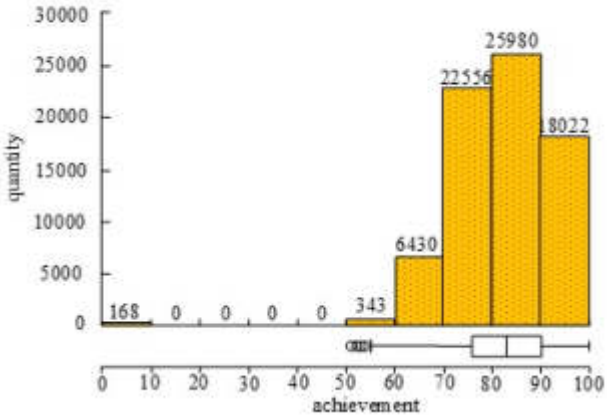

Fig. 3.1: Statistical Chart of Student Test Results

fast, and has a large amount of data. Attributes with strong correlations with scores are generally screened out, while those with weak correlations are excluded. Point-biserial correlation coefficients are used to analyse correlations between bivariate and continuous variables. The relation between student performance and gender is obtained by computing the point-biserial correlation coefficient, which is given in equation 3.1.

$$r_p b = \left(\overline{(Y_1)} - \overline{(Y_0)}\right) / S_Y \sqrt{((N_0 N_1)/(N(N-1)))} \tag{3.1}$$

In equation 3.1,Y_0 is the observed mean of the gender metric coded as 0. Y_1 is the mean of observations for gender indicators grouped under the code 1.N_0 is the approximate value of the observed values of males and females coded as 0. N_1 is the quantity of gender-specific views encoded as 0. N is the number of observations. S_y is the reference deviation of all metric measurements. If one starts with the complexity of the test paper, Pearson's coefficient of correlation is used to assess the intensity of the online relationship between two continuous entities. Pearson's coefficient is used to calculate the total complexity and its performance correlation, as shown in equation 3.2.

$$r = \frac{\sum (x - m_x)(y - m_y)}{\sqrt{\sum (x - x_m)^2 \sum (y - y_m)^2}} \tag{3.2}$$

In equation 3.2, m_x represents the mean of the total complexity of x. m_y denotes the average of the outcomes. y indicates the outcome of the correlation. The paper's complexity greatly impacts students' final grades and could be used to forecast their grades. In turn, the different points of English knowledge can have a differential effect on students' achievements. The data size is effectively reduced by reducing the dimensionality of the original data. To perform a non-negative matrix decomposition for an already existing matrix$V \in R_+^{n*m}$, the matrix $W \in R_+^{n*r}$ needs to be found with the matrix $H \in R_+^{r*m}$ such that it satisfies equation 3.3.

$$V_{n*m} \approx W_{n*r} H_{r*m} \tag{3.3}$$

In equation 3.3, $\approx$ is used mainly because the solution used is only an approximation. $r < n, r < m$. In the general case of $(n+m)\,r < nm$, the relationship between a more complex feature set is constructed by feature engineering. Table 3.1 shows the specific feature descriptions. Table 3.1 divides the college English exam papers into three granularities for each knowledge point from coarse to fine, namely, class, subsection and knowledge point. The student's performance will change in each test. However, the long-term performance will stabilize within the same range. After multiple exams, students learn from their previous mistakes and can avoid the same mistakes, so their performance on exams will have some influence on subsequent exams.

Table 3.1: Description of college English achievement characteristics

Features	Format	Describe
Student Id	String	Student ID
Exam Id	Integer	Exam ID
Complexity	Integer	Complexity
ComplexityRate1-5	Float	Proportion of complex 1-5
Type1-10	Integer	Chapter classification 1-10
Subjects1-10	Integer	Subjects classification 1-10
Knowledge1-100	Integer	Knowledge points 1-100

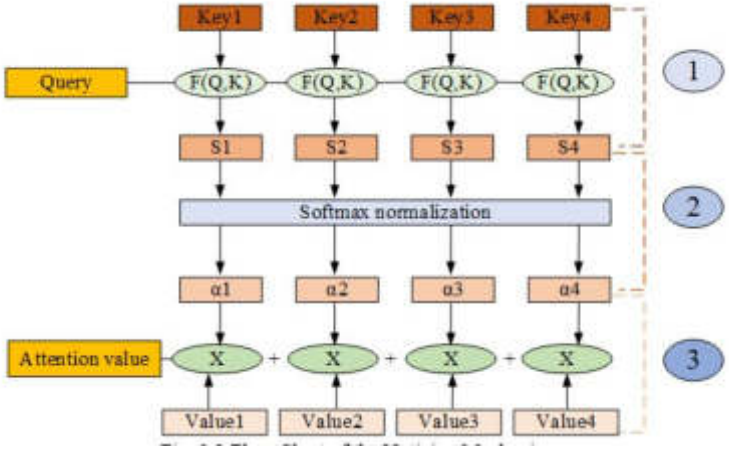

Fig. 3.2: Flow Chart of the Noticing Mechanisms

Therefore, the prediction of English grades in higher education can be seen as a time series prediction. In this study, student performance is predicted by the LSTM model, which incorporates an attention mechanism. The flow processing of the general attention mechanism is shown in Figure 3.2. In the general concentration mechanism, four key data values are available. The input is represented as a key-value pair (Q,K) of Q and K. The weights of the key-value pair are obtained by calculating the similarity between the Query and each Key. Then the values representing the importance are obtained by normalization. Finally, the attention values are obtained by summing the results for each value according to the importance values. The attention function can use addition or dot product. The attention function can be expressed as shown in equation 3.4.

$$Atteneion\left(Query, Source\right) = \sum_{i=1}^{L_x} Similarity\left(Query, Key_i\right) * \ Value_i \tag{3.4}$$

In equation (4), L_x is the total length of the input features. There are 3 main stages in the attention mechanism. The first step is to choose the appropriate method to find the correlation coefficient between the query and the key. Methods such as vector dot product method, vector similarity method and MLP neural network method can be used. The formula for the calculation method, see equation 3.5.

$$\begin{cases} F\left(Q, K_i\right) = Q^T K_i \\ F\left(Q, K_i\right) = \frac{Q^T K_i}{\|Q^T\| \|K_i\|} \\ F\left(Q, K_i\right) = MLP\left(Q^T, K_i\right) \end{cases} \tag{3.5}$$

In equation 3.5, $F\left(Q, K_i\right)$ is the correlation coefficient. Qis the Query. K_i is the different keyword Key. For K_i, the correlation coefficient $F\left(Q, K_i\right)$ can be expressed as S_i. The previous correlation coefficients are

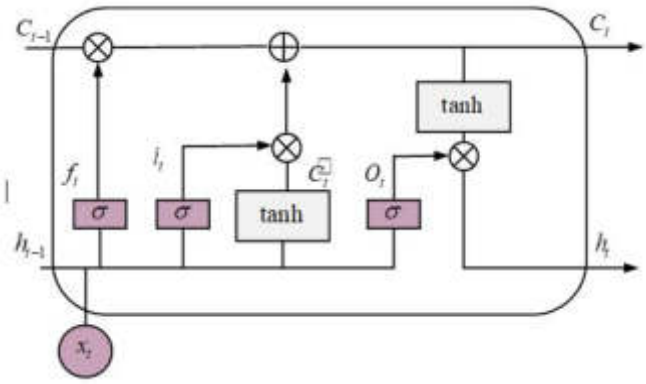

Fig. 3.3: Cell Architecture of LSTM

processed using Softmax on the second stage to obtain the weighting coefficients. The two advantages of this processing are that all keyword weights are processed as a probability distribution with a sum of 1, and that the importance of important keywords can be increased by its own function. The result of the Softmax formula is shown in equation 3.6.

$$a_i = Softmax\left\{(\right\} S_i) = Softmax\left\{(\right\} F\left(Q, K_i\right)) = \frac{e^{F(Q,K_i)}}{\sum_{j=1}^{L_x} e^{F(Q,K_i)}} \tag{3.6}$$

In equation 3.6, a_i is the weighting factor corresponding to K_i. In the third stage, the weighting coefficients a_i and V_i are calculated to obtain the final attention values, as shown in equation 3.7.

$$Attention\left(Q, K, V\right) = \sum_{i=1}^{L_x} a_i V_i \tag{3.7}$$

In equation 3.7, V_i denotes the value of the weight coefficient. LSTM is controlled by input, output, and forgetting gates, which enhance its long-term memory capability and effectively solve the gradient disappearance while filtering relatively unimportant information and reducing training time. The complete LSTM cell state is displayed in Figure 3.3.

From Figure 3.3, in the LSTM cell state, C_{t-1} is the cell preservation state after the previous processing. $h_{t-1}$is the retained state-of-play of the latent level after the last processing. σ is the input data where the sigmoid function is performed. $\otimes$ represents the need to perform a dot product operation on the data. *tanh* represents the activation function operation to be performed on the data. In the LSTM cell, the forgetting gate is represented by f_t, the entry gate is represented by i_t, and the out gate is represented by o_t. The input data of LSTM is represented by x_t. The hidden state input to the next cell after completing LSTM is represented by h_t. The cell state input to the next cell after completing LSTM is represented by C_t. LSTM is mainly used to obtain information about the input feature. The attention mechanism helps it quickly sift out the important messages from many features and focus on the most helpful information. Unimportant data are filtered out to increase the training efficiency of the mode. The $Att - LSTM$ market mode is designed by combining the attention mechanism. The model has good results for predicting English grades in colleges, and its architecture is shown in Figure 3.4.

Figure 3.4 shows that the college English grade prediction model of Att-LSTM contains a five-layer structure with an input layer, an LSTM, an attention mechanism, a fully connected layer and an output layer. The input layer is to import the student performance data into the model. Various data related to students and courses have been filtered and constructed through feature engineering. Feature vectors are constructed based on historical examination paper information, knowledge and performance information that can be identified.

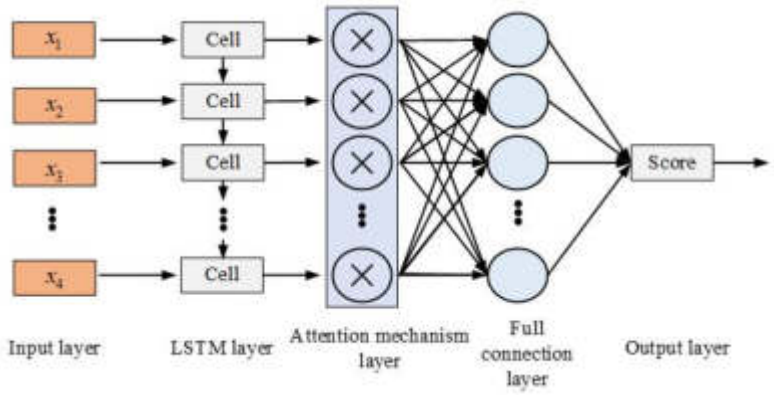

Fig. 3.4: Att LSTM Model Architecture

The exam count window is n. The feature window for consecutive exams is X_n. See equation (3.8) for details.

$$\begin{cases} X_n = (x_1, x_2, \ldots, x_n) \\ x_n = (r_1, r_2, \ldots, r_k) \end{cases} \tag{3.8}$$

In equation (3.8), x_n represents the nth test, where the data features of this test are represented by r_k. The LSTM layer is governed by three doors: the forgetting door, the input and the lower gate. The LSTM first filters the cell states by the activation function of the forgetting gate. A vector is calculated from the secrecy state h_{t-1} at the former time $t-1$ and the current input information x_t, and the vector takes values within 0-1, indicating the degree of data retention corresponding to the cell state. No retention at all is represented by 0 and full retention is represented by 1. The specific calculation is shown in equation (3.9).

$$\begin{cases} f_1 = \sigma\left(W_f x_t + U_f h_{t-1} + b_f\right) \\ \sigma(x) = \text{sigmoid}(x) = \frac{1}{1+e^{-x}} \end{cases} \tag{3.9}$$

In equation (3.9), f_1 is the forgetting gate. x_t is the input message for the present. W_f and U_f are the parameters of importance. b_f is the parameter for the correction offset. After the calculation of the forgetting gate is completed, the calculation of what new data should be entered for the cell state is then done. The data are updated by the hide status h_{t-1} from the previous time t-1 and the present input information x_t. Then the new candidate memory cell $\widetilde{C}_t$ is obtained using h_{t-1} and x_t via *tanh* function, calculated as shown in equation (3.10).

$$\begin{cases} i_t = \sigma\left(W_i x_t + U_t h_{t-1} + b_i\right) \\ \tilde{C}_t = \tanh\left(W_{\tilde{c}} x_t + U_{\tilde{c}} h_{t-1} + b_{\tilde{c}}\right) \\ \tanh(x) = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}} \end{cases} \tag{3.10}$$

In equation (3.10), i_t is the input gate for the current operation t. The parameters of importance are W_i, U_i, $W_{\widetilde{C}}$, and $U_{\widetilde{C}}$. $b_{\widetilde{C}}$ is the correction offset. $\widetilde{C}_t$ is the state of the memory cell selected for the current operation. $tanh\left\{(\right\} x)$ is the hyperbolic tangent function. Once $\widetilde{C}_t$ is calculated, C_{t-1} is updated and the value after C_t is determined. However, after x_t passes through i_t, i_t will use $\sigma\left(x\right)$ to fuse the data from $\widetilde{C}_t$ into C_t. The calculation results are shown in equation 3.11.

$$C_t = f_t \otimes C_{t-1} + i_t \otimes \widetilde{C}_t \tag{3.11}$$

In equation 3.11), C_{t-1} represents the memory cell state from the previous operation t-1. After calculating C_t, the information is sent to the next hidden layer of cells based on h_{t-1} and x_t. Then *tanh* is used to calculate

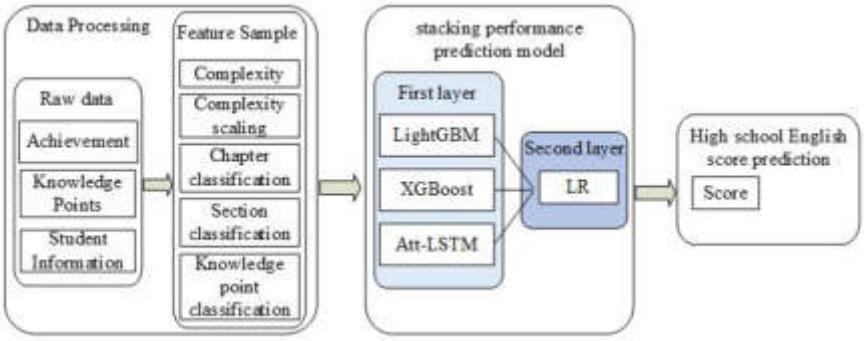

Fig. 3.5: Schematic Diagram of Student Achievement Prediction Model

a vector at o_t to obtain the final result. The calculation steps are shown in equation (3.12).

$$\begin{cases} \sigma_t = \sigma\left(W_o x_t + U_o h_{t-1} + b_o\right) \\ h_t = o_t \otimes \tanh\left(C_t\right) \end{cases} \tag{3.12}$$

In equation (3.12), o_t is the outgate. W_o and U_o are the significance parameters. b_o is the correction offset. x_t is the data source for the current operation t. h is the current hidden status. The input feature information is captured at the attention mechanism layer, and low-impact features are filtered out. The fully connected layer aggregates the results of the attention regime tier into the final prediction data.

3.2. Stacking-based multi-model overlay prediction model for English language performance in higher education. The stacking algorithm combines multiple prediction models and uses the prediction results of each model as a new training set for retraining, thus improving the prediction performance and making the predictions more stable. The construction of the Stacking model consists of two main layers, one consisting of three base regressors, LightGBM, XGBoost and Att-LSTM. The second is a meta-regressor using the LR algorithm, which uses the output data from the first layer as its input, and LR to make the final prediction of student performance. This constitutes a stacking prediction model with a two-layer structure, which is shown in Figure 3.5 below.

Figure 3.5 shows that in the first level of the training model, the whole data collection is organized first into a single set for training D_{train} and a test set at D_{test}. The three machine learning algorithms are then trained separately to obtain the three base regressors M_1, M_2, and M_3. To guard against modes that perform well on already existing known domains and behave badly on an unknown dataset, it is essential to ensure the generalization capability of the scale. In this study, a five-fold cross-validation method is applied to each underlying regressor during the definition. The set of training is partitioned into D^1_{train}, D^2_{train}, D^3_{train}, D^4_{train}, and D^5_{train} and each copy is taken as the validation set in turn for five times iterative coaching. The mode expression for each training is shown in equation 3.13

$$M^k_t = N_i\left(D_{train} - D^k_{train}\right) \tag{3.13}$$

In equation 3.13, M^k_i is the mode produced by the algorithm at the crisscross certification training. N_i is the $i-th$ algorithm. $i \in (1,3)$, $k \in (1,5)$. The trained base regressor M^k_i predicts the remaining validation set. The specific calculation is shown in equation 3.14.

$$\begin{cases} \hat{Y}^k_i = M^k_i\left(D^k_{\text{train}}\right) \\ \hat{Y}_i = \left(\hat{Y}^1_i, \hat{Y}^2_i, \hat{Y}^3_i, \hat{Y}^4_i, \hat{Y}^5_i\right) = \left(\hat{y}^1_i, \hat{y}^2_i, \hat{y}^3_i, \ldots, \hat{y}^n_i\right)^T \end{cases} \tag{3.14}$$

In 3.14, $\hat{Y}^k_i$ is the set of predictions from base regressors for the cross-validation training using M^k_i. $\hat{Y}_i$ is the predicted value of D^k_{train} for all validation sets for the $i-th$ base regressor after 5 cross-validations. During

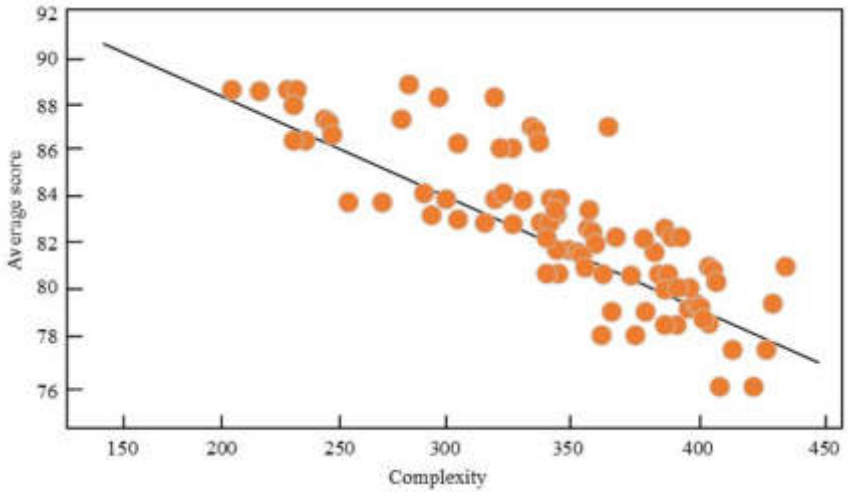

Fig. 4.1: Complexity of Papers and Mean Score Spread of the School Community

the cross-validation process, the base regressor M_i^k predictions at D_{test} are calculated. This average is then used as the test set for the next regressor. The detailed calculation is shown in equation 3.15.

$$\begin{cases} \hat{Z}_i^k = M_i^k\left(D_{\text{test}}\right) \\ \hat{Z}_i = \frac{1}{5}\sum_{k=1}^{5}\hat{Z}_i^k = \left(\hat{Z}_i^1, \hat{Z}_i^2, \hat{Z}_i^3, \ldots, \hat{Z}_i^m\right) \end{cases} \tag{3.15}$$

In 3.15, $\hat{Z}_i^k$ is the prediction result of the crisscross certification training of the $i-th$ base regressor used for the test set. $\hat{Z}_i$ is the mean of the predictions from the base regressor for the $i-th$ cross-validation. In the run of the linear regression model, the mediated results derived from the basis regressor in the first run are used in the stacking algorithm to construct a new training set S_{train} and test set S_{test}. The data formats for S_{train} and S_{test} are $\left(\left(\hat{Y}_{1i}, \hat{Y}_{2i}, \hat{Y}_{3i}\right), y_i\right)$ *and* $\left(\left(\hat{Z}_{1j}, \hat{Z}_{2j}, \hat{Z}_{3j},\right), y_j\right)$, and the prediction results are shown in equation '3.16.

$$\begin{cases} M_{\text{stacking}} = LR\left(S_{\text{train}}\right) \\ \text{PredSet} = M_{\text{stacking}}\left(S_{\text{test}}\right) \end{cases} \tag{3.16}$$

4. Experiments and Analysis of English Performance Prediction in Universities Based on Stacking Integration Model.

4.1. Experiments and analysis based on the Att-LSTM prediction model. In terms of feature-building choices, students' test scores were generally influenced by test difficulty. The harder the test question, the more challenging it is to obtain a high score. All knowledge points in English in higher education were categorized, and labelled, and their complexity determined. The distribution of the correlation between the complexity of a paper and the average score in a particular exam is shown in Figure 4.1 below.

Figure 4.1 showed that there were 5 levels of paper complexity, with the difficulty categorized into 1-5. The complexity of the paper was determined for a given examination. Overall, the complexity of the paper was negatively correlated with the mean score, the more difficult the paper, the lower the student's score. To verify the effectiveness of a neural network long and short-term memory performance prediction model incorporating an attention mechanism in predicting English performance in higher education, three benchmark models were used in the experiments for comparison. To further ensure the stability of the experimental results, a quintuple across the verification process was employed to split the database into 5 equal portions. One of them was used as the validation set, and the remaining four were used as the training set. The models were trained on the

Table 4.1: Experimental results

Models	Evaluation Indicators	1	2	3	4	5
RF	MAE	4.597	4.581	4.569	4.602	4.599
	RMSE	6.564	6.547	6.534	6.571	6.564
	R2	0.241	0.211	0.211	0.268	0.262
RNN	MAE	4.435	4.378	4.388	4.413	4.399
	RMSE	6.415	6.34	6.348	6.325	6.366
	R2	0.284	0.291	0.28	0.281	0.284
LSTM	MAE	4.269	4.295	4.284	4.292	4.291
	RMSE	6.23	6.266	6.261	6.262	6.251
	R2	0.244	0.239	0.245	0.233	0.247
Att-LSTM	MAE	4.213	4.219	4.208	4.217	4.204
	RMSE	6.136	6.175	6.164	6.178	6.146
	R2	0.244	0.236	0.248	0.238	0.248

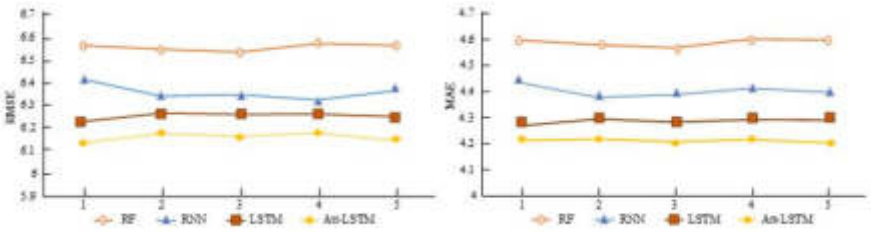

Fig. 4.2: Comparison of Forecast Results of Different Indicators

training set using different machine-learning algorithms. By iterating five times, the trained model was tested on the validation set for its effectiveness and predicted a result on the testing machine to obtain five test results. finally, the five results were averaged as the final model prediction results in Table 4.1.

In Table 4.1, the experiments provided statistics on the prediction findings of the different modes. The prediction results of the prediction models constructed by the four model algorithms tended to be stable over the five training sessions over multiple training sessions. Figure 4.2 compares the five prediction experiments for different students' performance prediction models at different metrics for a more intuitive view of the individual metrics.

In Figure 4.2, the performance metrics for each model were increasingly better from RF to Att-LSTM. The Att-LSTM model outperformed the other benchmark modes. Since the Att-LSTM model incorporated an attention mechanism, it could better capture the more valuable information when processing the data, and the prediction results would be better. However, to further ensure the stability of the experimental results evaluation, similar to the previous experimental setup, the constructed dataset was divided randomly into training and testing sets, and the ratio of the two data subsets was kept 8:2. A five-fold validation of crossover was used and the mean value was used as the final mode metric. The experimental outcomes are listed in Table 4.2.

From Table 4.2, the effectiveness of the Att-LSTM model in predicting English grades in higher education could be improved when the temporality of the dataset was enhanced. By comparing the different data results, the error was reduced by 1.04% on the MAE metric, 0.53% on the RMSE metric, and its value was improved by 4.12% on the R2 metric. Across the metrics, the addition of the new feature dataset resulted in better prediction results for the Att-LSTM mode. It was demonstrated that the Att-LSTM grade prediction model could achieve the task of student grade prediction on both datasets and had relatively good results.

4.2. Experiments on predicting English performance in higher education based on stacking integration model. To verify the effectiveness and accuracy of a stacking multi-mode overlay prediction

Table 4.2: Att-LSTM model prediction results

Models	Dataset	MAE	RMSE	R2
Att-LSTM	D1	4.201	6.142	0.214
	D2	4.112	6.121	0.221

Table 4.3: Att-LSTM model prediction results

Models	Evaluation Indicators	1	2	3	4	5
LightGBM	MAE	4.211	4.213	4.239	4.211	4.179
	RMSE	6.154	6.121	6.201	6.189	6.159
	R2	0.124	0.101	0.101	0.118	0.132
XGBoost	MAE	4.175	4.148	4.188	4.163	4.201
	RMSE	6.180	6.129	6.168	6.151	6.159
	R2	0.132	0.141	0.130	0.150	0.141
Att-LSTM	MAE	4.145	4.125	4.139	4.142	4.139
	RMSE	6.123	6.126	6.129	6.122	6.131
	R2	0.224	0.231	0.230	0.223	0.239
Stacking	MAE	4.131	4.121	4.121	4.122	4.114
	RMSE	6.114	6.125	6.101	6.101	6.046
	R2	0.230	0.231	0.229	0.232	0.238

model for college English grades, a comparison experiment was conducted using a Stacking integrated model with the base regressors LightGBM, XGBoost, and Att-LSTM. Five experiments were conducted on each of the four models in the training set, and the mean was obtained as the final test result, as indicated in Table 4.3.

In Table 4.3, the Stacking integrated model had improved in terms of evaluation metrics compared with the single performance prediction models, namely XGBoost, LightGBM, and Att-LSTM. To more intuitively verify the various performance of the Stacking integrated model and observe its stability, the experimental results of cross-validation of each model on different data sets were counted, and the change curves of MAE and RMSE of different prediction models under five experiments were plotted. This is shown in Figure 4.3. From Figure 4.3, the Att-LSTM model outperformed XGBoost and LightGBM in all indicators of the first three prediction models and achieved better experimental results by capturing the changes in students' historical performance. In the above figures (a) and (b), the XGBoost model had large fluctuations in the prediction of grades in the face of different data, while the Stacking integrated prediction model could avoid poor prediction and large overall deviation due to one regressor by integrating multiple strong regressors, which improved the robustness and prediction accuracy of the model. After determining the base regressors and meta-regressors, the stacking-integrated student performance prediction model was constructed. The experimental results showed that the Stacking integrated college English performance prediction model would have better prediction results than using only the base regressor.

5. Conclusion. The study addressed the problem of predicting English grades for students in higher education. Using a dataset of course knowledge points and historical English grades of college students, two prediction models were designed for grade prediction, thus enhancing the applicability of student grade prediction. Feature engineering was established based on students' test scores. Attributes with strong correlation to grades could be filtered out, while those with weak correlations were excluded. Attributes with test paper complexity were selected for the next grade prediction. The neural network long and short-term memory performance prediction model incorporating the attention mechanism is more effective than any other models. In further experiments, by comparing the results of different data, the error was reduced by 1.04% on the MAE metric, 0.53% on the RMSE metric, and its value was improved by 4.12% on the R2 metric. Across the metrics, the addition of the new feature dataset resulted in better prediction findings for the Att-LSTM model. This

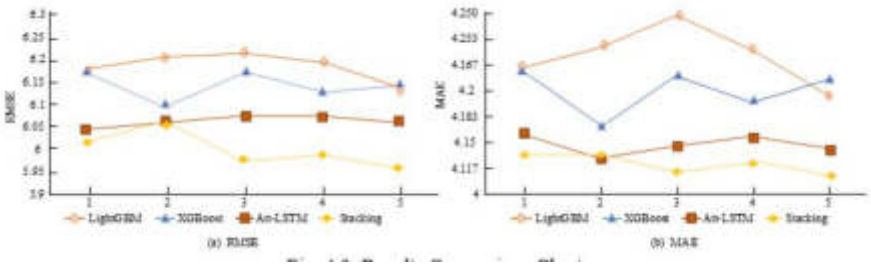

Fig. 4.3: Results Comparison Chart

indicated that enhanced dataset temporality could improve the efficiency of the Att-LSTM mode in predicting English grades in higher education. The stacked integrated prediction model, by integrating multiple strong regressors, could avoid poor prediction and excessive overall bias due to one regressor and improve its robustness and prediction accuracy.

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APPLICATION OF ANN IN TOURISM BUSINESS DEVELOPMENT FOR DEMAND FORECASTING AND MANAGEMENT OF TOURISM HEADCOUNT

HONGYING ZHANG* AND LINGYUN JIANG†

Abstract. With the rapid development of tourism, it is imperative to forecast tourism demand to maintain the long-term stable development of the tourism industry and make good planning for future tourism enterprises. The study uses the classical model of artificial neural network-BP neural network for tourism number demand prediction, given the problems of traditional BP neural networks, such as prematurity and poor convergence speed, this paper studies the iterative optimization of the algorithm of particle swarm fusion immune mechanism and finds out the optimal network parameters, to build an IAPSO-BP tourism demand prediction model. Tourist amounts from 2007 to 2017 in certain area-related data samples, the training model of iterative speed and fitting effect, and the rolling forecasting method will be used to predict the 2018-2022 years of travel. It can be seen from the convergence curve that the convergence speed of parameter optimization of the IAPSO algorithm is the fastest; the improved IAPSO-BP network has the best training fitting effect, with a relative average error of 2.03% and an absolute average error of 4.37%, which is better than other forecasting methods. The IAPSO-BP prediction model has higher accuracy and better performance, which can provide an effective basis for the development planning of tourism enterprises and has higher practical application value.

Key words: : tourism enterprises, BP neural network, demand forecasting, immune particle swarm

1. Introduction. Tourism is booming as people's living standards improve and their spiritual and cultural needs grow. Conducting tourism demand forecasting in future management planning work is extremely important [23]. Establishing effective and scientific tourism demand forecasting can provide tourism enterprises and the tourism industry with future directions for tourism development, help managers plan the rational application of tourism facilities and other resources, and provide a strategic basis for tourism companies to develop their development [9]. Due to the many factors affecting tourism demand, traditional forecasting models' demand prediction is ineffective; the prediction error is large, and the search for high-accuracy forecasting methods is an important issue in tourism research. Artificial neural networks are systems that simulate the brain to process information efficiently and have good classification and prediction functions. Among them, feedforward back propagation neural network (BPNN) has high fault tolerance and is widely used in various fields [25]. In traditional BPNN, the training is prone to local optimal and slow learning convergence, the research uses particle swarm algorithm combined with immunity mechanism to improve the BP network, optimize the parameters of the neural network, enhance the global search capabilities, and avoid the phenomenon of "premature". Using the improved BP algorithm to construct the tourism demand prediction model can improve the accuracy of prediction, promote the long-term stable sustainable innovation and development of tourism enterprises, facilitate the improvement of the tourism system, and realise the rational management and utilization of tourism resources.

2. Related Work. Establishing effective tourism demand forecasting models and finding efficient tourism demand forecasting methods are important research topics for many researchers. park E research team proposed a method for forecasting tourism numbers from news data, using seasonal regression averaging to select news topics, and testing the effectiveness of the selected news topics in forecasting demand. the results confirmed that forecasting models using news topics outperformed comparison models and can promote close integration between tourism destinations and news media [16]. Xiao Y research scholars proposed a hybrid model to predict tourism traffic demand to avoid tourism congestion, using an integrated empirical model decomposition to remove noise interference from the sequence and using the search composite index for tourism traffic prediction.

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The model training results showed that compared with the contrast model, the prediction error of the proposed model is lower, instructions to remove noise interference can improve the model prediction accuracy [22]. Chen L researchers developed a multivariate prediction method using data rearrangement technology, grouping tourism demand sequences to represent specific poles of demand each year and then reordering them to predict seasonal demand. The Hong Kong demand forecasting empirical analysis concluded that the model could significantly improve the prediction accuracy compared to the traditional univariate model [5]. Breda E and other scholars used tourism flow data from Italy as a sample to estimate expenditure elasticity concerning income and exchange rate for tourism demand in Italy. They found that the elasticity of tourism expenditure concerning the exchange rate was negative, varying from -0.5 to -0.7 and between -0.5 to -0.7. The factors affecting expenditure are mainly the number of tourists [3]. Ouassou et al forecasted the tourist demand of the Moroccan region, and proposed a hybrid prediction method combining traditional methods with artificial intelligence techniques, from the analysis of the prediction results, the hybrid prediction method can overcome the limitations of both traditional and artificial intelligence techniques and outperformed other contrasting models, with high accuracy of prediction results [15]. Nasirzadeh F et al. proposed a prediction interval method based on artificial neural networks to predict people's labour productivity more effectively. The results indicate that the method constructed by the research institute can effectively predict the value of labour productivity and can be widely applied in different projects with very objective performance [14]. Yang F's team proposed an optimization method based on artificial neural networks to improve the prediction accuracy of diesel engine preheating and recovery systems. In the experiment, a genetic algorithm was introduced to improve the BP neural network, and 7 committed steps improved the system's output power. The results show that the optimized data error is small, and the prediction accuracy of the system is significantly improved [23].

With the good achievements of artificial neural networks in the field of prediction, more and more researchers carry out in-depth research. Jahani A. et al researchers added multiple layers of perceptrons to an artificial neural network model to analyze the impact of human activities on biodiversity, through the analysis of vegetation, soil and other variables, found that human activities can affect soil moisture and reduce the diversity of vegetation, the results of the study can help managers develop plans to reduce some human activities [8]. Al R scholars conducted a study on the prediction of tourism visits. They proposed using artificial neural networks as a computational tool to predict tourism visitation data using multiple regression. The results showed that the method showed the correlation of the predictor variables and improved the accuracy of the prediction, which can help tourism sector managers understand the visitation [1]. Soh A N et al. researchers. Used the tourism composite index to predict the fluctuation of the tourism market, and the results showed that using the seasonal adjustment method could highlight the signal of tourism demand, predict the prospective development of the tourism market, and provide an information basis for macro regulation of tourism development [19]. Mandal A research scholars used artificial neural network models to estimate engine emissions from new fuels as well as to check performance attributes, using different algorithms and functions for training, and experimental results showed that artificial neural networks helped to predict data from the early stages of the experiment and that pollution from new fuels was reduced under different engine load conditions. That detection using artificial neural networks was better than other methods [12]. Cachim P researcher proposed the use of artificial neural networks for modelling to deal with complex problems in the face problems such as wood design specifications, training multilayer feedforward neural networks for predicting the temperature of wood cross sections under fire; the investigation results showed that artificial neural networks can effectively predict the temperature of wood cross sections and the results obtained can help to calculate the strength of members [4]. Hota S and other researchers proposed combining elephant swarm optimization methods with ANN models to apply to the mutual fund NAV data prediction. The performance of the obtained model was compared with ANN, ANN-GA, and ANN-DE models during the experiment. The results indicate that the comprehensive performance of the proposed model has always been optimal [7]. Researchers such as Park A proposed a research method based on improved artificial neural networks and vector autoregression to effectively predict the US dollar exchange rate. The root mean square deviation is used as the index to compare the predictive ability of different models. The data shows that the performance of the model built by the Institute is better, and more than 30% has reduced the Root-mean-square deviation [17, 13].

A brief description of the research results at home and abroad shows that artificial neural networks are

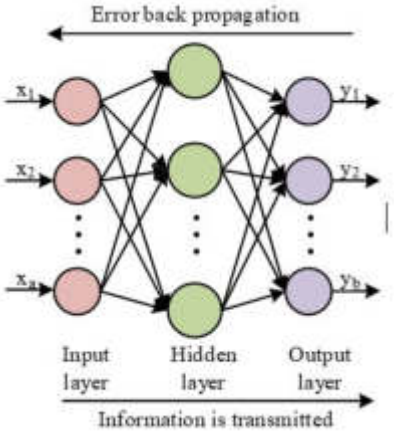

Fig. 3.1: BPNN structure diagram

widely used, and there are more methods to predict tourism demand. Still, the accuracy of the prediction needs to be improved. The study proposes a particle swarm algorithm combined with an immune mechanism to optimize the parameters of artificial neural networks and establish a tourism demand prediction model to improve the model prediction accuracy and promote tourism development.

3. Construction of a tourism demand forecasting model based on IAPSO-BPNN.

3.1. BP neural network algorithm and its optimization. Predicting tourism demand, providing a theoretical framework for business tourism management, and promoting the steady growth of tourism are all extremely important as the number of tourists increases. An information processing system called an artificial neural network (ANN) imitates the neural architecture of the human brain; it uses computers to combine electronic components to accomplish the brain's functions of memory, information processing and judgment, and so on. In practical applications, most use BP neural networks, which are the essence of the forward network in artificial neural networks [18]. In BP neural networks, information is propagated forward while the parameters in the network are corrected using error backward adjustment, gradually reducing the error between the ideal value and the actual value, achieving the effect of fast convergence to reduce the internal error of the system [24]. The three main components of BP neural networks are the input, hidden and output layers; by mutual connection weights between layer and layer, there is no connection between neurons; each layer contains multiple neurons, and a typical three-layer BP network structure is shown in Fig 3.1. When the BP network learning algorithm is run, it first selects a structurally reasonable network, sets all adjustable parameters (weights and thresholds) to uniformly distributed smaller values, and sets the expected error to ε. Secondly, the input sample calculation is performed, and the weights and thresholds of the output layer and hidden layer nodes are corrected. Finally, it sets $n = n+1$ and inputs new samples (or samples from a new cycle) until the network error meets the predetermined requirements. The input order of samples in each training cycle should be randomly reordered. When the BP neural network propagates forward, the data information passes through the input layer to the hidden layer, and the output layer obtains the result information through processing the hidden layer. It assumes that the input data information is $x = (x_1, x_2, \ldots, x_a)^T$, there are neural elements in the input layer, and a_1 neural elements in the hidden layer of the BP neural network, and the output information is $x' = R^{a_1}$. The output expression of the n neural element in the hidden layer is Equation (3.1).

$$x'_n = f\left(\sum_{i=1}^{a} w_{ij}x_i - \theta_n\right), n = 1, 2, \ldots\ a_1 \tag{3.1}$$

In equation (3.1),w_{ij} represents the weight value between the input layer and the hidden layer; x_i is the output of the input layer neuron, and $i\theta_k$ is the threshold between the two layers. The output layer has b neurons, and the output $y \in R^b$, and the output layer expression is shown in equation (3.2).

$$y_k = f\left(\sum_{n=1}^{a_1} w'_{ij}x'_n - \theta'_k\right), k = 1, 2, \ldots, b \tag{3.2}$$

In equation (3.2),w'_{ij} represents the weight between the hidden layer and the output layer; θ'_k is the threshold between the two layers and $f(x)$ is a continuously derivable Sigmoid function $f(x) = \frac{1}{1+e^{-x}}$, so the derivative of the function is equation (3.3).

$$f'^{(x)} = f(x)(1 - f(x)) \tag{3.3}$$

In practical application requirements, a bipolar Sigmoid function is also used, with an expression as in equation (3.4).

$$f(x) = \frac{1 - e^{-x}}{1 + e^{-x}} \tag{3.4}$$

After obtaining the output value and comparing it with the expected value, the error signal is propagated backwards, and the propagation process propagates forward from the output layer by layer, correcting the weights by feeding back the error so that the output value is infinitely close to the expected value. The error formula for calculating the first k sample is equation (3.5).

$$E_k = \frac{1}{2}\sum_{n=1}^{b}(y_{nk} - T_{nk})^2 \tag{3.5}$$

In equation (3.5),T_{jk} is the expected output value of the n neuron element; y_{jk} is the actual output value of the n neuron element. The correction formula for the connection weights of the neurons in each layer is shown in equation (3.6).

$$\Delta\ w(k+1) = \Delta\ w(k) - lr \times\ g(k) \tag{3.6}$$

In equation (3.6),lr stands for learning efficiency,$g(k)$ stands for local gradient vector, the expression is $g(k) = \frac{\partial E(w)}{\partial w}\Big|_{w=w(k)}$. and E stands for the error function. The execution flow of the BPNN algorithm is shown in Fig 3.2.

From Figure 3.2, it can be seen that the BP network model is based on the error backpropagation algorithm in artificial neural networks as its learning algorithm. Its learning process consists of four processes: The input mode is a "pattern forward propagation" process from the input layer through the middle layer to the output layer, and the desired output of the network and the actual output error signal of the network are corrected layer by layer through the middle layer to the input layer through the "error backpropagation" process of correcting the connection weight, The process of network "memory training", which involves the repeated alternation of "mode forward propagation" and "error back propagation", is the process of "learning convergence" where the global error of the network tends to the minimum. The nonlinear mapping ability of BPNN is strong, and each layer of the structure can be set with arbitrary parameters to obtain different effects according to the actual application, but the essence of the BP neural algorithm is using the gradient descent method, and the initial conditions can easily affect the performance of the algorithm [21]. The network training process will only go "downhill", which is very easy to appear prematurely and the global search ability is not strong; the BP algorithm has a fixed learning factor in the learning process, and the learning factor has certain values to achieve the minimum final error, which seriously affects the convergence speed of the algorithm. The amount of hidden layers and nodes in the network structure is difficult to determine, and there is no rigorous explicit

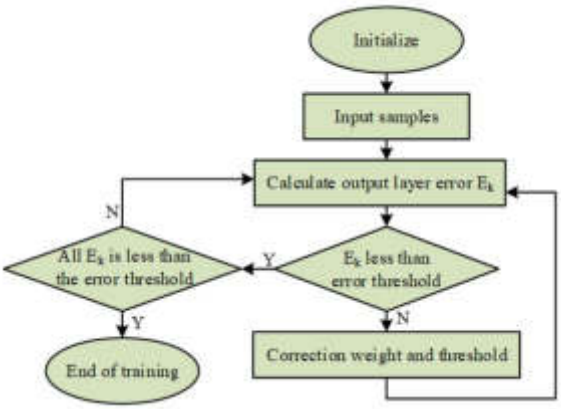

Fig. 3.2: BPNN algorithm execution flow chart

data support, and can only rely on experience, while in practical applications, the laws of the problem vary greatly and the structure is more difficult to determine, these shortcomings make BP neural networks much less effective for wide application [11]. In order to avoid the premature phenomenon of the BP algorithm and enhance the global search ability, the study uses the algorithm of particle swarm combined with an immune mechanism to train the network structure, and the results obtained are used as the parameters of the BP algorithm, which is trained to search for the global optimal parameters.

In Particle Swarm Optimization (PSO), particles determine the distance and direction of flight based on the velocity of the current optimal particle and the fitness value, search around the current optimal particle, and update their position information as the number of iterations increases until the global optimum is found [2]. In the P dimensional search space, there exists a population of M particles, and the ith particle' position in space is represented by $X_i = (x_{i1}, x_{i2}, \ldots, x_{iP}), i = 1, 2, \ldots, M$, the velocity variable of the ith particle is represented by $V = (v_{i1}, v_{i2}, \ldots, v_{iD})$. The particle fitness is generated according to the objective function, the optimal particle information obtained from the current search is represented by $P_i = (p_{i1}, p_{i2}, \ldots, p_{iP})$, and the location information of the optimal individual in the population is represented by $P_g, g \in \{1, 2, \ldots, M\}$. During the iteration, the particle is updated with the operation formula shown in equation (3.7).

$$\begin{cases} V_i^{t+1} = \chi\left(wV_i^t + c_1 * r_1 * (P_i^t - X_i^t) + c_2 * r_2 * \left(P_g^t - X_i^t\right)\right) \\ X_i^{t+1} = X_i^t + V_i^{t+1} \\ w = w_{\max} - \frac{w_{\max} - w_{\min}}{num_{\max}} \times num \end{cases} \tag{3.7}$$

In equation (3.7), t is the amount of iterations,c_1, c_2 is the learning factor, which is generally positive,r_1, r_2 is usually a random amount distributed at$[0, 1]$; w represents the inertia weighting factor,$wmin_{max}$ stands for maximum and minimum of w; χ is the compression factor, the expression of which is given in equation (3.8).

$$\chi = \frac{2}{\left|2 - \varphi - (\varphi^2 - 4\varphi)^{\frac{1}{2}}\right|} \tag{3.8}$$

In equation (3.8),$\varphi = c1 + c2, \varphi > 4$. The PSO algorithm is a global optimization algorithm, simple operation, and very easy to implement, but PSO converges faster and tends to fall into a local optimum. The immune system's antigen recognition and memory learning capabilities can increase the abundance of the population, improve the global search ability and avoid "premature maturity". In this study, the immune mechanism is introduced into the particle swarm algorithm, and the particles are regarded as antibodies to ensure that the particles can maintain high fitness values; in each iteration, the global optimal individual obtained by the PSO algorithm is regarded as the immune factor, and the particles are "vaccinated" to update the particle swarm

by immune selection [6]. The particle swarm algorithm improved with the immune information processing mechanism is called Particle Swarm Optimization with Immune Algorithm (IAPSO). In the IAPSO algorithm, the excellent particles generated in each iteration are regarded as memory cells, and when the newly generated particles are less adapted, they are replaced by the memory cell particles; the particles are reselected based on the affinity between antigen and antibody for the randomly generated N particles, and the expression of affinity is shown in equation (3.9).

$$Q_i = \frac{1}{F_i} \tag{3.9}$$

In equation (3.9), F_i is the particle's fitness calculation formula function. The selection of new particles is based on the affinity value, and the selection probability determined by the affinity is given by equation (3.10).

$$P_{i1} = \frac{Q_i}{\sum_{u=1}^{M+N} Q_u} \tag{3.10}$$

The particle concentration can also determine the probability of selecting a new particle, and the particle concentration formula can be inferred from the fitness function, whose expression is given by equation (3.11).

$$D_i = \frac{1}{\sum_{u=1}^{M+N} |F_i - F_u|} \tag{3.11}$$

The probability of selection determined by the particle concentration is shown in equation (3.12).

$$P_{i2} = \frac{D_i^{-1}}{\sum_{u=1}^{M+N} D_u^{-1}} \tag{3.12}$$

The probability of particle selection is determined by both the affinity and the probability of particle concentration selection and is expressed in equation (3.13).

$$P_i = aP_{i1} + (1-a)\, P_{i2}, i = 1, 2, \ldots, M+N \tag{3.13}$$

In equation (3.13), a is the weighting factor, which takes a value between 0 and 1. The size of P_i is used to rank the $M+N$ particles, and the first N with the larger value is selected. In the vaccination mechanism of the immune system, one vaccination is completed by randomly selecting a particle at the new particle and swapping the position of the randomly selected particle at P_g; The immune selection of the vaccinated particles is done by comparison of fitness and probabilistic selection values for discarding.

The IAPSO algorithm is strong in global search and weak in local search, while the BP neural network algorithm is the opposite; Combining the two and training the network can improve the generalization ability as well as the prediction accuracy of the neural network [10]. The flow of the IAPSO-BP algorithm to train the network and obtain the optimization parameters is shown in Figure 3.3.

In Figure 3.3, setting the initial parameters and GenerateN particles, the individual fitness of particles is calculated, and the best ones are retained as memory particles. According to Equation (3.7), new N particles are generated, detect the fitness and replace them. A total of M particles were randomly generated, and N particles were selected from M+N particles according to the affinity concentration and particle concentration; It regenerates N particles by immunization and vaccination operations and repeats iterations until the optimal particles are obtained; It converts the optimal particles into the initial parameters of the BPNN, and the parameters are modified by BPNN algorithm.

3.2. Construction of IAPSO-BP neural network-based tourism headcount demand forecasting model. The factors that affect the demand for tourism numbers are mainly the attractiveness of the destination to tourists, the income of individual tourists, travel preferences, etc., which need to be taken into account when predicting the demand for tourism numbers to provide a basis for the development of its tourism enterprises. Designing a network prediction structure is a comprehensive problem that needs to be considered to meet a

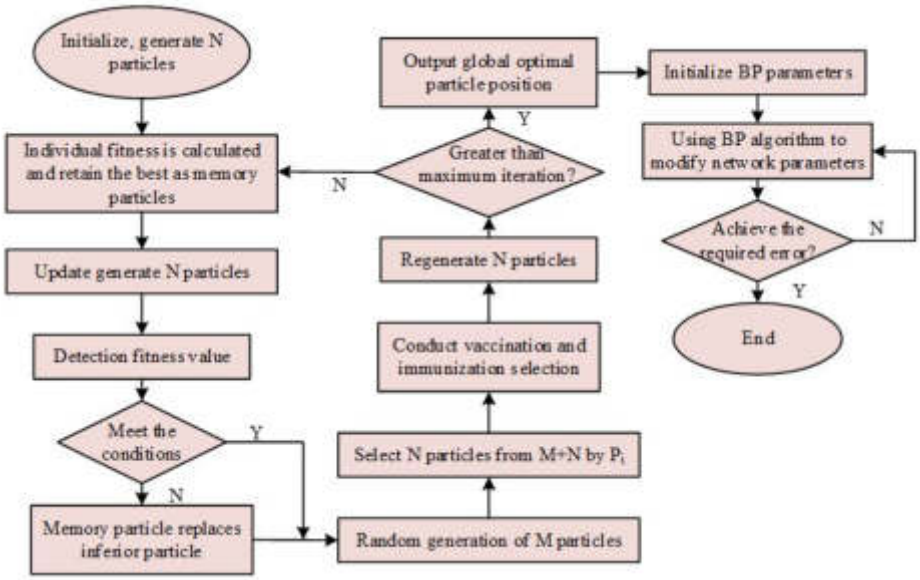

Fig. 3.3: IAPSO-BP algorithm training network flow chart

variety of different needs, and in constructing a model for predicting tourism headcount demand, it can simply be reduced to a problem of choosing a network size with a certain number of samples [20]. In a BP neural network structure, an implicit layer can solve the mapping relationship of any continuous function, and a simple three-layer BP neural network structure can accomplish the mapping of any space. With the increase of samples, can increase the amount of hidden layer neurons to improve the accuracy of network training, determining the amount of hidden layer neurons n_1 as shown in equation (3.14).

$$n_1 = \sqrt{n+m} + a \tag{3.14}$$

In equation (3.14), m and n represent the number of neurons in the output and input layers, $a \in [1, 10]$. The BP network model is a nonlinear system; if the initial value is too large, it will make the weighted output, and in the saturation zone of the function, the adjustment process of the weights cannot be stalled; the design process chooses a smaller initial value. The network is in the process of learning, the learning rate determines the amount of change in the resulting weights. A large learning rate indicates that the network is unstable, and when designing, a smaller learning rate is considered for training and adjusted at any time. In order to ensure that the data for sample training are of the same order of magnitude, the data must be normalized and pre-processed, and the processing formula is equation (3.15).

$$h_n = \frac{2\,(h - minh)}{maxh - minh} - 1 \tag{3.15}$$

In equation (3.15), h denotes the raw input data, and h_n denotes the pre-processed data. When training the network, sometimes overfitting occurs, and the sum of network weights and bias can be introduced on the basis of the mean squared difference MSE of the network as a performance function, which can be reduced to a certain extent; the network training method is studied using batch variation, and only one training function needs to be set for use in the network, which is relatively easy to operate. The tourism demand forecasting model using IAPSO-BP is shown in Fig 3.4. The indexes for forecasting are selected and the network parameters are initialized, the sample data and pre-processed data are input, the IAPSO algorithm is used for parameter search, the BP network model is constructed with the obtained optimal network parameter, the network learns itself, the threshold and weights are corrected, and the forecasting results are finally obtained.

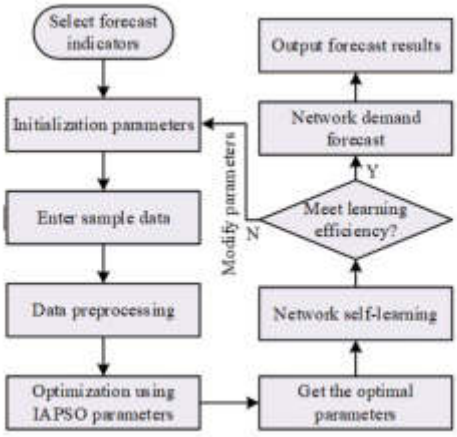

Fig. 3.4: IAPSO-BP prediction model flow chart

Table 4.1: Basic experimental hardware environment

Parameter variables	Parameter selection
Operating environment	MATLAB
CPU dominant frequency	2.62Hz
GPU	RTX-2070
Operating system	Windows10
System processor	Intel Core i7-8700K CPU 3.70GHz
System running memory	32.0GB
Programming program	Python
Data analysis platform	SPSS24.0
Data storage system	MySQL

The IAPSO-BP tourism demand forecasting model uses the logical relationship of neural networks to predict the value of the future moment by analyzing the value of the past moment. Reliable raw data can improve the accuracy of the model's prediction results, and to ensure the reliability of the data, the data collected should reflect the local tourism trend, i.e. collecting tourism data information over a continuous period of time; the sample information is complete in terms of elements and variables The data should reflect the actual local situation. Forecasting methods include single-step forecasting, multi-step forecasting and rolling forecasting. The study uses a rolling forecast method to forecast tourism demand, starting with a single-step forecast, inputting historical data $X_i, X_{i+1}, \ldots, X_{i+n}$ and outputting the forecast X_{i+n+1} and repeating the iterations until inputting $X_{i+m-1}, X_{i+m}, \ldots, X_{i+m+n-1}$ and outputting the forecast X_{i+m+n} at m.

4. . Analysis of tourism demand forecasting model based on IAPSO-BP. To verify the effectiveness of the IAPSO algorithm in solving the BP network parameters, four standard functions were selected for simulation experiments. Before the formal start of the experiment, the basic hardware environment of the experiment should be set up, as shown in Table 1. To ensure the experiment, the number of iterations of all algorithms was set to 1000, the population size was 100, and it repeated many times for the different basic functions obtained. Figure 4.1 shows the convergence curves of PSO, IA and IAPSO under four standard functions.

From Figure 4.1, it can be seen that under the four standard functions, when the number of system iterations is 100, the convergence accuracy of the research method begins to enter a stationary period and approaches zero infinitely in the subsequent stages. At the same time, when the number of system iterations is about 400 times, the convergence accuracy of the GA algorithm and the IA algorithm begins to approach a plateau and

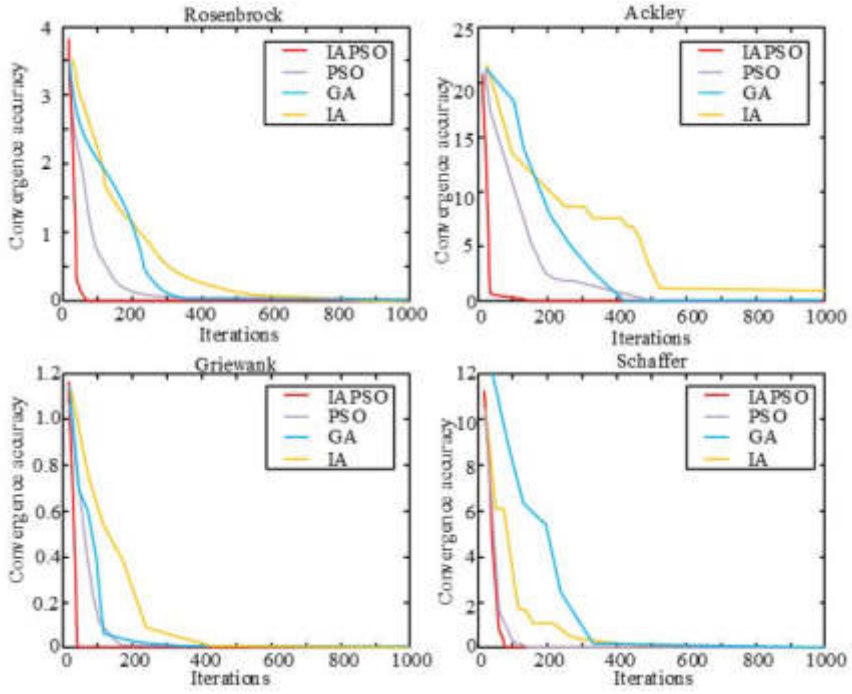

Fig. 4.1: Iterative curves of four algorithms

infinitely approaches zero. However, the rate of convergence has been slow, and there are obvious differences in the rate of convergence under the four functions. In addition, as the number of system iterations increases, the convergence accuracy of the PSO algorithm also decreases, and it performs a stable convergence accuracy state faster than the GA algorithm and IA algorithm. To sum up, the IAPSO algorithm has the fastest rate of convergence and the best performance, indicating that the IAPSO algorithm has the highest efficiency in BPNN parameter search. The number of tourists in a city from 2007-2017 was used as the network training sample, the number of tourists from 2007-2016 was used as the network input and the number of tourists from 2008-2017 was used as the output. The error threshold between the actual output value and the ideal output value is set as 0.01, and the neural structure of the network for predicting the number of people was determined to be 2-7-2. In order to test the performance of the proposed IAPSO-BP model, the training is compared with the basic BPNN model, the GA-BPNN model is improved using the genetic algorithm and the PSO-BPNN model is improved by particle swarm algorithm, and the minimum error plot of the network obtained from the training is shown in Fig 4.2.

From the analysis in Fig. 4.2, it can be concluded that the minimum error curves of the four neural networks have the same trend, all with the increase of training, the minimum error of the network slowly decreases, BP neural network in the training 7500 times, reached the set error, stopped training; GA-BP neural network in the training 6400 times, reached the set error to stop training; When the number of training reached 6000 times, PSO-BPNN The PSO-BPNN model reached the set error and stopped training when the number of training times reached 6000; the IAPSO-BP neural network reached the set error and stopped training when the number of training times reached 5000, indicating that the IAPSO-BPNN proposed in the study completed the training faster and performed better than other network models. The fitting effect of the prediction results obtained from the training is shown in Fig. 4.3.

From the analysis of the fitting effect in Figure 4.3, it can be seen that the predicted results of the four prediction models are consistent with the actual trend, but there are certain differences in the fitting effect. With the passage of time, the difference between the predicted results of the research methods and the actual

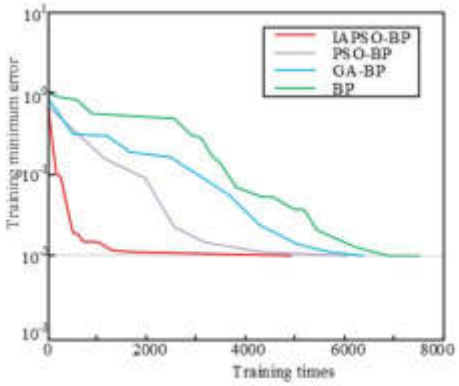

Fig. 4.2: Training minimum error result chart

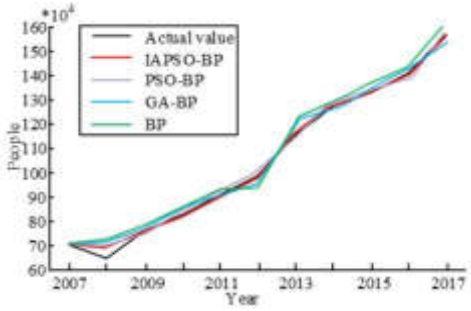

Fig. 4.3: Training fitting effect diagram

values becomes smaller and smaller, and it has always been in the state of the best fit. The fitting values of research methods, PSO-BP, GA-BP, and BP neural networks were 0.951, 0.932, 0.911, and 0.879, respectively. When the time was 2008, the number of tourists significantly decreased due to the impact of geological disasters, which resulted in inaccurate predictions from all four algorithms. The difference between the predicted curve of the BP neural network model and the actual value is significant, while the fitting effect of the GA-BP neural network model and the PSO-BP neural network has increased. Based on the above results, it can be concluded that the IAPSO-BPNN model constructed by the research institute has the highest prediction accuracy and high performance. To further illustrate the superiority of the IAPSO-BPNN prediction model, the errors of the predicted and true values were compared and the results of the relative mean error and absolute mean error obtained are shown in Table 4.2.

From Table 4.2, the relative mean error of the IAPSO-BPNN model is 0.83% smaller than PSO-BPNN, 1.64% smaller than GA-BP network, and 2.48% smaller than the BPNN; the absolute average error of the IAPSO-BPNN model is 0.75% smaller than the PSO-BPNN model, 3.42% smaller than the GA-BP network, and 3.86% smaller than the BPNN model 3.86% smaller, all indicating that the IAPSO-BPNN model prediction outcome have smaller errors and higher precision. Taking the number of tourists from 2007-2016 as the network input, the network calculated the number of tourists from 2008-2017 to get the prediction value of 2017, then the whole output was reused as a new input to calculate the number of tourists from 2009-2018 to get the predicted value of 2018, and the prediction number of tourists for each year from 2018 to 2022 was rolled out, and the prediction results are shown in Fig 4.4 is shown.

From Figure 4.4, it can be seen that over time, the predicted values of the four algorithms for the number of tourists' tourism demand gradually increase over time and are constantly changing. The prediction results of the IAPSO-BP neural network match the real situation best, with a prediction accuracy of up to 0.974. The

Table 4.2: Comparison of prediction precision

Prediction model	Relative mean error (%)	Absolute mean error (%)
BP	4.51	8.23
GA-BP	3.67	7.79
PSO-BP	2.86	5.12
IAPSO-BP	2.03	4.37

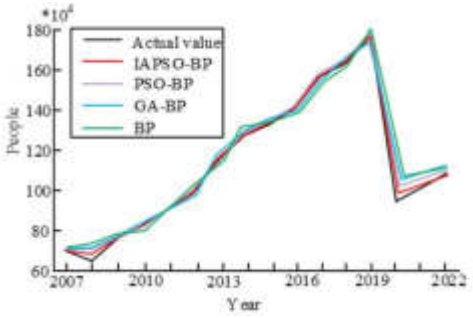

Fig. 4.4: Tourist demand forecast results

result curve of the PSO-BPNN model is in good agreement with the actual value, with a small error and a prediction accuracy of up to 0.928; The difference between the predicted results of the GA-BPNN model and the actual values is small, with a prediction accuracy of 0.913; The prediction accuracy between the number of tourism demand predicted by the BP model and the actual value is relatively high, and has always been at the lowest, with a prediction accuracy of only 0.901. The above results indicate that the degree of fit between the predicted curve of the number of people under the research method and the actual value is the highest, indicating that IAPSO-BPNN has the best prediction effect and superior algorithm performance. At the same time, it can be found that in 2008, the number of tourists suddenly decreased, which was caused by the earthquake disaster that year. However, from 2019 to 2020, the number of tourists dropped suddenly and significantly, which was because the outbreak of COVID-19 made forecasting more difficult. The box line plot in Fig 4.5 shows the dispersion of the absolute errors of the four forecasting network models. From Figure 4.5, the upper and lower quartiles, median and outliers of the absolute error box line plot of the BPNN model prediction are more than the other three neural networks, and the upper quartiles of the GA-BPNN model and the median of the PSO-BP are smaller than the upper quartiles and median of the IAPSO-BP network respectively, but both have more outliers than the IAPSO-BPNN model and overall, the IAPSO-BPNN outperformed the other three predictive neural networks in terms of prediction performance.

5. Conclusion. The tourism industry has opened up more and more development opportunities under the growing spiritual and cultural needs of people. Establishing tourism demand forecasting and doing a good job of tourism operation planning can develop the sunrise industry of tourism in a long-term and stable manner. The study uses the IAPSO algorithm to carry out parameter optimization of the BPNN, and the optimized parameters obtained establish the neural network predictive model, and the algorithm is tested and analyzed to predict the demand for the number of people conducting tourism in a certain area. The results show that the IAPSO algorithm parameters proposed in the study converge fastest and most efficiently in the search for optimization; among the four network models trained, the IAPSO-BP network reaches the set error the fastest, stopping training after reaching 5000 times; the rolling prediction fitting effect obtained, the IAPSO-BP network has the best fitting prediction curve, with a relative average error of 2.03% with the true value which was 0.83% smaller than the PSO-BPNN model, 1.64% smaller than the GA-BPNN model and 2.48% smaller than the BPNN model; the MAE was 4.37%, which was 0.75%, 3.42% and 3.86% smaller than other prediction models respectively; the prediction results of IAPSO-BPNN had smaller error with the true value, and the

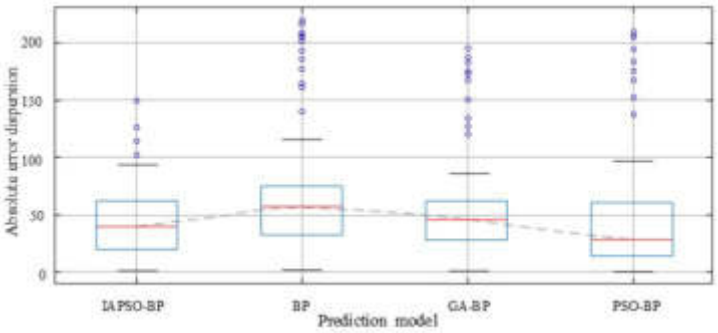

Fig. 4.5: Absolute error box diagram of four prediction models

prediction performance was better than other comparison models. The prediction results are more accurate and can provide a practical and effective basis for tourism enterprises and tourism economic management departments to formulate development plans and reasonably plan the allocation of resources in the tourism market. Although the research has achieved certain results, the training of the prediction model requires lots of historical data as samples, and the actual tourism statistics have obvious seasonal differences, the sample data is insufficient, which affects the precision of the predictive model, and the research on the application of the predictive model to more complex problems is not sufficiently studied. Due to the limitations of tourism demand, the experiment only applied the research method to predict tourism demand in southern regions such as Sichuan in China and did not apply the research method to other countries or regions for experimental data validation. Therefore, future experiments will focus on predicting more factors affecting tourism demand in other regions.

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APPLICATION OF FINANCIAL MATHEMATICAL MODELS COMBINED WITH ROOT ALGORITHMS IN FINANCE

YANFENG ZHANG*

Abstract. Investors in the financial markets must deal with various hazards, for which they must create prudent investment portfolios and risk management plans. A multi-objective optimisation approach is proposed using the root algorithm to create a multi-objective root system growth model based on many clusters. An investment risk management optimisation model based on root system growth is built into the study using distributed decision-making. To create a multi-objective root algorithm-based portfolio optimisation model, the Markowitz mean-variance model and a multi-objective root algorithm are employed. According to the findings, the multi-group multi-objective root system method has a real Pareto frontier solution that is more accessible, has a faster convergence rate, and has lower fitness values. The root algorithm's solutions are workable, and the final risk values of 0.0105, 0.0082, and 0.4623 for the 2, 4, and 6 investment objectives are all in the low-risk class range. The optimal set of solutions discovered by the algorithm had better distributivity and convergence. The Hypervolume values for the multi-group multi-objective root algorithm were 5.5298 and 3.9628 for the dual-objective portfolio and the tri-objective portfolio of investment return costs, respectively. The findings of this study can guide the development of portfolio and risk management strategies.

Key words: Financial Mathematics; Portfolio, Risk Management, Root Algorithms, Multi-Objective Portfolios

1. Introduction. A financial portfolio is a collection of various assets combined in a specific proportion with the goal of maximising stability and return on investment (ROI) while minimising risk management (RM). Investors are exposed to risks such as exchange rate risk, market risk, credit risk, and liquidity risk in the financial markets [20]. Investors must create and modify their portfolios differently based on their investment goals, risk tolerance, and other considerations. Financial institutions must employ financial portfolios and RM technologies to manage and mitigate risk, increase operational effectiveness, and boost profitability [13]. This study uses root algorithms (RA) as its foundation. It develops a Multi-Population Multi-Objective Root Algorithm (MPMORA), an Optimization Model for Investment Risk Management Based on Root Growth (OMIRM-RG), and a Portfolio Optimization Model Based on a Multi-objective root algorithm (POM-MORA) to address a portfolio and RM issues in the financial sector. There are four sections to the study. The study of objective optimisation issues in the financial sector and the use of bio-inspired algorithms (BIA) to solve combinatorial optimisation problems are covered in the first section. The second section is based on RA and uses the MPMORA, OMIRM-RG, and POM-MORA constructions. The third section examines the experimental analysis and performance testing of the three models, and the fourth section wraps up the study and identifies its flaws.

2. Related Works. The application of BIA in combinatorial optimisation problems has increased with the growth of bionics and computer science, and some specialists and academics have done studies in this area. To discover and study the occurrence of hazards in the Internet financial market, Qu et al. combined data mining technology and deep learning for processing and analysis. They also presented a radial basis function neural network for ant colony algorithm optimisation. The results of the experiments revealed that this neural network's real error was 0.249, which was different from the goal error of 0.149, demonstrating that the optimisation algorithm may improve calculation results and deliver targeted RM measures [6]. Y Li and colleagues developed a useful design optimisation technique for the symmetry of metamaterial cells. This approach involves the introduction of a cell division mechanism and the development of a new selection mechanism based on this mechanism. The numerical results of the prototype metamaterial cell and the solution of the multi-objective test function showed that the newly proposed method performs better in multi-objective

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optimisation [14]. B R Ke et al. employed particle swarm optimisation techniques, genetic algorithms, and simulated annealing methods to optimise the departure times to lower the building costs and electricity prices of electric buses using a bus system in the Penghu Islands as a study. make sure that each new schedule's price is kept as low as possible without hurting traffic and customer demand. According to research by H, the outcomes demonstrated that departure times could be optimised using the combined strategy, with all costs being lower than the pre-adjustment costs [11]. Wu et al. state that the range of an underwater glider will be directly impacted by how much energy it uses. The parameter values are controlled using a particle swarm multi-objective optimisation technique, which maximises the glider's energy efficiency and location accuracy. Based on a dynamical model of the underwater glider and considering the consequences of unpredictable input errors, a computational model and evaluation procedure for measuring the glider's position accuracy and energy usage are proposed. According to experimental data, the model can boost energy efficiency and improve position accuracy [22].

Since risk is a component of investment activity and no investor or company can be fully risk averse, financial risk management is crucial. Several academics have studied the difficulties with objective optimisation in financial RM. M.A.M. Al Janabi examines the value-at-risk technique's modelling parameters in a market setting and develops a scenario optimisation method for assessing structured portfolios [15]. By assessing available portfolios under operational and financial constraints, experimental results demonstrate that the optimisation algorithm can advance portfolio selection and management in financial markets [2]. A Xie and colleagues take into account a typical risk-averse investor and develop a multi-objective model pricing framework for credit default contracts with periodic payments using a utility non-differential pricing technique. Additionally, buyers of credit default swaps with various trading objectives are investigated to investigate risk aversion's effects on investments. According to the results, credit default swaps might factor in the negative base formation of bonds that followed the financial crisis [23]. The risk preferences of asset liability managers are described by Y Zhang using a hyperbolic absolute risk aversion utility. A generalised drifting Brownian motion with non-Markovian drift and diffusion coefficients defines the cumulative liability process. The best investment plan is constructed by solving a recursively linked stochastic differential equation method using a backward stochastic differential approach. According to experimental data, the model solved the best investment strategy for various parameters [25]. F Chen et al. make the assumption that a financial firm's surplus process is a correlated jump-diffusion process. The insurance company and the financial firm involved in the transaction have a trust issue, and filtering extension techniques are employed to take advantage of the information and alter the insurance business's wealth-creation process. The dynamic mean squared deviation criterion is used to build a bi-objective optimisation model for insurance and investing. The outcomes demonstrated how the model affected the efficient frontier and the equilibrium strategy [3].

In conclusion, BIA is used to solve combinatorial optimisation problems in a variety of domains. However, its use in RM is uncommon. Therefore, this research blends RA with financial mathematical models to address multi-objective optimisation problems in investment RM, which is crucial in investment RM for the financial industry.

3. RA-based Financial Mathematics Model Construction. This section is divided into three parts to construct the model. The first part is based on RA and introduces a multi-objective optimisation strategy to construct MPMORA. The second part is based on RA and uses distributed decision-making to construct OMIRM-RG. The third part is based on a multi-objective RA and constructs POM-MORA based on the Markowitz mean-variance model.

3.1. Construction of MPMORA. . Root Algorithm (RA) is a data structure-based classification algorithm that can divide objects with similar features into the same group. The algorithm's fundamental step is to build a tree structure to represent the objects in the dataset and then iterate through the tree structure to classify the data [11]. The RA algorithm can process ordinary numerical data and handle more complex discrete and structured data. In addition, it is possible to adaptively adjust the tree structure to adapt to different data types and shapes [10]. Since the portfolio problem in financial mathematics is a multi-objective optimisation problem, a multi-objective optimisation strategy is introduced into the underlying RA algorithm to solve it and construct MPMORA. To solve the parameter problem in the model, a fast-dominated sorting method is adopted, and the concept of crowding distance is introduced. Fast undominated sorting stratifies all

individuals in the population, assigning an ordinal number to the undominated solution at each level until all individuals are graded [4]. Crowding distance can represent the distance between individuals; the equation is shown in equation (3.1).

$$ip n_j \text{ iff } i_{\text{rank}} < j_{\text{rank}} \text{ or } (j_{\text{rank}} \text{ and } i_{\text{distance}} > j_{\text{distance}} = i_{\text{rank}}) \tag{3.1}$$

In equation 3.1, j_{rank} and i_{rank} denote the non-dominance rank of individuals j and i respectively,j_{distance} and i_{distance} denote the crowding distance of individuals j and i respectively. When selecting particles, preference is given to particles with low non-dominance ranks, and if the non-dominance ranks are equal, the solution with the larger crowding distance is selected. The Pareto optimality criterion (POC) determines the optimal solution [16]. The definition is shown in equation (3.2).

$$\left| P_i(v) = 1 - \frac{S_i(v)+1}{|K'|} \right. \tag{3.2}$$

In equation (3.2) $S_i(v)$ denotes the fast, non-dominated solution ordering method and $|K'|$ denotes the size of the feasible solution. The equation for searching the maximum Pareto frontier solution (PFS) is shown in equation (3.3).

$$\max f(v) = \max\left\{k - \sum_{i=1}^{k} P_i(v)\right\} = \max\left\{\sum_{i=1}^{k}(1 - P_i(v))\right\} = \max\left\{\sum_{i=1}^{k}|1 - P_i(v)|\right\} \tag{3.3}$$

In equation (3.3), $\sum_{i=1}^{k} P_i(v)$ denotes the sum of all PFS and k denotes the total number of individuals. The individual target values are ranked using Global General (GG), an evaluation model that measures the probability of risk, and all individual target values with variability are first summed, with the equation shown in equation (3.4).

$$GM(X_i) @ \sum_{X_i \neq X_j} \max\left(\left(\prod_{m=1}^{M} f_m(X_i) - \prod_{m=1}^{M} f_m(X_j), 0\right)\right. \tag{3.4}$$

In equation (3.4), X_i and X_j denote two solutions and M denotes the set target number. Thus, having a smaller value of GM dominates the ordering of solutions. The equation for the solution's Global Density (GD) is shown in equation (3.5).

$$GD(X_i) = \sum_{\substack{j=1 \\ i \neq j}}^{pop} d_{i,j} \tag{3.5}$$

In equation (3.5), $d_{i,j}$ denotes the Euclidean distance between j and i . The solutions are ranked by GM and GD values and the equation is shown in equation (3.6).

$$GG(X_i) @ \frac{GM(X_i)}{GD(X_i)} \tag{3.6}$$

In equation (3.6), $GG(X_i)$ denotes the overall ranking of the solution X_i , indicating that the solution has a better distribution. In multi-population multi-objective RA, all particles are first divided into multiple populations, and individuals in the higher levels are selected using the principle of non-dominated solution ranking. According to the size of the crowding distance, the individuals with large crowding distances are selected to form the set of populations, and the particles are updated several times to obtain the final set of multiple populations. The flowchart of the algorithm for multiple populations with multiple objectives is shown in Fig 3.1.

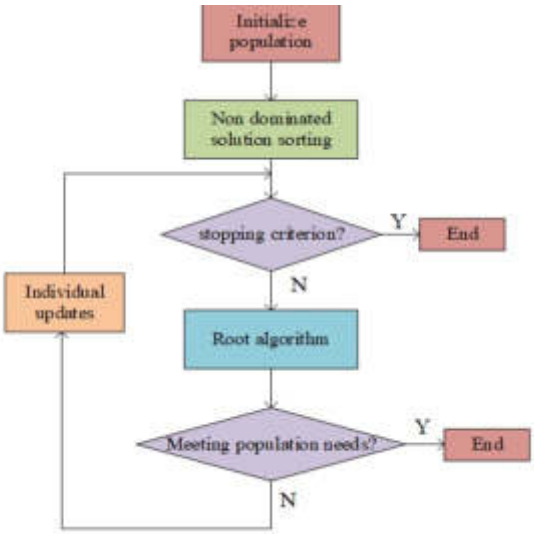

Fig. 3.1: Algorithm flowchart of multiple groups and multi-objective

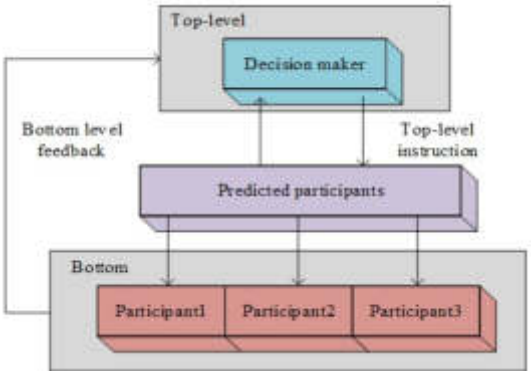

Fig. 3.2: Structure of DDM Decision model

3.2. Construction of OMIRM-RG.. A variety of investment tools and technical tools are frequently required to achieve investment risk management. For example, technical analysis and fundamentals, hedging of portfolios through financial instruments such as financial derivatives, and identification and prediction of investment risks through technical tools such as big data and artificial intelligence [5]. Therefore, distributed decision-making (DDM) is adopted to solve dispersed and complex problems in risk management, and a multi-objective root algorithm model is constructed. The core idea of this algorithm is to transform a multi-objective problem into a root problem, gradually explore the solution space through the root system's growth and branching, and select appropriate branch directions through distributed decision-making. The exchange and collaboration of information between different nodes can help to understand the global problem better and optimize the solutions of each sub-problem through reasonable decision-making. The upper layer model is solved taking into account the characteristics of the lower layer model, and the result of the solution is input to the lower layer and outputted if it meets the requirements, or fed back to the upper layer for re-solving if it

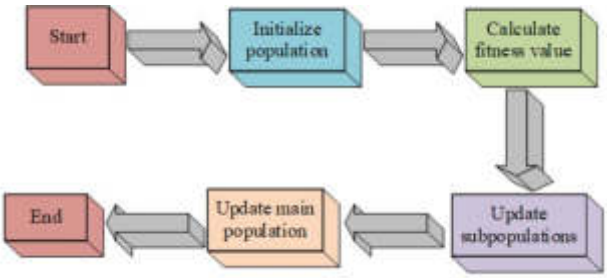

Fig. 3.3: Risk Management Flowchart Based on Root Algorithm

does not. The equation for solving the upper layer model is shown in equation (3.7).

$$\begin{cases} \min \sum_{i=1}^{M} \omega_i R_i \left(B_i\right) \\ \text{s.t. } \sum_{i=1}^{M} B_i \leq B_{\max} \\ R_i \left(B_i\right) \leq R_{\max}, i = 1, \text{ L}, M \\ B_i \in [0, K_i], i = 0, 1, \text{ L}, M \end{cases} \tag{3.7}$$

In equation (3.7), B_i denotes the investment funds received by the participant i and B_{max} denotes the maximum investment budget. $R_i \left(B_i\right)$ denotes the level of risk predicted by the decision maker for the participant, R_{max} denotes the maximum level of risk and ω_i denotes the weight. The solution equation for the lower-level model is shown in equation (3.8).

$$\begin{cases} R_i \left(B_i^*\right) \leq \min \sum_{h=1}^{N_i} \sum_{j=1}^{T} u_h f_{h_j}^h \left(x_{h_j}\right) d_j \\ \text{s.t. } \sum_{h=1}^{N_j} C_{i_h} \left(x_{i_h}\right) \leq B_i^* \\ x_{i_h} \in \{0, 1, \text{ L}, W_{i_h}\}, h = 1, 2, \text{ L}, N_i \end{cases} \tag{3.8}$$

In equation (3.8), x_{i_h} denotes the optimal strategy chosen by the participant, h denotes the risk factor,N_i denotes the number of risk factors faced by the participant,j denotes the risk level, T denotes the number of risk levels, and $f_{h_j}^h$ denotes the probability of risk occurrence. Since the problem solution of the upper model is a continuous function, while the problem of the lower model is a discrete function, RA is used to construct the distributed decision model [8]. The population is first initialised and the fitness function is used to solve for the fitness value, which is calculated as shown in equation (3.9).

$$\begin{aligned} F_T \left(X_{ik}^T\right) &= \sum_{\alpha=0}^{n} w_\alpha R_\alpha \left(X_{i(\alpha+1)k}^T\right) = w_0 R_0 \left(X_{ilk}^T\right) + F_B \left(X_{ikk}^L\right) + \phi \left(\sum_{\alpha=1}^{n+1} x_{i\alpha k}^T - \text{I}_{m\alpha\alpha}\right)^+ \\ &+ \eta \sum_{\alpha=1}^{n} \left(\sum_{\beta=1}^{m} \sum_{i=1}^{l} w_\alpha \mu_\beta f_{\beta\lambda} \left(\left|x_{i\alpha\beta kk}^L\right|\right) d_\lambda - R_{\max}\right)^+ \end{aligned} \tag{3.9}$$

In equation (3.9), $R_0 \left(X_{ilk}^T\right)$ denotes the risk level of the decision maker, ϕ and η denote penalty factors, μ_β denotes the weight of the risk factor, d_λ denotes the value corresponding to the risk rating, I denotes the number of risk ratings and $\left(\left|x_{i\alpha\beta kk}^L\right|\right)$ denotes the location index. Based on the solved fitness values, the current optimal particle is determined and the particle population is updated by equation (3.7). Distributed decision-making achieves optimisation of the decision problem through communication and collaboration between the upper and lower models, enabling the whole system to make rapid and efficient decision responses when faced with RM decision problems [12]. Fig 3.3 depicts the RA-based RM flow chart.

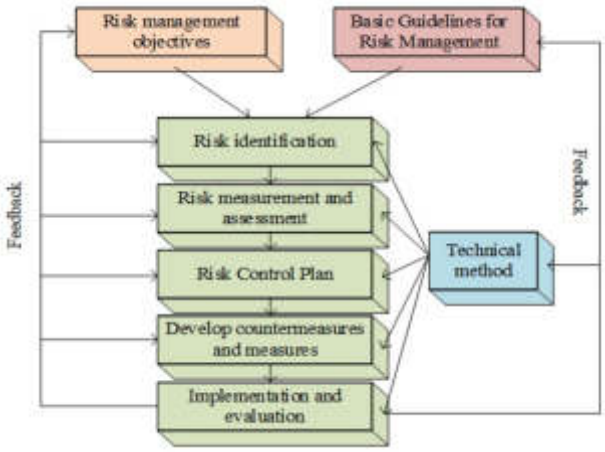

Fig. 3.4: Investment Management Risk Framework for Investors

3.3. Construction of POM-MORA. When constructing a PORTFOLIO, the asset allocation ratio and investment strategy must be determined based on the investor's risk tolerance, risk appetite, investment objectives and other factors [24]. The investor's investment management risk framework is shown in Fig 3.4. Typically, higher-risk investment varieties have relatively higher rates of return but are accompanied by higher risk, while lower-risk investment varieties have lower but more stable returns. The Markowitz mean-variance model was often used to solve the portfolio problem [17]. The Capital Asset Pricing Model (CPAM) is a classic portfolio optimization model mainly used to solve the problem of a single objective: finding a portfolio with minimal risk given the return and covariance matrix of a set of assets. This model is based on two important assumptions: firstly, investors are risk averse and prefer low-risk securities under the same expected returns. Secondly, investors can diversify risk by investing in multiple securities with different risks [19]. The equation for calculating the minimum risk for a given return is shown in equation (3.10).

$$\begin{cases} \min \sigma^2 = x^T W x \\ \max E = u^T x \\ \text{s.t.e } {}^T x = 1 \quad 0 \le x \le 1 \end{cases} \tag{3.10}$$

In equation (3.10), E denotes the sum of expected returns, σ^2 denotes the variance, x denotes a vector of investment weights, W denotes the covariance matrix and e denotes an n-dimensional one-way quantity. The equation for the expected return sum is shown in equation (3.11).

$$E = \sum_{i=1}^{n} u_i x_i \Rightarrow E = u^T x \tag{3.11}$$

In equation (3.11), u denotes the vector of returns and n denotes the type of security. Although the Markowitz mean-variance model laid the foundation for modern portfolio theory, it has shortcomings in practical application [9]. However, when faced with multiple objectives, the Markowitz mean square error model may not be applicable as it cannot directly consider and balance the trade-offs between different objectives [1]. In practical situations, the model results also find it difficult to satisfy a normal distribution, resulting in an inaccurate reflection of actual risks. This model requires investors to provide data on expected asset returns and volatility, but these data have biases that can affect the model's accuracy [18]. Therefore, Markowitz introduced covariance and average return to construct a dual objective investment portfolio. Therefore, Markowitz introduces

covariance and mean returns to construct a dual objective portfolio. the equation is shown in equation (3.12).

$$\begin{cases} \min \sigma^2 = \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j \sigma_{ij} \\ \max r = \sum_{i=1}^{N} w_i r_i \\ \text{Subject to } \sum_{i=1}^{N} w_i = 1 \quad 0 \le w_i \le 1, i = 1, 2, \text{ L}, N \end{cases} \tag{3.12}$$

In equation (3.12), σ^2 denotes the portfolio, $w_i w_j$ denotes the weights, σ_{ij} denotes the covariance between the two assets, N denotes the number of portfolios and r_i denotes the expected return. In the three-objective portfolio model, in addition to risk and return, there is the objective of minimising expected costs [21]. The semi-covariance is introduced instead of the variance shown in equation (3.13).

$$\begin{aligned} &\left(\frac{1}{T}\right) \cdot \sum_{i=1}^{T} \left[\text{Min}\left(R_{it} - B, 0\right) \cdot \text{Min}\left(R_{jt} - B, 0\right)\right] \\ &= \sum_{ij\beta} E\left\{\text{Min}\left(R_i - B, 0\right) \cdot \text{Min}\left(R_j - B, 0\right)\right\} \end{aligned} \tag{3.13}$$

In equation (3.13), R_i denotes the return on asset i, B denotes the comparative return, R_{it}denotes the return on asset i at t and R_j denotes the return on asset j . The transaction cost equation is shown in equation (3.14).

$$d\left(W_i, W_j\right) = \sqrt{\sum_{n=1}^{N} \left(w_n^i - w_n^j\right)^2} \tag{3.14}$$

In equation (3.14), W_i and W_j denote the covariance matrices of asset i and j asset, respectively, W_n^i and W_n^j denote the weights. Thus, the return-risk-cost triple objective portfolio model is represented by equation (3.15).

$$\begin{cases} \text{Max } E = \sum_{i=1}^{N} w_i r_i \\ \text{Min } R = \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j \sum_{ij} \\ \min C = \sqrt{\sum_{n=1}^{N} \left(w_n^i - w_n^j\right)^2} ji \end{cases} \tag{3.15}$$

In equation (3.15), E denotes the return, R denotes the risk and C denotes the cost. The multi-objective RA is used to solve the multi-objective portfolio problem. The proportional allocation particles for investment management are first initialised to form an initialised population. The fitness value of each particle is calculated and ranked to determine the number of non-dominated layers for each solution [7]. The particles are then selected based on the ranking of the non-dominated solutions and the magnitude of the congestion distance to filter out the unwanted particles and then update the particle population using the initialisation method. Finally, the PFSs are ranked according to the PFS and the solutions with large PFS are output in priority. For investors in the actual use of root growth based investment risk management optimization models, it is necessary to clarify multiple objectives of investors. These goals can include minimizing risk, maximizing returns, controlling transaction costs, etc. Investors should weigh the importance and priority of different goals. In addition to goals, it is also necessary to determine the constraints of investment decisions. These constraints can include funding restrictions, industry restrictions, liquidity requirements, etc. Constraints will help screen feasible investment portfolios. Prepare the data required for investment decisions, which can include historical returns on assets, covariance matrices, asset-related information, etc. Based on the established decision model, run the optimization solution algorithm. Depending on the nature of the algorithm, multiple iterations may be required to gradually approach the optimal solution. Each iteration will generate a new set of investment portfolios until the optimal solution meets the goals and constraints.

4. Model Simulation Experiments and Analysis. This section is divided into three parts to test the model: the first part is MPMORA performance testing and analysis, the second part is OMIRM-RG performance testing and analysis, and the third part is POM-MORA performance testing and analysis.

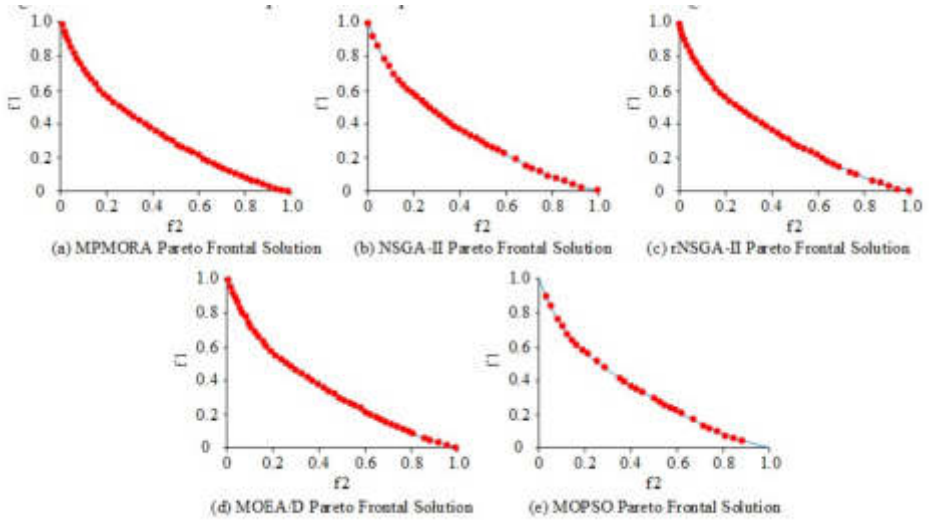

Fig. 4.1: PFS of Five Models on ZDT1

4.1. Performance Testing and Analysis of MPMORA. The experimental test platform was on an Intel core i5 processor and a computer with 8GB of RAM, and the program coding was compiled by the Matlab compiler. The number of populations was set to 200, and the dual-objective test function ZDT1 was used to select the second-generation Non-dominated Sorting Genetic Algorithms- (NSGA-), the second-generation Non-dominated Sorting Genetic Algorithms supporting reinforcement learning (Reinforcement Non- dominated Sorting Genetic Algorithms-II (rNSGA-II), Multi-objective Evolutionary Algorithm Based on Decomposition (MOEA/D), Multi-objective Particle Swarm (MOEA/D), Multiple Objective Particle Swarm Optimization (MOPSO) and MPMORA algorithms were tested for comparison. The experimental results are shown in Fig 4.1.

As can be seen in Fig 4.2, the MPMORA algorithm has a solution closer to the true Pareto front, the rNSGA-II algorithm and the MOEA/D algorithm are the next closest, and the MOPSO algorithm is the worst. The MPMORA algorithm has better performance on the ZDT1 test curve, and the solution results for the two-objective function are closer to the true value. The DTLZ1 three-objective test function and the results are shown in Fig 4.2. The MPMORA algorithm, NSGA-II and rNSGA-II methods, and MOEA/D and MOPSO algorithms are the least consistent with the genuine Pareto solution. The MPMORA algorithm is consistent with the true Pareto solution. Therefore, in the solution solution of the triple objective problem, a fast non-dominated ranking method in RA can be used to present the solution more accurately.

4.2. Performance Testing and Analysis of the OMIRM-RG. To test the performance of RA in investment risk, Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Artificial Bee Colony (ABC) were chosen as comparisons. The experiments were divided into three different enterprise sizes: decision makers set to one, participants set to two, four and six, and total investment set to 3000. Risk levels were divided into three levels, with a low-risk level for a risk range value of [0.00,0.38], a medium risk level for a risk range of (0.38,0.67 risk, and a risk level of high risk for a risk range of (0.67,1.00]. Fig 4.3 displays the test outcomes. The iteration curves for investors at 2, 4, and 6 are shown in Figures 4.3(a), 4.3(b), and 4.3(c), respectively. The RA method converges with a fitness value of 0.12 in Fig 4.3(a) after 30 rounds. The RA method converges with a fitness value of 0.4 in Fig 4.3(b) after 10 rounds. The RA method converges in Fig 4.3(c) after 10 iterations, with a fitness value of 1.1. Thus, it is clear that RA has a higher testing accuracy and convergence rate. The results of ten tests on the risk values of the four algorithms are displayed in Table 4.1 As can be seen from Table 4.1, the best result for RA at 2 investment objectives is 0.1851, the worst result is 0.2348 and the final value after 10 tests is 0.0105. at 4 investment objectives, the best result is 0.3123, the

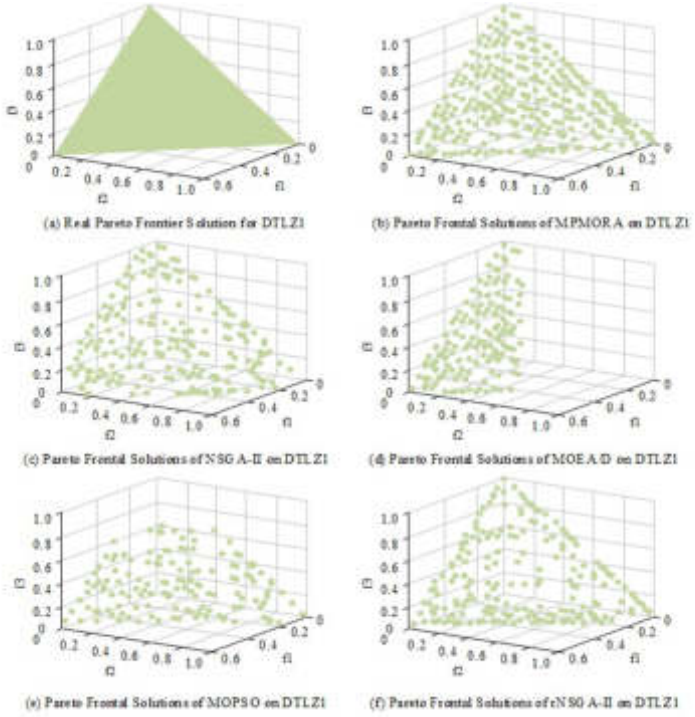

Fig. 4.2: PFS of Five Models on DTLZ1

Table 4.1: Risk Test Results

Number of participants		RA	PSO	ABC	GA
2	Best	0.1851	0.2045	0.2201	0.1825
	Worst	0.2348	0.2895	0.2534	0.2529
	Mean	0.2255	0.2407	0.2456	0.2305
	Standard	0.0105	0.0189	0.0112	0.0589
4	Best	0.3123	0.3167	0.3103	0.2568
	Worst	0.3457	0.4439	0.3772	3.1235
	Mean	0.3186	0.3519	0.3426	0.5029
	Standard	0.0082	0.3019	0.1567	0.5892
6	Best	0.2534	0.3202	0.3719	0.1925
	Worst	1.8623	4.5239	4.0278	2.6438
	Mean	0.5845	0.7598	0.7298	0.8239
	Standard	0.4623	0.8588	0.9236	0.4235

worst result is 0.3457 and the final value after 10 tests is 0.0082. at 6 investment objectives, the best result is 0.2534, the worst result is 1.8623, and the final value after 10 tests is 0.4623. It can be seen that the test values of the RA algorithm end up in the low-risk class range, and the solution provided by the RA algorithm is feasible. The results are plotted in Fig 4.4.

As can be seen from the ANOVA results in 4.4, the RA algorithm and the PSO algorithm have relatively similar variance values for investment targets of 2 and 4, but the RA algorithm shows better robustness for an investment target of 6. Therefore, the RA algorithm performs better and is more robust in dealing with larger-scale problems of risky investment management.

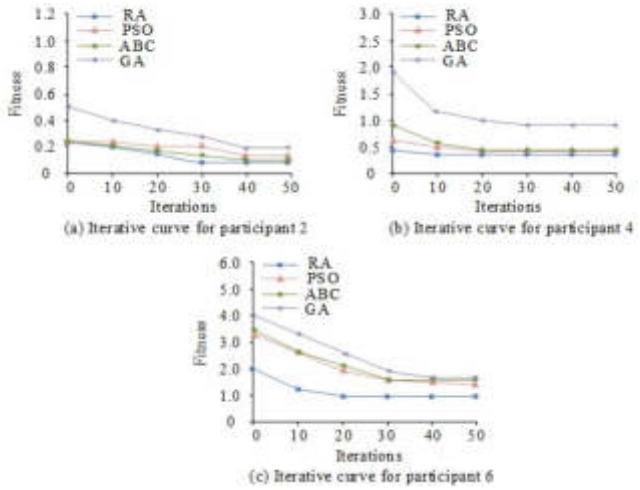

Fig. 4.3: Iteration curves for three different scales

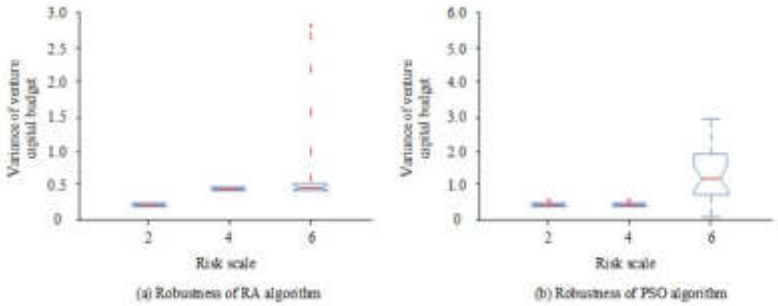

Fig. 4.4: Robustness Analysis Chart

4.3. Performance Testing and Analysis of POM-MORA. The experiment used data from 10 assets of the Beijing Stock Exchange, including monthly rates for each stock from January 2021 to December 2022. The NSGA-II algorithm and the MOEA/D algorithm were selected for testing against the MPMORA algorithm in an investment-return portfolio, the results of which are shown in Fig 4.5. In Fig 4.5, the MPMORA algorithm has better effective curve continuity, the NSGA-II algorithm has the second-best effective curve continuity, and the MOEA/D algorithm has poor effective curve continuity. Therefore, the MPMORA algorithm has a better PFS in the two-objective portfolio, and investors are better able to choose a portfolio approach based on risk appetite. The three algorithms were tested in an investment-return-cost tri-objective portfolio and the results are shown in Fig 4.6. In Fig 4.6, the solutions of the MPMORA algorithm are more homogeneous and diversified, the higher the risk, the smaller the expected return, and the opposite case of cost and risk, cost and expected return. Investors can choose appropriate investment strategies based on their own goals. Through distributed decision-making and information exchange between nodes, investors can better balance the trade-offs between different objectives. For example, while pursuing high returns, attention should also be paid to preventing risks. By exploring a combination of different investment options, investors can find effective solutions to meet multi-objective needs. Table 4.2 displays the test results and compares the Hypervolume values of the three techniques. The MPMORA algorithm's final Hypervolume value is 5.5298 for the two-objective payback combination and 3.9628 for the three-objective payback cost combination, as shown in Table 4.2. Compared

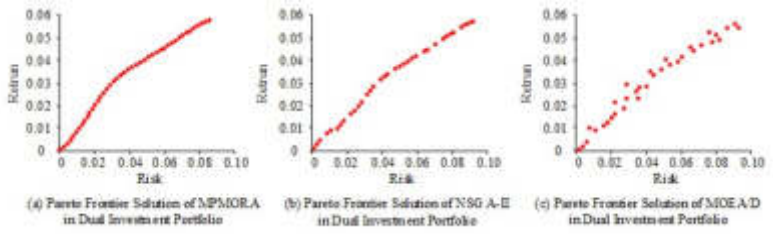

Fig. 4.5: Pareto Curve of Dual Portfolio

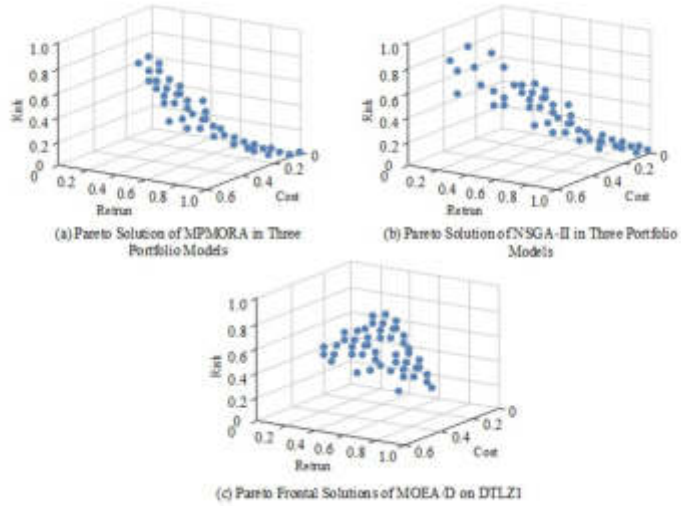

Fig. 4.6: Pareto value of three investment portfolios

to the other two algorithms, the MPMORA algorithm has a smaller Hypervolume value, and therefore, the optimal solution set obtained by the algorithm has better distributivity and convergence.

5. Conclusion. This paper builds MPMORA based on RA, experiments build OMIRM-RG and builds POM-MORA based on the Markowitz mean-variance model to address the multi-objective problem in investment RM. The MPMORA method has a solution that is closer to the real Pareto front, the rNSGA-II algorithm and the MOEA/D algorithm are the next best, and the MOPSO algorithm is the worst, according to the experimental data. The dual objective function solution solutions for the MPMORA method are more accurate and have superior performance on the ZDT1 test curve. After 30 rounds and a 2 investment amount, the RA algorithm converges with a fitness value of 0.12. After 10 iterations and a $4 investment, the RA algorithm converges with a fitness value of 0.4. After 10 iterations and a 6 investment amount, the RA algorithm converges with a fitness value of 1.1. At two investing objectives, RA has a top result of 0.1851 and a worst result of the best outcome for 4 investing objectives is 0.3123, the worst outcome is 0.3457, and the final value is 0.0082. The best outcome for six investment objectives is 0.2534, the worst outcome is 1.8623, and the final value is 0.4623. The RA algorithm's tested values fell within the low risk class range, and the solution it offered was workable. The MPMORA algorithm produced an optimal solution set with improved distribution and convergence, with final Hypervolume values of 5.5298 for the two-objective ROI combination and 3.9628 for the three-objective ROI cost combination. The multi-objective root algorithm based on distributed decision-making can help investors make more informed decisions in multi-objective optimization problems. By decomposing problems, making node decisions, and exchanging information, investors can comprehensively consider different

Table 4.2: Results of Different Portfolio Models

Dual investment target portfolio		MPMORA	NSGA-	MOEA/D	GA
Hypervolume	Max	1.0916	5.8902	3.4527	0.1825
	Min	4.1628	5.192	9.9828	0.2529
	Average	8.3562	5.5362	1.5627	0.2305
	Standard	5.5298	5.9827	7.8392	0.0589
Three investment target combinations		MPMORA	NSGA-	MOEA/D	0.2568
Hypervolume	Max	1.4827	5.4129	6.3862	3.1235
	Min	3.6527	9.8736	7.0382	0.5029
	Average	8.1627	1.0627	2.8617	0.5892
	Standard	3.9628	2.5839	3.9203	0.1925
	Worst	1.8623	4.5239	4.0278	2.6438
	Mean	0.5845	0.7598	0.7298	0.8239
	Standard	0.4623	0.8588	0.9236	0.4235

goals, constraints, and market conditions to optimize their investment portfolios, thereby improving investment effectiveness and risk management capabilities. There are shortcomings in this study. The experimental section selected fewer test parameters and test datasets. In future research, more parameters and experimental data should be selected as the detection objects for testing.

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SPATIAL AND TEMPORAL CHARACTERISTIC ANALYSIS BASED LONG SHORT-TERM MEMORY FOR DETECTION OF SENSOR FAULT IN AUTONOMOUS VEHICLES

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Abstract. The artificial intelligence required to create self-directed automobiles relies heavily on the capability of precisely perceiving the environment around oneself. Most self-driving automobiles include several detectors, which work together to form a multi-source perception of the surroundings. Extended use of a system that drives autonomously will introduce a variety of worldwide and local failure indications due to the extreme sensitivity of the instruments involved to ambient or environmental situations. These failure indications pose significant risks to the technique's security. The paper presents a real-time information synthesis system incorporating techniques for identifying flaws and accepting faults. The compact connection can be recognized if the qualities mentioned above are provided, and the input information properties may be retrieved in real-time. One way to use the newly introduced method for assessing device reliability is to compute the detectors' worldwide and local degrees of trustworthiness. In order to ensure the precision and dependability of information combination, problem data is filtered out, and monitor duplication is used to assess both the worldwide and local assurance levels of data from sensors at the moment. The chronological and geographic association of data from sensors allows for this. Experimental findings show that the network's algorithms can outperform current techniques in terms of both rapidity and precision and can pinpoint the object's location even when specific sensors are blurry or broken. This research established that the proposed hybrid structure benefits autonomous vehicles' real-time reliability and speed.

Key words: Self-driving cars, Observation of objects, Combining statistics, Automatic failure analysis, Neural network with convolutions, Combining data, Robot on wheels.

1. Introduction. In the process of driving, unmanned vehicles need to rely on a large number of sensors to read and receive real-time road condition data from roadbed units, traffic signals, radar base stations and other vehicles. In order to achieve uninterrupted navigation with high reliability, multiple sensors are usually installed on the vehicle body at the same time to obtain sufficient redundant position information.Generally, unmanned vehicle network attacks are mainly divided into internal attacks and external attacks, external attacks mainly invade equipment other than unmanned vehicles, such as attacks and interference to infrastructure such as roadbed measurement units, traffic signals, road signs, communication equipment and other vehicle data; Internal attack is mainly to invade the system and sensor of the unmanned vehicle body, typically including the vehicle control system, navigation sensor, vehicle diagnosis system and other vehicle sensors.Among the many attack types, the attack of navigation sensor is the most direct and common And one of the most harmful types of attack it can be on people at all Noticeable cases of sudden or slow changes in the car's driving vehiclePath, travel speed and direction, the attack is extremely stealthy, giving people The psychology of creating a huge fear is the current industry forced to solve One of the key technical problems.

Recognizing obstacles on the road is crucial for entirely autonomous vehicles. The method provides self-driving automobiles with real-time data about many road elements, including other automobiles and humans [5]. Existing object detection technology uses cameras and other types of ambient awareness devices. The

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machine learning system can detect the object that interests it and decide its proper classification thanks to the camera's capacity to gather data about the surroundings, including its color and outlines [14].

In the 1990s, artificially generated characteristics combined with data mining were used for most road object detection tasks. HOG, LBP, and Haar characteristics are examples of synthetic characteristics that were popular then. A set of feature vectors will be generated when artificial characteristics are extracted from discrete areas of the image [9]. By classifying vectors of features using characteristic algorithms like SVM, it is feasible to ascertain both the location and classification of objects of interest.

This article will be the cutting edge of artificial intelligence The deep learning technology is introduced into the anomaly detection of unmanned vehicle navigation sensors In this paper, we propose a novel approach based on one-dimensional convolutional neural networks (1D Convolutional neural network, 1D-CNN) driverless car guide Intelligent diagnosis method and system framework of aero sensor anomaly. The model consists of Input layer, 1D convolution layer, 1D pooling layer, 1D global mean pooling Layer (1D Global average pooling, 1D-GAP) and Softmax Classifier composition.With the advent of machine learning, neural networks based on convolution have taken over the role of visual sensors in performing object identification. The AlexNet system reduced the error rates for the Top-5 categorization task to 15.7 percent [4]. ResNet divides the network into many blocks, each with its own output and input parameters, and connects them directly using a Shortcut architecture to solve the gradual vanishing problem. In order to accomplish object identification, the RCNN network proposed employs three phases: an extraction of features backbone, a network for proposing regions (RPN), and a region of interest (RoI)-Pooling. This addresses the time-consuming issue of typical algorithms for identifying objects repeatedly traversing sensor data. Influenced by RCNN, scientists are improving the effectiveness of identifying objects in certain circumstances, like traffic. Using the image frame difference data from traffic camera footage to teach the neural network and monitor the moving automobiles in the video in actual time improves the framework of RCNN. The goal was to improve the RCNN's motion detection capabilities. The investigation uses the Faster-RCNN algorithm combined with the selected search method to locate forward autos, which significantly helps with the automobile loss problem. In order to effectively detect detached moving vehicles and achieve a high degree of accuracy, employ CNN to process the data gathered by UAVs. To increase the subject's recognition rate to 25 frames per second (fps), we propose using a one-stage system to complete the bounding box and perform classification and regression simultaneously. This will fix the problem of the multiple-phase model's subpar performance in real-time [16].

Data fusion approaches are being developed for processing data from several sources on environmental perception. These techniques provide superior object identification results compared to using only one of the sensors available on autonomous cars. This will lessen the burden on the autonomous vehicle's processing and memory systems. Data fusion may be broadly classified into two approaches: before and after the fusion. The locations of fusion reactions provide the basis for these classifications. In the former approach, sensor data from the initial input layer is pooled, and the object identification network is designed to function with all the information [3].

The post-fusion method's conflict location and methodology are more malleable and dynamic than the pre-fusion method's. Feature extraction (FE) is often used to extract characteristics from the data collected by every detector, and then specialized fusion procedures are constructed following predetermined goals [10].

The detector will eventually start sending out failure indications after prolonged use. The safe functioning of self-driving automobiles depends on several elements, including the stability of the algorithm and the capacity for error diagnosis and tolerance. The authors describe a cutting-edge transfer learning technique for the identification of transmission failure with an adverse domain choice machine. When there is little data to work with, transfer learning of this kind is an excellent tool for tackling the real GFR problem [6]. As shown, the proposal of a faster and more accurate deep learning system for exact equipment fault identification using transfer teaching and its achievement of cutting-edge results for the primary mechanical records and transfer acquisition have been shown to allow and speed up the development of deep learning networks with excellent precision.

In this study, we provide a novel approach to recognizing objects, emphasizing addressing concerns that have been overlooked in other efforts.

To be more explicit, we provide a novel data integration framework that is compact in design and can do

real-time analysis of massive amounts of multi-modal data. To guarantee the precision and dependability of road object recognition, this research presents a fault diagnosis and avoidance (FDA) mechanism inside the data fusion architecture. It identifies mutual fault through the time and space relationship between sensor data. Because sensor faults might occur while driving, this is done to prepare for them.

The following is a summary of the main results of this investigation.

We choose a structure that is a lighter feature pyramid network (FPN) compared to the previously employed object recognition network to ensure the real-time efficiency of the data synthesis system while analyzing massive volumes of multi-modal data.

In order to guarantee reliable and precise identification results, it is recommended that the information integration framework involve a method called fault detection and isolation (FDA).

Finally, tests are conducted to verify the instantaneous precision and dependability of the fusion architecture in terms of its efficacy in 2D object detection and defect prevention using surrounding sensory information gathered in various circumstances. These tests are performed to ensure the accuracy of information on how people perceive their surroundings [21].

2. Related Works. The LSTM model is based on a variant of Recurent NeuralNetwork (RNN). RNN model is proposed to solve the problem of time series data dependence and is very sensitive to short-term input. However, due to the characteristics of the tanh layer inside RNN, it is possible to remember or forget all the memories, which will lead to the possibility of gradient dispersion and gradient explosion in long-term time dependence. Compared with ordinary RNN,LSTM model is a more efficient tool to obtain long time series information. In order to solve the long-term time dependence problem, LSTM adds the mechanism of gate and introduces the concept of cell state.To prevent situations that could be harmful, self-driving cars must have access to precise and trustworthy issue identification and monitoring technology. This piece outlines our plan for an integrated approach to defect identification and monitoring. First, condition faults in the self-driving car are identified by training the intersection curve between the secure and risky domains using the One-Class Support Vector Machine (SVM) method. This is done so that secure network users may quickly identify themselves as in the secure zone. Meanwhile, the linear kinematic vehicle bicycle model is used to inform the development of a Kalman filtering observer that can anticipate where the vehicle is. To assess whether the course of events has changed, the test known as Jarque-Bera is used to determine if the distribution of probabilities of the leftovers between forecast and observation is normally distributed. This is done to see whether there has been a change in direction. We use a fuzzy system to further categorize the faults that have been discovered. This architecture is based on a neural network variant, adding an affiliation layer following the input layer. Black box testing refines the fuzzy system's initial membership function, revealing the likely failure scenarios. This is because neutral networks have an impressive capacity for self-learning. The system's capacity to identify and diagnose issues was evaluated through a battery of tests on the real autonomous vehicle platform, Xinda. The trials' findings and the results of performance comparisons with other fault sensors proved the methods' worth. In this last section of the report, we will briefly overview our efforts. Our goal in this study is to develop a diagnosis and fault-finding system for autonomous vehicles [2].

Sensor fault pre-detection method The residual sequence obtained by the predicted value and the measured value is the key to analyze the sensor fault. When the sensor is in normal operation, the expectation of the obtained residual sequence should be infinitely close to 0. However, in the actual collection process of the field, it will be affected by complex environmental factors and the system itself, and the expectation of the residual sequence will have a certain deviation from the 0 value, but the residual sequence obtained from the normal operation data still conforms to the normal distribution.

Approaches to fault detection and diagnosis may be broadly classified into three types: model-based, signal-based, and knowledge-based.

Hybrid approaches are employed when considering practical uses for autonomous vehicles. To start, we utilize a One-Class SVM to check for physical flaws in the car's condition.

The distribution is then inferred by constructing a Kalman filter and acquiring the residuals between the predicted value and the measured value. This is done in order to figure out who gets what. This approach of finding errors validates the normality of the residual distribution and establishes whether or not the trajectory deviates in a checking period. Ultimately, a fuzzy system is built to examine the likelihood of each possible

component that might cause failures. Our neural network's implementation acquires fuzzy system membership functions, and fuzzy system inclusion function parameters are adjusted via black box testing and fitting.

One component of future work is identifying the source of the problem.We call the many potential defect-causing factors "Advanced Alarm" and "Steering Alarm" to indicate an abnormality in the longitudinal or lateral condition. Based on this classification, we may examine the part of the system that seems to be malfunctioning. If the alarm type is "Moving Alarm", for instance, the dynamic system of the car or the ABS may have been to blame, whereas if the alarm type is "Steering Alarm", the steering system may have been to blame. Assuring the safety of the autonomous vehicle requires isolating the faulty system, which can only be done if we know which subsystem caused the problems. It is also essential to examine and address ELM-based approaches, which are suitable ways to improve the training process of neural network-based methods and display the features of fast learning speed and strong adaptation capacity.

Uncrewed aerial vehicles (UAVs) rely heavily on fault diagnostics to ensure the security and dependability of their equipment. Problem-solving for UAV instruments is addressed, and a combination of feature modeling and a neural network-based approach is presented. Errant signals from failed sensors, such as the global locating network, inertial measurements (IMU), and air data system (ADS), were acquired. In this study, we employed STFT to convert the residual signal into a time-frequency representation. The malfunction diagnostic of the UAV instruments was then carried out, and a convolutional neural network (CNN) was utilized to extract the map's features. Finally, UAV flying tests are used to assess the effectiveness of the suggested technique. Compelling fault diagnostic logic between leftovers and good health status may be built from visualizing data using CNN to extract sensor defect knowledge. This research presents an advanced learning-based defect detection system for UAV sensors that combines a hybrid feature model. We used the short-time Fourier transform (STFT) to prepare for deep learning and produce nine time-frequency mappings from the EKF estimate residue. The input of CNN was formed from the two-dimensional pictures by creating a CNN architecture with eight subnetworks. Using multiple validations, we decided on the variables to use. Lastly, in-flight trials prove that the suggested strategy works. The suggested method's principal benefits were its hybrid nature, allowing fault identification and deep understanding. Model-based defect detection may also be used with other forms of machine learning, such as neural networks with recurrent architecture and layered auto-encoding [7]. CNN is one of the most representative deep learning algorithms in the field of artificial intelligence. It uses deep network structure to simulate the working mechanism of animal vision system, and can automatically extract key features directly from the original data, with strong feature extraction ability.Different from pattern classification tasks in computer vision and speech recognition, the unmanned vehicle network attack anomaly diagnosis task requires both high accuracy of the diagnosis model and fast real-time detection speed.

The primary goal of self-driving vehicle studies is to improve transportation accuracy and reliability. Despite significant advancements, even the most advanced algorithms might occasionally make errors; in some instances, the sensors are to blame. Refrain from failing to do so might have disastrous results.

This is why self-driving cars must be able to foresee and respond appropriately to problems as soon as they happen. It is possible to train data representations with the help of artificial intelligence techniques by combining real-world data with data gathered from correctly operating sensors and then artificially injecting a range of sensor flaws into the resulting dataset. This research proposes a novel paradigm for identifying faults, separation, recognition, and predictions (depending on observation) for multi-fault in multi-sensor systems, such as self-driving cars. This layout was designed with fault diagnosis, isolation, and identification. By combining the strengths of two distinct and very efficient profound neural network architectures, our recognition, verification, and separation solution delivers remarkable efficiency.

We then utilize the sensor defect identification system's output to develop our gauge for the health index and feed it into the healthcare index prediction network's training procedure. This research looked at the underlying physical causes of sensor failures and classified them into four broad categories. The final goal was to develop a system for identifying faults, loneliness, proof of identity, and forecasting in-car electronics. Effectively handling many defects collected for various fault configurations that occurred in a multi-sensor scenario has been shown using a CNN-based sensor fault detector/classifier. This was demonstrated by its successful handling of the issues mentioned above. The proposed approach was evaluated and shown to be

99.95% accurate in finding errors. If a defect is detected, a signal is transmitted to the identity and isolation systems; if no malfunction is detected, the signal is forwarded to the detector's health prediction system. The outcome of the inspection for defects will inform this choice.

It has been shown that the proposed architecture, in conjunction with deep learning algorithms, may allow autonomous vehicles to perform fault isolation and identification. The signals will be sent to the system that evaluates and forecasts sensor health if the defect identification system finds the sensors functioning correctly. Three unique decay curves were used to help the detector identify defects in the system's output to get an HI value. This has been done so that we may speculate on the sensors' health. The HI metric is the information sent into the TFT network to foresee how the sensors will act and spot issues before they become critical.

This study employs a quantified reduction as a measure of effectiveness. Accordingly, obtainable losses of 0.0315, 0.0611, and 0.0299 at the 10th, 50th, and 90th percentiles have been reported. Audi, a German automotive manufacturer, has made public a dataset from the real world dubbed A2D2, which was used to validate the proposed method [22].

When coping with the challenging finding of damage challenges common in mechanical components, one possible option is to use a fault diagnostic strategy based on a combination of information from numerous sensors. Two potential problems with this approach are the challenge it may be to separate characteristics from many sources of sensory data and how challenging it can be to determine the optimal fusion level. Choosing the most appropriate feature or fusion level for a given fault diagnosis task can be challenging. This procedure requires a great deal of human work in addition to a deep understanding of the subject matter. We provide a multi-sensor data fusion approach to defect identification using deep convolutional neural networks that is both flexible and effective. To get around those two issues, we resort to this. The described method can automatically adapt to the requirements of each defect diagnosis task by learning features from raw data and maximizing the most practical combination of different fusion levels. In order to evaluate the effectiveness of the proposed technology, the global transmission test rig is used. In this study, we evaluate the performance of two traditional intelligent models, a back-propagation neural network and a support vector machine, in contrast to characteristics and integration levels that were created by hand, chosen by human judgment and applied to data from a single sense. Evidence from this trial suggests that the proposed technique outperforms all others in its ability to diagnose problems with the planetary gearbox quickly and precisely. To assess the condition of planetary gearboxes, this research presents a DCNN-based adaptive data fusion method. Information combination, a combination of features, selection combination, learning features, and detection of errors are adaptively merged into a single DCNN model. The proposed method utilizes the deep-layered configuration of DCNN to learn features from raw data while also adaptively fusing data, features, and choices. In addition, less time and effort from humans are needed to extract features and establish fusion levels when using this technique. The experimental results obtained using the planetary gearbox fault test apparatus serve as a gauge of the proposed method's efficacy. In this study, we put two widely used AI methods, BPNN and SVM, through their paces and compared their performance on various tasks, including feature-level fusion, decision-level combination, features created by hand, individual sensory information, and more. The experimental results provide persuasive proof that the proposed method works. When compared to other approaches utilized in the experiment, the suggested method achieves the best degree of testing precision.

In the future, we want to expand the range of mechanical items, failure modes, operating situations, and sensor types on which we conduct DCNN model-based learning of features and data fusion experiments. This will help us validate the techniques' efficacy and find further practical application recommendations. Also, due to the large number of variables in deep learning models, traditional parameter tuning can take a long time and result in a local optimum. At the same time, standard automated searching techniques can settle on a suboptimal solution quickly.

In order to adjust the parameters immediately, it is vital to investigate ways that are both more effective and faster. In summary, combining several neural network systems should enhance fault identification quality. Incorporating a self-encoding structure into the framework may increase its capability to learn more complex properties, making it particularly well-suited for forecasting potential problem situations. The model might be suited for such forecasts if the recurring structure was added [8].

Due to its importance, academic journals have extensively covered fault identification. To this end, several

machine learning algorithms have been created to better understand the diagnostic process and its constituent parts. In this study, we introduce a framework for learning termed a Hybrid Deep Belief Network (HDBN) for intelligent fault identification in motor-driven devices. The system combines data in various ways. The drive system of an automobile is an example of such a system. Based on our research, we provide three unique approaches to data fusion: data partnership, information arrival, and information hybridization. Looking at the fusion from the perspective of the energy contained in the signal might also shed light on its significance. More precise issue identification may be possible with the correct data fusion methods and formats suitable for model training purposes. In addition, a novel fusion method called mixed-precision training is employed to improve the model's overall performance. Our proposed model outperforms state-of-the-art methods, as shown by experiments performed on datasets provided by the modeling platform. As part of this body of work, we propose using data sources and their integration outcomes to build diagnostic models that extract depth information more efficiently. After establishing a DBN-based deep fault feature learning strategy, the HDBN diagnostic model was built using the hybrid data fusion technique. Second, three separate data fusion methods were developed in line with the nature and interpretation of the tangible form of the signal, rather than employing "information unification or information blend" as was done in the previous research.

The main contributions of this paper include the following three aspects: Firstly, a new scheme of network attack detection using the original location data of multi-sensor of unmanned vehicle is presented; Secondly, the deep learning technology is introduced into the field of unmanned vehicle network attack detection to solve the difficult problem that slow and small attacks are difficult to detect through its powerful feature extraction capability. Third, the existing 1D convolutional neural network algorithm is improved, and the 1D-GAP-CNN algorithm structure is designed, so that it is more in line with the fast real-time requirements of unmanned vehicle network attack detection.

The results of the experiments showed that the different data-fusing approaches were related to the true qualities of the data and that the learning accuracy could be improved by combining the correct data fusion methodology with the appropriate manner of dataset construction. Third, we applied a novel data fusion approach called mixed-precision learning to improve the model's overall accuracy significantly. The experimental findings showed that HDBM's artificial intelligence and information integration abilities significantly improved cognitive defect detection accuracy, far outperforming the other diagnostic systems. The author intends to continue investigating the problem of fault diagnostics in complicated environments. As part of this study, we will refine diagnostic procedures for usage in settings with a mix of loading and driving input interference [28].

3. Proposed Methodology.

3.1. Proposed Layout of Networks for Geographic Areas.

1. Feature Extraction Network (FEN)

This paper is about the network layer Number, size of convolution kernel, number of convolution kernel, activation function, pooling kernel The size and the number of pooling layers are adjusted repeatedly. The model consists of 10 network layers. There are five 1D convolution layers, two 1D pooling layers, and four RELUs Activation layer, 1 1D-GAP layer and Softmax output layer, all Both the convolution kernel and the pooling kernel are set to Padding= "Same", using Adam adaptive learning rate optimizer and mini-batch training method, 65 samples per batch, 210 rounds of training.Once a frame of a picture is acquired, it must be compressed, encoded, and run through an artificial brain to recover the structural data hidden in the spaces between the frames. The larger the perceived region of the resulting component map, the higher the FEN's complexity, but the more local detail is lost in the process [15]. The FEN presented here is based on the architecture of a neural network with residuals. This is done in order to tighten up the network's settings. The quantity of computational horsepower required by the system may be significantly lowered if, during the creation of the framework procedure, a priori characteristics are included to lower the size of map structures. The network's basic structure is laid out in Table 3.1.

The computational capacity of the network may be used to roughly estimate the quantity of work that must be performed by the neural network's computation and memory components.

Computational energy within the system may be used as a proxy for the workload of the brain system's computation and memory components. The computational capability of a CNN level may be approximated

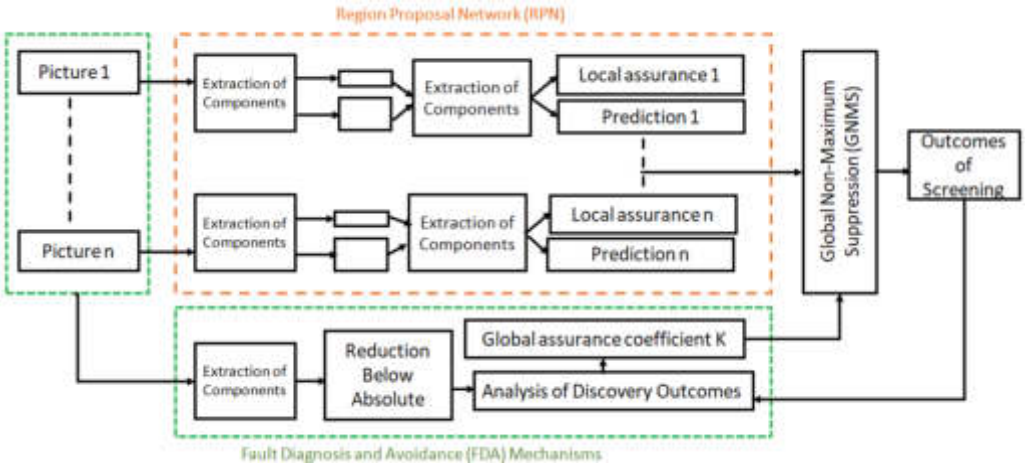


Fig. 3.1: Structured integration of information

Table 3.1: Feature extraction structure

	Category	Channel	Filter size	Outcome
	Input	4		416*416
	Ramification	32	3*3/2	104*104
2x	Ramification	64	3*3	52*52
	Ramification	64	3*3	
	Ramification	64	3*3	
	Remainder			52*52
2x	Ramification	64	3*3/2	26*26
	Ramification	64	3*3	
	Ramification	64	3*3	
	Remainder			26*26
2x	Ramification	128	3*3/2	13*13
	Ramification	128	3*3	
	Ramification	128	3*3	
	Remainder			13*13
	Required computing power: $0.69*10^9$ FLOPS			

using Eq. (3.1):

$$P = 2IX(C_{\text{in}}k^2 + 1)C_{\text{out}} \tag{3.1}$$

I and X stand for the length and breadth of the map of features, respectively; C_{in}, C_{out} stand for the number of input/output channels; and k stands for the length of the kernel.

The FEN uses a two-layer, 3x3 convolutional framework to reduce the size of the input picture. This takes 3.6 floating-point operations of processing power at the start. The technology strength for the system's Molecular weight layer is calculated to be 0.7*108 FLOPs, which is 1/27 of the calculating strength needed by DarkNet-53.

The compact FPN system uses a 26 x 26 and 13 x 13 feature map extracted from the core when building a characteristic structure. The bounding box extrapolation variables x, w, h as well as the desired category forecast probabilities Q(0), Q(1), and Q(2), are then computed to provide the output vector "x", "y", "w", "h", "C", and "Q(0)", "Q(1)", and "Q(2)". Remember that the i^{th} sensor will capture the predicted D_i area

after passing over the ultralight FPN connection. The GNMS component, discussed in more depth below, will synthesize data from all of the sensors to predict D_i and the related actual time probability. K_i, the RPN unit, determines where the goal D_{fusion} is in the 2D image and communicates this knowledge to the box-regression system, an element of the knowledge-merging structure [23].

2. Region Return on Investment Estimation

After the initial picture has been encoded and compressed by the FEN, numerous map files with different reduction levels have been generated. This is quite similar to the characteristic tower that the SIFT algorithm generates. Root regions are used to categorize the condensed and encrypted map of features in this piece of writing. The target's position and local probability data are reconstructed from these zones. Precisely, three roots of fixed dimensions are placed at each location of a feature chart in order to determine the object of interest using a grid-by-grid characteristic map. The quaternion vector "x, y, w, h" frequently expresses the anchoring point as a straightforward triangular boundary in both dimensions. The anchor coordinates and the enclosing box's dimensions combine to generate this data vector. The network can also predict the probabilities $P(0), P(1), \cdots$, and $P(n)$ that each Anchor's internal destination belongs to one of these categories. The output vector size of each item recognition level is determined by the system's capacity to distinguish between three unique goal classifications: people walking, cars, and bikes [18].

In order to establish a baseline for the Anchor information set, we first conduct K-mean clustering on the KITTI training set. With a more negligible size difference between the anchor and the target, the network can better pinpoint its location inside the local area divided by the Anchor. The final sizes of the six anchors obtained from clustering with $k = 6$ are (45, 42), (101, 61), (84, 168), (175, 98), (261, 160), and (377, 215). This study proposes two layers with features for the ultralight FPN system.

3. Loss Function

Following the completion of the system's framework, the impairment value must be used to direct the converged path of the network's settings in order to coax the system into continuous self-learning toward the specified quadratic value [19]. The coefficient of loss may be used to guide the development of the network's variables toward the target value. The system loss equation is divided into three subcomponents, each representing a distinct aspect of the algorithm's production vector: the boundaries box change loss, the leaping box object identification loss, and the objective categorization reduction. The entropy loss cross-product is utilized to calculate boundaries box change loss and the leaping box object identification loss since both the assurance of the box with boundaries and the expected value of the desired category are output as probabilities. However, the result of plugging in "x, y, w, and h" is a specific number, and this is what the square error loss function model uses to determine l_{bbox}. Each pixel in the final feature map is instructed to select the anchor with the highest Intersection-over-Union (IoU) score throughout testing. The standard setting of 1 has been assigned to these anchors, which equates to 1_{ij}; their anticipated value will be used for calculating l_{bbox} and l_{cls}. An anchor is considered empty and has no objects inside it if its IoU with any target is less than 0.5, and the associated 1_{ij} is set to 1. In addition, the anchor's expected confidence C will be used as a penalty term in the logarithmic shape to determine l_{conf}. This holds for anchors with a value of 0 in 1_{ij}.

Since the bulk of the information is made up of the anchor that does not have a target in the output, the value of grid2 i=0 A j=0 1_{ij} log C_{ij} will immediately affect the long calculation. A loss function of this kind makes no sense since the network consistently predicts C_{ij} to be very close to zero. We will manipulate the input data distribution using the weight coefficient 1_{ij} to achieve this objective. Similarly, pedestrian identification for autonomous driving focuses more on the accuracy of target position prediction than on more common tasks requiring object recognition [20].

The single-sensor object detection network supplies data fusion's "preprocessing" connection. The success of the data fusion process depends on the precision with which this network determines the target's position. Therefore, a more excellent weighting factor box should be applied to l_{bbox} when calculating the total loss. This will increase the "penalty" of the bounding box's regression error on the network. Following is the formula for determining the ultimate network loss function:

$$l = l_{\text{conf}} + l_{\text{bbox}}\lambda_{\text{bbox}} + l_{\text{cls}} \tag{3.2}$$

3.2. Detection and Correction of Errors. Adverse climates, such as smog and precipitation, may be encountered during the functioning of the autonomous automobile. The communication on the data bus may

be disrupted, or the camera's optics could become soiled, rendering the device useless. These problems will create noise throughout the information utilized for contextual awareness, which may create issues like the failure to recognize or incorrectly identify goals, both of which pose severe threats to the security of self-driving cars. An error-finding and evasion method in the perception model has been developed to ensure redundant information [12]. With the help of redundant information for fault testing, the accuracy of sensor data can be evaluated right now, and the problem signal can be eliminated. This study uses The variable weight method to execute the FDA procedure. The information fusion architecture calculates the global degree of trust K and local credibility level C for data from sensors. Problems with both local and global flaws may be solved with the use of these confidence levels. During the fusing of the RoI region, the GNMS method filters away redundant and faulty signals to ensure accurate union outcomes are returned as the output of object detection. The K and C symbols represent the assurance factors used in this procedure.

1. Investigation of Flaws in a Sensor That Picks Up on Our Environment

The sensor's scanning architecture renders the image information susceptible to electromagnetic contamination from the surroundings. The lens is just like this. Dim lighting, blurry surrounding details, and shifts in viewpoint will impair the detectors' ability to see details [13]. The lens can roughly classify the background noise as "natural" or "human-made".

i. There is a fault line throughout the world. Poor lighting, a busy background, or a blurry lens will all contribute to an overall haze in the image.

ii. Localized failure. Information truncation, complete obstruction, and lens staining are just a few of the issues plaguing the photoreceptor chip. Because of these problems, the chip cannot do its job.

When a self-driving car gets motivated, the driver's perspective, the background, and the available light all shift continuously. Our method for recognizing defects uses an adaptive load strategy, which enables the score to be modified in real-time based on the data provided from all frames of a reputation to ensure the reliability of the sensory technology. In real-time, we employ a Kalman filtering approach to assess the reliability of every sensor's information and its impact on the overall outcome. We also fine-tune the sensor's general trust parameter as time passes. We correct worldwide sensor failures in this manner. To cope with local flaws in real-time, an assurance parameter for each local area of the image is calculated using RPN. The structure for combining data employs GNMS to combine local and global factors for reliability and accuracy in the final results of the information merging procedure.

2. Adjustment of International Reliability Rates

The detection zones of multiple cameras in a self-driving vehicle overlap; thus, the collected environmental information is redundant. By combining sensor measurements in a manner that accounts for local and worldwide reliability parameters, an information merging system produces potentially ideal outcomes for recognizing an object. As Root Truth, this information will be sent back into the network of fusion devices and used to fine-tune each sensor's broad reliability factor L [17].

The broader reliability factor L was calibrated using the Kuhn-Munkres (KM) method and the filter developed by Kalman in this research. In order to solve the problem of locating the most potent weight pairing in the divided chart, the KM approach was used. In this research, we know both the anticipated following mark S from the frame before it and the object recognition outcome C from the current frame. They form one of the two subgroups of the divided graph G. The prediction made in the prior frame by the sensor mark T is known. The KM method decides which of the two links is more reliable based on a preset set of principles and guarantees.

$$\sum_{j=0}^{n-1} N_{ij} \leq 1, \sum_{j=0}^{m-1} N_{ij} \leq 1 \tag{3.3}$$

Only one possible grade can be assigned for every test outcome. Before the KM method can be run, the Pearson correlation coefficient between the divided graph's nodes must be obtained. The value of this coefficient represents the degree of similarity between the indicator and the detection outcome. This article uses the IoU between the box boundaries as the association factor. Using the cross-section ratio, which comprehensively expresses the similarity of the position and the dimension of the two box boundaries, simplifies and improves the correlation coefficient calculation. The ratio of the points of intersection is also a helpful tool. Any

permutations where $T(i,j)$ is below 0.25 will be omitted once the value of the correlation matrix has been calculated.

These pairs of bounding boxes do not contain the same object because they are far apart. The absence of a correlation coefficient for the omitted combination shows no connection between the two points in the issue. In order to find the optimal combination of L and M, the KM technique repeatedly investigates the remaining connections. This is done so that the maximum number of correlation coefficients may be obtained between Tracker and Recognition by utilizing this specific conjunction:

$$\hat{N} = arg_{\max} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} N_{ij} T_{ij} \tag{3.4}$$

After obtaining the detection-tracking corresponding matrix T, we use the Kalman filter to update Tracker's monitoring of object data. It is possible to define the presence or absence of vehicles and people on the road based on the target's position and velocity relative to the world's geographic coordinates. The Kalman filter works on the premise that the target follows a Gaussian distribution in the kth structure, as this is the best approximation to the destination's natural state that can be made [1]. The mean of this distribution's values is sk, and its variance is s. Targeted velocity between successive frames may be roughly interpreted as consistent linear motion if the sample rate of the ambient awareness sensor is large enough. This happens when the ambient awareness sensor has a high enough sample speed.

Conversely, the law of object movement cannot be a perfectly uniform linear motion. The longer the time delay t, the more significant the discrepancy between the projected and actual values. This means that the measured data returned from the sensor must be used immediately to correct the predicted value.

In this article, we aggregate the data gathered from the sensors to learn about the target's location, size, and direction in a three-dimensional space. The sensor's speed data may be acquired by dividing the time gap between recognizing and the Tracker's locations by their magnitudes. Add the sensor readings for position and speed and write the result down as zk. Then, the Kalman filter merges the distributions of sensor readings P_{sensor} and the goal state prediction P_{pred}. After the two distributions have been reunited, they must be re-projected onto the initial target space of states. This distribution will be saved in the relevant Tracker so that a prediction can be made on the intended state of frame k+1. The SK file's location data will be used to fine-tune the four cameras' global weights. The following procedures constitute this process:

1. The 2D object recognition system predicts the perimeter of an object using the conventional NMS technique, which involves creating separate forecast data D_i for each image component.
2. Using the point of view projection alterations, read the sk file to determine the raster dimensions of the target's position pk and subsequently store the resulting ck file.
3. Frame k's worth of forecasts should be used as the Ground Truth to get the mean IoU value for B_i under cw.
   Find the ck in D_i corresponding to each bounding box's topographical center representing a prediction. First, using D_i as the appropriate ck, build a bounding box and then calculate the IoU value of the box. Using a weighting scheme based on the assurance parameter C of D_i, we can get the average IoU value of D_i under ck.
4. Update the sum confidence for each sensor to be consistent with its average IoU. The following is an illustration of a possible method for updating the K_i reliability factor for the sensing device i:

$$\alpha = \frac{1}{2} \ln \left(\frac{mean(IoU)}{1 - mean(IoU)} \right) \tag{3.5}$$

3. Non-maximal Inhibition on a Global Scale

At time t 1, the camera's universal assurance level Ki is modified, and the outcome is sent back to the GNMS component for incorporation into the next information frame. After that, images captured at time t are sent into a data fusion system. After the compact FPN network has finished manufacturing, an ROI area with $\{D\}_{i=1}^{M}$ is built [27].

The GNMS method performs fault diagnosis in line with the present frame's reliability coefficient (K, C). Reliable fusion outcomes may be achieved when unnecessary or inaccurate sensor data is discarded.

Table 4.1: KITTI information complexity classification

Degree of complexity	Minimal case e levation (Pixels)	Extreme obscuration	Most severe abbreviation (%)
Simple	45	Visible	20
Moderate	30	Partial	35
Hard	25	Not visible	45

Unlike traditional algorithms for environmental awareness, GNMS may focus on combining data operations and limit input from sensors in real-time using calculated regional and global reliability factors.

After the picture region of interest (ROI) set $\{D\}_{i=1}^{M}$ is muted by the global non-maximum value, junk data is purged, and gaps are filled in.

The results of object identification utilizing shared sensor information have finally been obtained.

4. Experimentation & Results.

4.1. Assessing the Efficiency of Networks.

1. Laboratory Environment

The following sections will illustrate how these setups are used to produce all of the results. The model is first pre-trained for 0.5 million cycles in a batch size of 8 using the COCO dataset. The Adam optimizer's training begins with a learning rate 103 and is further enhanced at steps 400 thousand and 500000 by multiplying by a hyper-parameter of 0.01. The pre-trained model is then utilized to train at an ongoing pace for an additional hundred iterations on the KITTI dataset. The weighting coefficient of the bounding box regression loss specified previously has been set to 1 to facilitate faster convergence. Two RTX 2300Ti GPUs are used in every training session [24].

2. Evaluation of Object Identification Efficiency

Scientists now have a fully developed model evaluation mechanism due to the KITTI information set. The program improves upon the PASCAL VOC-created computational method called average accuracy. The system cares little about anything that is too little to be seen by the camera or too far away from it to be of interest [25]. The strictness of the model's requirements is reduced. In addition, KITTI's model evaluation method categorizes the job into simple, mild, and complicated categories, depending on the size of the target boundaries and the degree of obstruction. Table 4.1 provides a detailed description of the difficulties.

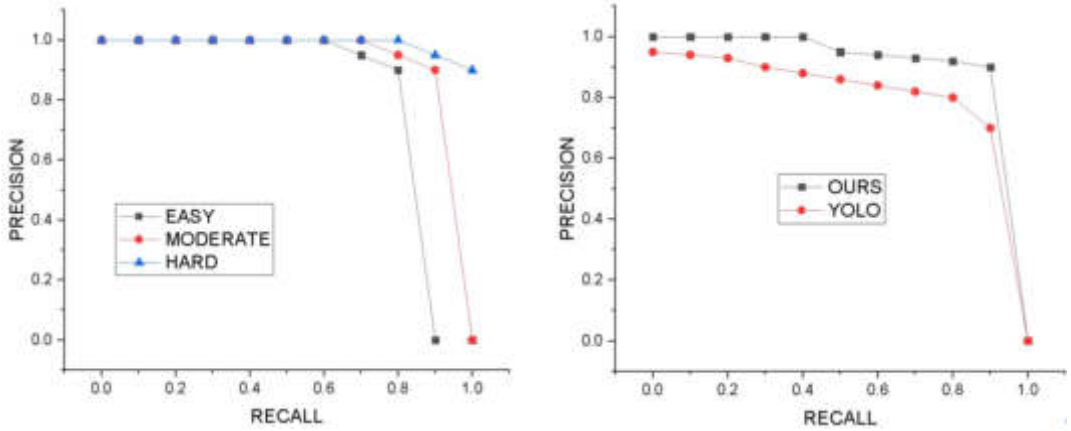
The items in the KITTI dataset are divided into three categories for evaluation. Vehicles, customers, and cyclists are all examples of these types. The AP70 measure should be used for vehicle goals, and the AP50 metric should be used for passenger and bicycle goals when assessing the efficacy of the network.

We chose to use the set-aside method to assess network performance because the test set that the KITTI provided lacked a clear name. The test set was built by selecting 2000 snapshots at random from the initial training set. Please remember that these 1,000 images are not part of the network's training [11]. Finally, we compile the evaluation findings of other notable networks on the Leader Board of the official KITTI website and use them to evaluate our network's efficiency. Table 4.2 displays our comparative findings.

In this article's network, the precision and recall (PR) curve is shown in Figure 4.1(a) for three different levels of complexity. During this process, the PR50 curve for YOLO_V3 is compared across all of the test sets, as shown in Figure 4.1(b). The object detection network must process four separate 2D images simultaneously. In order to reduce the number of network variables and the required amount of processing power, we have used several methods, including HOG feature extraction and residual networks. This was accomplished keeping the algorithm's real-time speed and memory size of the GPU in mind. Table 4.2 and Figure 4.1 show that even after extensive optimization of the network's settings and calculating velocity, our device identification system still ensures a high accuracy and recall rate, and its object detection capabilities can meet the current needs of self-driving cars in terms of the precision of their sense of the environment.

Table 4.2: Evaluating 2D image detection's effectiveness

Community	Existing Duration (s)	Simple (%)	Medium (%)	Difficult (%)
YOLO800	0.14	79.12	75.32	64.84
Fast-SSD	0.07	86.11	67.8	58.9
ResNet-RRC	0.07	92.43	86.34	75.25
MonoFENet	0.16	92.68	85.64	77.72
RefineNet	0.3	92.9	82.02	66.69
RetinaNet	0.3	94.3	83.74	69.38
Faster-RCNN	2.2	89.56	84.17	73.63
Proposed method	0.03	96.46	89.21	87.45



(a) PR curve for 2D image detection (b) Performance of 2D image detection compared with YOLO_V3

Fig. 4.1: Evaluating 2D image detection effectiveness

4.2. Effectiveness in Detecting and Preventing Problems. This paper's FDA architecture is developed primarily for two sorts of problems: worldwide problems and localized failures.

The study mimics the worldwide defects with the device's out-of-focus issue. When a photograph is down-sampled, its overall quality decreases, resulting in a blurrier, less distinguishable, and more difficult-to-find picture.

For the sensor's out-of-focus defect, we may utilize the down-sampling procedure as indicated in Eq. (10), where the input image matrix is I and the output fault image matrix is E.

$$E = I(i - (i \mod t), j - (j \mod t)) \tag{4.1}$$

where t is the number of rounds in the down-sampling process.

For regional issues, we employ the picture-shortening issue as a model, and we replicate the most severe jumbled impact by disrupting the vertical organization of the localized portion of the picture. This form of distorted coding additionally renders the system more vulnerable to identifying error issues, and the resulting impact is more noticeable in the test scenario since the error message is created on the foundation of the initial information [26]. Assuming the shuffling() method can cut and rearrange a stream of constant information, we can write an expression that represents the effect of regional garbling on the individuals:

$$E = I(\text{shuffle}(i), j) \tag{4.2}$$

Table 4.3: Evaluation of reliability under stress

Video routine	Out of focus (FDA)	OoF	Shortened (FDA)	Shortened
09-27-0010	0.8092	0.74	0.82	0.69
09-27-0018	0.8834	0.81	0.89	0.67
09-27-0052	0.7723	0.66	0.78	0.61
09-27-0057	0.8823	0.76	0.89	0.83
09-27-0058	0.8465	0.75	0.83	0.81

Table 4.4: Multi-sensor reliability assessment of efficiency

Video routine	Out of focus (FDA)	OoF	Shortened (FDA)	Shortened
09-27-0010	0.803	0.699	0.801	0.643
09-27-0018	0.882	0.743	0.872	0.612
09-27-0052	0.771	0.641	0.763	0.601
09-27-0057	0.880	0.740	0.873	0.822
09-27-0058	0.844	0.721	0.802	0.791

The full results are shown in Table 4.3. Table 4.4 shows the average IoU acquired by our intranet and the group serving as the control when two cameras experience both local and global faults at the same time.

When serving as a comparison group, the network uses the same system variables as when actively fusing information. However, it does not utilize the GNMS module or the Kalman filter section, instead relying only on the weight-based method. The software sensor failure simulation is applied to the KITTI Raw-Data dataset, and we then run our fusion framework and the control group to achieve object identification results. Next, we compare the Mean-IoU value from out-of-focus and truncated fault data to see how they compare. The FDA effectiveness of these two networks may be compared more understandably by drawing the mean IoU curve of the system below the footage data, with the total number of pixels functioning as the x-axis and the IoU value of each picture functioning as the y-axis.

Figure 4.2 depicts the mean IoU curve for this network and the conventional data fusion network with the sensor down using the video data with the identifier 09-26-0056 as input.

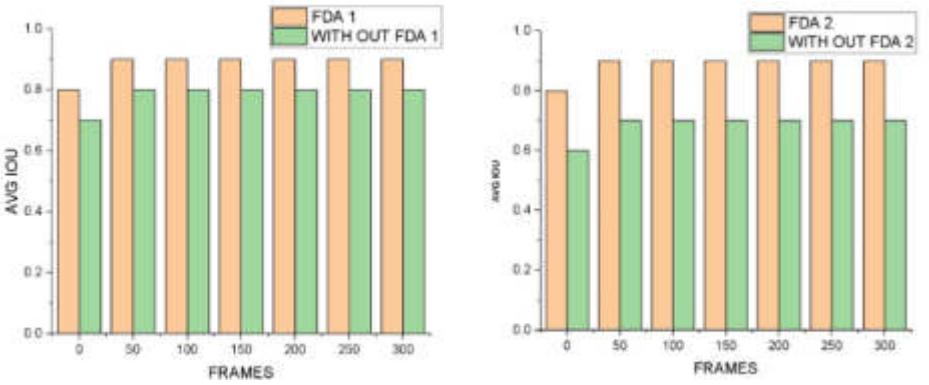
In order to evaluate the maximal defect capacity of the information integration architecture developed for this article, we inflict progressively severe global and local sensor malfunctions on the sensor data of numerous webcams and calculate the mean IoU value in the same manner. This enables us to learn the framework's maximum fault tolerance. Select the 07-19-0073 footage as the input and draw the IoU graph that occurs when both sensors fail simultaneously, as shown in Figure 4.3.

Figure 4.4(a) demonstrates that when the same defect is presented to 3 of the four recording devices, the problem-prevention mechanism of the network developed in this study malfunctions. The inability to recover has also led to a significant drop in the mean IoU gradient.

Difficulties arise because our system considers every finding outcome genuine and modifies the detector's load based on this information. The fault tolerance mechanism becomes useless due to the discrepancy between the first collision identification outcome and the actual reality. When subjected to the identical fault condition, every single camera will provide error findings that are comparable to one another. When garbled characters with different positions and ways of making them are sent to all three cameras, as shown in Figure 4.4(b), and the mean IoU curve is calculated from this data, the faults added to the sensor are correctly removed.

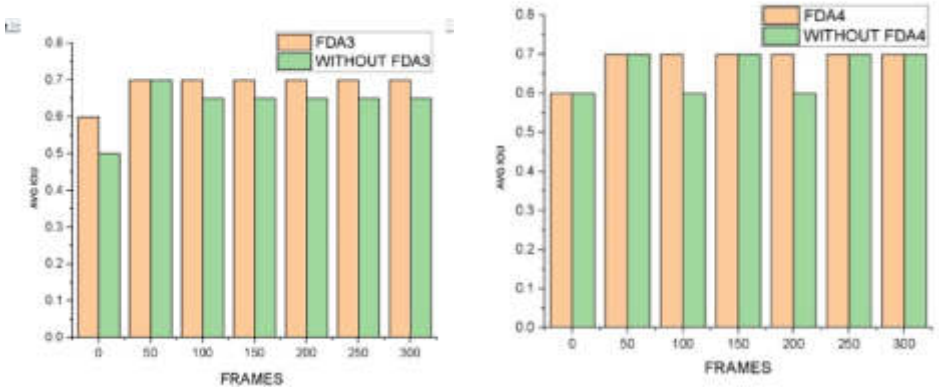
The effect of error messages on how well an object is recognized and how well our system works to get rid of problem detection findings can be shown more clearly by distributing the detection findings of the information combination structure described in this study and comparing them with the initial image information for the control group.

Tests show that when two or more cameras have accurate data, the fault-detection approach developed for



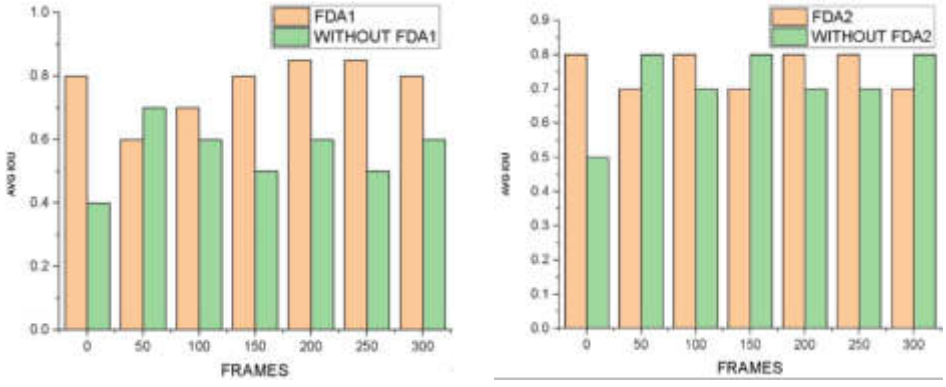
(a) Out of Focus Failure (b) Truncation Failure

Fig. 4.2: Performance of FDA



(a) Out of Focus Failure (b) Truncation Failure

Fig. 4.3: Evacuation of FDA



(a) Create a similar flaw] (b) Use a variety of failure scenarios

Fig. 4.4: Assertion from the Food and Drug Administration (three defective sensors)

this research can effectively filter out the distracting data caused by the sensor's global and local flaws. Global and local conviction procedures may eliminate perception mistakes during network functioning in time, and they can make full use of more precise data from sensors to provide the optimal combination impact even if the sensor in question does not have a substantial failure event. This is the case even if no significant failure occurs with the device.The results show that The proposed method can effectively diagnose the unmanned vehicle GPS sensor The same anomaly under cyber attacks, compared to mainstream intelligence The diagnostic algorithm has higher diagnostic accuracy and faster anomaly detection Measure the speed.

5. Conclusion. In this paper, an improved navigation sensor for unmanned vehicles is proposed to solve the problem of being vulnerable to hackers 1DGAP-CNN's new deep learning algorithm for detecting unmanned vehicles Driving a car's GPS navigation sensor due to physical failure or cyber hacking A variety of abnormal problems arising from intentional attacks.In this paper, one dimensional convolutional nerve, which is at the forefront of deep learning, is firstly introduced The network algorithm is introduced into the field of attack diagnosis of unmanned vehicle sensor network. Secondly, the real-time requirement and realization of unmanned vehicle network attack diagnosis Row 1D-CNN algorithm parameters too many insufficient, through the design of one A one-dimensional global mean pooling layer to replace the current 1D-CNN Flatten layer and the fully connected network part of Layers 2 to 3. The results show that The improved method can effectively reduce the number of model parameters and improve them And the diagnostic accuracy rate reached more than 99%.

1. An information integration architecture with a defect diagnostic method has been suggested to address the problem of identifying objects in self-driving situations. This structure eliminates the background data provided by the instruments during external information gathering. It allows for the reciprocal detection of defects amongst perception devices by establishing global and local reliability values.
2. Experiments with the KITTI collection show that the information integration system proposed in this study significantly reduces the load on the computing and storage units of the multi-source environmental monitoring technology without affecting the accuracy of item detection.
3. If the image sensor has an extensive global or local flaw, the data integration system would be able to erase malfunctioning data in a timely way using the FDA technique proposed. Doing so will guarantee trustworthiness and precision in the merged dataset.

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APPLICATION OF DEEP LEARNING ALGORITHM IN VISUAL OPTIMIZATION OF INDUSTRIAL DESIGN

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Abstract. In order to understand the application of degree learning algorithms in industrial design visual optimization, the author proposes an application research based on deep learning algorithms in industrial design visual optimization. The author first starts with the basic principles of deep learning algorithms and provides a detailed explanation of the basic structure of the single-layer network of deep learning algorithms, as well as the restricted Boltzmann machine and its training process. Finally, an example of the performance improvement brought by the application of deep learning technology in handwritten digit recognition was given through an automatic encoder, and a simple summary of deep learning technology was made. Secondly, the NCI matching algorithm is used to match industrial design products and reconstruct the point cloud of industrial products to accurately detect their features. On this basis, deep learning algorithms are applied to construct a visual optimization model for industrial design, determine the output format of the model scene and the output situation of industrial design, and process the model according to the changing characteristics of the industrial design model to comprehensively edit the data of the model. Finally, targeted optimization of the industrial design visual optimization model is carried out based on the technical characteristics of deep learning algorithms, in order to complete the industrial design visual optimization. The experimental comparison results show that the industrial design visual optimization method optimized in this design has higher visual clarity than the traditional industrial design method, reaching 98%. Greatly improves the visual clarity of industrial design.

Key words: Deep learning: Industrial design; Visual optimization

1. Introduction. Industrial design, also known as industrial product design, is formed by industrial development and division of labor, which is significantly different from other art, craft production, and production activities. It is also an interdisciplinary product formed by the joint action of various disciplines, technologies, and aesthetic concepts. Industrial design can generally be divided into four categories, namely communication design, product design, environmental design, and design management, including mechanical design, clothing design, graphic design, network design, display design, animation design, architectural design, and many other branches. Industrial design involves various knowledge such as sociology, psychology, aesthetics, photography, mechanical construction, color, and ergonomics. In a broad sense, industrial design is a set of highly feasible design schemes from creative conception to design establishment, aimed at achieving a specific purpose. It is also a series of behaviors expressed through scientific methods and methods. The broad definition of industrial design includes all design processes that use modern means for production and service.

In a narrow sense, industrial design is product design, which responds to the demand for tool and equipment production in the connection between humans and nature. It includes the material equipment design of a series of tools, instruments, products, and other materials that meet the needs of survival and development. Because industrial design has been dominated by product design since production, product design is also known as industrial design. As a highly professional academic term - visual optimization design, it is a design that expresses and disseminates the information to be expressed through visual communication media. With the continuous development of science and technology, the development and utilization of new materials and energy, and the field of visual communication design is gradually expanding. Visual optimization design includes display design, printing design, packaging design, impact design, visual environment design, etc.

The research on visual optimization design in industrial design is the process of conveying the product itself, product promotion and design information, and consumers' visual perception of the product through visual communication design. It also focuses on the targeted research and design of integration issues for consumers in the process of purchasing and consumption. When optimizing visual design, it is necessary to position the

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visual experience throughout the entire process, in order to elevate the quality of the product and enhance its taste.

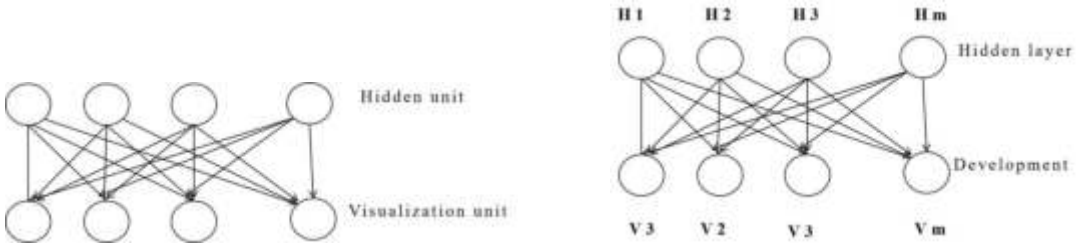
With the continuous progress of the times, people's quality of life is increasingly improving, so there is also an increasing emphasis on the visual aspect of industrial design. In the 21st century, this visual design has become a visual culture that permeates people's lives. The formation of visual culture is not accidental, but a product that conforms to the development of the times. In the context of global economic integration, the level of technology is constantly improving. With the application of various new technologies, industrial production is also constantly incorporating visual design concepts. Under the influence of this visual design concept, many industrial products pay more attention to personalized design while meeting the rationality of the product. Not only that, many industrial products widely solicit people's opinions at the beginning of design, achieving an organic integration of industrial products and art, so that people can not only feel practicality but also meet their own aesthetic needs.

In today's constantly advancing technology, science and technology itself can be regarded as an art, and its added value has greatly exceeded its usage function. In this context, modern industrial design is also advancing with the progress of the times, with obvious characteristics. For example, modern industrial design is no longer limited to the original intention of visual cultural design, not only for the aesthetics of industrial products, but also to increase the connotation and usability of products. In addition, modern industrial design is based on visual culture, through the organic integration of art and technology, in order to increase industrial production and enhance the popularity of industrial products. Therefore, the vigorous development of industrial design is an inevitable trend of the times, which has important practical significance for the inheritance of human civilization and the dissemination of art and culture [1, 2].

2. Literature Review. Human activities cannot be separated from human senses, and human perception determines the process of activity. As a crucial research field in cognitive psychology, the field of perception mainly includes the five senses of human beings, namely vision, hearing, smell, touch, and taste, vision is the most important of the five senses. Perception is the overall understanding of things formed in the mind through the direct effect of external information stimuli on the senses. External information directly affects perception, and human perception is influenced by their own stored knowledge and experience. Different human individuals are also affected differently, resulting in differences in human activities. Therefore, the sensory perception stimulated by external information and human past knowledge and experience determine the cognition of things. Among many forms of perception, visual perception exists as the most core form of perception, and its research significance is also the most valuable compared to other forms of perception. At the same time, it serves as one of the main channels to obtain a large amount of external information. However, human attention is limited and can only allocate a certain amount of resources to the visual system. Visual selective attention will play a role in this process, and visual selective attention mainly reflects eye movement at the physiological level of the human body. Therefore, eye movement research is particularly important, which can obtain the cognitive mechanisms and characteristics of users when observing objects.

Through research on the visual perception process, it has been found that it mainly consists of three parts: capturing visual stimulus information, organizing visual stimulus information, and generating cognitive responses to stimulus information. The entire process can be reflected as follows: The eyeball captures external visual stimulus information, then obtains and processes the stimulus information through the brain, and finally generates corresponding cognitive responses.

Deep learning is a new area of machine learning research that relies on neural networks to generate experimental models of human brain analysis, learning, cognitive processes, goals, and visual information in the human brain. A representative success of this is the "Auto Encoder" proposed by Hinton in 2006, which has been very successful in encoding. Previous neural network studies have also attempted to address this issue, but have not achieved significant results due to the lack of deep network models and training problems. Deep learning is machine learning that aims to generate deep patterns that typically include at least three hidden layers. This type of network with many hidden layers is difficult to train using simple neural network algorithms such as the BP algorithm. This is due not only to the need to process large data samples and the slow training process, but also to the fact that it is not easy to exchange internally rather than global optima, which have disadvantages. Moskola, W. et al. A restricted Boltzmann machine (RBM) was introduced as a simple model



(a) Boltzmann machine (b) Restricted Boltzmann machine

Fig. 3.1: Boltzmann Machine and Restricted Boltzmann Machine

of a single-layer network and a deep network was trained by hierarchical training. This type of effect has been demonstrated using automata and laid the foundation for deep learning concepts and models [3].

There are three main steps in deep learning: Firstly, training the system in an unsupervised manner, which involves extracting layers from a large number of unlabeled samples and automatically forming features without guidance. This process is similar to how people automatically form different types of information impressions in their brains after receiving image and sound information through sensory systems such as the eyes and ears. Secondly, alignment. This process uses some labeled samples to classify features, and further adjusts system parameters based on the classification results to optimize the system's performance in distinguishing different types of information. Similar to people knowing what a deer is, what a horse is, or what voice quality is good and what is bad. Thirdly, testing is conducted to test the learning effectiveness of the system using unknown sample data, such as the correct classification rate of samples, the correlation between quality evaluation and subjective evaluation.

Only the ideas are visible, and another layer of deep learning is hidden behind the last layer, making it difficult to determine how much information they contain. It's like seeing an animal, from being updated to making a final decision like a horse, from the brain gradually abstracting information at the same level. It's not easy to tell. But to train a deep network layer by layer, it is necessary to specify the information data of each hidden layer and show their relationship. Good for those who know a lot. Peng, Z. et al. The solution is to use RBM as the core process of the network and train the network layers from the bottom up until the desired results are produced at the top level. The learning process of all layers is the same: The lowest layer uses data as input and output data as output; Upper layers use the output of lower layers as input and generate information based on the upper layer. For example, the input can be any number of digits and the output can be 0-8. The input and output dimensions of each layer, as well as the number of layers in the deep network, can be written without special restrictions as needed [4].

In the visual design of traditional commercial design, the floor plan is often used as the basic equipment to solve this, creating visual illusions, interactions and realism. algorithms. Those. NCI matching algorithms are used to match these models to product models and verify their features. Deep learning algorithms are used to test business models and gain design insights [5, 6].

3. Methods.

3.1. Deep learning models and training methods. A restricted Boltzmann machine is an improvement of the random network Boltzmann machine. As shown in Figure 3.1 (a), the learning process of the network is slow because the units in its layers are interconnected. In 1986, Somlensky introduced a constrained Boltzmann machine consisting of a visible layer and a hidden layer without interactions between units in the layers, as shown in Figure 3.1 (b). Using RBM for inference in this way is very effective.

Assuming that the RBM has n visible units and m hidden units, it is recommended to use vectors v and h to represent the states of the visible and hidden units, where vi represents the state of the ith visible unit. and hj represents the state of the jth hidden unit. room. Therefore, for a set of states v and h, the joint probability

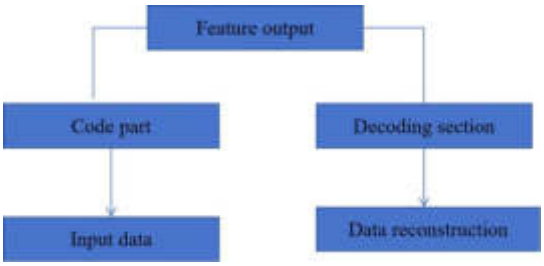


Fig. 3.2: Automatic coding

of the RBM system can be expressed as a power function using equation (3.1):

$$E(v,h) = -\sum_{i-1} w_{ij} v_i, h_j - \sum_{i-1}^{n} vi, b_i - \sum_{j-1}^{m} h_j cj \tag{3.1}$$

Infashion, w_{ii}; Ci is a measure of RBM. Among them, w_{ij} represents the coupling strength between visible unit i and hidden unit j, b_i represents the bias of visible unit i, and c_j represents the bias of hidden unit j. The task of learning an RBM is to estimate the values of these parameters that fit the training data.

Given the choice u of the training data, the latent class probability is based on the condition that the value of the latent class depends only on the distribution of the specified classes (3.2):

$$p(h_j)\sigma(\sum_{i-1}^{n} w_{ij} v_i + c_i) \tag{3.2}$$

Similarly, the conditional probability of the explicit unit can be conveniently calculated as equation (3.3):

$$p(v_j) = \sigma(\sum_{j-1}^{m} w_{ij} h_i + b_i) \tag{3.3}$$

3.2. Handwritten Digit Recognition. Autoencoders are the best example of deep learning. It consists of several layers of RBM. The working principle is that the input data enters the multi-layer RBM, converts high data into low data, completes the encoding process, and forms a middle layer process. Then, starting from each layer, the parameters of each layer generated by the coding process are reused, and the input data is reconstructed to arrive at a decision work(as shown in Figure 3.2). The entire network achieves fine-tuning of model parameters by minimizing the cross correlation between input data and reconstructed data, enabling the intermediate code layer to output more essential features [7, 8].

Here is an experiment using a 5-layer automatic encoder to classify handwritten digits in the dataset MNIST. The process is as follows: Firstly, preprocess the input data by converting the pixel values of the original digital image 29×29 into row vectors of 1×755. Therefore, during the training process, a four layer automatic encoder network with 794 units in the display layer and 1100-550-260-40-20 in the hidden layer can be established; Secondly, convert the original pixel intensity values between 0 and 265 to grayscale values between 0 and 2; Finally, the 65000 training samples in the database were divided into 650 small batches in groups of 120, and each training cycle processed these 650 small batches in sequence. The weights were only updated after each small batch ended [9, 10].

After the training of the automatic encoder is completed, the labeled samples can be used to test its classification performance and calculate the error rate. Table 3.1 compares the error rates of the automatic encoder introduced here with other classifiers. It can be seen that using automatic encoding machines can improve classification performance. It should be noted that the number of hidden layers and hidden layer units in deep learning networks can affect classification results, and there is currently no objective inference method for these quantities, so they have greater flexibility.

Table 3.1: Recognition performance of different classifiers on MNIST database

learning algorithm	Error rate%
automatic coding (1100 - 550 - 260 - 40 - 20)	1.3
BP algorithm	1.54
nearest neighbor method	2.9
Linear classifier	8.5
40PCA+particle algorithm	3.4
Support vector machine	1.5

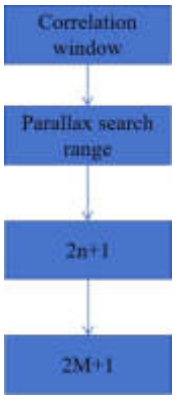


Fig. 3.3: Schematic diagram of NCI matching algorithm

3.3. Recognition of Visual Characteristics of Industrial Products. Before optimizing the visual design of industrial products, identify the visual features of industrial product design to improve the visual optimization effect of the design. View the industrial design to be visually optimized, streamline the number of product grid faces, use NCI matching algorithm to match industrial design products, and remove hidden objects from the products. The schematic diagram of NCI matching algorithm is shown in Figure 3.3.

In Figure 3.3, first give a point in the upper view and search for a matching point in the lower view based on neighborhood similarity. This neighborhood is a window that matches with the authentication point as the center. Reconstruct the point cloud of industrial products, give a three-dimensional point, use a normalization function to represent the projection of product images, and perform matching and feature tracking between industrial product images [11, 12].

Set the reference plane as p (n), k (n), and estimate the position of the three-dimensional point by finding the maximum average value of NCI. The calculation formula is as follows (3.4):

$$v(p) = \frac{1}{D(F) - 1} \tag{3.4}$$

3.4. Optimization of Visual Features in Industrial Design. Building intelligent models for business modeling based on deep learning algorithms. Use deep learning techniques to simplify the modeling process during development. First, based on the deep learning algorithm, prepare the design data of the business scene, clarify the business background information, maps and animations of the design process, satisfy the need for dimensional analysis of the design in three dimensions, and reduce the computer operation. Define the model output from the scene model and business model output and get a 3D scene that matches the actual business model. For design clarification, refer to the final EHF data for relevant design information [13, 14].

Applying deep learning techniques to create specific business models will create an image of a design model with differences, as not all models can achieve complete design. According to the business model image of the whole model, in order to ensure a good image of the business model design and reduce the model design error,

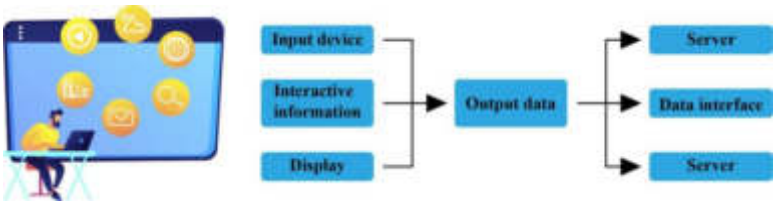


Fig. 4.1: Experimental Environment

the special model (3.5) is as follows.

$$I_1 - I_2 = \frac{1}{N} \cdot \sum_m i \tag{3.5}$$

In the formula, I_1 and I_2 respectively represent the industrial product models before and after error control; $\frac{1}{N}$ represents the model parameters for control optimization; $\sum_m i$ represents the image quality of industrial products.

After determining that the error of the optimized model meets the expected standards, detailed model parameters for industrial design are obtained through deep learning algorithms, and comprehensive data evaluation and analysis are conducted using the effectiveness of virtual simulation to obtain corresponding parameter data. After constructing a visual optimization model for industrial design, use the graphic acceleration process in deep learning algorithms to deeply interpret the industrial design model. On this basis, industrial design is optimized and processed according to the changing characteristics of industrial design models. On the basis of achieving real-time display of model information, the display effect of industrial product models is improved. Perform comprehensive data editing of the model using deep learning algorithms, using equation (3.6) to accelerate the model [15, 16].

$$d(m) = min(x - e) \tag{3.6}$$

In the formula: d (M) represents the vector length of the image; X-e represents the distance parameter from point a to point é within the industrial model product; Min is the optimization parameter. Set direction parameters based on the key points of industrial design to enhance the robustness of matching, and make targeted judgments on the visual optimization model based on the technical features of deep learning algorithms to ensure that the visual optimization effect of industrial design meets the expected goals.

4. Experimental Comparison.

4.1. Experimental Environment. The experimental environment mainly includes the Aiamond 3D Fire GL graphics card, which uses a 256-bit graphics scanner; The hard drive is a SCSL hard drive with 256 GB of memory; Large capacity external storage device; ADSL broadband network modem, etc. The specific experimental environment is shown in Figure 4.1. In the figure, the hardware mainly receives relevant industrial visual information; The purpose of input and output devices is to interact with the virtual environment through visual, auditory, and tactile means, mainly including displays, joysticks, and data gloves, to establish connections with the virtual environment; The data interface is connected to the tested machine to view experimental data in real-time. In the experiment, 20 simple industrial designs, 20 slightly difficult industrial designs, and 20 complex industrial designs were selected and compared using traditional methods and the author's design methods [17, 18].

4.2. Experimental Conclusion. Comparing the visual clarity of two industrial designs, the highest clarity is 100%. The higher the clarity, the better the optimization effect of industrial design. The experimental comparison results are shown in Figure 4.2.

From Figure 4.2, it can be seen that traditional methods have higher clarity in simple industrial design, while for slightly difficult and complex industrial design, visual clarity is poor and cannot display more industrial

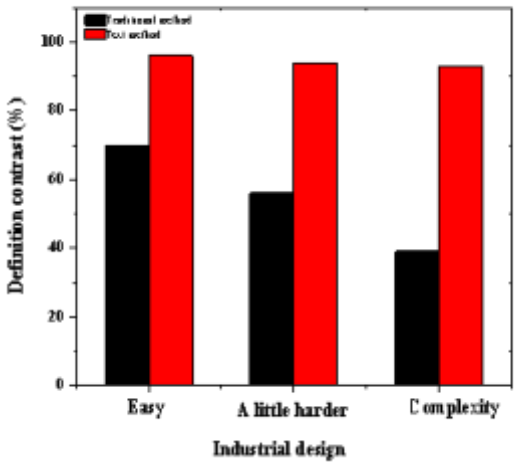


Fig. 4.2: Experimental comparison results

designs. The author's method has high clarity in simple industrial design, but for slightly difficult and complex industrial design, the visual clarity of industrial design remains unchanged and can still display more industrial design information [19, 20]. Explanation: The industrial design visual optimization method designed using deep learning algorithms can be displayed and processed according to the changing characteristics of industrial design, presenting a clearer industrial design effect.

5. Conclusion. Deep learning is how to use multilayer techniques to learn and represent the distributed capabilities of data models. It minimizes the requirements for quantitative and descriptive data models and automatically extracts many hierarchical features needed for classification using layerless learning methods. It has many features that differentiate it from existing machine learning. Currently, this technology is in the early stages of development and some important issues still need to be resolved. However, breakthroughs such as autoencoders show that deep learning has new ideas and great potential, which will have a significant impact on technologies such as machine learning and artificial intelligence in the coming years. The visual optimization method designed by the author for industrial design has higher visual clarity than traditional methods, which can improve the visual clarity of industrial design and provide certain assistance for industrial design, helping to promote the development of industrial design.

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RESIDUAL LIFE PREDICTION OF ROTATING MACHINERY GUIDED BY QUANTUM DEEP NEURAL NETWORK

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Abstract. In order to avoid the low prediction rate and high evaluation rate in estimating the service balance life of rotating machinery, this paper presents a quantum gene chain encoded bidirectional neural network (QGCCBNN) for estimating the service balance life of rotating machinery. In QGCCBNN, quantum bidirectional transmission mechanism has been developed. In order to improve the global optimization ability and convergence speed, we have developed a quantum gene chain encoding method to transform the gradient descent into the data transmission and updating. Because of the advantages of QGCCBNN in nonlinear estimation ability and convergence speed, the proposed QGCCBNN for predicting the remaining service life of rotating machinery can achieve higher prediction precision and optimization.The predicted value of the proposed method for the remaining service life of double row roller bearings is 6.33h (actual value is 7.17h), with a prediction error of only 0.84h and a relative prediction error of only 11.72%. The experimental results demonstrate the effectiveness of the proposed method.

Key words: Quantum bidirectional transmission mechanism; Quantum gene chain encoding; Prediction of remaining service life; Rotating machinery

1. Introduction. In the current era, China's industrial production is rapidly developing. With the proposal of "Made in China 2025", various types of mechanical equipment are experiencing rapid development [1]. There are various types of rotating machinery in various industrial fields, such as aviation engines in the aerospace field, gas turbines and wind turbines in the energy field, and automotive transmissions in the transportation field.

Although there are various types of rotating machinery, they generally include some common basic rotating components, such as rotors, rolling bearings, and gearboxes. This type of precision rotating mechanical equipment has the characteristic of complex operation and difficult maintenance. In the production process, many factors, such as decreased performance of components, inaccurate measurement of important components, and wear and tear of easily worn components, can lead to damage or shutdown of the entire equipment, causing economic losses, major accidents, and even casualties. Prognostics and Health Management (PHM) is an effective means to improve the availability, reliability, and safety of rotating machinery, and has a wide range of applications in practical industrial production environments [2, 3].

Researchers in the field of fault diagnosis are committed to developing an effective method that can detect faults that occur in the early stages of a fault and determine the severity of the fault. Ensure that production can be stopped and corresponding components can be replaced in a timely manner to avoid causing greater losses and better ensure the safety of people around.

The condition monitoring and fault diagnosis of rotating machinery play a crucial role in ensuring safe operation, reducing maintenance costs, and avoiding industrial accidents. In recent years, data-driven methods have gradually been developed and applied, and this technology has been reflected in many fields. It aims to learn the operational status of the system from data, achieve decision-making and control of equipment and production processes, and is currently the most common fault diagnosis technology.

This method can explore the internal information of various collected data through methods such as machine learning and statistical analysis, thereby establishing a fault diagnosis model. In response to this research issue, Xiao, W. et al. A network monitoring system which has three specifications is proposed to predict the

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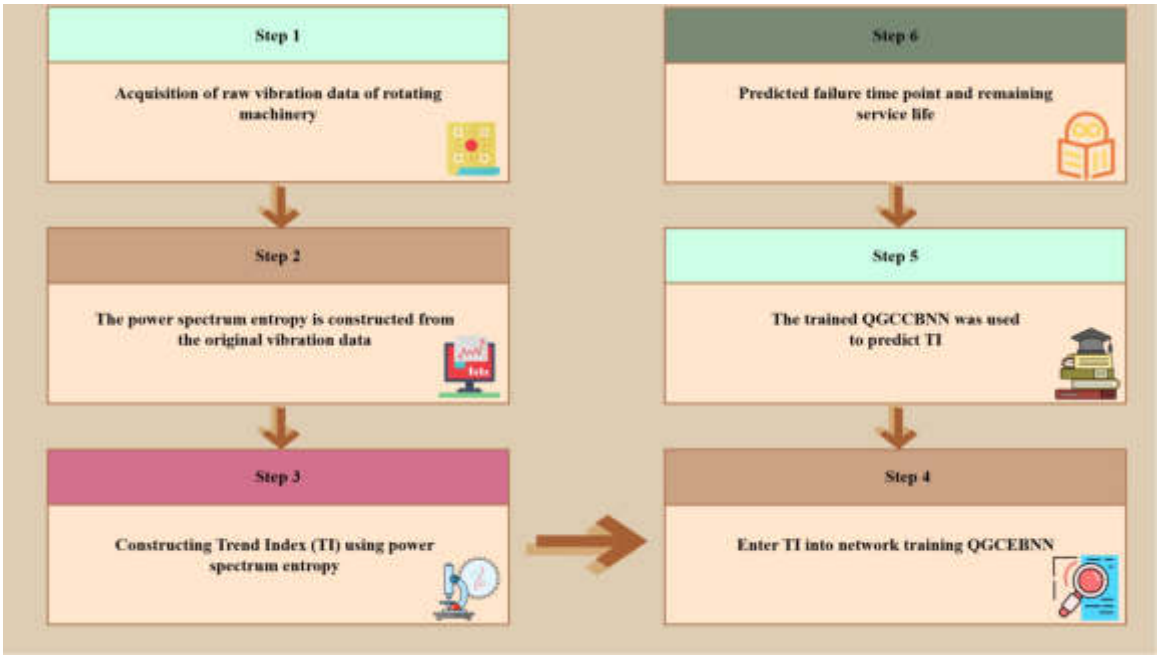

Fig. 2.1: Implementation process of residual service life prediction method for rotating machinery based on QGCCBNN

remaining service life of the bearing.First, connect channel listeners and broadband with a series of additional neural networks to get new attention in the network, making new deep learning more suitable for dynamic state feedback systems. Secondly, using the concept of "three characteristics" as the color in the network enables in- depth study of the network to better understand the changes in the carrying capacity and achieve better prediction of carrying RUL. Finally, the effectiveness of this method is verified by the establishment of experimental data. The results show that this method is simple, effective, has high prediction precision, and reduces manual interference [4].

In the prediction of time series, there is a cumulative effect of historical information, and it has shown certain application prospects in the prediction of remaining service life [5]. However, due to the lack of a reverse feedback mechanism from output to input in the network structure of recurrent neural networks, the bidirectional transmission mechanism can compensate for the aforementioned shortcomings.Which has good global convergence ability and convergence speed. Based on the above mentioned results, the author proposes a method to estimate the service remaining life of rotating machinery based on QGCCBNN. Firstly, the indicator model (TI) was established using the vibration data of rotating machinery as the feature of dynamic parameters. Then, TI was introduced into QGCCBNN to predict the damage of rotating mechanism. Finally, the failure probability model is established by estimating the transient dynamic curve (i.e. TI curve) to predict the remaining service life of the rotating machinery. This method has high prediction accuracy and efficiency [6, 7].

2. Prediction Method for Remaining Service Life of Rotating Machinery Based on QGCCBNN.

2.1. Implementation process of QGCCBNN based prediction method. The implementation process of the residual service life prediction method for rotating machinery based on QGCCBNN is shown in Figure 2.1 [8, 9].

Collect raw vibration data of rotating machinery; Constructing power spectral entropy using raw vibration data [10]; Extract trend features from power spectral entropy to obtain trend index (TI), and use TI as a performance degradation feature; Using well trained QGCEBNN to predict TI.

2.2. Prediction process of QGCCBNN. Use the trained QGCCBNN to predict degradation trends. The author used a multi-step prediction method for prediction, with specific instructions as follows: Input the test sample $(x_{b-n+1}, x_{b-n+2}, ..., x_b)$ into the trained QGCCBNN to calculate the output value $\tilde{x}_{b+1}$ at time b+1 [11, 12]. Input the latest test sample $(x_{b-n+2}, x_{b-n+3}, ..., x_{b+1})$ into the trained QGCCBNN to calculate the output value $\tilde{x}_{b+2}$ at time b+2. Input the latest test sample $(x_{b-n+3}, x_{b-n+4}, ..., x_{b+2})$ into the trained QGCCBNN to calculate the output value $\tilde{x}_{b+3}$ at time b+3 [13].

2.3. Prediction of remaining service life. Based on TI prediction results of QGCCBNN, a failure probability model for predicting the remaining service life of rotating machinery was established. Specific procedures are as follows: First, the regular operation of the process of rotating machinery can be expressed as:

$$x_t = x_0 + \lambda t + \sigma B_t \tag{2.1}$$

where x_0 and x_t are the initial and cumulative values of performance degradation characteristics (i.e. TI), respectively; λ is the degradation rate [14]; Because $B(t) \sim N(0, t)$, then x follows the following probability distribution:

$$x_t \sim N(x_0 + \lambda t, \sigma^2 t) \tag{2.2}$$

In order to find out λ and σ^2, using the maximum likelihood estimation method, represent the likelihood function $\Psi(\lambda, \sigma)$ as:

$$\Psi(\lambda, \sigma) = \prod_{k=1} \Phi_k(x_{t_k} - x_{t_{k-1}}) \tag{2.3}$$

Among them, $\Phi(\cdot)$ is the probability density function of the standard normal distribution [15, 16].
According to the maximum likelihood estimation method, take the derivative of $l(\lambda, \sigma)$:

$$\begin{aligned} \frac{\partial ln\psi(\lambda,\sigma)}{\partial\sigma} &= \sum_{k=1}^{n} \frac{x_{t_k} - x_{t_{k-1}} - \lambda(t_k - t_{k-1})}{\sigma^2} = 0 \\ \frac{\partial ln\psi(\lambda,\sigma)}{\partial\sigma} &= \frac{1}{\sigma}(-n + \sum_{k=1}^{n} \frac{(x_{t_k} - x_{t_{k-1}} - \lambda(t_k - t_{k-1}))^2}{\sigma^2(t_k - t_{k-1})}) = 0 \end{aligned} \tag{2.4}$$

According to equation (2.4), λ and σ^2 can be obtained as follows:

$$\begin{aligned} \lambda &= \frac{\sum_{k=1}^{n}(x_{t_k} - x_{t_{k-1}})}{\sum_{k=1}^{n}(t_k - t_{k-1})} \\ \sigma^2 &= \frac{1}{n}\sum_{k=1}^{n} \frac{(x_{t_k} - x_{t_{k-1}} - \lambda(t_k - t_{k-1}))^2}{(t_k - t_{k-1})} \end{aligned} \tag{2.5}$$

After obtaining λ and σ^2, the probability of failure can be expressed as follows:

$$F(t) = 1 - P(x_t < w) \tag{2.6}$$

where w is the TI value of the failure point. At this point, the failure probability model was established [17]. The predicted remaining service life of the rotating machinery is calculated as follows:

$$RUT_{predicted} = (NT_{QGCCBNN} - NT_1 + 1) \times \Delta NT \tag{2.7}$$

$NT_{QGCCBNN}$ is the predicted failure probability threshold point in the power spectral entropy curve, and s is the number of rows in the reconstruction matrix P.

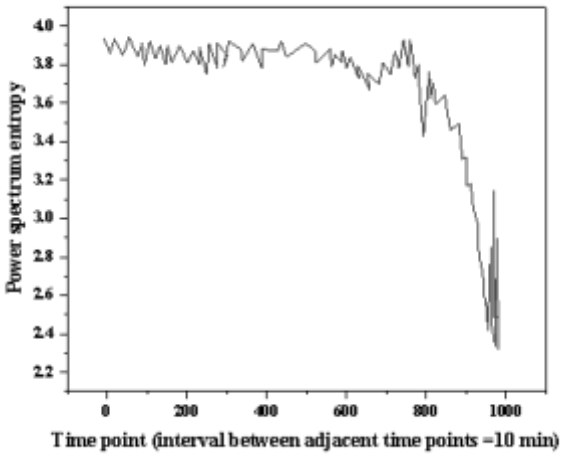

Fig. 3.1: Power spectral entropy of bearing 1

3. Example analysis.

3.1. Experimental Platform. The residual service life prediction method for rotating machinery based on QGCCBNN has been validated using rolling bearing quality data measured by the University of Cincinnati [18]. Install four ZA-2115 double row roller bearings produced by Linuo Company on rotary bearing test bench, use 2000r/min motor to drive the shaft through belt, and apply radial load of 6000 pounds to rotating shaft and bearing by spring mechanism. Install pressure sensitive ICP accelerometer on bearing seat and collect vibration data every 10 minutes.

3.2. Prediction Results of Bearing 1 Based on QGCCBNN Method.

3.2.1. Prediction process and results. Bearing 1 ran continuously for 9840 minutes (about 7 days) and began to experience outer ring failure at a later point in operation. A total of 984 sets of vibration data were collected, each with a length of 20480 points. The power spectral entropy of each set of data was calculated to obtain the power spectral entropy curve for the full life interval as shown in Figure 3.1 [19].

From the beginning to point 805, the power spectral entropy is still stable,which is the early fault; From NT2=948 to the end point,the power spectral entropy curve becomes irregular,indicating that the outer ring defects of the bearing expand rapidly and eventually become incomplete.

Next, 729 TI values are constructed from the power spectral entropy. As shown in Figure 3.2, the TI changes slowly from the starting point to point 550. After point 693 (for example, the actual TI value shown in figure 3.2 is input into the failure probability model in section 2.5, and the actual failure probability is calculated as the failure probability F(t)=90 of NT2=948), the TI is increased, indicated that the bearing was in a high speed stage and finally met the outer ring failure.

Use TI values from point 551 to point 650 as training samples, and use point 651 and its data extension (i.e. section 79 TI values) as test samples. The number of chromosomes τ=50, the update step of quantum bit phase Δw_0=0.07 π, the maximum number of chromosome iterations g_{max}=50, and the predicted mean square error threshold $E^t_{mse-min} = 5 \times 10^{-6}$ are shown in Figure 3.3. It is not difficult to find that within the interval [651729], the predicted TI value of QGCCBNN is very close to the actual value, and the trend of change between the two is highly consistent.

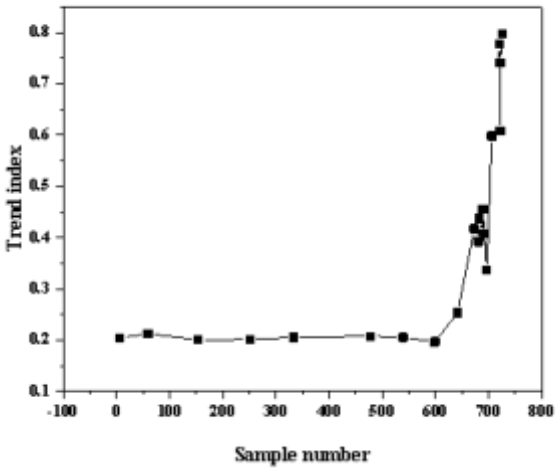

Fig. 3.2: Trend index of bearing 1

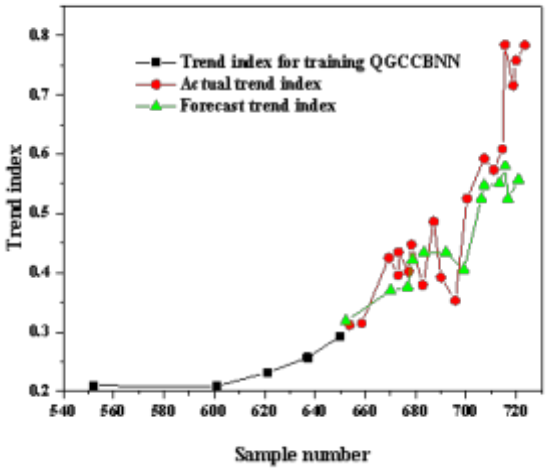

Fig. 3.3: Trend index predicted by QGCCBNN

Based on the incomplete probability model, in terms of parameters λ and σ During the calculation process, the approximate value of TI value is proposed, and then the approximate incomplete probability F(t) is calculated, as shown in Figure 3.4.

Then, predict the program's remaining lifecycle behavior 1. Because the remaining service life can often be represented by a time interval $[SN_{\text{forecast}}, SN_{\text{Lose effectiveness}}]$ between the initial prediction point SN_{forecast} and point $SN_{\text{Lose effectiveness}}$ failure, this interval corresponds to the interval $[NT_1, NT_{QGCCBNN}]$ shown in Figure 3.4, which is the predicted remaining service life of bearing 1. According to equation (2.7), $NT_1 = SN_{\text{Lose effectiveness}} + s - 1$, where s=256 is the number of rows in the reconstruction matrix P. Therefore, the predicted remaining service life is $RUL_{\text{forecast}} = (NT_{QGCCBNN} - NT_1 + 1) \times \Delta NT = 6.33h$; Meanwhile, the actual remaining life is $RUL_{\text{actual}} = (NT_2 - NT_1 + 1) \times \Delta NT = 7.17h$[20].

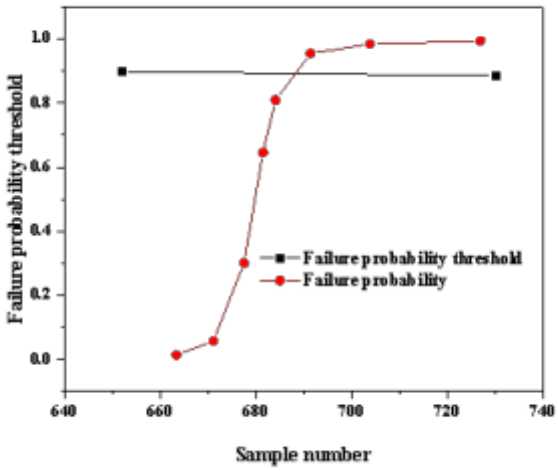

Fig. 3.4: Failure Probability Predicted by QGCCBNN

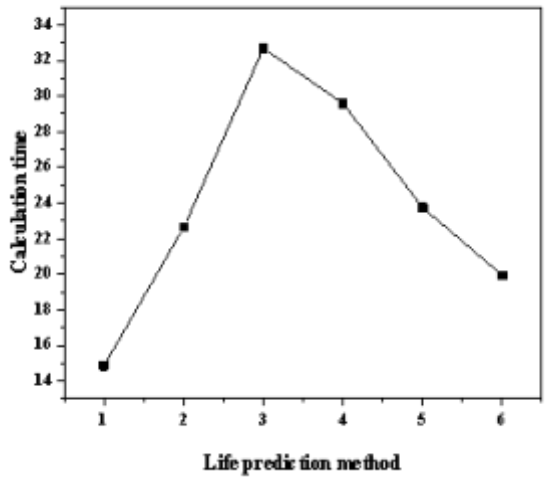

Fig. 3.5: Comparison of calculation time for remaining service life prediction methods

3.2.2. Comparative analysis with other methods. In order to ascertain the quality of QGCCBNN as a service life prediction tool for rotating machinery, the calculation time (training/training time, TI prediction time, total service life prediction time) was compared with QGCCBNN as the service life prediction method and RNN, DADNN, GRUNN, FCRBFNN, LS-SVM based methods. The results are shown in Figure 3.5. Obviously, the calculation time of the QGCCBNN based prediction method is shorter than that of the RNN, DA DNN, GRUNN, FCRBFNN, and LS SVM based methods, indicating that using QGCCBNN for predicting the remaining service life of double row roller bearings has faster convergence speed and higher computational efficiency compared to the compared methods.

4. Conclusion. When applying QGCCBNN, quantum bidirectional transmission mechanism was designed to establish the relationship between time and weight based on feedback from output network, thus improving the consistency between input data and the whole network memory, and having better nonlinear estimation ability. During the training of QGCCBNN, quantum gene chain encoding was designed to transmit and transfer information, avoiding the problems of slow convergence and high time value caused by gradient loss and gradient dispersion in the traditional value system.Therefore, QGCCBNN has better global convergence ability and faster convergence. Because of the advantages of QGCCBNN such as poor prediction ability, global convergence ability, and fast convergence, the service life prediction of rotating machinery based on QGCCBNN can achieve high prediction precision and reduce computation cost.

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STABILITY EVALUATION METHOD OF HIGH FILL LOESS FOUNDATION BASED ON NUMERICAL SIMULATION

WENLI WU, LEI WANG, JIHENG CHENG, AND RENZHUO HAO *

Abstract. In order to understand the stability evaluation method of high fill loess foundation, the author proposes a study on the stability evaluation method of high fill loess foundation based on numerical simulation. The author first established a three-dimensional finite element model of a multi-level high fill slope using PLAXIS 3D software based on a loess high fill slope engineering project in a certain section of northwest China. The study investigated the effects of changes in fill materials, fill boundaries, slopes, and unloading platforms on slope stability. Secondly, based on the vertical and horizontal displacement of the top and foot of each level of slope under step-by-step filling, the distribution pattern of the most dangerous points of each level of slope and the overall deformation trend of the slope were analyzed. The results indicate that the cohesion and internal friction angle of the filling material are key factors affecting the stability of high fill slopes. Reducing the height of the steps at the boundary between the filling and the undisturbed soil, deepening the width of the steps, reducing the slope, and widening the unloading platform can all improve the stability of the slope. During the construction of lower slopes, there is a significant vertical displacement mutation, while the horizontal displacement mutation is relatively slow; After the construction is completed, the deformation situation is good, and the vertical and horizontal displacement of the higher slope during construction changes greatly, with uneven distribution; After the completion of construction, the consolidation settlement period is long and the deformation is large; Emphasis should be placed on strengthening deformation monitoring at high altitudes after construction is completed. Finally, the platform width can be selected within this range based on the actual engineering situation. After the platform width is greater than 3.6m, as sufficient platform width has been reached at this point, further increasing the platform width has little impact on the safety factor, and the curve gradually flattens out. The research results have determined the stability influencing factors, deformation trends, and development laws of loess high fill slopes in the northwest region, providing a scientific basis for further research on deformation control of loess high fill slopes.

Key words: Numerical simulation; Stability assessment; Loess land

1. Introduction. Loess is widely distributed, covering an area of approximately 640000 km2, accounting for 6.6% of the total land area, with the Northwest Loess Plateau being the main distribution area of loess. The Loess Hilly and Gully Region is the most vast landform area on the Loess Plateau. Due to the combined influence of internal and external dynamic geological processes and water flow erosion, the area is mainly characterized by longitudinal and horizontal gullies, and scattered beam shaped hills. In recent years, with the development of the national economy and society and the deepening of the Western Development, the speed of urbanization construction has been continuously accelerating, and the expansion of western cities has also been parallel to it. Due to the unique terrain and geomorphic conditions of the Loess Plateau, there is a shortage of available land resources in the area, which greatly hinders social development. Therefore, "cutting mountains, filling ditches, and creating land" is essential.

Large scale land filling projects have become common in China. Based on the existing engineering experience and practical engineering characteristics, several issues need to be paid special attention to when carrying out high fill projects in loess hilly and gully areas, including:

(1) Changes and impacts of groundwater environment. The gullies in the loess hilly and gully areas are developed, with steep slopes and deep gullies. Most gullies have surface water flow exposed in the form of descending springs. The main types of groundwater are Quaternary phreatic water and bedrock pore and fissure phreatic water. The practice of "cutting mountains, filling ditches, and creating land" in loess hilly and gully areas will inevitably block channels and springs, thereby changing the original groundwater seepage path

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Fig. 1.1: Numerical simulation of stability evaluation of high fill loess foundation

and breaking the groundwater seepage balance. Moreover, the compacted loess fill itself has poor drainage conditions, this is likely to cause surface water and groundwater to seep into the fill, causing the water level inside the fill to rise, and affecting the deformation and stability of the high fill foundation.

(2) Settlement deformation of loess filling body. Settlement deformation is one of the most concerned issues in high fill engineering, which mainly involves the following aspects. Due to the high height of the filling and the high self weight stress, the additional stress generated by the filling body on the original foundation is also large, which will lead to significant post construction settlement deformation of the original foundation; Due to the high self weight stress of the filling body, it will also experience compression settlement under the influence of its own gravity. In addition, due to the differences in engineering properties between the original rock and soil mass and the filling body, uneven settlement is prone to occur at the overlap between the filling body and the original valley slope.

The post construction settlement of high fill is influenced by various factors such as the engineering properties of the original foundation soil, the properties and compactness of the fill soil, the height of the fill, the geometric form of the fill area, construction technology, and surrounding hydrogeological conditions. In the hilly and gully areas of the Loess Plateau, loose loess is used as the main filling material, and the water sensitivity of loess can cause its strength to decrease and deformation to increase when immersed or humidified. Therefore, it is particularly important to consider the impact of changes in hydrogeological conditions on settlement deformation, especially when the water level inside the filling body continues to rise. For the settlement of the original foundation and the settlement of the filling body itself, predecessors have done a lot of research work and proposed various settlement calculation and prediction methods. However, there is very little research on the settlement deformation of the loess filling body under the continuous rise of water level. Therefore, it is necessary to conduct further research and exploration to guide engineering practice.

(3) Stability of Loess High Fill Slope. Filling the ditch will form a high fill slope at the mouth of the ditch. Due to the development of gullies and complex geological conditions in the loess hilly and gully areas, the issue of slope stability is quite prominent. The stability of the fill slope is also affected by factors such as the weak structural plane of the original foundation, rainfall, earthquake, filling engineering properties, construction technology, and surrounding hydrogeological conditions. As analyzed above, the filling project in the loess hilly and gully area has destroyed the original natural drainage system, obstructing the original drainage channels, which is highly likely to cause water to seep into the filling soil and flow towards the slope. At the same time, due to the infiltration of water, the shear strength of the filling soil is also reduced, which can easily induce instability of the loess high fill slope. Therefore, it is particularly important to analyze the stability of the loess high fill slope in this situation [1,2].

The stability of high fill slopes is another core issue of concern in high fill engineering. In order to ensure the stability of high fill slopes, the slope gradient is sometimes designed to be very small, which results in a large land area for the entire slope, wasting land resources and increasing engineering costs. If the slope gradient is increased, it will also bring hidden dangers of slope instability. In order to solve such problems, certain support measures can be applied to high fill slopes, and the use of high-strength, low-cost, corrosion-resistant, and flexible geogrids to form reinforced soil slopes is an economical and practical method.

The existing engineering practice has also proven the superiority of reinforced soil slopes, as shown in Figure 1.1.

2. Literature Review. The settlement deformation of high fill foundation is mainly composed of the

settlement deformation of the original foundation under the influence of the self weight stress of the filling body and the settlement deformation of the filling body itself.

There are many engineering practices for predicting the settlement and deformation of the original foundation, and the classic layered summation method is often used as one of the more mature methods. However, there is currently no mature method for predicting the settlement and deformation of the filling body itself.

The settlement deformation of the filling body mainly consists of three parts: instantaneous settlement, consolidation settlement, and creep settlement. Instantaneous settlement and consolidation settlement mainly occur during the construction process and have little impact on engineering construction, but creep settlement mainly occurs after construction and lasts for a long time, which has a serious impact on the safe use of fill sites. Nevertheless, numerous scholars have never interrupted their research on predicting the settlement and deformation of filling bodies, and have achieved fruitful results, proposing various prediction methods.

In recent years, the development of computer technology has improved the applicability of numerical simulation methods, and the application of strength reduction methods based on numerical simulation technology in slope stability analysis is becoming increasingly mature. The so-called strength reduction method refers to the gradual reduction of the shear strength parameters of rock and soil in an ideal elastic-plastic calculation, until the slope loses stability and fails.

Firstly, it is an improvement based on the classic hierarchical summation method. Tang, L. et al. improved the layered summation method based on the characteristics of phased settlement deformation of fill soil, and found through calculation that the settlement curve of the filling body itself was not significantly different from the actual situation, and this method was simple and fast to use. However, the prerequisite for using this method is to assume that the fill only undergoes vertical deformation and ignores lateral deformation, which is inconsistent with the actual stress-strain state of the fill [3]. Another method for predicting the settlement and deformation of filling bodies is the numerical calculation method. By numerical calculation, the complex constitutive relationship of soil can be considered, and the complex on-site construction process can be simulated. It is an effective method to solve the nonlinear problem of settlement deformation of foundation soil. Sun, J. Q., and others used the high fill project of Jiuzhai Huanglong Airport as an example to analyze the settlement deformation of the high fill foundation using FLAC3D finite difference software, the settlement of high fill foundation is closely related to the original foundation stiffness and fill thickness, and the maximum settlement is directly proportional to the fill thickness [4].

This study takes a slope engineering project in a certain section of Longnan City as the background, and uses PLAXIS 3D three-dimensional finite element software to conduct finite element numerical simulation analysis on the deformation of loess high fill slopes without support. By changing the physical and mechanical properties of the slope filling material, the boundary between the filling and the original soil, the slope of the filling body, and the width of the unloading platform, the variation law of the safety coefficient is analyzed, and real graded construction conditions are simulated to study the deformation of various points on different levels of slopes. The deformation law of loess high fill slopes is analyzed, with the aim of benefiting the design and construction of loess high fill slopes in the northwest region [5,6].

3. Methods.

3.1. Principles of Safety Analysis. The PLAXIS 3D software uses the finite element strength reduction method to calculate the overall stability of the slope. In the initial soil strength parameters, the internal friction angle tangent $\tan\varphi$ tangent and cohesion c gradually decrease until the slope undergoes instability and failure, and the slope safety factor and optimal sliding surface position are obtained. The reduced soil strength parameter values in each calculation stage are defined according to the total multiplier $\sum m_s F$, that is Equation (3.1):

$$\sum m_s f = \frac{\tan\varphi}{\tan\varphi_r} = \frac{c}{c_r} \tag{3.1}$$

In the formula, $\sum m_s F$ is the reduced total multiplier; c, φ is the cohesion and internal friction angle of the fill; C_r and φ_r are the reduced cohesion and internal friction angle.

At the beginning of the program calculation, all soil strength parameters are taken as initial values, $\sum m_s F$ =1.0. During the calculation process, the total multiplier $M_s f$ is controlled by the load increment process, and

Table 3.1: Soil Layer Parameters

Soil layer name	severe $(kN \cdot M^{-3})$	cohesionc /kpa	internal friction angle $\varphi/(^\circ)$	Elastic modulus E/mpa	Poisson's ratio u
Plain loess	18	13	21	15	0.33
Loess like silt	18	13.3	21	16	0.4
pebble	23	11	36	85	0.026

the increment multiplier Msf is used to control the reduction of soil strength parameters, that is, $\tan\varphi$ and c are synchronously reduced. The default first step is 0.1. The strength parameters are automatically gradually reduced until all steps are completed, and then the model is checked to see if the slope has reached a complete failure state. If complete failure is achieved, a constant $\sum m_s F$ safety factor F_s is given in the calculation step immediately following the occurrence of failure. From this, Equations (3.2) and (3.3) are obtained.

$$Fs = \frac{\tau m}{\tau b} = \sum M_s f_d \tag{3.2}$$

$$\tau = C + \sigma \tan\varphi \tag{3.3}$$

In the formula, π_m represents the maximum shear strength of the soil when it is not damaged, and τ_b represents the shear strength of the soil when it is in equilibrium; $\sum m_s F$ is the incremental multiplier when the soil undergoes failure; τ is the shear strength of the soil; σ is the normal stress.

3.2. Project Overview. The project is located in a certain section of Longnan City, with a height of 30 meters and a slope ratio of 1:1 for manual slope cutting at section K0+460. It is divided into three levels of slopes, with each level of 10 meters. An unloading platform is set between the slopes, with a width of 3 meters. The site is classified as a Class II site, with a seismic fortification intensity of Class III. The design earthquake group is the second group, and the characteristic period is 0.40 seconds. The site strata are divided into three engineering geological layers from top to bottom, namely the plain fill layer, the Quaternary Holocene loess like silt layer, and the pebble layer. The main mechanical parameters of the site soil layer are shown in Table 3.1.

3.3. Establishing a finite element analysis model. Establish a numerical analysis model using PLAXIS 3D software. The slope height H is 40 meters, the top boundary is 30 meters, the bottom boundary is 16 meters, and the width is 20 meters, which can effectively weaken the boundary influence. Simplify the actual engineering terrain and establish an unsupported three-level fill slope, with the original slope surface steps having a height and width of 3m; 4 meters of unloading platform between slopes; The slope ratio is 2:2. When analyzing the factors affecting stability, modify the height and width of the steps, slope, and unloading platform width based on different conditions, using the Mohr Cou lomb model and Boit consolidation theory, the uniform compaction degree of the filling material is used. The groundwater level in this area is relatively low, so the influence of groundwater is not considered in the simulation process. The boundary condition of the model is a fixed constraint on the bottom surface, which controls the deformation in the c, y, and z directions; Horizontal constraints in the y-direction on both sides of the model; The upper surface deformation is open. During the calculation process, the corresponding filling layer is gradually activated to simulate the real construction process. The slope is filled in three stages, and the first, second, and third filling conditions are used to simulate the first, second, and third layers of slopes with heights of 20, 30, and 40 meters [7,8].

4. Analysis of software calculation results.

4.1. Impact of different c values on slope stability. The variation curve of slope safety coefficient is shown in Figure 4.1 when the value is fixed at 25° and the c values are 10, 20, 30, 40, and 50kPa, respectively. When the cohesion c value is o kPa, the safety factors of the three heights of slopes are not significantly different, all of which are the lowest, and even one layer of slope is less than 0.4. At this point, there is no cohesive force

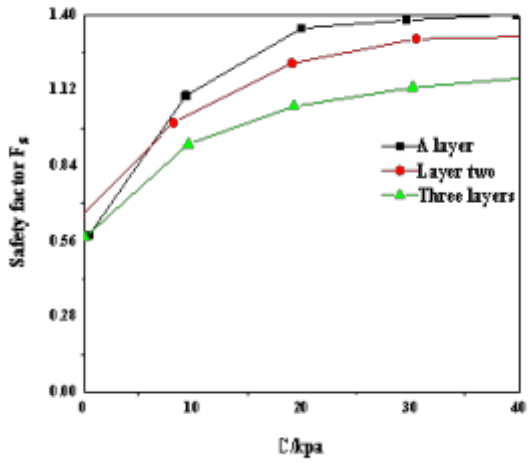

Fig. 4.1: Effect of Cohesion on Safety Factor

inside the filled soil, which is approximately pure sand and gravel, and there is also no cohesive force between it and the original soil. A large amount of filled soil is extremely unstable and very dangerous. When the cohesion c value increases to 10 kPa, the stability of the slope changes greatly, and the safety factor suddenly jumps to twice that of close to 0 kPa. When the cohesion is low, slightly increasing the cohesion of the fill can effectively improve the stability of the slope. Subsequently, as the cohesion increases, the safety factor slowly increases, and the upward trend gradually slows down and tends to stabilize. At this point, the cohesive force reaches a certain limit, which is sufficient to stabilize the slope. Increasing the cohesive force of the fill again has a smaller effect on improving the stability of the slope. When the cohesive force of the fill is less than 2300 kPa, the safety factor of the slope is small and the slope is not stable enough; When the pressure is higher than 30 kPa, the increase in cohesion has a slightly smaller impact on the safety factor. Therefore, it is most reasonable to choose a filler with a cohesive force of 30 kPa.

4.2. Impact of Different Values on Slope Stability. Change the internal friction angle φ value of the filling soil parameter in the model, and analyze the impact of different internal friction angles of the filling soil on slope stability. The above analysis shows that when the cohesive force is 30 kPa, the trend of changes in the slope safety coefficient before and after is more obvious, at this point, a cohesive force of 30 kPa is selected to analyze the impact of different φ values on slope stability. When the value of φ is calculated every 20° from 0° to 60°, the variation curve of the slope stability coefficient is shown in Figure 4.2. When filling the first layer of slope, the height is low, the amount of filling is small, and only the self weight of the soil is sufficient to support the deformation of the slope. The growth of the safety coefficient is gentle, and the change of the internal friction angle φ value has little impact on the stability of the slope. When filling the second and third layers of slopes, the curve increase is basically the same, and the overall safety factor of the third layer slope is slightly lower than that of the second layer slope [9,10]. When the internal friction angle is small, the slope increases linearly due to the large number of layers, high height, large amount of filling, and significant changes in safety factor; After the internal friction angle reaches 20°, the slope tends to stabilize. Increasing the cohesive force of the fill again has a small effect on improving the stability of the slope, and the safety coefficient curve grows slowly. The internal friction angle of the soil is directly proportional to the safety coefficient.

4.3. Impact of boundary changes between fill and undisturbed soil on slope stability. In the filling slope, in order to avoid the formation of sliding surfaces between the filled soil area and the original surface area, the natural ground needs to clean the surface and build steps. The cohesive force c value of the filled soil in the model is 30 kPa, and the internal friction angle φ value is 30°. Analyze the trend of slope

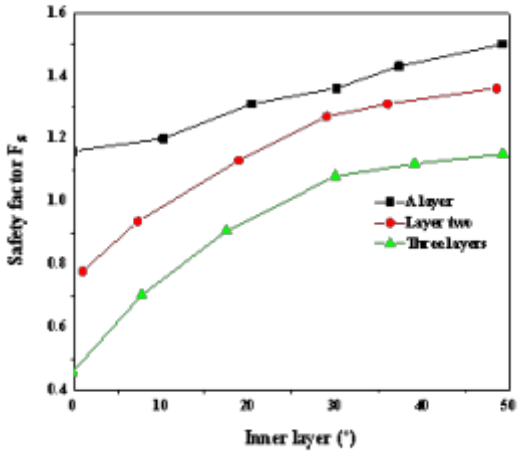

Fig. 4.2: Effect of internal friction angle on safety factor

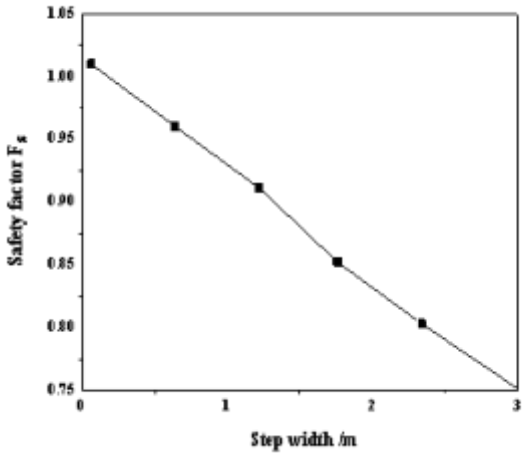

Fig. 4.3: Influence of changing step height on safety factor

stability by changing the height and width of steps at the fill boundary [11,12].

4.3.1. Impact of step height on slope stability. The width of the step is fixed at 1 m, and the height gradually increases to 4 m with a difference of 0.6 m. The safety coefficient variation curve of the three layer slope is shown in Figure 4.3, and the step height shows a linear trend with the safety coefficient of the slope. Due to the fixed width and height of the steps, the original slope angle becomes larger, and the contact interface between the fill and the original soil becomes steeper. The original slope cannot provide good support, and only relying on the gravity and cohesion of the fill itself to support, the safety factor decreases, and the stability of the slope deteriorates. The height of the steps is inversely proportional to the safety factor, and there is no obvious sudden change trend.

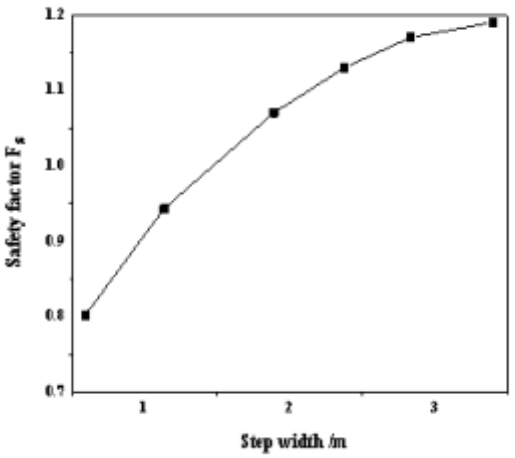

Fig. 4.4: Impact of changing step width on safety factor

4.3.2. Impact of step width on slope stability. The height of the step is fixed at 1m, and the width gradually increases to 4m with a difference of 0.6m. The safety coefficient change curve of the slope is shown in Figure 4.4. When the height of the step is fixed and the width increases, the original slope angle decreases and the slope slows down. The overall curve presents a parabolic shape, with an increase in safety coefficient and a strengthening of slope stability. When the width of the step is small, the amount of filling is small, but the original slope is steep and the support force is insufficient, increasing the width of the step has a significant effect on improving the safety factor of the slope; When the width of the step is greater than 1.6m and the slope angle is less than 34°, the filling amount is large but the slope surface is gentle, and a large amount of soil accumulates on the original slope surface. The original slope surface can provide good support force, which can be balanced by the self weight of the filling and the friction force between the original slope surface. Continuing to increase the step width and slow down the support force provided by the original slope surface is weak, and the safety coefficient increases slowly and tends to stabilize [13,14].

4.4. Impact of Different Slopes on Slope Stability. Change the fill slope in the model, establish a model every 6° from 25° to 90○, and analyze the variation curve of slope stability as shown in Figure 4.5. As the slope increases, the fill surface gradually steepens and the safety factor decreases. When the slope changes between 25° and 45°, the slope of the curve is steeper and the safety factor changes significantly. At this time, changing the slope has a significant impact on the safety factor; When the slope exceeds 38° and changes towards 90°, the slope of the curve gradually flattens out and the rate of safety factor change is small. At this point, changing the slope has a small impact on the safety factor, indicating that the slope has a significant impact on the stability of the fill slope. When the slope is small, changing the slope has a significant impact on the safety of the fill slope. However, when the slope is greater than 38°, the slope continues to increase. Although the safety factor still shows a continuous decreasing trend, the rate of change decreases and gradually tends to be gentle [15,16].

4.5. Impact of different unloading platform widths on slope stability. Change the width of the unloading platform in the model, and establish a model every 0.6 meters from no platform to a 6 meter wide platform. The slope stability change curve is shown in Figure 4.6. As the width of the platform increases, the safety factor continues to increase, presenting a parabolic form as a whole. From no platform to a 0.6 m platform, the slope is decomposed from one whole into three secondary slopes, and the overall damage is dispersed, borne by the secondary slope, significantly improving the overall safety. Subsequently, the platform width continued to increase to 3.6 meters, and the safety factor gradually increased, with a relatively stable

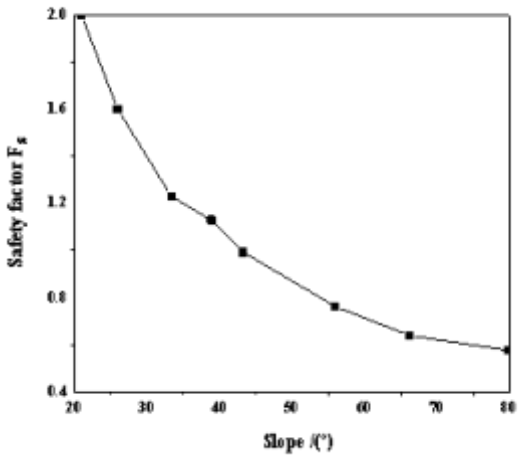

Fig. 4.5: Impact of Changing Fill Slope on Safety Factor

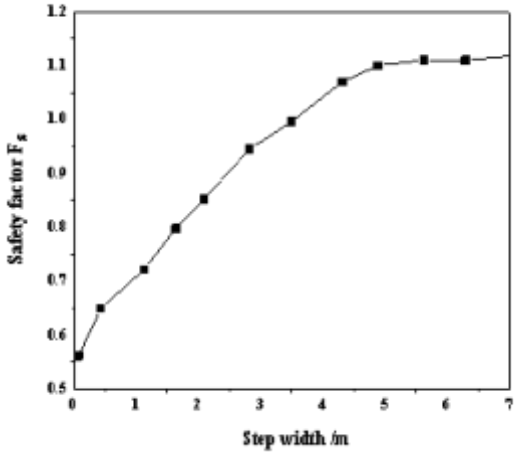

Fig. 4.6: Impact of changing the width of the unloading platform on the safety factor

trend and the curve showing a linear trend.

According to the actual situation of the project, the platform width can be selected within this range. After the platform width is greater than 3.6m, as sufficient platform width has been reached at this point, further increasing the platform width has a small impact on the safety factor, and the curve gradually tends to flatten [17,18].

4.6. Deformation and displacement of various points on the slope during the filling process. Select the original slope top A, fill the third layer of slope top B, slope surface C, and slope foot D, the second layer of slope top E, slope surface F, and slope foot G, the first layer of slope top H, slope surface I, and slope foot J, as well as a total of 13 points K, L, and M inside each layer of filled soil as the analysis objects.

4.6.1. Vertical displacement. When filling the first layer of slope, due to the disturbance of the original slope body during construction, the vertical displacement at the top A of the original slope changes the most. The surface and internal points of the fill gradually increase with the vertical displacement of the first layer of slope construction, and there is a small amount of compaction settlement in the fill. G. The two points H are at the same height, but due to the presence of the unloading platform, the displacement of point G is slightly smaller than that of point H.

Fill the second layer of slope, add an unloading platform in the middle of the two layers of slope, apply the self weight pressure of the filling soil at the slope, and the filling amount reaches more than half of the entire slope. The vertical displacement of point A is effectively controlled, and the settlement increment at each point of the first layer of slope is significantly reduced, tending to be stable. The point G is located at the foot of the second layer of slope, and is affected by the self weight pressure of the second layer of slope filling, resulting in a second settlement phenomenon. The vertical deformation slightly increases, and the points on the first layer of slope are less affected and tend to stabilize. The points D, E, F, and L are located at the key points of the newly added second layer of slope. The consolidation settlement of the fill begins, and the vertical displacement gradually increases with the progress of construction conditions, with a clear curve trend.

4.6.2. Horizontal displacement. The horizontal displacement curves of the filling soil correspond one-to-one with the construction conditions, with an overall trend of displacement towards the direction away from the soil. Only a small portion of the soil in the early stage moved towards the soil. The maximum displacement point is at the foot of the third layer of slope, which is within the maximum displacement required by the specifications.

When filling the first layer of slope, the original slope itself is in a state of consolidation settlement. Point A is at the highest point of the original slope, and the initial filling of the lower layer slope has little impact on it, showing a natural consolidation settlement trend, and a horizontal displacement trend towards the interior of the slope. The horizontal displacement of each point on the first layer of slope gradually increases with the working conditions, and the deformation at the shoulder is guided by vertical displacement. The horizontal displacement changes little. The vertical displacement at the foot of the slope is supported by the lower undisturbed soil layer, and the change is small. The upper part is squeezed by the vertical settlement of the newly added fill, and horizontal thrust is applied. The horizontal displacement increases rapidly towards the outer side of the slope. As the height of each point on the first layer of slope decreases, the displacement gradually decreases.

When filling the second layer of slope, a large amount of soil was filled at the bottom, and a horizontal thrust was applied to the original slope. The displacement of point A towards the inside of the slope was affected, resulting in a trend of displacement towards the outside of the slope. At this point, the settlement trend of the first layer of slope is similar to vertical displacement and tends to stabilize. E. The F and L points are located at the key points of the second layer of slope. At the beginning of the filling condition of the second layer of slope, the filling soil was not stable, and the horizontal displacement suddenly increased to 6 mm. In the later stage, the trend was relatively slow, and the displacement gradually increased.

During the construction period of filling the third layer of slope, the increased filling pressure slightly slowed down the displacement trend of point A towards the outside of the slope. After the construction was completed, the compaction degree of the filling gradually increased, and the horizontal displacement of point A rapidly increased with the newly filled third layer of slope towards the outside of the pit. The horizontal displacement trend of each point on the first layer of slope continues to the filling condition of the second layer of slope, slightly increasing, and overall stabilizing. Points D, E, F, and L produce horizontal creep deformation under the large sliding thrust of the third layer of slope, and the displacement trend is similar to the vertical displacement change trend. During construction, the sudden change trend of points stops, and gradually increases after completion. The displacement trend of each point on the third layer slope during construction is similar to the vertical displacement trend, and after completion, consolidation settlement and creep continue to occur under high self weight stress. At this time, it is the period of post construction settlement of the fill slope. The fill has a large self weight, a long consolidation time, and a large amount of displacement change. In addition, external factors in the later stage are prone to deformation, cracks, and even landslides and collapses [19,20].

5. Conclusion. Based on actual engineering, numerical simulations were conducted on loess high fill slopes in the northwest region to study the factors affecting slope stability, simulate actual filling conditions, and analyze the deformation patterns of displacement at various points on the slope. The conclusions obtained are as follows:

1. The cohesion of soil, internal friction angle, boundary between fill and undisturbed soil, slope, and width of unloading platform all have significant effects on the safety factor of loess high fill slopes. The relationship curves between soil cohesion, internal friction angle, step width, and unloading platform width and slope stability all exhibit a parabolic form. When the values are small, increasing their values significantly improves slope stability; When the numerical value is large, further increase has a small impact on slope stability. The height of the step, the slope of the fill, and the safety factor show an inverse trend. Increasing the height of the step and the slope of the fill will cause a decrease in slope stability.
2. During the filling period of the first and second layer slopes, there is a significant sudden change in vertical displacement, and the impact of consolidation settlement is relatively small after the construction is completed; During the filling period of the third layer slope, there is a significant difference in the vertical displacement mutation at different points. In the later stage, the soil gradually consolidates and settles, resulting in a large amount of deformation. It is necessary to strengthen deformation monitoring of the lower layer slope during slope construction, and strengthen deformation monitoring at the top of the high-rise slope after construction is completed.
3. During the filling period of the first layer of slope, the horizontal displacement is small and the growth is slow. After the filling is completed, other working conditions have little impact on it; During the filling period of the second and third layers of slopes, there is a significant sudden change in horizontal displacement. After the construction is completed, the consolidation settlement period is long, the deformation trend is obvious, and the displacement is large. In the later monitoring, it is necessary to pay attention to the horizontal displacement of each point in the middle layer of the slope.

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A RAILWAY ROADBED DEFORMATION MONITORING SYSTEM USING DEEP LEARNING AND AI INTELLIGENT TECHNOLOGY

PENGFEI PAN*, PENG LI† AND SHIHAO ZHANG

Abstract. The author has designed an automated monitoring system for settlement and deformation of high-speed railway subgrade. Firstly, an automated monitoring system is designed based on sensors, data collection and transmission, client tracking and querying, monitoring result processing, automated warning, manual monitoring data analysis, monitoring data analysis and evaluation. Secondly, the system software and hardware are designed, the author calculated and analyzed engineering examples from the perspective of practical applications using artificial neural network methods, obtained corresponding deformation analysis models, and predicted deformation. Finally, the practical application of the system was analyzed for its effectiveness. The experimental results indicate that, the BP artificial neural network method is used to model and predict the Deformation monitoring data. On the premise of 20 learning samples and 4 prediction samples, the Root-mean-square deviation of the prediction is 0.32mm, which shows that the deformation prediction using BP model is feasible and effective in a certain precision range. It has been proven that the application of artificial neural network methods in monitoring and prediction of practical engineering has certain practical significance.

Key words: Artificial neural network; AI intelligence technology; monitoring system

1. Introduction. The infrastructure of high-speed railways presents a typical layered structure. When trains run at high speeds, the wheel rail load of the train directly acts on the track structure and transmits energy, load, deformation, and vibration to the lower layers of the structure. Due to factors such as train speed, lateral bending of steel rails, vertical load deviation, and track irregularity, the dynamic interaction between wheels and rails presents different characteristics. The purpose of continuous wheel rail force detection is to identify wheel defects such as flat scars. When applying the system, it is necessary to replace ordinary fasteners with a force measuring fastener system in sections, which requires a large amount of construction and high cost [1]. The intermittent wheel rail force detection system can identify the peak value of wheel rail force when a train passes, with the aim of statistically analyzing the distribution pattern of a large number of wheel rail force loads. Only a small number of sensors need to be installed to build the system, which is relatively low in cost. This is mainly aimed at analyzing the intermittent wheel rail force monitoring system [2].

For railways, safety and stability are the core, especially for high-speed railway trains with fast speed, high density, and large passenger volume, safety is even more crucial. High speed railway engineering is an important component of railway infrastructure, and its high stability and reliability are important foundations for ensuring the safe and stable operation of high-speed trains, as well as the main premise for ensuring people's comfort and safety in travel [3]. In the trend of gradually expanding the scale of high-speed railway engineering, due to complex geological conditions and other factors, some sections are prone to roadbed settlement and deformation problems, which are closely related to track smoothness and driving safety. However, the current high-speed railway subgrade Deformation monitoring mode is not perfect, which is still dominated by manual monitoring, with large time and cost investment and too large limitations to meet the monitoring needs. Therefore, the author designed an automated monitoring system for high-speed railway roadbed settlement and deformation.

2. References. At present, artificial intelligence technology has developed rapidly and is widely applied in the intelligent transportation industry. Artificial intelligence has solved many thorny problems through particle swarm optimization, genetic algorithm and other means, and effectively promoted the development and progress of intelligent transportation system. The application of artificial intelligence in intelligent trans-

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Fig. 3.1: Overall frame of the system

portation systems mainly focuses on two aspects: intelligent travel and traffic control [4]. The research on intelligent transportation systems in countries such as the United States, Japan, and Europe began in the 1990s. After 30 years of vigorous development, a relatively complete structural system has been formed [5,6]. Japan's research on intelligent transportation systems mainly focuses on vehicle electronic toll collection, emergency vehicle management, commercial vehicle management, public transportation management, and traffic information dissemination.

Japan's research on intelligent transportation system mainly focuses on vehicle electronic toll collection, emergency vehicle management, commercial vehicle Fahmy, and K. A. S is selecting the most appropriate and best hidden layers and Activation function types for neural networks. Then, define the patient data sent through the Internet of Things protocol. Check the patient's medical sensor data to make appropriate decisions. Then it sends the diagnostic results to the doctor. In this study, artificial intelligence technology will be combined with the Internet of Things [7]. The purpose of Khajehei, H is to use artificial neural networks to predict the rate of orbital geometric degradation. Collected, processed, and prepared positioning geometric measurements, asset information, and maintenance history for five sections of the Swedish railway network to develop an ANN model. We considered the information of the track and used different features of the track section as input variables for the model. By analyzing the performance of the model, we found that artificial neural networks have an acceptable ability to explain the changes in degradation rates at different orbital positions [8]. Gek, D. K creates an intelligent system to determine the quality of predictions. Such a system will become a manual assistant for determining the quality of predictions. If necessary, the system will also be able to indicate necessary adjustments to its prediction method. As part of this work, a software product will be created that will determine the quality of the trade procurement plan created and assist users in adjusting the prediction methods used by the branch if necessary [9].

In recent decades, many domestic and foreign experts and scholars have done a lot of work in performance optimization based on BP algorithm. As a black box method with good data approximation performance, many scholars at home and abroad have studied the use of BP neural networks for deformation prediction. This article designs an automated monitoring system for settlement and deformation of high-speed railway subgrade. Firstly, an automated monitoring system is designed based on sensors, data collection and transmission, client tracking and query, monitoring result processing, automated early warning, manual monitoring data analysis, monitoring data analysis and evaluation.

Secondly, the system software and hardware are designed. Starting from the perspective of practical application, this article calculates and analyzes engineering examples using artificial neural network methods, obtains corresponding deformation analysis models, and predicts deformation, Finally, analyze the practical effectiveness of the system through practical application.

3. System Design.

3.1. Overall System Framework. The overall framework of the high-speed railway roadbed settlement deformation automation monitoring system is shown in Figure 3.1.

3.2. System functional modules.

3.2.1. Sensor module. The sensor module usually converts the response information of various sensor combinations into electrical signals, processes them by transmitting and transmitting data, and converts them

into analog signals.-digital [10].

3.2.2. Collection and Transmission of Information. Data transmission and transmission operations include adjusting sensor signals, converting them to analog and digital form, and sending them to an Ethernet-based monitoring station. Designed and developed data collection software DPServer to facilitate data collection and transmission. This application uses a SQL Server database as a medium and can create a frequency of data entry, collection and evaluation. After the configuration is completed, the program automatically analyzes the message and stores it in the database according to the standard.

3.2.3. Client tracking and query module. The client tracking and query module can achieve system visualization functions, which can be divided into two main parts according to its form, namely a real-time tracking platform based on the site; A remote query access platform based on network clients. The on-site real-time tracking platform can be installed on a computer, not only fixed to the on-site monitoring center, but also allows for real-time random inspection and monitoring. This platform can promote users to fully understand the changes in monitoring indicators and limit standards [11]. The client remote query access platform is a key component of this module, which can achieve diversified network clients and real-time query access detection data. Access the interface to query monitoring results, provide warning threshold values by displaying curves, and display temperature and construction content to intuitively understand the monitoring results.

3.2.4. Monitoring result processing module. The function of this module is to automate the generation of data reports and analysis graphics. Users can design standard report templates based on automatic report software according to their own needs, including text, pictures, monitoring data tables and curves. After the template design is completed, Word documents can be automatically generated based on the template content to improve the efficiency of monitoring results report generation [12].

3.2.5. Automatic warning module. Firstly, preliminary warning. During monitoring, any deformation sensor reading exceeding 1.5 times the accuracy value indicates deformation of the roadbed at the measuring point. The system issues a preliminary alarm and promptly notifies the staff to analyze and resolve the issue. Secondly, process monitoring. Continuously observe the settlement status of deformation measurement points, calculate the settlement amount, and observe the deformation trend throughout the entire process. Thirdly, alarm and handling. According to the standard, if the settlement of the roadbed in any area exceeds the limit value of 30mm, a rapid alarm must be given to transmit the location information of the measuring points and the actual situation, so that construction personnel can handle it in a timely manner.

3.2.6. Manual monitoring data analysis module. In order to ensure the efficiency of manual monitoring results analysis, this module transmits the manual monitoring content to an automated platform for unified analysis and processing. Through comprehensive planning and in-depth analysis, seamless integration between manual monitoring data analysis module, automated warning module, and monitoring result processing module is achieved to achieve unified platform management [13].

3.2.7. Monitoring data analysis and evaluation module. The ultimate goal of system monitoring is to identify and evaluate the settlement and deformation status of high-speed railway engineering structures. When evaluating, it is necessary to first construct a high-speed railway roadbed and bridge structure analysis model, and combine the measured data information to modify the calculation model. The modified model is used to accurately analyze and calculate the settlement deformation trend of the structure, in order to facilitate the correct decision-making of high-speed railway operation and maintenance [14]. On this basis, the core function of the system monitoring data analysis and evaluation module is to transform the data information collection results jointly obtained by the bottom modules into evaluation indicators that can effectively reflect the settlement and deformation status, laying a data foundation for correcting the model.

3.3. System Software Design.

3.3.1. System monitoring software. In order to solve the problems of complex types of monitoring equipment and inconsistent data standards, the system monitoring software adopts a three-layer framework mode and provides a unified data interface standard. For different instruments and equipment, it is only

Table 3.1: System monitoring software

Type	Acquisition end software	Server-side software	Client software
Running position	Monitoring on-site data collection instruments	Cloud server computer	Remote client
Function	Control the automatic collection of data, package the results and transmit them to the server	Calculate, analyze, alert, and store monitoring data in response to client query requests	Data Query and Project Configuration

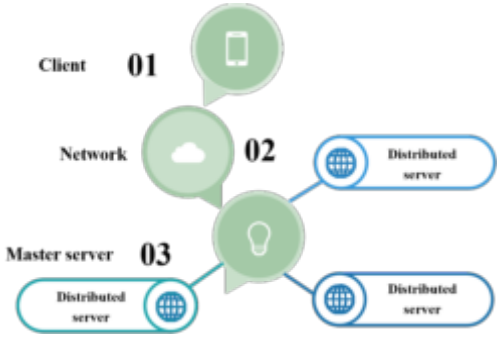

Fig. 3.2: Distributed server framework

necessary to develop targeted acquisition software to ensure that it meets the data interface requirements and can be compatible. The specific system monitoring software is shown in Table 3.1.

3.3.2. Distributed server. The distributed server framework disperses computing resources and broadband pressure across multiple servers to enhance the system's computing power and scalability, meeting the real-time and concurrent requirements of automated monitoring of high-speed railway roadbed settlement and deformation. The distributed server framework is shown in Figure 3.2.

3.3.3. Artificial neural network algorithm. BP neural network algorithm steps:

1. Determine the number of layers o in the neural network, the number of neurons n in the input layer, the number of neurons m in the output layer, and the number of neuron nodes p in the hidden layer [15].
2. Initialization of weights and thresholds.
   Assign random values w_{ij} between (-1,1) to the connection weights w_ij,w_{jk}, and thresholds θ_j,θ_k, where w_{ij} is the connection weight between the input layer and the hidden layer, and w_{jk} is the connection weight between the hidden layer and the output layer. θ_j,θ_k is the threshold $(i = 1, 2, ..., n, j = 1, 2, ..., m)$ for the hidden layer and the output layer, respectively.
3. Given the input mode vector $X_t = x_1, x_2, ..., x_n$ and the output mode vector $Y_t = y_1, y_2, ..., y_m$,(t=1,2... q) q is the logarithm of the input learning sample mode.
4. Calculate the actual output mode vector $C_t = c_1, c_2, ..., c_m$ of the neural network using the following algorithm.
   Firstly, calculate the inputs for each unit in the middle layer using the following formula:

$$S_j = \sum_{i=1}^{n} w_{ij} \times x_i - \theta_j (j = 1, ..., p) \tag{3.1}$$

   Simulate the nonlinear characteristics of biological neurons, take as the independent variable, calculate

the excitation function f (x), that is, the output of Interneuron, and generally select Sigmoid function as the excitation function.

$$f(x) = \frac{1}{1 + e^{-\frac{x}{x0}}} \tag{3.2}$$

Obtain the incentive value of $b_j = f(S_J)$, and then transfer it to the output layer to obtain the actual output:

$$L_k = \sum_{j=1}^{m} w_{ij} \times b_j - \theta_k (k = 1, ..., m) \tag{3.3}$$

$$c_k = f(L_k) \tag{3.4}$$

5. Calculate the backpropagation error d_t of each neuron in the output layer from the actual output C_t and the expected output Y_t.
   Among them, d contains m components $d_t^k = (y_k - c_k) \times c_k \times (1 - c_k)(k = 1, ..., m)$
6. Calculate the backpropagation error e_t of the intermediate layer by considering the connection weight w_{jk}, the output b_j of the intermediate layer, and the backpropagation error d_t of the output layer:

$$e_i^j = (\sum_{k=1}^{m} w_{jk} d_t^k) \times b_j \times (1 - b_j)(j = 1, ..., p) \tag{3.5}$$

7. Correct the weight w_{jk} and threshold θ_k from the middle layer to the output layer based on the output layer backpropagation error d_t :

$$w_{jk}(n+1) = w_j k(n) + \alpha \times d_t^k \times b_j \tag{3.6}$$

$$\theta_k(n+1) = \theta_k(n) + \alpha \times d_t^k \tag{3.7}$$

   In the equation, $\alpha \epsilon (0, 1)$ is the Learning rate.
8. Learn new samples, re iterate the above process t=t+1, and re enter step 3) until the global Error function E of the network is less than the preset amount, that is, the network converges, or reaches the upper limit of the number of learning times to end the iterative calculation, that is

$$E = \frac{1}{2} \sum_{t=1}^{q} \sum_{k=1}^{m} (y_t^k - c_t^k)^2 \tag{3.8}$$

3.3.4. BP model and its application in Deformation monitoring. A Inter-city rail is a passenger dedicated high-speed railway with a speed of 350km/h, which is an overpass project under the high-speed railway, the whole planned line is 459.45m, the site is on soft soil foundation and the groundwater level is high, so the settlement requirements are very strict[16].

In order to ensure that there is no serious impact of roadbed settlement and deformation during construction, a high-precision automated monitoring system needs to be installed to monitor the affected road sections in real-time throughout the entire process, in order to apply the high-speed railway roadbed settlement and deformation automatic monitoring system designed by the author. The monitoring has a total length of 290.11m, covering the roadbed section, with 42 measurement points arranged. Sensors are installed on the shoulder and cantilever plate of the bridge, and safety protection buckets are designed for them. In addition, install automated collection units, collection software, computers, wireless transmitters, and conduct automated monitoring every 10 minutes, transmit measurement results to the monitoring center through message transmission. This high-speed railway engineering project uses the author's design system to collect, analyze data, and provide alarms[17].

Considering that the factors affecting the settlement change of observation points in Deformation monitoring are complex and difficult to determine, the BP neural network algorithm in the time domain is used here, that is, only historical observation data input is used for prediction, without considering the characteristic quantity input of other factors.

Since the 23 layer network can realize the mapping of Continuous function with arbitrary precision, the simplest 3-layer neural network design is adopted here, and the Matlab neural network toolbox is used to realize the BP algorithm and apply it to the actual Deformation monitoring analysis and prediction. The specific model implementation is as follows:

1) Selection of sample data. Considering the full utilization of data and the reproducibility of network training learning, the observed data is divided into learning samples and prediction samples, and the rolling sample collection method is used to determine the learning and prediction samples. Assuming the input parameter of the BP model is 4 and the output parameter is 1, 20 learning samples and 4 prediction samples can be obtained based on the sample data.
2) Selection of excitation function. The excitation function of the intermediate layer adopts a logarithmic s-shaped transfer function, while the intermediate layer to the output layer is a linear function.
3) Selection of initial parameters. The optimal range of hidden layer nodes is determined based on the empirical formula:

$$m = \sqrt{l+n} + a \tag{3.9}$$

In the formula, l and n are the number of input and output nodes, and a is a constant between 1-10. The optimal hidden layer node is determined by the above formula, and then the specific number is obtained through repeated experiments.

In addition, the selection of Learning rate α should not be too large or too small, which determines the Rate of convergence of the network and the final network error. This time, a variety of Learning rate are selected for calculation, and the best Learning rate is determined according to the results.

4) Objective function of training network. The global error E for selecting the objective function of the training network:

$$E = \frac{1}{2}\sum_{t=1}^{q}\sum_{k=1}^{m}(y_t^k - c_t^k)^2 \tag{3.10}$$

That is, the sum of squares of the difference between the actual output value of the network and the expected output value, until it converges to a certain error standard, otherwise the parameter modification will continue [18].

Use the above parameters to realize and calculate the Learning rate α in Matlab. The selection of includes 0.01, 0.05, 0.1, 0.5, 0.8, 0.95 values. The number of neuron nodes in the middle hidden layer ranges from [5,12]. The combination of different Learning rate and the number of hidden layer nodes is calculated and tested, and the network Mean squared error is obtained respectively as shown in Figure 3.3.

It can be seen from the figure that when the Learning rate is high, the result of selecting any number of nodes is not very good, and some models with 12 nodes, for example, even have a divergent trend in the later stage.

Considering that the Mean squared error of the network is the smallest, better two groups of combinations are obtained (α=0.1, hidden layer nodes 5) (α=0.01, the number of hidden layer nodes 7) were predicted for four periods, and the prediction results were analyzed to determine the optimal combination, as shown in Figure 3.4.

It can be seen from the figure that when the Learning rate is 0.1, basically the number of most neuron nodes can get good simulation results, but for some nodes 6, 7 and 12, there is a trend of gradually deviating from the sample in the later stage. It can be predicted that when the Learning rate is 0.01 and 0.05 respectively, the simulation effect of learning samples is relatively good, and there is little difference between the two. It can be clearly seen from the prediction results that, α the prediction results of 0.01 hidden layer nodes are significantly better than those of other groups, except for the large prediction deviation in the first stage. The specific predicted values are shown in Table 3.2.

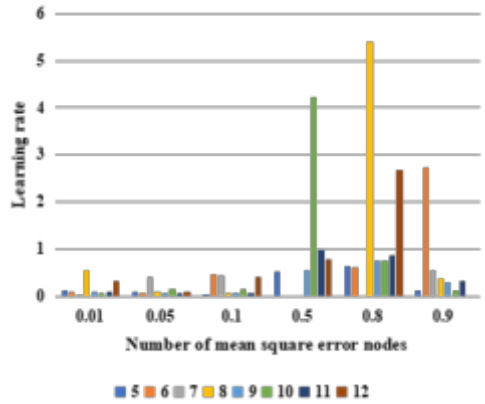

Fig. 3.3: BP model calculates the test network mean variance results

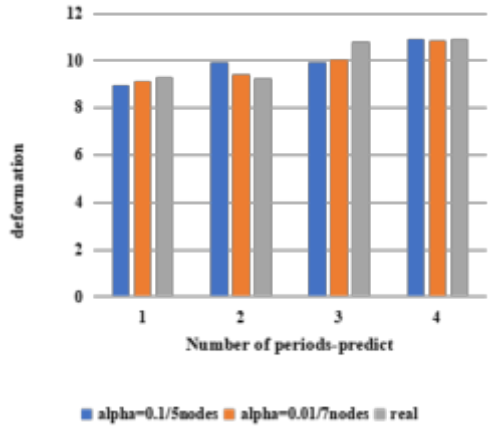

Fig. 3.4: Combined prediction and simulation results of the two groups

Note: Combination 1, i.e α=0.1, with 5 hidden layer nodes; Combination 2, i.e α= 0.01, with 7 hidden layer nodes.

To sum up, it is recommended that when the number of nodes in the hidden layer of the network is 7 and the network Learning rate is set to 0.01, the minimum Mean squared error of the network is 0.05, and the prediction effect of the trained prediction model is good and the prediction accuracy is high.

4. Conclusion. In summary, in order to effectively solve the problem of settlement and deformation of high-speed railway subgrade, the author has designed an automated monitoring system. The system is based on the settlement automatic acquisition instrument as the sensor, configured with automatic monitoring software, and realized fully automatic operation with the aid of computer control to realize the visualization and real-time goal of settlement Deformation monitoring. Artificial neural network systems have high fault tolerance and adaptability, which are suitable for solving the ambiguity and uncertainty problems involved in deformation prediction. This time, the BP artificial neural network method is used to model and predict the Deformation monitoring data, on the premise of 20 learning samples and 4 prediction samples, the Root-mean-square deviation of prediction is 0.32mm, which shows that under a certain precision range, the deformation prediction using BP model is feasible and effective. The determination of learning rate and the number of hidden layer neuron nodes in the BP artificial neural network method plays a key role in the process of network

Table 3.2: Comparison of two groups (units: mm)

Forecast period	Observed value	Combination 1 Predicted value	Combination 1 Absolute error	Combination 2 Predicted value	Combination 2 Absolute error
1	9	9.247	0.247	9.077	0.077
2	10	9.249	0.751	9.465	0.535
3	10	10.816	0.816	10.076	0.076
4	11	10.910	0.090	10.864	0.136
RMS	-	0.66	-	0.32	-

modeling and learning, which directly affects the Rate of convergence and modeling accuracy of the network. In addition, the BP artificial neural network model still has many shortcomings of its own, and needs to be improved and perfected.

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ENVIRONMENTAL PROTECTION CONTROL SYSTEM BASED ON IOT AND DEEP LEARNING INTELLIGENT MONITORING SENSORS

SHICHAO CAO, XIAOYING LIU, AND NAN LI*

Abstract. In order to improve the multi-sensor intelligent control performance of environmental pollution detection, this paper proposes a design model of environmental pollution detection intelligent system based on Internet of Things technology. Firstly, this paper uses ZigBee's Internet of Things networking technology to design the network of the pollution detection system. Secondly, in order to verify the effectiveness of the environmental pollution detection method, this paper carries out system debugging analysis and simulation test, and uses visual dsp++simulation system to debug the system. The network of ZigBee Internet of Things networking technology is adopted to realize the network design of pollution detection system, and VIX bus technology is adopted to carry out environmental pollution detection data communication and information processing, so as to realize the optimal design of intelligent system of environmental pollution detection system. Finally, the experimental test and analysis were performed. The collection period of environmental pollution data is 10 s and the monitoring time is 22 h. Finally, according to the environmental model and parameters, we determine that the system can accurately detect environmental pollution information, and the results are accurate and reliable.

Key words: Internet of Things, Intelligent detection, Sensor, Environmental protection

1. Introduction. With the continuous progress of environmental protection and ecological governance in China, the density of environmental pollution monitoring is increasing, combined with artificial intelligence Technology, environmental pollution detection, improve the real-time environmental pollution monitoring and treatment ability. The detection of environmental pollution is mainly for the detection of air pollution and water pollution.

The architecture of intelligent environmental monitoring system is mainly composed of three parts: sensor, data center and user interface. The sensor collects environmental data by monitoring environmental parameters, such as temperature and humidity. The data center is a centralized server for storing and managing environmental data, and uses data processing and analysis algorithms. The user interface displays environmental data and reports. Sensor is one of the most important components in the intelligent environment monitoring system. The sensor can measure various environmental parameters through corresponding sensor technology. For example, temperature sensors use thermocouples or thermistors to measure temperature. Humidity sensors can use capacitive or resistive sensors to measure humidity. The pressure sensor can use piezoresistive sensor or capacitive sensor to measure the pressure.

Internet of Things IoT (Internet of Things) refers to the deployment of various information sensing devices with certain sensing, computing and execution capabilities in the entities of the physical world, which implement information transmission, collaboration and processing through network facilities, so as to realize the information exchange and exchange between people and objects in a wider or larger scope.

The sensor can use infrared or chemical sensors to measure the concentration. The data collected by the sensor is transmitted to the data center through the communication link of the Internet of Things. The user interface is the final interface of the environmental monitoring system. Its purpose is to make the environmental data easy to understand and access. The user interface can now be a Web application or an application. Users can view environmental data and reports and get updated data at any time [1,2].

Combined with intelligent computer processing and chip control technology, the optimization design of environmental pollution detection equipment is conducted, and the intelligent environmental pollution detection system is constructed to improve the detection efficiency of environmental pollution. Intelligent environmental

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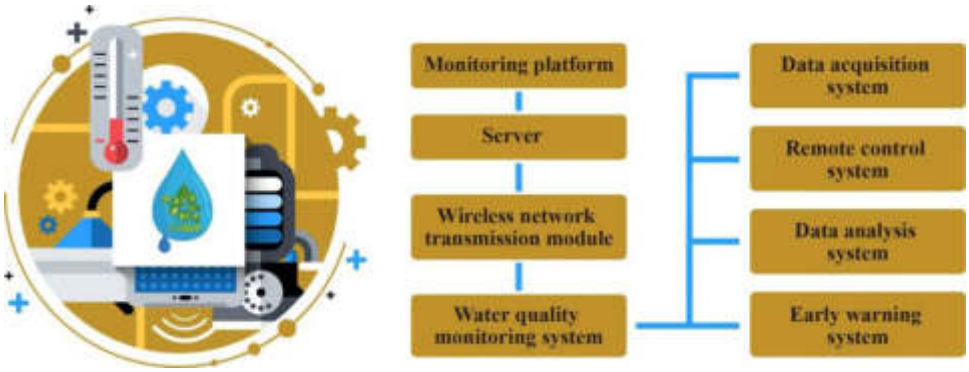


Fig. 1.1: Intelligent monitoring sensor

monitoring system can be applied to various scenarios, such as indoor and outdoor environmental monitoring, urban air quality monitoring, garbage can emptying plan, etc. The environmental monitoring system can track the changes of environmental parameters and help users understand and manage environmental conditions. In addition, it can also help users formulate appropriate policies and take corresponding measures to promote environmental protection and sustainable development.

Under the Internet of Things technology, combined with the ZigBee network protocol, the wireless sensor network design of the environmental pollution detection system is carried out, and the Internet of Things network optimization technology is used to conduct multimedia environmental pollution detection, so as to improve the network control ability of environmental pollution detection and improve the efficiency of environmental pollution detection (as shown in Figure 1.1).

Using iot technology and wireless sensor networking technology, introduced into the environmental pollution detection system design, environmental pollution information collection and data analysis, put forward a kind of environmental pollution detection based on the Internet of things intelligent system design model, environmental pollution detection overall structure of intelligent system design model to establish the embedded ARM kernel based on the ZigBee Internet of things network technology for pollution detection system network design, using VIX bus technology for environmental pollution detection data communication and information processing, realize the optimization design of environmental pollution detection intelligent system. Finally, the experimental test and analysis were performed.

2. Internet of Things technology. In order to realize the optimal design of the environmental pollution detection intelligent system and the system for environmental pollution detection, the system bus design and software development are based on the Internet of Things technology system. The Internet of Things technology is to integrate TCP / IP protocol into the BSDUNIX communication system, and combine GPRS technology and ZigBee technology to realize the sensor network design of environmental pollution detection. The sensor communicates with the Internet to ensure the intelligent recognition of the target. With the passage of time, the scope of network development has gradually expanded, but it is often mistaken for directly transmitting information and acquiring computer data through wired sensors and wireless networks. Effective information should be identified to ensure the links between projects or people and projects, and increase access to information and communication technologies [3,4].

(1) Sensor network layer. The sensor network layer mainly connects the physical sense world and the actual information network world through the virtual hardware network, and senses the internal environment or the external environment attributes of the material.

(2) Network layer. The network layer is mainly responsible for transmitting information directly from the physical sense network layer to the actual application, using the network layer.

(3) Application layer. The application layer collects and converts data, processes data through subsystems, and provides services for related industries.

2.1. Structural design of intelligent environmental monitoring system. The overall structure model of environmental pollution detection intelligent system design is established based on embedded ARM kernel, combined with fuzzy PID integration detection method for pollution information acquisition and intelligent information processing, the system includes multi-sensor intelligent control module, environmental pollution detection information processing module, multi-threaded control module, cross compilation module and human-computer interaction module, etc.

(1) Main program structure of the system. The intelligent environment monitoring system is divided into two parts, namely hardware design and software design. The software design also includes three parts, namely data acquisition, data transmission and control output. Each part uses multiple processes to cooperate to complete the function. Each process has a single responsibility, but it is also mutually cooperative. In this system, Contiki embedded operating system is used to schedule the task process of each part.

(2) Data collection process. Data acquisition mainly refers to the use of special software to read the digital signals output by each sensor, and directly cache these digital signals with relevant instruments, and then wait for the data transmission process to extract data. It mainly includes the reading of digital signals obtained from environmental information sensors with corresponding instruments.

(3) Data transmission process. The data transmission process mainly refers to the process of using the special FIFO queue to extract the sensor data according to the JSON format, and then using the serial port to transmit the data through WI4I. The detailed process is as follows:

Use the sensor data byte stream bytes of the sensing layer to transfer to the FIFO node structure - put it into the receive FIFO cache queue - read the bytes from the receive cache in turn - judge that the protocol packet header is equal to read the entire header to check the header to read the data domain - check the entire data to store the data in a special structure to store it in the receive packet buffer queue to remove the protocol packet from the receive packet - judge the target address of the packet - delete the response packet-send response packet - process the packet [5,6].

2.2. Significance of intelligent environmental monitoring system in practical application.

(1) Comprehensive monitoring and perception. Multi-dimensional environmental monitoring is the basic link for the environmental protection department to carry out environmental protection work. Massive data can be obtained through the intelligent environmental monitoring system. On the one hand, it can help the environmental protection department understand the specific situation of the current environment, and take corresponding measures to solve the environmental pollution problem by analyzing the current environmental situation; On the other hand, help environmental protection departments to study the relationship between environmental quality and pollution sources, so as to better prevent environmental pollution from the source. According to the current application of the intelligent environmental monitoring system, the overall application effect is very good. It can expand the range of environmental perception. More importantly, the intelligent environmental monitoring system can obtain more complete and accurate environmental data, so as to reduce the probability of error reporting of environmental data, so that the environmental protection department can put forward more feasible governance plans based on the data [7,8].

(2) Multi-network integration, chimera transmission. In the process of processing environmental data, the distributed collaborative processing mechanism is adopted. Massive raw data is transmitted to the system, and through the front-end collaborative processing, more high-quality information data is refined and transmitted to the system platform. In order to ensure the efficiency of data and image information transmission, appropriate communication protocol system will be supplemented to greatly improve the efficiency of data transmission. In the design of network transmission system, a scientific combination of sensor networks, wireless networks, wired networks, satellite networks and other networks is adopted, and the principle of flexible, fast, reliable and applicable is always adhered to to to transmit sensing data to the common platform of the environment-friendly Internet of Things, and to provide reliable network resources and traffic management for heterogeneous transmission networks [9].

(3) Massive computing, intelligent analysis. Massive environmental data has mixed objectives, and the environment is always in the process of change. The content of environmental protection is also very complex. In the process of data analysis, it is necessary to predict the change of the comprehensive quality of the early warning environment in combination with meteorological, water conservancy, land, agriculture and forestry

departments. All of the above need to identify, sort, filter, classify and analyze massive data, which requires the intelligent environment monitoring system to have fast computing ability to calculate massive data and lay a complete data foundation for intelligent analysis.

2.3. Practical application architecture of intelligent environmental monitoring system. Based on the Internet of Things technology, the intelligent environment monitoring system uses various advanced sensing methods to comprehensively and thoroughly perceive the environmental objects, and transmits the sensed information to the intelligent analysis platform based on cloud computing at high speed for intelligent analysis such as data mining and model calculation. The conclusions and rules from intelligent analysis are provided to the intelligent management system for scientific decision-making. Relevant personnel carry out environmental governance and ecological restoration activities according to the decisions and governance measures made by the intelligent management system, so as to continuously improve the environmental quality. According to the existing environmental monitoring capacity of City A, the system is divided into four levels, namely: perception interaction layer, network transmission layer, basic support layer and intelligent application layer [10].

(1) Network transport layer. Based on the application design of the front-end intelligent environment sensing layer, with the goal of achieving more comprehensive interconnection, build a high-speed, seamless and reliable data transmission network that integrates sensor networks, wireless networks, wired networks, satellite networks and other network forms, and can flexibly and quickly transmit sensing data to the intelligent environment monitoring system management center. One of the key points is to carry out online data transmission of 86 existing water quality monitoring equipment, 70 pollution sources online monitoring, and 13 atmospheric monitoring equipment, so as to realize networked high-speed data transmission and centralized management of efficient equipment for environmental monitoring of water, air, noise, soil, and hazardous waste.

(2) Foundation support layer. Based on cloud computing technology, the city cloud service platform will build the most advanced high-performance computing and massive data storage support platform for multi-dimensional environmental protection information in China on the basis of high-performance parallel computing technology, massive data mining technology, data visualization technology, and other technologies with industry universality. The research results of environmental protection theory and various environmental protection expert experience models are widely combined. Through high-performance calculation and data mining of a large number of real-time and historical data, the environmental conditions and change trends are accurately judged, and the calculation tasks such as early warning, situation analysis, emergency linkage, etc. of environmental protection emergencies are rapidly provided with accurate results [11].

(3) Smart application layer. The construction of intelligent environmental protection comprehensive management service platform in the intelligent environmental monitoring system can be divided into the following four centers: monitoring and early warning center

The pollution source monitoring center, emergency command center and data exchange center form an efficient "intelligent environmental protection" integrated management service system platform, which can provide decision-making departments, environmental protection management departments and citizens with effective management of environmental protection data, strict implementation of environmental protection regulations, and support for in-depth scientific research.

The intelligent environmental monitoring system makes full use of advanced technologies and concepts such as the Internet of Things and cloud computing to significantly improve the environmental monitoring capacity of regional environmental protection departments, and generally achieve the goal of "accurate measurement, fast transmission, clear calculation and good management" [12,13].

3. Overall design description and functional component analysis of pollution detection system.

3.1. Overall design framework of environmental pollution detection system. In order to realize the optimal design of the intelligent system for environmental pollution detection, this paper carries out the system bus design and software development based on the Internet of Things technology system. The Internet of Things technology is to integrate TCP/IP protocol into the BSD UNIX communication system, and combine GPRS technology and ZigBee technology to realize the sensor networking design for environmental pollution detection. We use Zig - Bee for environmental pollution detection data communication and processing, use test instruments such as analog bus for environmental pollution detection and control, and use the unique bus

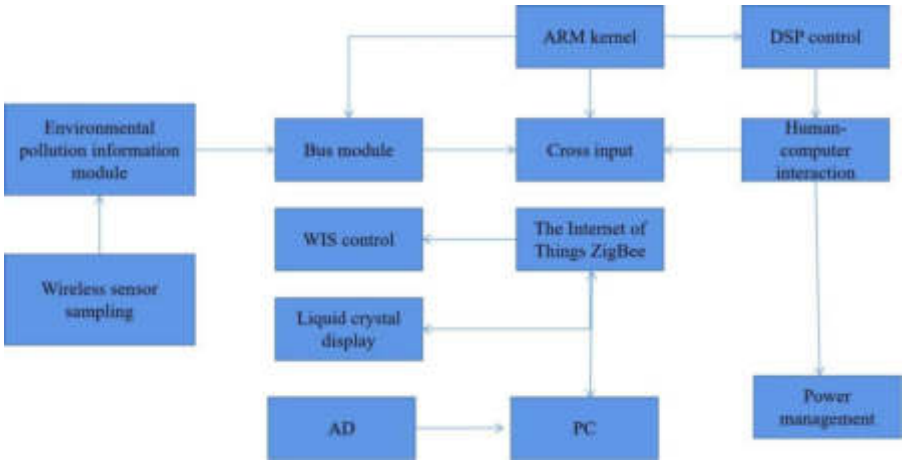


Fig. 3.1: Overall system architecture

data transmission function of the Internet of Things transmission channel to call the re - evfrom function to receive the air pollution, water pollution and other monitoring data of the environmental pollution detection intelligent system. The remote transmission of air pollution, water pollution and other monitoring data in the environmental pollution detection system is realized by using Wi-Fi, infrared, Bluetooth and GPRS communication technology. The clock control module is established to carry out the clock AD sampling of the intelligent environmental pollution detection system, and the monitoring data distribution module and cross-compilation module of the air pollution, water pollution and other monitoring data of the environmental pollution detection system are constructed to carry out the overall development and scheduling of the intelligent environmental pollution detection system under the environment of the Internet of Things. Firstly, the collected multimedia information of environmental pollution detection is converted into digital and analog through AD module, and the ZigBee network application service layer is constructed. The network service application layer is divided into four spaces of BASE2-5, which can meet the requirements of reading and analyzing the monitoring data of air pollution and water pollution in the multi-channel environmental pollution detection system. According to the above design idea, the designed environmental pollution detection system is obtained. The overall hardware design framework of the system is shown in Figure 3.1 [14].

3.2. System development environment description and functional component analysis. According to the overall design framework of the environmental pollution detection system shown in Figure 3.1, the functional modular design of the system is carried out. The designed environmental pollution detection system adopts a three-layer architecture, including the perception layer, the network layer and the application layer, and uses TCP/IP server or UPD server to build the network transmission protocol under the Internet of Things technology mode. Data transmission is carried out through the LTGA bus, and the overall design and functional component analysis of the environmental pollution detection system are carried out. In the database management module of the environmental pollution detection intelligent system, the monitoring data bus scheduling of air pollution, water pollution and other monitoring data in the environmental pollution detection system and USB serial port communication are realized. The functional and technical indicators of the designed intelligent system for environmental pollution detection are described as follows:

1. ZigBee and wireless sensor network are used to form the environmental monitoring network, with 4-channel environmental pollution detection information input function. The internal storage area is divided into 11 sectors. 16-bit fixed-point DSP is used to adjust the stability of the environmental pollution detection data output. Cross-compiling is performed in the B/S network architecture system. The multimedia information of the environmental pollution detection system is scheduled through dual-port RAM cache control.

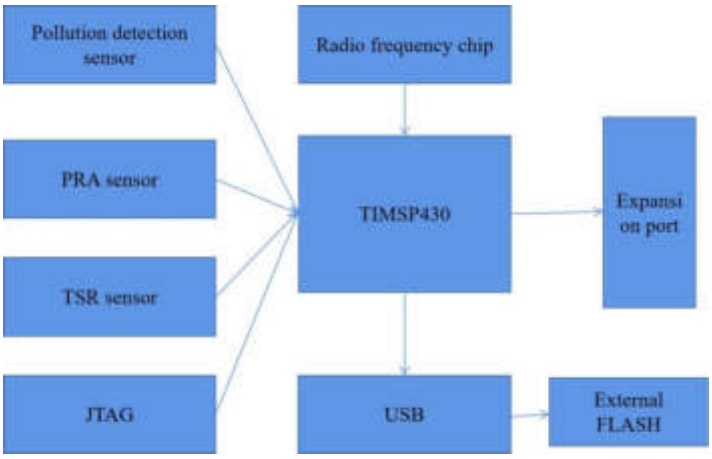


Fig. 3.2: Component composition of system functional structure

2. The full-duplex communication design of the environmental pollution detection system is carried out through the real-time control protocol (RTCP). The monitoring data of air pollution and water pollution in the environmental pollution detection system are transmitted by the DMA controller. The address communication range of the system is 00H-16H.
3. The data memory address range of the intelligent system for environmental pollution detection is 32K words, the off-chip 16K (address range 0000H FFH), and the serial port clock is LA B1:28. The dual-port data bus transmission of air pollution, water pollution and other monitoring data in the environmental pollution detection system is realized through PCI data bus [15].
4. Set the status register (Status) for data cache management and base address allocation of the environmental pollution detection intelligent system, use four AD8582 for multiplex transmission control, and access the L0OCAL local register through the Zig - Bee network at the PCI end. According to the above design indicators, the functional structure components of the environmental pollution detection system are shown in Figure 3.2.

3.3. System development design and implementation. The overall structure model of the design of the intelligent system for environmental pollution detection is based on the embedded ARM core and combined with the fuzzy PID integrated detection method for pollution information collection and intelligent information processing. The system includes multi-sensor intelligent control module, environmental pollution detection information processing module, multi-thread control module, cross-compilation module and human-computer interaction module. The development and design of each functional module are described as follows:

3.3.1. Multi-sensor intelligent control module. Multi-sensor intelligent control module realizes pollution data collection and information output functions, installs data collection sensors in the application layer of the Internet of Things system, and uses different databases to store environmental pollution information. DSP integrated signal processor is used for environmental pollution energy consumption data acquisition and real-time information processing to improve the intelligent control ability of environmental pollution detection. We use the Internet of Things technology for the network design of environmental pollution detection, and get the structure of the multi-sensor intelligent control module as shown in Figure 3.3.

3.3.2. Environmental pollution detection information processing module. The environmental pollution detection information processing module is the core of the whole system. It is connected to the I0 port of CC2530 at the OUT port. The infrared sensor is used as the bottom module of the pollution detection system. In the environment of the Internet of Things, Zigbee network is formed through self-organization, and the general PPI mode and ITU-656 PPI mode are used for A/D sampling to realize the environmental pollution detection information processing.

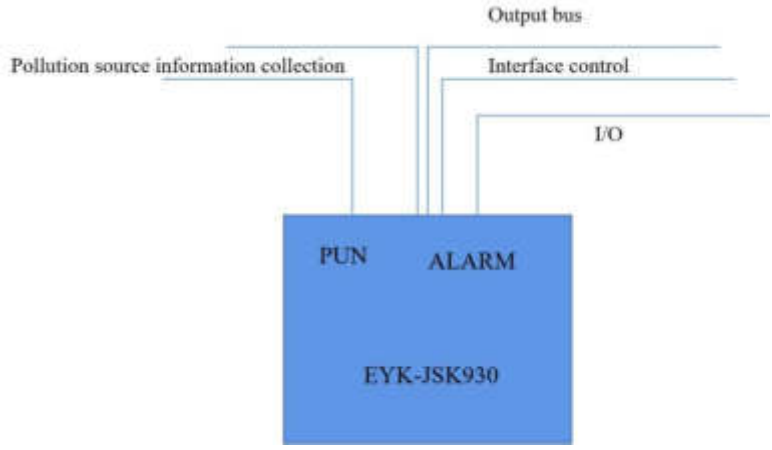


Fig. 3.3: Multi-sensor intelligent control module

3.3.3. Multi-thread control module. Based on the embedded ARM kernel, the multithread control module combines the fuzzy PID integrated detection method to collect pollution information and process intelligent information. The 8-bit A/D chip is used for AD conversion control of environmental pollution real-time monitoring information, and the floating-point DSP and fixed-point DSP are used for cross-compilation design to carry out integrated control of environmental pollution detection system [16].

4. Experimental test. In order to verify the performance of the method in realizing the environmental pollution detection, the system debugging analysis is carried out. In the experimental establishment of Simulink, the visual dsp++simulation system is used for system debugging. The cycle of the collected environmental pollution data is 10s, and the monitoring time is set to 22h. According to the above simulated environment and parameter settings, the environmental pollution detection is carried out, and the detection output is shown in Figure 4.1 (a) (b). According to the results of environmental pollution data in the figure, the system can accurately test environmental pollution information, and the collected results are accurate and reliable.

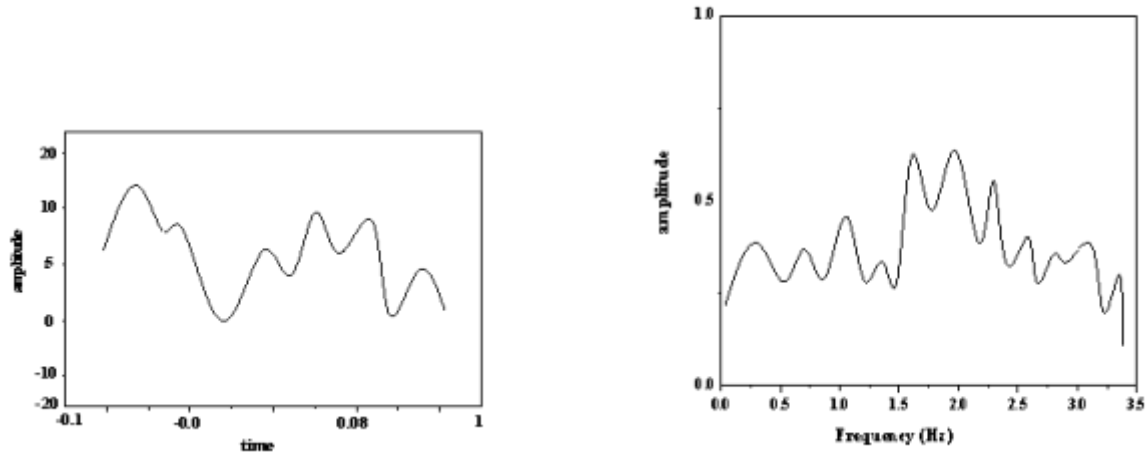
The environment monitoring system based on intranet technology mainly includes the on-site monitoring system and platform, which is responsible for the on-site data collection, processing and transmission operation. The monitoring platform is responsible for receiving data from the aircraft site. According to the characteristics of monitoring, a system structure is implemented, including environmental video observation, geographic information system and short message function module [17,18].

4.1. Environment video control. As a visual monitoring module, the environment video control can view the environment through video. During the monitoring process, it sends commands to the monitoring camera. The camera loads and saves the video. The video can be saved before viewing. Search equipment can find surveillance video [19].

4.2. Geographic information system. GIS spatial data management technology can effectively select and manage data. Considering different geographical coordinates and the need for multi-point operation of current environmental monitoring, GIS research can directly reflect the status of geographic information and more effectively disseminate relevant information.

4.3. SMS function. The SMS function is to transmit the pollution information to the controller in time. The monitoring personnel can obtain the environmental pollution information in time, respond to the pollution emergencies in time, and effectively carry out the environmental protection work.

4.4. Discussion. The construction of intelligent environmental pollution detection system can improve the detection efficiency of environmental pollution. Under the Internet of Things technology, we combine ZigBee network protocol to design the wireless sensor network of the environmental pollution detection system,



(a) (b)

Fig. 4.1: Detection output

and propose a design model of the environmental pollution detection intelligent system based on the Internet of Things technology. The overall structure model of the design of the intelligent system for environmental pollution detection is built on the basis of the embedded ARM core, combined with the fuzzy PID integrated detection method to collect and process the pollution information, and the overall design framework of the environmental pollution detection system is carried out. The system includes multi-sensor intelligent control module, environmental pollution detection information processing module, multi-thread control module, cross-compiler module and human-computer interaction module. We use ZigBee's Internet of Things networking technology to carry out the network design of the pollution detection system, establish the Internet of Things network system of the environmental pollution detection intelligent system on the basis of ZigBee and GPRS, and use VIX bus technology to carry out the environmental pollution detection data communication and information processing, to achieve the optimal design of the environmental pollution detection intelligent system. The research shows that the method has high accuracy and system reliability for environmental pollution detection [20].

Build an intelligent environmental pollution detection system to improve the detection efficiency of environmental pollution. Under the Internet of Things technology, Combined with the ZigBee network protocol, Conduct wireless sensor network design of environmental pollution detection system, To propose an intelligent system design model for environmental pollution detection based on the Internet of Things technology, Based on the basis of the establishment of embedded ARM kernel, Combined with the fuzzy PID integrated detection method for pollution information collection and intelligent information processing, The overall design framework of the environmental pollution detection system, The system includes multi-sensor intelligent control module, environmental pollution detection information processing module, multi-threaded control module, cross-compilation module and human-computer interaction module, Network design of the pollution detection system using the networking technology of the ot of ZigBee, Using the IEEE802.15.4 protocol standard, In the ZigBee vs on the basis of GPRS, the Internet of Things network system of environmental pollution detection intelligent system is established, and VIX bus technology is adopted to conduct environmental pollution detection data communication and information processing, so as to realize the optimal design of the intelligent system of environmental pollution detection.

5. Conclusion. The architecture of the intelligent environment monitoring system mainly consists of three parts: sensor, data center and user interface. The sensor collects environmental data by monitoring

the environmental parameters such as temperature and humidity. A data center is a centralized server for storing and managing environmental data, and uses data processing and analysis algorithms. The intelligent environment detection system based on the Internet of Things designed in this paper has achieved the expected function, and can collect the environmental parameters that need to be investigated remotely. This paper also analyzes and processes the collected data in order to understand the environmental conditions of the monitored area and better propose corresponding measures to prevent and improve the local environment.

This paper uses the Internet of Things network technology of ZigBee company to design the network of pollution detection system. Secondly, in order to verify the effectiveness of the environmental pollution detection method, this paper conducts a system debugging analysis and simulation test, and adjusts the system using a visual dsp + + simulation system.Environmental pollution data were collected for 10s and monitoring time for 22 h. Finally, according to the environmental model and parameters, we determine that the system can accurately detect the environmental pollution information, and the detection results are accurate and reliable.

The intelligent environment detection system replaces the traditional detection method, and makes up for its shortcomings, so as to better play the role of the intelligent environment detection system in environmental monitoring.

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APPLICATION OF DEEP LEARNING AND COMPUTER DATA MINING TECHNOLOGY IN ELECTRONIC INFORMATION ENGINEERING MANAGEMENT

KUN JIANG*

Abstract. This article studies the application of deep learning and computer data mining technology in electronic information engineering management to meet the library's demand for larger collection space and alleviate the management pressure of book preservation, borrowing, and return. This article also utilizes the general information mining function to further improve the information retrieval function. The conclusion of this article is as follows: Based on the traditional April algorithm, an improved address based April algorithm is proposed. The improved Apriori algorithm can reduce the final number of permanent data packets and save about 70% of time. For the minimum supported changes, the improved Apriori algorithm has lower execution time and approximately 60% time reduction. This article develops a data mining algorithm that is more suitable for electronic library management information systems based on existing data mining technologies. Has clear theoretical and practical significance.

Key words: Data mining, Cluster analysis, Apriori algorithm, Electronic Library

1. Introduction. The rapid development of computer technology, Internet technology, and information technology has brought about significant changes in people's production methods and lifestyles, as well as profound changes in the library industry. Libraries have long considered paper books to be the most important resource. However, as information technology deepens, paper books need more collection space to cover a more comprehensive amount of knowledge, which also puts great pressure on the management of book preservation, borrowing and return [1]. In this case, colleges and universities, scientific research institutions and other units have begun to build electronic libraries. Electronic library is a library model that stores information in the form of e-books. The emergence of electronic library benefits from the emergence of electronic production technology of books and publications [2]. As soon as the electronic library appears, it shows a variety of advantages over the traditional library, and quickly gets the favor of users.

Electronic libraries use disks and optical discs as storage, which have a much higher storage capacity than paper books, resulting in the storage of massive amounts of information; The borrowing of e-books is more convenient, and users can download them through the internet; E-books are easy to keep and extend their service life indefinitely: in addition to text information, e-books can also conveniently store sound information, image information and video information [3].

Since the emergence of electronic library, it has been proved by indisputable facts that it will become the mainstream model in the field of library. However, e-library also puts forward a series of new challenges to developers.

The most important problem is how to quickly and accurately retrieve what users need in the massive book information. Mass storage is an important advantage of e-library, but the larger the storage, the greater the difficulty for the retrieval process.

In this case, data mining has become the first choice to improve the retrieval performance and improve the service quality of E-library[4]. From a processing point of view, data mining technology is the process of extracting information and extracting knowledge using various algorithms. Some of these algorithms depend on statistics, some on artificial intelligence, and some on machine learning perspectives. No matter what type of algorithm is adopted, data mining is a technology with independent analysis ability and automatic retrieval of knowledge [5]. Even if the information provided by users is not comprehensive enough, data mining can still retrieve or extract useful data for users, which is the advantage of data mining. This is undoubtedly of

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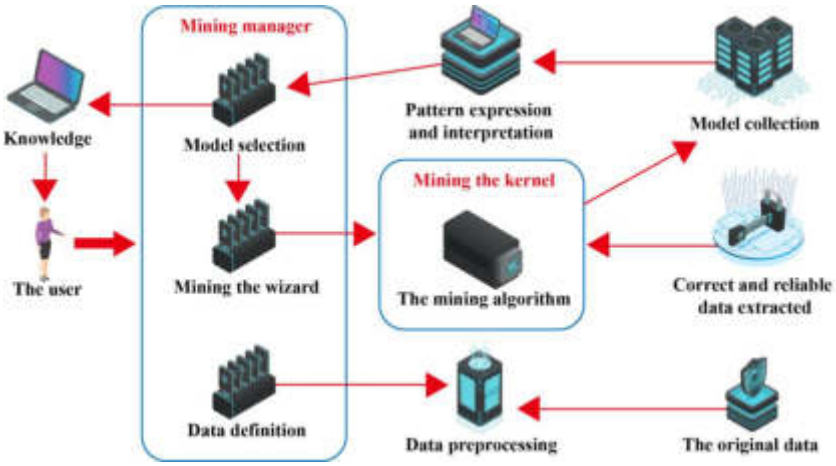

Fig. 1.1: Application of computer data mining technology in electronic information engineering

great significance for electronic libraries [6]. In recent years, data mining technology has been used in similar information management systems.

In the case of an electronic library system, the purpose of using data mining technology in it is, on the one hand, to obtain general information and, on the other hand, to complete the function of sorting further information. From this perspective, this article develops a data mining algorithm that is more suitable for electronic library management information systems based on existing data mining technologies, which has certain theoretical and practical significance [7]. Figure 1.1 shows the use of computer data extraction technology in electronic information engineering.

2. Literature Review. After the 1990s, human society officially entered the information society, and the amount of data showed an explosive growth trend. It has been difficult to effectively sort out and analyze such large-scale data by relying on human ability.

Data mining technology can quickly and accurately organize and analyze information, which has become an inevitable technical requirement [8]. After entering the 21st century, data mining technology has been recognized as the first of the key technologies that will have a significant impact on human production and life in the next decade, and has gradually become one of the key targets of enterprise investment. In this case, data mining technology has developed rapidly [9]. Attari, M. and others systematically summarized data mining technology. According to the development of data mining technology, data mining technology is positioned as a multi technology cross field of database technology, statistical theory, machine intelligence technology, visualization technology and digital technology [10]. Wang, R. and others pointed out that the nature of data mining technology determines that it is inseparable from intelligent algorithms. Neural network intelligent algorithms, fuzzy theory intelligent algorithms and knowledge theory intelligent algorithms are the basic algorithms of data mining technology. Mining technology is a knowledge integration tool. Data mining technology can use many existing knowledge, such as information retrieval knowledge, signal processing knowledge, image processing knowledge, web database knowledge, pattern recognition knowledge, etc. [11]. Gao, J. and others proposed a data mining method based on maximum range search, and constructed a visual data mining system according to this method. This system can not only automatically execute the data mining process, but also be very convenient for human operation [12]. Parvez, I. and others focused on the data mining technology with sequence attributes on the basis of general data mining technology, and proposed a data mining method based on association rules, which is specially used for data mining of sequence data. This is a very important problem in the process of data mining [13]. Only the accurate segmentation of the information to be extracted before mining is conducive to the accurate positioning of the extraction results. With the development of technology, a data mining method based on gene distribution and cluster analysis is proposed, which can deal with more

subtle data mining problems. Li, J et al. pointed out that rough set theory is a very effective data mining tool that can effectively preserve important attribute degrees and exclude non important attribute degrees. We can use rough set theory to achieve quantitative mining. For this type of data mining method, others have developed a set of evaluation indicators that can evaluate the mining performance of different methods [14].

3. Research methods.

3.1. Data mining. The key of the concept of data mining is mining two words, which determines that it is different from simple data processing and data integration. Data mining discovers more valuable information hidden behind surface data information, such as the development and change trends of certain data, typical feature attributes of certain data, and correlations between certain data.

In terms of implementation, data mining must be combined with database theory, machine recognition theory and intelligent learning theory to achieve better results [15-16]. From the general implementation process of data processing, building a data warehouse is a prerequisite work. Only when the data is stored in the data warehouse, can data mining have operable objects. Therefore, data warehouse is the basis of data mining. Data mining is to find or extract more valuable information in the data warehouse [17].

OLAP technology also comes from the semantic translation of loanwords. Its corresponding English word is online analytical process, and its Chinese meaning is online analytical processing. Data mining technology is based on a series of assumptions, but these assumptions cannot be verified by data mining technology itself. OLAP technology just solves this problem. It can verify whether the results of data mining meet the assumptions [18].

Machine learning refers to that after some intelligent algorithms are executed on computers and other machines, they can learn some knowledge and form memory, so as to deal with subsequent problems more effectively. Data mining technology sometimes needs to use machine learning methods. For example, in large medical databases, patients have a lot of information and different conditions. At the same time, these information will also have the same or similar situations.

At this time, the implementation efficiency of data mining technology can be improved by using machine learning [19]. The core task of data mining is to select the most suitable mining algorithm. Due to the many existing mining algorithms, different algorithms have different application ranges. Choosing the most suitable and accurate algorithm for one's own problems directly determines whether the mining performance can achieve the expected results [20].

3.2. Cluster analysis. In the automatic service of e-library, the main service object is readers who need various types of books. The final service result is to provide them with e-books they may need for downloading. Therefore, if we can classify reader data and book data appropriately before deep mining, we will complete the service process faster and more accurately. In this paper, K-Mean is an average clustering method that analyzes important e-library data into clusters, so that the subsequent mining process can be better realized. Cluster analysis is the process of further subdividing an original data set according to abstract attributes or physical attributes to form multiple subclasses or sub clusters. This refinement can make the subsequent mining objects more clear, the scope more narrow and the results more accurate.

The K-Means cluster analysis algorithm is a common way to create a distance-based cluster. It can realize completely automatic and unattended cluster analysis, and the whole implementation process is also very simple. Especially when the number of clusters is determined, the clustering effect of this method is very obvious. The basic idea of K-means clustering analysis is: firstly, k data positions are randomly determined as the central position of cluster analysis, and then the distances from each point in the original data set to these central positions are calculated and included in each cluster.Then, based on the new data of each cluster, we need to continuously update the position of the cluster center and repeat the clustering, clustering again until the position of each cluster center remains unchanged, and then the entire clustering process ends [21,22].

As a clustering method based on distance, K-means clustering considers that the closer the distance between two data is, the higher the similarity is. If the distance between two data is, the lower the similarity is. After this judgment and processing, K-means clustering will get a very compact and independent cluster.

The implementation process of K-means clustering is as follows:

1. Randomly select one data from all the data as the central position to perform clustering.

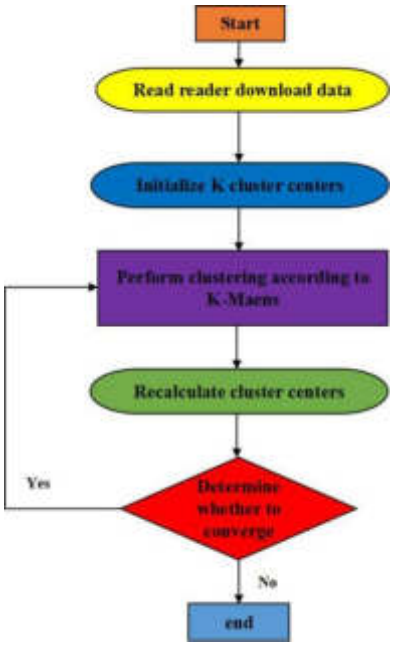

Fig. 3.1: Reader cluster analysis

2. For other data, the distance from the center of the cluster is calculated, and each data is classified according to the results of the calculation.
3. According to the data that has been summarized into each cluster, calculate the average value of each data and update the position of the cluster center.
4. According to the new clustering center, repeat the work from step 2 to step 3 until the clustering results meet the preset conditions, and the clustering ends.

K-means clustering selects a cluster center from the original data set. These clusters are shown in Equation 3.1:

$$C = \{C_k | i = 1, 2, ..., K\} \tag{3.1}$$

If the centers of these clusters are, the distance between other data and these centers can be calculated by the following formula, such as Equation 3.2:

$$J(c_k) = \sum_{x_i \in C_k} ||x_i - \mu_k||^2 \tag{3.2}$$

In the formula, x_i represents each data.

To determine whether the final clustering is completed, it is necessary to determine whether the sum of squares of all distances is the smallest, as shown in Equation 3.3:

$$J(C) = \sum_{k=1}^{K} J(c_k) \tag{3.3}$$

When reaches the minimum, the clustering is determined as the end. In this paper, K-means clustering analysis is performed on users based on the number of downloads of readers [23]. The specific process see Figure 3.1.

In the electronic library, in addition to user data, book data is another kind of very important data. If we can effectively cluster the download frequency of books, it will help to analyze what are hot books, also help to

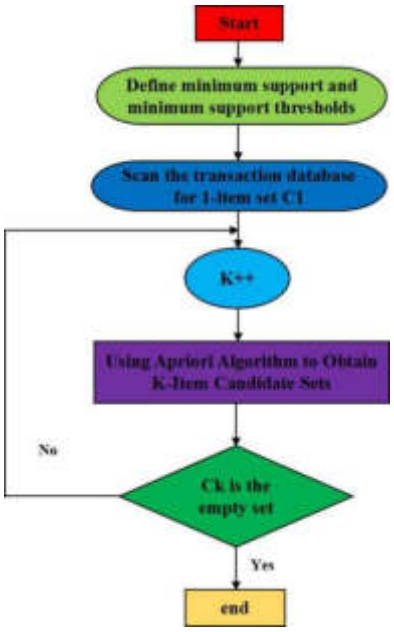

Fig. 3.2: Apriori algorithm flow

analyze the interests of users, and is more conducive to the rational purchase of subsequent e-book resources [24].

3.3. Apriori algorithm. Since the advent of the a priori algorithm, it has always been the main algorithm in the field of data mining and has been widely used in various data mining systems. Its core idea is to perform frequent item search on the database to be processed, and establish a set of frequent items to form a priori knowledge for subsequent use. Then, we determine the association rules of the original dataset by gradually searching for the relationships between frequent items in the database system, providing decision-making basis for users to deeply analyze the data.

Frequent item sets have two properties, which become the theoretical basis for the construction of Apriori algorithm [25]. These two properties are:

First, for infrequent item sets, its parent set must also be infrequent item sets.

Second, for frequent item sets, its descendant sets must also be frequent item sets.

According to these two properties, if a set can be represented as an infrequent N-term pattern, then any n + 1-term pattern to represent the set is also infrequent. Accordingly, the Apriori algorithm is formed, as shown in Figure 3.2.

3.4. Improved Apriori algorithm. This article discusses some of the improvement measures to address the common problems of a priori algorithms, to reduce the complexity of frequency packages, and to improve the efficiency of algorithm performance. The basic strategy for improving the algorithm is to increase the address configuration to increase the pruning efficiency of the Apriori algorithm. A priori algorithm is a very classic data mining algorithm. It is widely used because of its simple theory, convenient operation and high mining efficiency. Of course, Apriori algorithm is not absolutely perfect. It also has some typical problems, as follows:

1. The candidate frequent set CK formed by the algorithm is too large.
   In fact, among the data objects processed by Apriori algorithm, the more data items and entry items, the scale of candidate frequent sets will increase exponentially. This will greatly increase the processing time of data mining process, greatly increase the occupation of memory space, and greatly reduce the execution speed of the whole Apriori algorithm.

Table 4.1: Clustering results of some books

Book number	Book name	Average number of downloads per year	Total Downloads	Book type
0A041138	Three days proficient in office	51	106	Normal books
0Z012153	Yi Zhongtian's view of the Three Kingdoms	220	412	Hot books
0C080920	CET4 real exercise	41	83	Normal books
0Z012275	Political situation of the two Song Dynasties	112	170	Hot books
0D110003	Biological basis	15	21	Unpopular books

2. The algorithm performs too many scans on the processing object.
   The key is to scan the candidate items frequently and execute the Apriori algorithm frequently. If the final frequent item set is k-level, the scanning of data objects must reach k-1 times. When the data scale increases, the corresponding scanning times will be very many. Such multiple scans will be directly congested by the I / O of the computer, greatly reducing the execution efficiency of the algorithm.
3. Many association rules formed by the algorithm are redundant.
   As the scale of processing objects continues to expand, the number of candidate frequent set operations, self linking operations, and scans will significantly increase, and the final association rules will also rapidly expand. However, not all association rules have guiding significance for practical problems. Many association rules are invalid and redundant. When there are too many association rules, it is difficult for users to judge which rules can be used.

4. Result Analysis.

4.1. Cluster analysis examples. According to the different classification basis of cluster analysis, the clustering results of some books are obtained, as shown in Table 4.1. According to this classification result, the download types of different books are obtained. Among them, the book "Biological basis" is an unpopular book; Proficient in office in three days "Four true exercises" these two books are normal books; "Yi Zhongtian's view of the Three Kingdoms" and "Political situation of the two Song Dynasties" are two hot books. It shows that the clustering results have good results, which can be used for the next experiment.

4.2. Performance test of improved Apriori algorithm. Performance tests of the two algorithms are performed to better understand the performance of the a priori algorithm and the improved Apriori algorithm. From the perspective of distance, the improved Apriori algorithm does not scan the original data set many times, but uses one scan and address traversal to complete the search of frequent items, which greatly saves time and cost. In addition, judging only frequent items from address comparison can not only realize effective search, but also greatly improve the search efficiency. Address based storage also greatly saves memory space. Based on these characteristics, the improved Apriori algorithm greatly improves the mining efficiency.

The following experimental methods are used in this paper to quantify the performance of the improved Apriori algorithm. The specific test process is divided into two methods: the first method is to fix the minimum support rating in the Apriori algorithm and the improved Apriori algorithm, and the two algorithms check the time to generate the last frequency items of the same series, respectively. The second method is to convert the minimum support rating in the Apriori algorithm, improve the Apriori algorithm, and check the execution times of two algorithms with different lower support levels. Minimum support does not change Set the minimum support to 4, the set of candidate frequent and complex items is shown in Table 4.1, and the time of the frequent item set finally generated by the two algorithms is shown in Table 4.3.

It can be seen from table 4.3 that in the mining process of the improved Apriori algorithm, the number of final frequent item sets becomes less and the time is less, saving about 70%. Draw the data in Table 4.3 into

Table 4.2: Configuration of candidate frequency complex item set

Candidate frequency items	Set C_1	Set C_2	Set C_3	Set C_4	Set C_5	Set C_6
Number of frequent items	21	345	1077	646	64	7

Table 4.3: Time of generating the final frequent item set by the two algorithms

Algorithm	L1	L2	L3	L4	L5	L6	Total time
Apriori algorithm	135	160	237	181	126	110	1001
Improved Apriori algorithm	136	78	100	62	20	-2	370

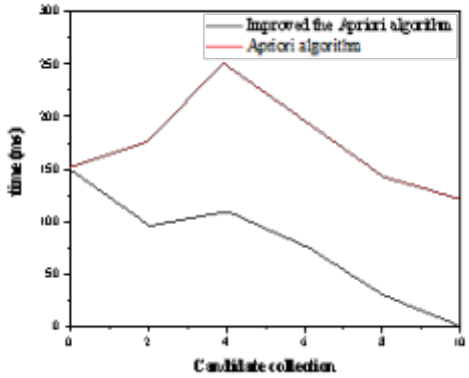

Fig. 4.1: Execution time of two algorithms

the following curve form, as shown in Figure 4.1.

As can be seen in Figure 4.1, the execution time of the improved Apriori algorithm is significantly reduced under the established minimum support.

As shown in Figure 4.2, the degree of minimum support, the minimum degree of support for multiple conversions, and the change in performance time of the Apriori algorithm and the improved Apriori algorithm were examined.

5. Conclusion. In recent years, data mining technology has been applied in similar information management systems. From a processing point of view, data mining technology is the process of extracting information and extracting knowledge using various algorithms. Some of these algorithms are considered from a statistical point of view and some from an artificial intelligence point of view, and some from the perspective of machine learning. No matter what type of algorithm is used, data mining is a technology with independent analysis ability and automatic retrieval of knowledge. Even if the information provided by users is not comprehensive enough, data mining can still retrieve or extract useful data for users, which is the advantage of data mining. This is undoubtedly of great significance for electronic libraries. For electronic library systems, data mining technology can not only complete general information retrieval functions, but also further improve information sorting functions. From this point of view, based on the existing data mining technology, this paper designs a data mining algorithm more in line with the electronic library management information system, which has certain theoretical significance and practical value for improving the service quality of electronic library and expanding the application of data mining algorithm.

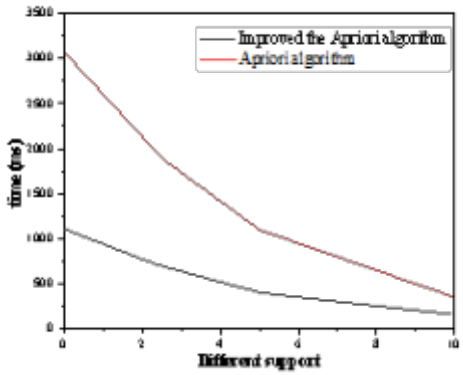

Fig. 4.2: Execution time of two algorithms

This paper has done some work in the following aspects:

1. Based on the principle of K-means clustering, this paper designs the clustering analysis function for the electronic library management information system, and arranges the data from two levels: user data and book data.
2. Based on the traditional Apriori algorithm, an improved address-based Apriori algorithm was developed. This method has been experimentally proven to significantly improve the speed of the cutting operation in the data mining process, improve the efficiency of the data mining system.

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APPLICATION OF CNC ROBOTS IN DEEP LEARNING INTELLIGENT CONSTRUCTION OF GREEN BUILDINGS

WEI ZHANG*

Abstract. In order to achieve automated cleaning of photovoltaic devices in green buildings and reduce the labor intensity of workers, the author has developed a photovoltaic device intelligent cleaning CNC robot intelligent cleaning system. Through the analysis of the use of the green building photovoltaic device, the green building photovoltaic device cleaning robot and its cleaning system are designed according to the environmental situation and the use requirements. This intelligent cleaner system consists of a transmission guidance system, a cleaning system, and a control system, using only one motor to complete the overall action, at the same time, an independent walking mechanism is designed, and the walking wheel system is not in contact with the photovoltaic device, which does not harm the photovoltaic device, at the same time, it can cross two adjacent photovoltaic panels with included angles to achieve the function of cleaning complex photovoltaic panel surfaces for a single device, the cleaning layer design has a diagonal protrusion similar to a spiral output, which can automatically discharge accumulated dust from the cleaning roller while cleaning, providing a certain self-cleaning function, extending the replacement cycle of the cleaning layer, and can be used for both dry and wet purposes. Realize wet cleaning; when the cleaning solution is not used, use the cleaning layer and its surface oblique raised to remove dust, achieve dry cleaning. On the whole, the robot structure is reasonable, simple control process and high degree of automation, which can effectively solve the cleaning problem of green building photovoltaic devices, and can provide effective guarantee for the efficient work of photovoltaic devices.

Key words: CNC robot, Green buildings, Intelligent construction, Photovoltaic devices, Intelligent cleaning

1. Introduction. Building intelligence is the integration of building systems, structures, services, and management to provide convenience and a reasonable living environment for urban residents. Building intelligence refers to the creation of a people-oriented green building environment, and the organic integration of construction equipment and construction equipment management through the improvement of automation technology for construction equipment.

In recent years, photovoltaic power generation technology has developed on a large scale, and the installation of photovoltaic power generation devices on green buildings for power generation has also increased significantly. The State Council's Development Plan for Zhangjiakou Renewable Energy Demonstration Zone in Hebei Province said that Zhangjiakou will build a national renewable energy demonstration zone by 2030, with an installed photovoltaic power generation capacity of 24 million kilowatts. At present, photovoltaic generating units have been built in the roof of residents, barren hills, both sides of expressways and other areas, and put into use. According to research, due to the existence of dust accumulation, the loss of ordinary 20MW photovoltaic power station caused by dust deposition is more than 2 million yuan per year. According to the year-on-year scale of photovoltaic power generation capacity in Zhangjiakou reaching 24 million kilowatts in 2030, the annual loss caused by dust accumulation problem will reach 240 million yuan.

With the widespread application of intelligent technology in green buildings, green buildings have developed rapidly, providing convenience and safety guarantees for the daily lives of urban residents, and effectively achieving resource conservation. Green buildings have energy-saving characteristics. In green buildings, the application of intelligent technology has effectively improved the energy recovery and utilization rate. The use of recyclable materials during construction can effectively save resources. But from the point of the development of construction industry in our country, intelligent green building is still in its infancy, both in the application effect and penetration are some deficiencies, more concentrated in first-tier cities of large enterprises and institutions and government projects, but for small and medium-sized enterprises and residential areas, the application

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of intelligent green building is very limited, especially in three or four line city, the gap is more obvious. In the development of construction industry, intelligent green building has become one of the more advanced technology, but in the specific application will still produce larger energy consumption, in order to solve these problems, must increase investment in technology, to develop more advanced technology and equipment, with the help of all kinds of clean energy, such as photovoltaic power generation technology, provide guarantee for the sustainable development of the construction industry, create a better environment for development.

Green building design meets social needs. Various emerging technologies have been applied in green buildings, making construction operations simple and efficient. Architectural designers carry out green and environmentally friendly design from the perspective of urban residents, with the ultimate goal of solving residential environmental problems. Design a reasonable plan to prevent power outages and utilize the sun to meet the living needs of residents. Building intelligence technology mainly relies on intelligent sensors and other devices, combined with information system integration to complete the overall and framework construction, and can complete the collection, storage, and automatic analysis of information. The function of building shading systems is to reduce "overheating" and "glare", and improve indoor comfort.

Driven by the industrial revolution, the concept of green development has been widely recognized by people. In the process of promoting economic development, more effective measures need to be taken to maintain the balance of the ecological environment and realize the sustainable development of the economy and society. In the development of construction industry, architectural designers in order to better improve the construction project ecology and intelligence, whether in building materials selection, or in the architectural design, need as much as possible to save resources, realize the protection of ecological environment, to create a green healthy living space photovoltaic technology can convert light into usable energy, the light to give full play to the value of the new energy. Through the effective combination of photovoltaic power generation technology and smart green building, the scientific concept of development can be better implemented, and the sustainable development of human society can be realized.

The intelligent lighting control system can perform intelligent adjustment on individual lighting facilities, achieving the goal of saving energy and extending the service life of lamps. The intelligent lighting control system has automation, networking, compatibility, and easy to operate building intelligence technologies, including communication technology, automated management and control technology, computer information technology, system integration technology, and fire safety technology.

In the process of rapid development of science and technology, the application of green intelligent building is increasingly widely, in real application, green intelligent building refers to the building as a platform, automation, intelligent office, at the same time do system service management optimization and communication network centralized building way in green intelligent building, need to emphasize the concept of green environmental protection, for people to create a safe, comfortable, clean office environment and living space. Thus, in the development of the intelligent and green building industry, it is necessary to start from the two aspects of intelligence and green to make up for the deficiencies in the development of the traditional building industry.

Introducing system integration technology in the architectural design process, integrating computer, automatic control, modern communication technology with green buildings, and effectively managing information data through automation technology. Green buildings refer to buildings that maximize resource conservation (energy conservation, land conservation, water conservation, and material conservation), protect the environment, reduce pollution, provide healthy, applicable, and efficient usage space for people, and coexist harmoniously with nature throughout the entire lifespan of the building.

In recent years, China has made remarkable achievements in the development of intelligent green buildings. Under the leadership of the government, the intelligence of comparative systems has been constructed. The green building system is also being implemented nationwide.

The construction process of a building, as an important part of its entire lifecycle, is of great significance for the quality, conservation, and environmental protection of the entire building. At present, the concept of green building has deeply rooted in people's hearts, and related technologies have rapidly developed, however, the construction process of buildings still remains in a labor-intensive, low processing accuracy, and extensive resource utilization mode, this undoubtedly cannot meet the requirements of green building. Therefore, improving the construction process and introducing new construction methods will become an important aspect

of green building development in the future. At present, the domestic cleaning means are mainly manual cleaning, which has problems of low efficiency and high cost. For a 10MW photovoltaic power station to keep its solar panels clean requires at least 20 cleaning workers to work continuously. In addition, the regional characteristics of low temperature, drought and water shortage in winter also make artificial cleaning more difficult. The research and development of robots that can automated operations is of great significance for cleaning photovoltaic devices equipped in green buildings.

In order to realize the automatic cleaning of green building photovoltaic devices and reduce the labor intensity of the staff, a set of photovoltaic device intelligent cleaning CNC robot intelligent cleaning system is developed. This intelligent cleaner system is composed of transmission guide system, cleaning system, and control system, using only 1 motor to complete the overall action, design independent walking mechanism, walking wheel system does not contact with photovoltaic device, no damage to the photovoltaic device, and can cross the Angle and two adjacent photovoltaic panels, realize a complex photovoltaic panel function cleaning system cleaning layer design with similar spiral output oblique raised, can automatically clean roller, cleaning side discharge dust with certain self-cleaning function, prolong the replacement cycle of the cleaning layer, and can dry and wet dual use.

2. Application of CNC robots in intelligent construction of green buildings . The method of building construction based on CNC robot technology emerged in the early 21st century and has become a new hot topic in the current construction field after nearly a decade of rapid development [1]. This method stands out from many explorations mainly because it has the following advantages compared to traditional construction methods. Firstly, CNC robots undertake high-risk and harmful construction operations, which can ensure the occupational health of construction personnel. The harmful factors in the construction process mainly include toxic gases such as SO2 generated during the processing of building materials, as well as a large amount of dust and strong noise generated during the construction process, therefore, it is clearly pointed out in the Green Construction Guidelines that "Occupational hazard such as dust, toxic gas and radiation shall be reduced as far as possible to ensure the long-term occupational health of construction personnel". Traditional building construction is a labor-intensive production mode, construction workers not only have to undertake heavy and dangerous physical labor, but also have long-term Close encounter with toxic gas, dust, noise and other harmful factors, and their bodies are inevitably damaged, therefore, the traditional construction method contradicts the "Green Construction Guidelines" and therefore does not meet the requirements of green buildings. The use of digital control robot technology in building construction can replace the construction personnel to complete some heavy and dangerous work, as well as work such as welding, masonry and other work that produces a lot of toxic gas, dust and other harmful substances. While reducing the labor burden of construction personnel, it can reduce their Occupational hazard and ensure their long-term occupational health. It can be seen that the method of building construction based on CNC robots is more in line with the requirements of green construction and green buildings than traditional construction methods. Figure 1 shows the robot control system [2].

Secondly, in order to achieve certain performance demands of green buildings, components such as shading and curtain walls often adopt complex and irregular shapes. With the development of parameterization technology and computer simulation technology, architects can better calculate and compare complex shapes, thus obtaining the most ecological and energy-saving component forms of buildings. However, these complex shapes increase the difficulty of construction: Traditional construction methods have poor accuracy, usually only reaching the centimeter level, and the reliability of manual calculations is limited, making it inevitable to encounter significant errors, therefore, it is difficult to ensure the accuracy of complex forms completed using traditional construction methods, which in turn affects the ecological performance of these components. In the method of building construction based on CNC robot technology, CNC robots can directly read computer models of complex shapes, accurately locate and move according to digital instructions, with an accuracy of at least millimeters and high reliability, therefore, it can effectively meet the processing and construction requirements of complex shapes. It can be seen that using CNC robot technology for the construction of green buildings can improve the accuracy of complex components and ensure the realization of building ecological performance. Once again, as the foundation of the building process, the pollution and energy consumption caused by the acquisition, production, processing, and other processes of building materials account for a significant proportion

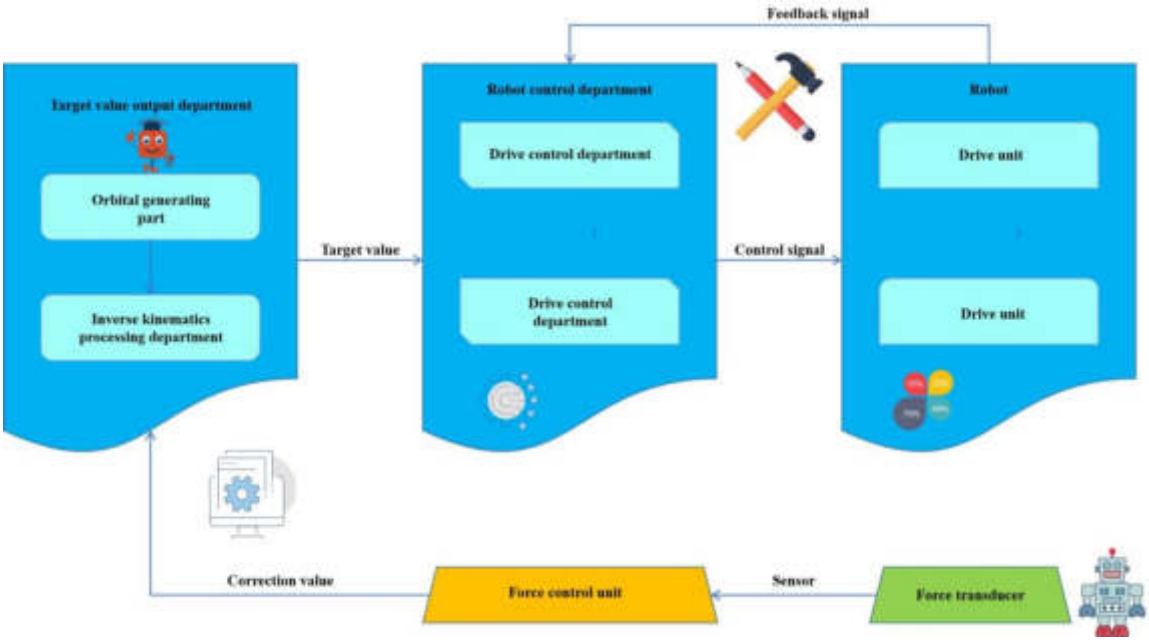

Fig. 2.1: Robot Control System

in the entire life cycle of the building. Therefore, the evaluation standard for green buildings regards ”material conservation” as an important content. Due to the limitations of workers' technical level and reliability, traditional construction methods inevitably make mistakes in machining steps that require high process accuracy such as cutting and welding, resulting in waste materials and significant waste of construction materials. In contrast, CNC robots have stronger controllability in processing and construction. As long as the operator's instructions are correct, there will be no material waste caused by misoperation and process accuracy issues. Therefore, using CNC robot technology for building construction can effectively reduce waste of building materials, making buildings more energy-efficient and environmentally friendly throughout their entire life cycle. In summary, the method of building construction based on CNC robots has multiple advantages compared to traditional construction methods and is more in line with the requirements of green buildings. As a result, this method has gradually stepped out of the laboratory exploration stage in recent years and has been applied in practical green building construction [3].

The basic principle of photovoltaic power generation: photovoltaic power generation system refers to the solar energy into electric energy technology, mainly under the action of a new energy of the sunlight, with the aid of solar panels, converted into electricity, and then with the aid of charge and discharge controller, charging battery pack, under the condition of the load appropriate, realize direct power supply. If the AC load is set in the system, it is necessary to use the direct AC inverter to convert the direct current into AC current, to provide convenient conditions for daily use. For this system, the important components are mainly the controller, volt battery module, battery group, inverter and measuring equipment, etc., the photovoltaic cell module can realize the conversion of solar radiation to electric energy, in the module power, must be in strict accordance with the load standard. The controller plays a vital role in the photovoltaic power generation system, which can prevent the shortening of the battery life due to excessive charge and discharge.If there is an AC load in the system, it is necessary to use the inverter to convert the direct current to form the alternating current that meets the load requirements. At the same time, with the help of the charge and discharge controller, the electric energy is connected into the network. The battery is mainly to for electric energy to ensure that the power can power the load at any time. Intelligent measurement equipment can measure the important parameters in the system, and carry out remote information transmission and remote control.

In order to realize the environmental protection, safety, energy saving and efficiency of architectural design and achieve the strategy of sustainable development, it is necessary to promote the integration of smart green building and photovoltaic power generation technology and give play to its advantages in the construction industry. For the development of green intelligent building system, need to build more system of science and technology, a variety of energy technology parameters into among them, various detection of energy, environment, ecology, technology and security elements, so as to build a common ecological management system, to calculate all kinds of energy consumption, realize the combination between resource security and environmental protection.In the application of photovoltaic power generation technology, in order to better meet the development needs of intelligent green buildings, it is necessary to build a co-joint mode control model, parallel operation between each technical component, and then control the energy saving degree, and calculate the green intelligent number. In the controller center, it can complete the data conversion and processing work, providing a scientific energy saving computing system for the development of intelligent green building.

3. Methods.

3.1. Implement automatic cleaning function. It is required to use automation control technology to complete the automated cleaning of solar panels, reduce the labor intensity of workers, simplify the control process, have high system stability, and minimize the number of drive motors selected.

3.2. Separate design of walking mechanism. It is required to design an independent walking mechanism, with the walking wheel system not in contact with the solar panel, which does not cause damage to the solar panel. At the same time, it can achieve the function of crossing two adjacent photovoltaic panels with included angles, that is, one device cleaning the complex photovoltaic panel surface.

3.3. The cleaning operation end is easy to replace and has a certain self-cleaning function. In order to facilitate the replacement of cleaning operations, it is required that the end of the cleaning system be easily replaced, and to reduce the frequency of replacement, the cleaning system should have a certain self-cleaning function [4].

3.4. Detailed design content.

(1) Structural Analysis of Green Building Photovoltaic Devices. Green building refers to maximizing resource conservation throughout the entire life cycle of a building, including energy conservation, land conservation, water conservation, material conservation, etc., protecting the environment and reducing pollution, a building that provides a healthy, comfortable, and efficient space for people to use and coexist harmoniously with nature. Green buildings are a popular means of energy conservation through photovoltaic devices, photovoltaic devices are often installed on the top and sunny side walls of buildings through brackets. The main structure design of the CNC robot, including the transmission and guidance system, is arranged along the direction and inclination of the brackets, allowing the CNC robot to operate completely on the layout route of the photovoltaic device, when there is an angle between two photovoltaic panels, the chain structure of the guidance system is arranged according to the angle, and an intermediate sprocket is set at its bending position [5,6].

(2) Main structure. The main structure design of the CNC robot consists of a transmission guidance system, a cleaning system, and a control system. As shown in Figures 3.1, 3.2 and 3.3, in which: 1. Rack, 2. Transmission chain, 3. Guide rail, 4. Guide wheel, 5. Connecting piece, 6. Cleaning component, 7. Solar panel, 8. Tensioner, 9. Motor, 10. Driving sprocket, 11. Driven sprocket, 12. Center shaft, 13. Follow sprocket, 14. Fixed chain, 15. Cleaning roller, 22. Travel switch A, 23. Travel switch B, 24. Chain tensioner, 25. Bearing, 26. Cleaning cover, 27. Bearing. Among them, the transmission guide system includes frame 1, transmission chain 2, guide rail 3, guide wheel 4, connecting piece 5, tensioning wheel 8, motor 9, driving sprocket 10, driven sprocket 11, fixed chain 14, and chain tensioner 24; Guide rail 3 is fixed on rack 1 and is located on both sides of solar panel 7, it is used to guide the operation of the cleaning system and lift the cleaning system to avoid damage to solar panel 7, guide wheel 4 is located on guide rail 3 and connected to the cleaning system, guide wheel 4 can drag the cleaning system to move flexibly left and right on guide rail 3, driven sprocket 11 and driven sprocket 10 are respectively fixed on frame 1 and located on the upper left and right sides of solar panel 7, drive chain 2 meshes with driven sprocket 10 and driven sprocket 11 to form a chain transmission

pair, and the direction of drive chain 2 is consistent with that of solar panel 7, the chain transmission pair forms the main transmission route and is arranged along the direction of solar panel 7, the tensioning wheel 8 is fixed on frame 1 and meshes with the transmission chain 2, located on the inner side of the transmission chain 2 to tension the transmission chain 2, the cleaning system is fixedly connected to the transmission chain 2 through connector 5, enabling the cleaning system to move together with the transmission chain 2, the active sprocket 10 is connected to the motor 9, which drives the operation of the transmission chain 2 through the active sprocket 10, the fixed chain 14 is located on the upper side of the solar panel 7, and the direction of the fixed chain 14 is consistent with that of the solar panel 7, the fixed chain 14 is arranged along the direction of the solar panel 7, with both ends of the fixed chain 14 fixed to the frame 1, the fixed chain 14 is equipped with a chain tensioner 24 to achieve tension on the fixed chain 14; The cleaning system includes two sets of cleaning components, the front and rear 6, the front cleaning components complete the main cleaning work, and the rear cleaning components complete further cleaning work, cleaning component 6 includes central shaft 12, follower sprocket 13, cleaning roller 15, bearing 25, cleaning cover 26, and bearing 27, both ends of central shaft 12 are connected to guide wheel 4, the central shaft 12 is connected to the connecting piece 5 through the bearing 25, which is fixed on the transmission chain 2, enabling the central shaft to move freely along the guide rail under the drive of the transmission chain 2, the follow-up sprocket 13 is fixed on the central shaft 12 and meshes with the fixed chain 14 to form a transmission pair, the follow-up sprocket 13 is located below the fixed chain 14, and the follow-up sprocket 13 is located below the fixed chain 14 to ensure that the fixed chain 14 sinks under the action of gravity without affecting the meshing effect of the two, the follow-up sprocket 13 rotates synchronously with the central shaft 12, the cleaning roller 15 is fixed in the middle part of the central shaft 12 and rotates synchronously with the central shaft 12, when the central shaft 12 moves left and right, the driven sprocket 13 drives the central shaft 12 to move left and right, due to the simultaneous engagement of the follower sprocket 13 with the fixed chain 14, and the fact that the fixed chain 14 is in a fixed state, the follower sprocket 13 will passively rotate, because the follow-up sprocket 13 is fixedly connected to the central shaft 12, the central shaft 12 also rotates together, thereby achieving the drive chain 2 to drive the cleaning roller 15 to move, the follow-up sprocket 13 drives the cleaning roller 15 to rotate, and since the follow-up sprocket 13 is located below the fixed chain 14, the rotation direction of the cleaning roller 15 precisely causes the linear velocity direction of the edge of the cleaning roller 15 to be in the same direction as the movement direction of the cleaning roller 15, further increasing the relative velocity of the cleaning roller 15 and the solar panel 7, increase the cleaning effect, the upper end of the cleaning cover 26 is fixed on the connecting piece 5, the lower end is connected to the central shaft 12 through the bearing 27, and the cleaning cover 26 is located on the periphery of the cleaning roller 15, the cleaning cover 26 provides protection, encapsulation, and other functions for the cleaning system. The control system includes industrial PLC, travel switch A22, and travel switch B23 [7-8]; Among them, the industrial PLC is responsible for the operation control of the entire machine, and the travel switch A22 is installed on frame 1, located on the right edge of solar panel 7, just in contact with the right running station of cleaning component 6, used to detect the signal of cleaning component entering the working station, the travel switch B23 is installed on frame 1, located on the left edge of solar panel 7, just in contact with the left running station of cleaning component 6, and is used to detect the signal of cleaning component leaving the working station [9].

(3) Clean component design. The design of the cleaning component is shown in Figure 3.4, where: 4. Guide wheel, 12. Center shaft, 13. Follow up sprocket, 15. Cleaning roller, 19. Oblique protrusion. Among them, both ends of the central shaft 12 are connected to the guide wheel 4, and the driven sprocket 13 is fixed on the central shaft, the follow-up sprocket 13 rotates synchronously with the central shaft 12, and the cleaning roller 15 is fixed in the middle part of the central shaft 12 and rotates synchronously with the central shaft 12, a cleaning solution storage layer is designed in the front cleaning component 6, and a cleaning solution absorption layer is designed in the rear cleaning component 6 [10,11].

(4) Design of cleaning rollers. The design of the cleaning roller is shown in Figure 3.5, where: 12. Center shaft, 16. Rigid support ring, 17. Flexible support ring, 18. Cleaning layer. Among them, the rigid support ring 16 is fixedly connected to the central shaft 12 and evenly distributed around the periphery of the central shaft 12. The rigid support ring 16 plays a role in supporting and connecting other peripheral parts, the flexible support ring 17 is fixedly connected to the rigid support ring 16 and evenly distributed around the periphery of

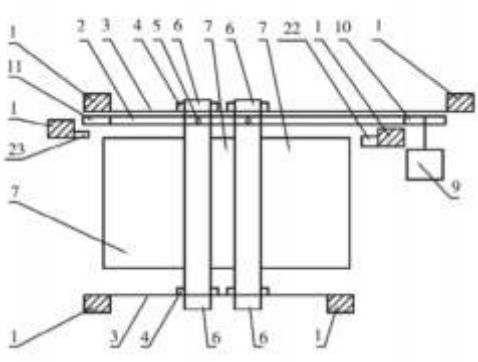

Fig. 3.1: Schematic diagram of the main structure

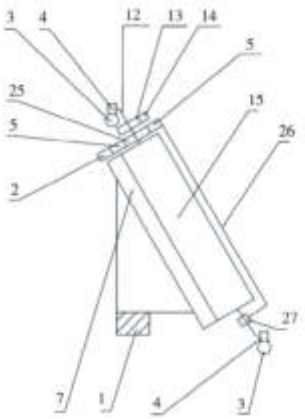

Fig. 3.2: Left view schematic diagram of the main structure

the rigid support ring 16, the flexible support ring 17 serves as a support for the cleaning layer, and the cleaning layer 18 is detachably installed on the flexible support ring 17 and evenly arranged around the periphery of the flexible support ring 17, the cleaning layer 18 is tightly attached to the solar panel 7 and used to clean the dust accumulation on the surface of the solar panel 7, the cleaning layer 18, flexible support ring 17, and rigid support ring 16 can rotate synchronously with the central axis 12, the rotation of the central axis 12 will drive the rotation of the cleaning layer 18, thereby achieving cleaning operations, the flexible support ring 17 is designed as a porous and loose structure, and the flexible support ring 17 located in the front of the cleaning roller 15 stores cleaning fluid, the flexible support ring 17 of the cleaning roller 15 located at the back is used to adsorb residual cleaning solution on the solar panel 7 [12].

(5) Clean layer design. The design of the cleaning layer is shown in Figure 3.6, where: 18. Cleaning layer, 19. Oblique protrusion, 20. Glue A, 21. Glue B. Among them, the front design of 18 has a diagonal protrusion 19, which tilts in the left diagonal direction. The diagonal protrusion 19 on the front is responsible for cleaning the surface dust drop of solar panel 7, the oblique protrusion of 19 is matched with the rotation direction of the central shaft to form a downward spiral output effect, timely eliminating dust accumulation and improving cleaning efficiency, on the other hand, the cleaning roller 15 can have a certain self-cleaning function, reducing the frequency of equipment maintenance, the reverse side of the cleaning layer 18 is designed with fasteners A20 and B21, which can be bonded together to achieve portable disassembly and assembly of the cleaning layer 18, shorten the maintenance time of the equipment and increase its convenience of use [13,14].

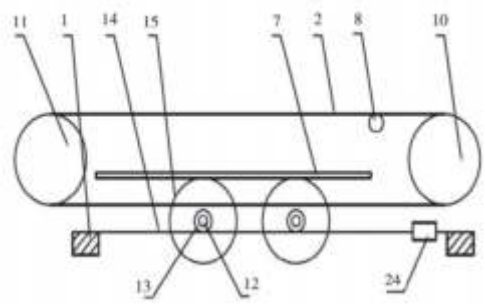

Fig. 3.3: Top view schematic diagram of the main structure

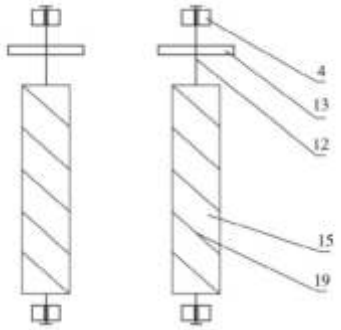

Fig. 3.4: Internal structure diagram of the cleaning system

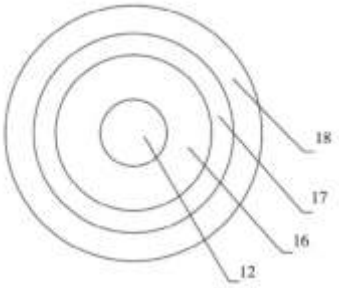

Fig. 3.5: Structural diagram of the cleaning roller

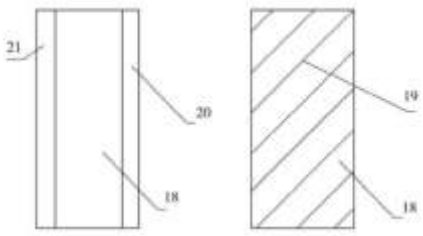

Fig. 3.6: Structural diagram of the front and back sides of the cleaning layer

(6) Other accessory designs. The guide rail 2 of this CNC robot is set to two, with a 45 degree slanting angle and a 20mm spacing between the slanting protrusions, the slanting protrusions coordinate with the rotation direction of the central axis to form a downward spiral output direction, the transmission chain 2 is a double row chain, the fixed chain 14 is a double row chain, and the fasteners A20 and B21 are both set as ribbons, the two sets of cleaning components share the same cleaning cover 26.

Application effect of photovoltaic power generation technology in smart green building: technology energy saving effect: in smart green building, the application of photovoltaic power generation technology can play energy saving effect, through reasonable use of solar energy, effectively reduce the demand for other energy, and then play a role in saving power supply cost. In addition, under the action of photovoltaic power generation equipment, it can effectively absorb solar energy, play a role in cooling in summer, residents in this environment, can reduce the use of air conditioning, and then achieve the reduction of energy consumption. Therefore, under the application of photovoltaic power generation technology, effective energy conservation can be realized, and the cost of thermal power generation in China can be controlled, and the conservation of coal resources can be realized while reducing pollution.

In the process of the rapid development of China's social economy, the level of science and technology is also constantly improved, a complete technical system has been formed in photovoltaic power generation technology, the cost is constantly reduced, can be promoted on a large scale. Although the installation cost of photovoltaic power generation equipment is relatively high, but after the operation, the subsequent maintenance cost is very low, basically does not need too much maintenance, only need to be repaired after the failure. Under the current technical conditions, the photovoltaic power generation equipment can be installed and operated after 7 years of installation and operation, the cost recovery, in the following 18 years of service life, can create huge economic benefits and save a lot of electricity. In a 499kW photovoltaic power generation system, in addition to maintenance and other costs, can create nearly ten million economic benefits.

4. Work process design.

First step, start the device. Start the device, complete self check, restore the original device to its original position, and clean component 6 in the right position of solar panel 7.

Step 2, perform dry cleaning. The CNC robot system starts the operation, and the motor 9 runs, driving the transmission chain 2 to run quickly, and then driving the cleaning component 6 to quickly run, causing the position of the travel switch A22, travel switch A22 detects that cleaning component 6 has entered the work station, and the PLC controls motor 9 to run at low speed to start the cleaning operation, at this time, the spindle 12 moves from right to left under the drive of transmission chain 2, the follow-up sprocket 13 on the main shaft 12 moves to the right together, and due to the meshing between the follow-up sprocket 13 and the fixed chain 14, the follow-up sprocket synchronously and passively rotates, driving the main shaft 12 to rotate, thereby driving the cleaning roller 15 to rotate, the cleaning roller 15 is attached to the surface of the solar panel 7, and the cleaning operation begins, the cleaning layer 18 on the surface of the cleaning roller 15 is equipped with oblique protrusions 19, as the cleaning roller 15 rotates, these oblique protrusions 19 remove the accumulated dust on the surface of solar panel 7 and transport it to the lower side of solar panel 7, thereby achieving cleaning and to some extent self cleaning, the front and rear two sets of cleaning components operate repeatedly, which not only improves cleaning efficiency but also improves the service life of cleaning layer 18, thereby reducing the frequency of equipment maintenance [15].

Step 3, Equipment Reset. When travel switch B23 detects that cleaning component 6 is running to the left edge of solar panel 7, it is considered that the cleaning operation is completed, and the PLC controls motor 9 to run at high speed, quickly drive the cleaning component 6 to the starting station through the active sprocket 10 and the transmission chain 2, and the equipment enters a standby state [16,17].

Wet cleaning. The difference between wet cleaning and dry cleaning is that a certain amount of cleaning solution is stored in the flexible support ring 17 of the cleaning component 6 in the front, the CNC robot automatically wets the cleaning layer 18 and wets the solar panel 7 for the first step of cleaning during the cleaning operation, while the cleaning component located at the back performs a secondary cleaning, clean the accumulated dust on the surface of solar panel 7 again, while adsorbing the residual cleaning solution on the surface of solar panel 7, achieving wet cleaning [18,19,20].

5. Conclusion. By analyzing the usage of green building photovoltaic devices and designing a CNC robot and cleaning system for cleaning green building photovoltaic devices based on environmental conditions and usage needs, the CNC robot achieves automated cleaning of solar panels and reduces the labor intensity of workers, only one motor is used to complete the overall motion, with simple control and high system stability, the CNC robot is designed with an independent walking mechanism, and the walking gear system does not contact the solar panel, causing no harm to the solar panel, at the same time, it can cross two adjacent photovoltaic panels with included angles, achieving the function of cleaning complex photovoltaic panel surfaces for one device, the adhesive type cleaning layer designed for the cleaning system makes it more convenient to replace cleaning materials, the surface of the cleaning layer is designed with a diagonal protrusion similar to a spiral output, which can automatically discharge accumulated dust from the cleaning roller while cleaning, it has a certain self-cleaning function and extends the replacement cycle of the cleaning layer, the dual cleaning roller structure of the CNC robot, on the one hand, it increases the cleaning effect, on the other hand, it reduces the cleaning burden of a single roller, prolongs the maintenance cycle of the cleaning roller, and at the same time, the cleaning layer used up by the rear roller can continue to be used on the front roller, reducing maintenance costs. The cleaning system can be used both wet and dry, the flexible support ring located at the front can carry cleaning solution for cleaning solar panels, while the flexible support ring located at the back can wipe off excess cleaning solution to achieve wet cleaning; When not using cleaning solution, the cleaning layer and its oblique protrusions on the surface are used to remove accumulated dust, achieving dry cleaning. Overall, the CNC robot has a reasonable structure, simple control process, and high degree of automation, which can effectively solve the cleaning problem of green building photovoltaic devices and provide effective guarantee for the efficient work of photovoltaic devices. Build a systematic photovoltaic power generation system, fully tap its own energy-saving effects and economic effects, and inject new vitality into the development of the intelligent green building industry.

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RESEARCH ON LABORATORY CONSTRUCTION AND MANAGEMENT BASED ON INTERNET OF THINGS AND DEEP LEARNING

MIN CAO*

Abstract. A computer laboratory intelligent management and control system based on Internet of Things technology and deep learning is proposed to address the shortcomings of traditional university laboratory management.The system adopts the main embedded technology, mobile communication technology, wireless sensor technology and database storage technology in the Internet of Things technology, laboratory areas and equipment, identify and collect relevant data, monitor abnormal conditions in real time, and alarm. At the same time, the user is provided with a preview of the experimental content and a demonstration of the results through the handheld client APP. The experimental results show that: when the system is powered by 0.35A current, the total system power is about 3W. The NTC thermistor used has a B value of 3435. Under normal temperature, $T2 = 298.15K, R = 10K\Omega, R0 = 10K\Omega$. The current temperature value can be calculated according to the value obtained after the analog-to-digital conversion of the microcontroller. The output frequency of the humidity detection circuit is measured by the single-chip microcomputer, and the current ambient humidity can be obtained by substituting the result into the above formula, that is, when the output frequency dimension of the circuit is 6853Hz, the ambient humidity is 40%. Through the application of this system, the inefficient and extensive manual management method of the computer experimental teaching center is completely solved, so that it can bring more intelligent and efficient services to the teachers and students of the whole school, so as to comprehensively promote the experimental teaching of the school.

Key words: Internet of Things, laboratory management, environmental monitoring, deep integration, management research system

1. Introduction. With the continuous improvement of university laboratory environment and hardware conditions, it is urgent to establish a more scientific and effective laboratory management and operation mode based on modern information technology. The Internet of Things management and control system will be cross-integrated with the existing laboratory management system to gradually improve the open and sharing rate of practical teaching resources of the center, effectively relieve the pressure of laboratory safety management, and effectively serve teachers and students. As the world ushered in a period of great development and great change in digital transformation, the new generation of information technology has accelerated to lead breakthroughs in technological applications, bringing about major changes in industrial forms, organizational management, social governance, etc, and the development of new generation technologies such as the Internet of Things, bringing new impetus and new opportunities to the development of the digital economy [1].

With the introduction of the new engineering concept, experimental teaching has become an important practice link for scientific development, knowledge innovation and talent training in colleges and universities, under the guidance of applied talent training, practical ability has become a rigid indicator, the result is to increase the proportion of experimental courses, improve the effective utilization of the laboratory, and increase the investment in laboratory construction to promote the self-improvement of students' practical ability [2]. As an important place to cultivate students' practical and innovative ability, university laboratories play a decisive role in the teaching process of universities. Under the new situation, the laboratory must gradually improve the utilization rate and sharing rate of open resources, and give full play to its important role in innovation and entrepreneurship education.

Internet of Things laboratory is an intelligent laboratory management system using Internet of Things technology. With the help of various sensors through the Internet and relays, the ubiquitous link between things and things and between things and people can be realized. Its technology can bring revolutionary

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changes to the entire laboratory environment. In contrast to this, the management and use of the laboratory still remain in the old mode of the original experimenter management, teacher's explanation and students' classroom operation [3]. Therefore, how to manage the laboratory scientifically and reasonably, it has become an urgent problem to make it serve the teachers and students of colleges and universities efficiently. Traditional laboratory management mostly adopts manual management mode, lacking systematic and scientific laboratory information management software, and the efficiency is low [4]. After class, the laboratory is closed, and it is difficult to meet the individual needs of students for experiments. The so-called open experiment means that from the selection of experimental time, experimental items, experimental instruments and equipment, in order to the formulation of the program and the implementation of the project, students can complete it independently.Open experiment breaks the various limitations of traditional experimental teaching and realizes the autonomy and diversity of experiments [5]. This kind of flexible teaching can fully mobilize students' enthusiasm for learning, and is conducive to cultivating students' innovation and entrepreneurship ability, cultivate more complex skilled talents needed by society [6]. The construction objectives of the training room in higher vocational colleges should be based on application-oriented infrastructure construction and curriculum construction, characterized by practical courses, and characterized by different industries, application examples and rich application scenarios. The room is committed to cultivating professional talents with certain electronic technology and information technology foundation, and cultivating professional talents with the application development ability of the Internet of Things.

2. Literature review. In recent years, the construction of laboratory management system has attracted great attention from related industries at home and abroad [7]. The construction of Internet of Things laboratory is of great significance for improving students' comprehensive quality, promoting students' employment, improving the Internet of Things research environment and enhancing scientific research strength. The Internet of Things laboratory is divided into two areas: the Internet of Things application display area and the student experiment area. Relevant practical training resources and experimental operation guidance are managed uniformly through the Internet of Things practical training management system. Teaching and practical training, application and innovation will be better integrated. However, most of these systems are aimed at the management and monitoring of biochemical laboratories, with low comprehensiveness, relatively single functions, and high prices. In traditional laboratories, equipment management has always been managed by laboratory administrators on the spot, regularly checking the safety hazards such as water and electricity consumption in the laboratory, only a small number of scientific research institutes have joined the assistance of information technology, temperature, humidity, light and smoke are monitored [8]. With the rapid development of Internet of Things technology, the real-time collection of laboratory environmental information and equipment information can be realized by sensors, which can greatly facilitate the effective management of experimental equipment [9]. In experimental teaching, most colleges and universities still use the traditional face-to-face teaching method, that is, teachers teach and students do the same, this form of teaching has certain unfavorable factors for students' thinking and exploration and after-class review, and cannot form a systematic system. In recent years, with the development of network technology, remote video teaching methods have sprung up and have been widely used, the distance teaching technology realizes the centralized utilization of teaching resources such as excellent teachers and advanced teaching methods, and meets the various needs of users at different levels [10]. Applying this concept, efficient and rich experimental equipment and experimental resources can be effectively used in experimental practice teaching, and audio and video teaching and operation demonstrations can be used to explain experimental tutorials and experiments, so that students can flexibly learn experimental knowledge from various aspects and improve their practical ability. Some enterprises and scientific research institutions in my country have also begun to pay attention to the informatization construction of laboratory management [11].

Umashankar, M. L. et al. launched Bio-LIMSV1.0 for biological research and development, pharmaceutical manufacturing and chemical enterprise management, to a certain extent, the laboratory management system realizes the main functions of biochemical laboratories in daily life, project topics, inventory, material consumption and ordering [12]. In addition, it can intelligently allocate the inventory and usage of chemical reagents in the laboratory, a customized management plan is designed for some special chemical reagents [13]. In addition, some laboratory management systems have emerged in the industry to meet the needs of specific fields. Zhang,

Y. et al. developed a laboratory energy consumption management control system, which senses the working conditions of electrical equipment in the laboratory through sensor detection technology, and conducts differential management, greatly reduces the loss of laboratory electricity [14]. Zheng, X. et al. developed a set of commercial laboratory management system, which is mainly used for course scheduling management and charging management of teaching units and teaching institutions. In foreign countries, StarLIMS has been committed to the research and development of laboratory management and solutions for public health and environmental monitoring for several years, and has occupied a large market share in Europe and North America [15].

Internet of Things application and practical training scene construction: On the basis of the experimental teaching platform of basic courses, an exhibition environment covering intelligent home, intelligent building, robot control, industrial monitoring and other Internet of Things application scenes is built. Enable students to intuitively understand the specific application of the Internet of Things industry, and make use of the open interface to carry out the actual development of the Internet of Things engineering, cultivate the students' application level of comprehensive knowledge, improve their comprehensive skills of the Internet of Things.

On the basis of the above research, the author proposes a laboratory construction and management research system based on the Internet of Things and deep integration, through the experimental observation of the circuit current, temperature, humidity and other parameters in the laboratory, in order to carry out the daily management and environmental monitoring of the laboratory.

3. Research methods.

3.1. IoT-based laboratory management system. The daily safety management of the laboratory is faced with some safety risks, such as water and electricity safety, hazardous chemicals management, the use of instruments and equipment, open use, etc. The traditional surveillance system has many loopholes, and the camera equipment usually leaves many blind spots. Moreover, the surveillance video cannot deal with the abnormal situation in real time, so it needs to be judged by human afterwards. In addition, the collection of information is single, the provision of effective information is not comprehensive, and there is no effective analysis tools, can not be remote monitoring.

There are many kinds of instruments and equipment in the laboratory, with different functional components and different requirements for the environment, and even some instruments and equipment have very strict requirements on the environment. According to this characteristic, the management work of the laboratory is mainly the management and maintenance of the experimental equipment and the monitoring and control of the laboratory environment. In addition, the opening of experimental activities is limited by time and place, which cannot meet the students' follow-up exercises and summaries, repeated experiments in batches increase the workload of teachers. In response to this problem, if you integrate excellent experimental content and methods and other resources, and store them on the central control server in the form of documents or videos, students can access them remotely through handheld terminals, which can facilitate review, summary and self-learning thinking, the workload of experimental teachers.

The application of Internet of Things technology can strengthen laboratory security management, and effectively improve the timeliness and efficiency of security control. Through the Internet of Things perception system, environmental monitoring system, power safety system, smoke alarm system, real-time monitoring of hazardous chemical cabinets, air conditioners, projectors, light incubators, ultra-low temperature refrigerators, access control and other equipment safety and environmental safety, in case of abnormal conditions, can immediately start the automatic alarm function, real-time information feedback to the laboratory manager.

The overall structure of the laboratory management system is shown in Figure 3.1. In this system, the administrator can monitor the laboratory information in real time through the PC client or the mobile phone, so as to realize the effective management of the management laboratory equipment. Students can also learn teaching resources such as experimental content and experimental instrument usage instructions through the terminal [16].

Combined with the three-tier architecture of the Internet of Things and the actual construction requirements, the system is divided into layers. The perception layer mainly acquires information, and uses the wireless sensor network to monitor the natural information such as temperature and humidity, illuminance, and smoke and dust concentration in the laboratory in real time [17]. Through the scanning equipment, the experimental

Fig. 3.1: Overall structure of the system

Fig. 3.2: System function structure diagram

equipment, experimental equipment and other information can be quickly and accurately identified and obtained. The collected information is transmitted to the central control storage unit using wireless transmission technology.

The large instrument room of the center is used as a pilot to introduce the Internet of Things technology and connect things Network management and control system and large instrument platform existing management system cross integration, real Instrument and equipment reservation, access control authorization, remote monitoring, equipment status tube Management, environmental monitoring, data reporting and other functions of intensive, intelligent management.

The network layer mainly completes the network transmission design according to the actual needs, in order to realize the fast and accurate data transmission to the central control unit, an embedded system needs to be constructed to complete the relay transmission of the perception layer information.

The application layer mainly completes the establishment of the database and the design of the application program, which is used to store the data collected by the sensing device, process different data separately, and make corresponding responses to different applications.

System specific design. Apply IoT-related technologies to design the laboratory management system, referring to the IoT hierarchy model, combined with the specific application space, the functions of laboratory environment data acquisition, system integration central control, sensing data storage, and interactive application are realized [18]. The laboratory environment data collection is realized by the perception layer function, the system integration central control is guaranteed by the network layer transmission protocol, and the perception data storage and interactive application are realized by the application layer function.The functional division of the system is shown in Figure 3.2.

The data acquisition function module is mainly used to acquire the environmental information inside the

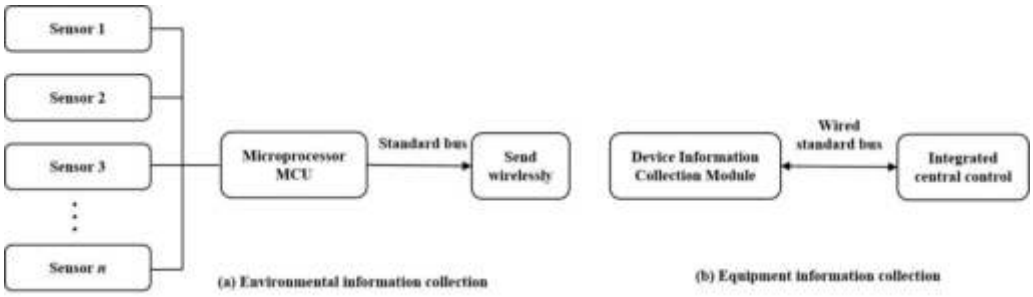

Fig. 3.3: Schematic diagram of the data acquisition part

Table 3.1: Barcode Encoding Rules

information bits	illustrate
1	Floor
2	
3	Laboratory number
4	
5	Equipment type
6	
7	
8	Serial number
9	
10	

laboratory and the status information of the experimental equipment, collect the laboratory environmental data in real time and input the information of the experimental equipment, finally, the acquired information is transmitted to the system integration central control through the network protocol [19]. The data collection process is shown in Figure 3.3.

The collection of indoor environmental data mainly applies wireless sensor network technology and sensor technology, real-time monitoring of laboratory temperature, humidity, light, smoke and other data information [20,21]. As a component, sensors must be used in conjunction with microcontrollers to detect environmental data information. The system uses ARM Cortex-M3 as the microcontroller, uses ZigBee module for wireless transmission, and completes the perception of laboratory environmental data in combination with sensors. The hardware part of the microcontroller is composed of power supply, signal amplification circuit, crystal oscillator and wireless transmission module to transfer serial port. The signal collected by the sensor is transmitted to the microcontroller through the amplifier, and then the data is converted by the microcontroller, finally, it is sent to the server via ZigBee for use and processing by the application [22].

The experimental equipment information coding is carried out according to certain rules, and the building number, laboratory number, equipment type and equipment serial number to which the equipment belongs are combined in order to form a bar code in a unified format. The specific rules of barcode coding are shown in Table 1, with the help of barcode generation tools, printing barcodes can be generated. Enter or view the information of the experimental equipment by scanning the barcode with a USB scanner or manually entering the coded information [23].

The integrated central control part plays the role of data transfer and transmission in the whole system, and completes the storage and forwarding of data information, which is the specific embodiment of the network layer function in the Internet of Things system. After the sensor receives the monitoring data and device data, it sends the data to the service central control terminal using standard network protocols [24]. Considering the future upgrade and function expansion of the system, enough interfaces are reserved in the hardware structure

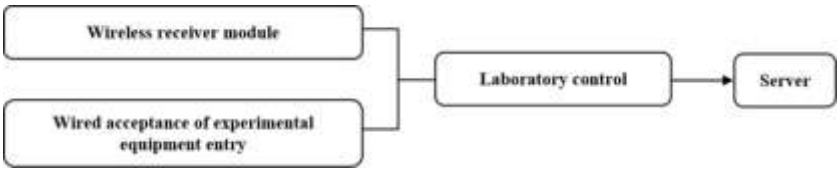

Fig. 3.4: Structure diagram of transit storage unit

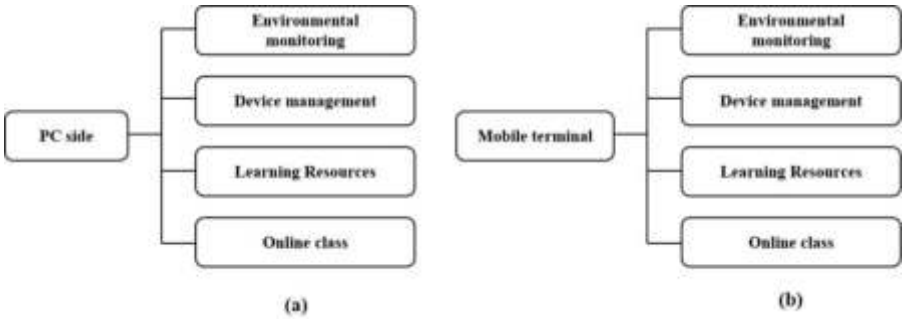

Fig. 3.5: Application unit structure diagram

of the integrated central control for future expansion of the system. The memory cell structure is shown in Figure 3.4.

The wireless monitoring module uses the ZigBee protocol standard to transmit the environmental perception information to the central control unit, ZigBee is a highly reliable wireless data transmission network, similar to CDMA and GSM networks. The ZigBee data transmission module is similar to the mobile network base station, and the communication distance ranges from the standard 75m to several hundred meters and several kilometers, and supports unlimited expansion. It is based on the IEEE802.15.4 standard and has the characteristics of high reliability, high cost performance, and low power consumption [25].

The design of the integrated central control system needs to build an embedded system, including embedded hardware and embedded software. The embedded hardware part adopts the integrated development board, which mainly includes the design of the core processor and its peripheral circuits. This system chooses ARM9 of ARMV5TE architecture as the core processor of the system. In the embedded software design, it is necessary to build an embedded operating system, and design applications based on the operating system, mainly based on the Linux system and build a cross-compilation environment arm-linux-gcc. In this environment, the input environmental information is processed, and the output data is transmitted via the ZigBee wireless network.

The storage application part needs to complete two aspects of work, namely: Parsing the data transmitted by the central control unit and saving it to the database; All kinds of teaching resources required for the experimental course are entered and accessed by visitors. The system uses SQL Server database to store and manage data. Considering the practical application, when designing the database, it is necessary to set a threshold value for each monitoring data, when a certain value exceeds the threshold value, an alarm message must be generated to prompt the administrator. At the same time, it is necessary to set user classification information, and set different operation access rights for different users.

The application part realizes the interaction between users and the system, and presents environmental monitoring data and experimental resources to different users according to different application needs. Application functions include mobile phone applications and PC applications, allowing users to view information in real time through the terminal. The application part mainly realizes functions such as environmental monitoring, equipment management, and experimental teaching. Figure 5 shows the functional block diagram of the application part of the system.

Both the web application and the mobile application include four functional applications of environmental monitoring, equipment management, learning resources, and online classroom. Environmental monitoring mainly displays the monitored laboratory environment information to administrators; Equipment management can facilitate administrators and teachers to view experimental equipment information; Learning resources provide teachers and students with teaching resources such as experimental teaching documents and videos; The online class is for teachers and students to exchange and discuss experiment-related techniques, experiences and questions.

3.2. Analysis of brightness, temperature and humidity.

(1) Design analysis of LED brightness adjustment circuit. PT4115 is a step-down constant current source chip, which is in continuous inductor current conduction mode and can drive one or more LEDs in series. The input voltage is 6∼30V, and the output current can be adjusted up to 1.2A. The pull tab can drive up to tens of watts of LED lights, depending on the input electrode and external devices. The chip has a built-in power switch, and the average LED drive current is selected through an external sampling resistor, in addition, PWM is input through the DIM pin to achieve dimming. When the voltage of the DIM pin is lower than 3V, the power switch is turned off, the PT4115 enters the standby state, and the working current is extremely low. The output current of PT4115 is set by R3 and R4 in the schematic diagram, and the relationship is shown in the following formula:

$$I = \frac{0.1 \times (R_3 + R_4)}{R_3 \times R_4} \tag{3.1}$$

when $R_3 = 1\Omega, R_4 = 0.4\Omega, I = 0.35A$. The single LED used by the author is 0.5W, so two LEDs are connected in parallel to form a group, and then three groups of LEDs are used in series, when using 0.35A current to supply power, the total power is about 3W.

(2) Design and Analysis of Temperature Detection Circuit. The temperature sensor used by the author is an NTC thermistor with a nominal resistance of 10K ohms and has a negative temperature coefficient. The thermistor is mainly composed of metal oxide materials, and the conduction mode is similar to that of semiconductor materials such as germanium and silicon. When the temperature decreases, the number of carriers in the material decreases, and the resistance value increases; On the contrary, the resistance value decreases. At room temperature, the resistance value varies in the range of 100-1000000 ohms, and the temperature coefficient is about $-2\% \sim -6.5\%$. In addition, NTC thermistors are widely used in temperature measurement, temperature control and temperature compensation.

The author connected a 10K ohm NTC thermistor in series with a 10K ohm fixed value resistor and connected it to a 3.3V power supply. Detecting the voltage value on the thermistor can be converted to obtain the resistance value of the thermistor at the current temperature. The specific calculation process is as follows:

If the voltage value across the thermistor is X after analog-to-digital conversion, and the on-chip ADC of the MSP430G2553 has 10-bit resolution, the voltage across the thermistor is as follows:

$$V = \frac{x \times 3.3}{1023} \tag{3.2}$$

If the resistance value of the fixed value resistor connected in series with it is R_0, the current resistance value of the thermistor is

$$R_t = \frac{R_0 \times X}{1023 - X} \tag{3.3}$$

Thermistor resistance meets

$$R_t = R \times e^{B \times (\frac{1}{T_1} - \frac{1}{T_2})} \tag{3.4}$$

In the formula, R_t is the resistance value of the thermistor at the temperature of T_1, R is the nominal resistance value of the thermistor at the normal temperature of T2, and B is the parameter of the thermistor itself. In addition, T_1 and T_2 are both Kelvin temperatures.

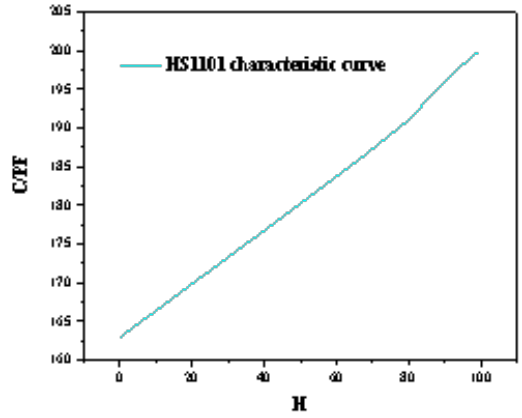

Fig. 3.6: HS1101 characteristic curve

It can be obtained from the above formula that the current temperature and the resistance of the thermistor have the following relationship:

$$T_1 = \frac{1}{ln\frac{R_t}{R}/B + \frac{1}{T_2}} \tag{3.5}$$

Substitute $R_t = \frac{R_0 \times x}{1023-x}$ to generated

$$T_1 \frac{1}{ln\frac{R_0 \times x}{R \times (1023-x)}/B + \frac{1}{T_2}} \tag{3.6}$$

The NTC thermistor used in this paper has a B value of 3435, when $T_2 = 298.15K$ at normal temperature, $R = 10K\Omega, R_0 = 10K\Omega$. The current temperature value can be calculated according to the value obtained after the analog-to-digital conversion of the microcontroller.

(3) Design and Analysis of Humidity Detection Circuit. HS1101 is a kind of humidity sensor based on capacitance principle, which is widely used in various fields, such as home, automobile, office and engineering control system. Compared with other sensing products, it has the following advantages: (1) Unique solid polymer structure; (2) No calibration required; (3) Fast response time; (4) Instant dehumidification; (5) Adapt to automatic assembly; (6) Suitable for linear voltage output, linear frequency output; (7) High reliability and stability.

With the change of relative humidity, the capacitance value of HS1100 changes nearly linearly, as shown in Figure 6. In the monitoring system, the change of the capacitance value is equivalent to the change of the voltage value or the frequency value, in order to carry out effective data collection, the oscillating circuit is composed of 555 integrated circuits, and the HS1100 humidity sensor acts as an oscillating capacitor, thus, the conversion of humidity to frequency is completed.

$R_8 + R_9 = R_a, R_3 + R_4 = R_b$ in the circuit schematic diagram of the temperature and humidity monitoring node, the output frequency f of the humidity detection circuit satisfies the following formula:

$$f = \frac{1}{C \times (2 \times R_S + R_b) \times ln2} \tag{3.7}$$

Combined with the HS1101 characteristic curve, the relationship between the output frequency of the humidity detection circuit and the humidity can be obtained. As shown in Table 3.2.

Therefore, the output frequency of the humidity detection circuit is measured by the single-chip microcomputer, and the result can be substituted into the above formula to obtain the current environmental humidity.

Table 3.2: The relationship between the output frequency of the humidity detection circuit and the humidity

humidity (%)	0	10	20	30	40	50	60	70	80	90	100
frequency (Hz)	7351	7224	7100	6976	6853	6728	6600	6468	6330	6186	6033

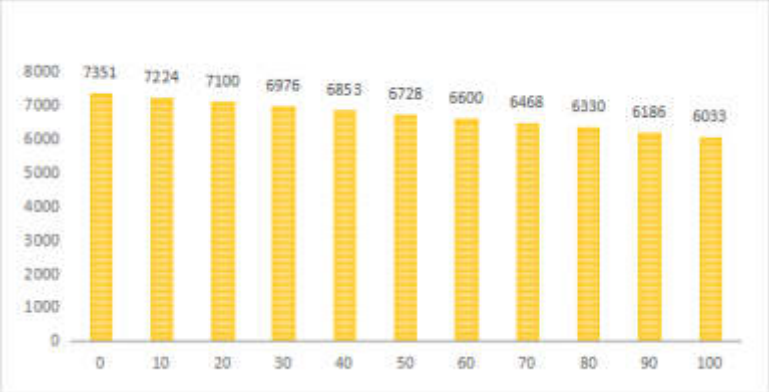

Fig. 4.1: The relationship between the output frequency of the circuit and the humidity

4. Result Analysis. According to the above calculation results, the following relationship can be obtained: When the system uses 0.35A current to supply power, the total system power is about 3W. The NTC thermistor used has a B value of 3435. At normal temperature $T_2 = 298.15K, R = 10K\Omega, R_0 = 10K\Omega$. According to the above calculation results, the following relationship can be obtained: When the system uses 0.35A current to supply power, the total system power is about 3W. The NTC thermistor used has a B value of 3435. At normal temperature Equation 3.7, the output frequency of the humidity detection circuit is measured by the single-chip microcomputer, and the result is substituted into the above formula to obtain the current ambient humidity, thus obtaining the relationship diagram as shown in Figure 4.1.

That is, when the circuit output frequency dimension is 6853Hz, the ambient humidity is 40%, and when the circuit output frequency dimension is 6600Hz, the ambient humidity is 60%.

5. Conclusion. The construction of the Internet of Things laboratory focuses on both theoretical learning and the improvement of practical innovation ability, allowing students to have access to as many technologies and products as possible on the open platform of the laboratory, stimulating students' awareness of independent learning, and completing practice and innovation in their spare time. The author proposes a system for laboratory construction and management research based on the Internet of Things and deep integration. The laboratory management system is designed by applying the related technologies of the Internet of Things, so that the management of the laboratory can integrate environmental monitoring, equipment management and experimental teaching. Administrators, teachers and students can view laboratory conditions and learning resources anytime and anywhere through wireless and wired methods, which greatly facilitates administrators' control of the laboratory, it also increases the initiative and flexibility of students' learning. After testing, the system has fast transmission speed and high accuracy, and can respond to various needs of users in real time, which greatly improves the efficiency of laboratory management, enhance students' practical ability and thinking ability.

The Internet of Things is not a new technology, but the integration of embedded systems, wireless sensor networks and other technologies and innovation. Based on the engineering application of the Internet of Things, the advantages of the school's own industrial application background should also be considered in the construction process of the laboratory, so as to cultivate professionals with certain industrial application background of the Internet of things.

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RESEARCH ON A HUMAN MOVING OBJECT DETECTION METHOD BASED ON GAUSSIAN MODEL AND DEEP LEARNING

YUMA SUN*

Abstract. In order to understand human motion object detection methods, the author proposes a research on human motion object detection method based on Gaussian model. Firstly, traditional Gaussian models are unable to detect complex scenes or slow moving targets. Therefore, an improved Gaussian model based moving object detection algorithm is proposed. Secondly, multiple Gaussian models are used to represent the features of each pixel in the moving target image, and based on the matching of each pixel in the image with the Gaussian model, it is considered as a background point. Conversely, it is based on the principle of the foreground, and the Gaussian model is updated. Finally, by updating the foreground model and calculating short-term stability indicators, the detection effect of moving targets is improved. By determining the Gaussian distribution and pixel relationship, new parameters are set to construct the background model and eliminate the impact caused by sudden changes in lighting. The experimental analysis results show that this method can effectively detect and track moving targets, with good noise resistance, high clarity, and an accuracy rate of up to 99%. Compared with traditional Gaussian model methods, the improved method can more effectively detect moving targets and has better robustness.

Key words: Gaussian model, Human movement, object detection

1. Introduction. The ways in which humans perceive the world include touch, taste, hearing, vision, etc. Due to the presence of the human brain, eyes, nose, and other organs, these perception methods can accurately and harmoniously process the information obtained by these "sensors" from the outside world, enabling humans to have a good understanding of the external world. With the continuous accumulation of human knowledge, as well as the development of scientific and technological foundations and computer information technology, and the increasing maturity and popularity of computer software and hardware at present, the demand for using computer technology to help humans perceive and understand the world is also increasing. A large portion of the various information that humans obtain from the outside world is obtained through visual information channels. Visual information also includes static image information and image sequence information (video information). Due to its temporal stillness, static image information can only contain information within one frame of an image, which cannot demonstrate the temporal correlation of information, on the contrary, video information, relying on its spatial and temporal connections and correlations, can contain a lot of information that is of interest to humans, especially the motion part of the video signal. It also includes the main information in the video signal, making it a key object in video signal processing. With the continuous deepening of research, video image signals play an increasingly important role in information processing and computer cognition, thus forming the emerging discipline of computer vision [1,2].

At present, the commonly used moving target detection methods are as follows: Optical flow method, time difference method, background difference method, etc. These three methods have their own advantages and disadvantages. The Optical flow can detect the moving area when the camera is not fixed, but its calculation is large, stability and accuracy are not ideal; The time difference method calculates the difference between the corresponding pixels of two or more consecutive frames of the image, and then uses a certain threshold to determine whether there is a moving object. It has good adaptability to environmental changes, but the detected motion area is incomplete, which may lead to the phenomenon of voids in the moving entity; The background subtraction method is currently the most commonly used method. By learning from existing video scenes and using mathematical models to model the background of video image scenes, the corresponding motion region can be obtained by subtracting the simulated background from the current video scene frame image.

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Fig. 1.1: Human motion target detection

The processing effect of this method depends on whether the selected mathematical model can effectively simulate the background in real time. Due to the flexibility of the mathematical modeling method and its strong adaptability to different scenarios, this method has become a fundamental method in the field of motion detection research. Many related research work in this field is based on background subtraction methods [3] (as shown in Figure 1.1).

2. Literature Review. When detecting and tracking moving targets, such as leaves and water surfaces, the motion frequency of background images is high, and traditional background subtraction methods cannot effectively extract dynamic backgrounds. Therefore, some scholars have proposed using Gaussian models to solve the interference caused by these background images in detecting and tracking moving targets. The Gaussian model can update certain parameters through pixels in the time series, while using the Gaussian model to expand modeling at each pixel position. However, the Gaussian model also has some drawbacks, such as: If the background conditions are complex or the moving target speed is low, the Gaussian model cannot detect and track well, therefore, improving the Gaussian model has always been a direction of effort for relevant researchers. Gaussian M ix ture M odel (GMM) is a semi parametric estimation method that can effectively represent background changes by replacing the old Gaussian distribution with a new learning distribution. At present, this method is one of the most effective methods for studying moving object detection, which has been recognized by many scholars and various improved methods have been proposed. Vaina, L. M. et al. proposed an improved method that combines the spatial depth information and color brightness information of images. This method can effectively detect the motion of multiple targets, but when different targets are at the same pixel depth, although there is different color information, it is difficult to detect moving targets [4]. Liang, S. et al. used EM learning to update the Gaussian model, and through the introduction and analysis of the algorithm, the EM algorithm is an effective algorithm for parameter estimation, but it requires pre allocation of a large amount of storage space and has poor real-time performance. Here, an improved Gaussian model for moving object detection is proposed [5]. In order to make the mean as close as possible to the background signal while ensuring the stability of variance, a weighting idea is proposed based on adaptability, which is to give different weighting values for the mean and variance in model updates to ensure that the mean updates relatively large points and the variance updates relatively small points. Finally, median filtering and pixel connectivity are used to suppress the influence of noise.

Moving object detection refers to extracting moving objects from video image sequences to obtain their differences from the relative background, and clearly marking the regions of the moving objects, thereby providing conditions and convenience for subsequent research work. The research on moving object detection has significant practical research value, making it a research hotspot in this field in recent years. With the continuous deepening of research on moving object detection, its application fields are also expanding, resulting in various practical applications and increasing research difficulty and challenges. People have also put forward higher requirements for the stability, accuracy, and robustness of detection systems. The author improves the traditional Gaussian model to achieve detection and tracking of moving targets, and verifies it through experiments [6,7].

3. Methods.

3.1. Gaussian model. The features of each pixel in the moving target image are represented by N Gaussian models, which update with each frame of the image. The Gaussian model matches each pixel in the current image, if it cannot be matched, determine that the pixel is the front attraction. If it can be matched,

then the pixel is the background point. Set the grayscale value of a certain pixel in the image to g, and the grayscale values of the pixel from time 1 to time t are represented as (a1,..., ai,..., at,). The detailed description of the pixel grayscale value requires the use of N Gaussian distributions, which need to be weighted to obtain the probability density function as shown in Equation 3.1:

$$g(a_t) = \sum_{i=1}^{t} \lambda_{t,i}\gamma(a_t, u_{t,i}, \sum_{t,i}) \tag{3.1}$$

In the equation: $y(a_t, u_{t\cdot i}, \sum it)$ represents the probability density function of the Gaussian distribution; Ut, i is the mean of the Gaussian distribution; λ_{ti} is the weight; $\sum it$ is the Covariance matrix of Gaussian distribution. The probability density function of the Gaussian distribution is calculated as follows Equation 3.2:

$$y(a_t, u_{t+i}, \sum_{t,i}) = \frac{1}{(2\pi)^{\frac{d}{2}} \sum_{t,i}} s^{-\frac{1}{2}(a_t - w_{t,i}) \sum_{i=1}^{i} (a_t - w_{i,t})} \tag{3.2}$$

The dimension of at in the equation is d. When the observation point is updated to a_{t+1}, compare the pixel value and the mean value $\pi_{t,i}$ of N Gaussian function distribution, and use Equation 3.3 as the judgment rule to match and select the Gaussian function.

$$a_{t+1} - \tau_{t,i} < 0 \cdot \varepsilon_{t,i}^2, i = 1, 2, ..., N \tag{3.3}$$

In the equation, 0 represents a custom parameter, typically with a value of 2.6. When Equation 3.3 is satisfied, the ith Gaussian function matches a_{t+1}.

When the Gaussian function is not matched successfully, the variance and mean value remain unchanged. Equation 3.4 represents the parameters generated after the Gaussian function and at are matched, and it is updated by Equation 3.4:

$$\tau_{t,i} = (1 - \varsigma) \cdot \tau_{t-1,i} + \varsigma \cdot a_t \tag{3.4}$$

where ς is the parameter Learning rate.

3.2. Improved Gaussian Model for Moving Object Detection and Tracking (Figure 3.1).

3.2.1. Modeling methods. In common methods of moving object detection and tracking, the use of foreground models is relatively limited and only used as an auxiliary. However, in improved Gaussian model modeling, the foreground model generated when background matching fails is utilized, combined with short-term stability indicators for comprehensive foreground judgment. On the basis of the Gaussian model, if all N corresponding background models fail to match the current pixel value, the variance and mean of the minimum weight model will be replaced by the larger value and the current pixel value, the model generated at this time is the foreground model $y = T_f \varepsilon_f$. If the threshold value Hf is greater than the difference between the mean of the foreground model and subsequent points, Equation 3.5 needs to be used to update the foreground model and Equation 3.6 needs to be used to calculate short-term stability:

$$R = \frac{p \sum_{i=1}^{p} a_{t+1}^2 - \sum_{i=1}^{p} a_{t+i}}{p(p-1)} \tag{3.5}$$

$$\tau_{f,t+1} = (1 - u_f)\tau_{f,t} + u_{fat+1} \tag{3.6}$$

where: $uf\epsilon[0, 1]$ represents the Learning rate of the foreground model; P represents the frame range of the sliding window. When matching the current pixel point, the foreground model is prioritized to reduce the decision risk caused by errors in matching the background model and the front attraction.

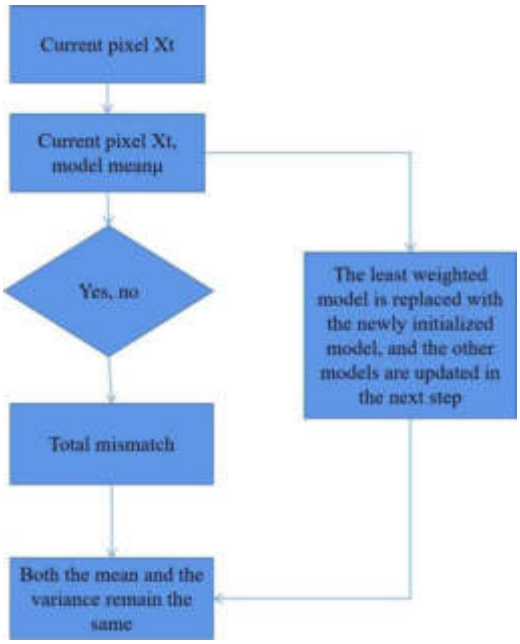

Fig. 3.1: Flow Chart of Parameter Update for Improved Gaussian Model

The appearance of moving targets varies, and the calculation window length for short-term stability of moving targets with uniform colors value setting range is 2-5. If the color of the moving target is relatively rich and the pixel value change time is too short, it will cause the target to be mistaken for the background. At this time, it is necessary to The value is controlled within 5-20, and the P-value is positively correlated with the detection effect, but if If the value is too large, the response speed of the indicator will slow down [8,9]. After obtaining the stability through Equation 3.7, the judgment threshold Rth is obtained as:

$$R_{th} = R_{min} + \frac{R_{max} - R_{min}}{L} \tag{3.7}$$

The maximum value of stability in the current L frame is Rmax, the minimum value of stability is Rmim, and L is a constant. The condition for determining the current pixel as the previous attraction is that within a continuous L-frame range, the current pixel exceeds the short-term stability threshold. The change in stability is positively correlated with the pixel value, so stability can fully describe the appearance and persistence of the foreground. If the pixels in the moving target area change in a short time, it is easy to be incorrectly detected as the background. Using short-term stability index to improve the Gaussian function can effectively avoid this situation. When traditional Gaussian models detect target motion at a slow speed, they may fail to detect. The author adopts a combination of short-term stability indicators and foreground models to solve common problems with Gaussian models and improve the detection effect of target motion [10].

3.3. Eliminating Light Mutations. The improved Gaussian model can improve the impact of slow target motion on background extraction, but once disturbed by sudden changes in lighting, pixels will be incorrectly detected as foreground pixels. The movement of targets and changes in lighting can cause pixel grayscale mutations, and the mutation area caused by lighting changes is larger than that caused by target movement. Therefore, to achieve better detection and tracking results, it is necessary to eliminate lighting mutations.

The specific methods are as follows.

In order to determine whether the Gaussian distribution within the current frame matches pixels, it is necessary to set a new parameter w for each pixel in the image, and set the value of w to improve background

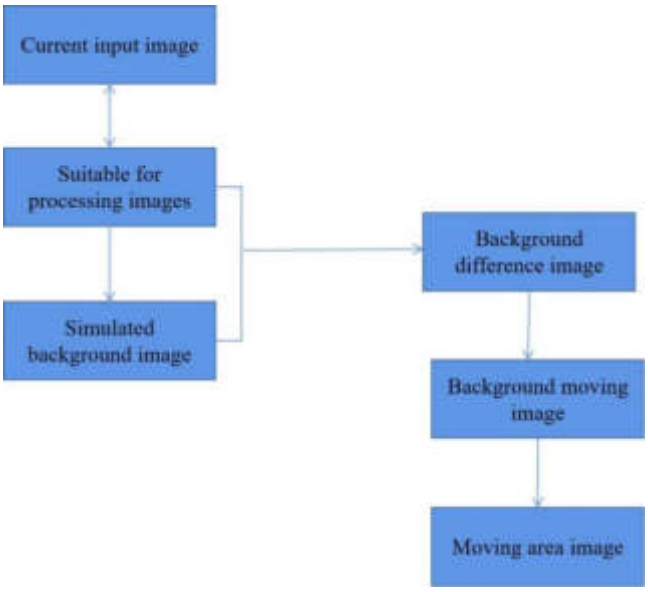

Fig. 3.2: Flow Chart of Background Difference Method for Motion Detection

estimation. If N Gaussian function and pixels can match, the value of w is 0; If it is not matchable, the value of w is 1. If the area of pixel mutation is large, it is caused by lighting mutation. Count the number of w values in the image with a value of 1. If equation 3.8 is met, it indicates that the background lighting has undergone a mutation.

$$\frac{\sum_{i=1}^{k} w_i}{k} > H_1 \tag{3.8}$$

When there is a sudden change in lighting, the proportion of pixels with grayscale changes in the image is the threshold, represented by H1. In actual experiments, H1=0.66. If the image can comply with Equation 3.8, the background pixel is determined as a pixel block with a value of w of 1. In this case, by improving the background model to implement updates, the one with the smallest weight in the first N distributions is replaced by a Gaussian distribution based on the grayscale value of the pixel block as the mean, becoming the background model.

3.4. Background subtraction method. The background subtraction method is currently the most commonly used method in moving object detection algorithms. Its main idea is to create a background model image corresponding to the image sequence, then calculate the difference with the corresponding input image, and then determine the moving area through a certain threshold.

In moving object detection based on background subtraction methods, the accuracy of background image modeling and simulation directly affects the detection effect. Regardless of any moving object detection algorithm, it is necessary to meet the processing requirements of any image scene as much as possible. However, due to the complexity and unpredictability of the scene, as well as the presence of various environmental disturbances and noise, the sudden changes in lighting, fluctuations in some objects in the actual background image, camera jitter, and the impact of moving objects entering and exiting the scene on the original scene make background modeling and simulation more difficult [11,12].

Regardless of the mathematical model used to simulate the background image, the general background subtraction method includes several steps such as image preprocessing, background image mathematical modeling, foreground object detection, and motion object post-processing, as shown in Figure 3.2.

As shown in Figure 3.2, the workflow of the commonly used background subtraction method is as follows:

1. Read a frame of image from the original image sequence that needs to be processed, and perform some preprocessing operations on the frame of image, such as filtering the image data in a simple spatiotemporal or frequency domain to eliminate noise caused by camera jitter, focal blurring, environmental disturbances, etc., so that subsequent processing can detect the image data more accurately; Alternatively, the format of the original image frame can be transformed into an image format that is convenient for subsequent processing, such as RGB, HVS color space, etc. Introducing color space can achieve better processing results than simply grayscale or brightness space.
2. After preprocessing, a suitable image is obtained, and then a background model corresponding to the processed image of that frame is established using the processed image of that frame and the previously obtained background model. This enables the background model to be updated with changes in input image data, in order to more realistically simulate an accurate background image corresponding to the current input.
3. After obtaining the background model corresponding to the current input image data through the previous step, the background difference image can be obtained by calculating the difference between the current input image and the simulated background image. This image represents the change of each pixel in the current image and the corresponding pixel point of the simulated background. This change is the displacement change between the current input image and the theoretical background image pixels [13,14].
4. The difference map obtained in the previous step is binarized using the preset threshold to obtain the motion region. Suppose that the current input image after preprocessing is F (x, y, t), the simulated background is B (x, y, t), the processed Binary image is I (x, y, t), and T is the threshold value for binarization, then the expression for determining the motion region can be written in Equation 3.9:

$$I(x,y,t) = \begin{cases} 1 & F(x,y,t) - B(x,y,t) > T \\ 0 & \text{otherwise} \end{cases} \tag{3.9}$$

   In Equation 3.9, when the difference between the current input image and the simulated background is greater than the threshold T, the binarized image is represented as 1 (we use the number 1 to represent the value of the foreground motion area), when the difference between the current input image and the simulated background is equal to or less than the threshold T, the binarized image is represented as 0 to indicate that the pixel is part of the background. For all motion detection algorithms that use background subtraction method for judgment, the selection of threshold during binarization is the key to detection processing, so the selection method of this threshold has become a hot research issue in this type of algorithm.
5. The previous step calculated the motion region after binarization, but due to factors such as the complexity of the image sequence, noise interference, and imperfect threshold selection, there may be some errors or errors in the binarized image. At this point, it is necessary to perform some post-processing on the binarized image, try to eliminate some errors that can be processed, and obtain the most accurate detection results.

There are several commonly used methods for post-processing:

① Morphological filtering: This method can eliminate small and disconnected false motion information caused by periodic moving objects in the background, such as leaves and water waves, and can merge the required disconnected motion regions to obtain a complete and accurate motion region.

② Optical flow: The average optical flow vector is obtained by calculating the differential equation of optical flow, which can be used to distinguish the moving area and "ghost", because the motion region has a relatively large motion vector, and because the "motion" of the "phantom" is instantaneous, the "phantom" part of the Mean motion vector is very small.

③ Color segmentation method: In general, the colors of the same moving target pixel have similar features, so similar colors can be segmented to make the detected motion area more complete.

The principle of using background subtraction method for motion detection is simple, but it is indeed difficult to simulate a highly accurate and stable background image, which is also the core and difficulty of this type of algorithm. The quality of background image modeling directly affects the final detection effect.

For video images captured by fixed cameras, the simplest way to model the background is to directly select a certain frame of image as the background image and calculate the difference between other images and that image. The background of this method cannot be updated with changes in the scene, and the detection effect will have a significant degree of error with changes in the scene; And the detection effect of this method is very good only when the scene image without any moving target is selected as the background, which restricts the use of this method.

The background subtraction method has now become the mainstream algorithm for moving object detection, and many studies in this field are based on the background subtraction method. Although this method can be implemented through various background modeling methods, it still has some common characteristics as follows: These background subtraction algorithms build models based on single pixel features and Areal feature, while ignoring the high correlation between adjacent pixels in the same image; They all learn and model the background by utilizing a known sequence of adjacent finite images; In order to make the background model better simulate the real background, it is necessary to update the background model in real time. The update speed can be controlled by adjusting the length of the time window or changing the size of the model's Learning rate [15,16].

4. Experiments.

4.1. Simulation testing. The simulation platform selects Matlab, and the parameter selection of this method is to determine the number of Gaussian models as 4, the threshold as 0.8, and the weight as 0.4. Compare the detection and tracking effects of optical flow field detection method and median filtering method on moving targets with this method. The image detected and tracked by the optical flow field detection and tracking method is greatly affected by background interference, the detection range is too wide, there is too much useless information, the detected moving targets have many holes and noise, the moving targets are not clear, and the accuracy is low. The median filter detection and tracking method detects and tracks moving targets with less noise compared to the optical flow field detection and tracking method, but the detected moving target details are missing and still not accurate enough. This method detects and tracks moving targets with clear contours, and the detection effect is relatively accurate. The detection results are not affected by noise interference, which is better than the median filter detection and tracking method and the optical flow field detection and tracking method.

Compare the detection and tracking effects of three methods under sudden changes in lighting conditions. Under the influence of sudden changes in lighting, many color blocks appear in the images detected and tracked by the optical flow field detection and tracking method. The noise impact is even more severe, the detection range is still large, and there is too much interference information, indicating that sudden changes in lighting have a significant impact on detection. The median filter detection and tracking method is affected by changes in lighting, resulting in many burrs in the detection results and serious leakage of details. When tracking moving targets, the noise continues to increase, and the detection effect becomes worse and worse. After being affected by sudden changes in lighting, this method still performs well in detection and tracking, with minimal noise interference, clear detection results, and good tracking performance [17].

The image integrity of the comparison of moving object detection results is shown in Figure 4.1.

From Figure 4.1, it can be seen that the median filter detection and tracking method has a wide detection range, and as the sequence increases, the detection range shows an upward trend, indicating that the increase in validation sequences leads to a greater impact on the detected moving target noise. The detection range of this method has always been stable, with an increase in validation sequences but no significant changes in the detection range. Therefore, the detection results of this method are more accurate and effective.

Extract the clarity of the tracking results of the three methods and compare their ability to handle interference, as shown in Figure 4.2.

In Figure 4.2, the tracking image clarity of this method remains at its highest, while the anti-interference ability of the optical flow field detection and tracking method is the weakest. As the tracking image verification sequence increases, the clarity gradually decreases. Therefore, the optical flow field detection and tracking method has the worst anti-interference effect when tracking moving targets. The clarity fluctuation of the median filter detection and tracking method is relatively smooth. As the validation sequence increases, there is no significant change in clarity, but the clarity is only around 380, so the anti-interference effect is not

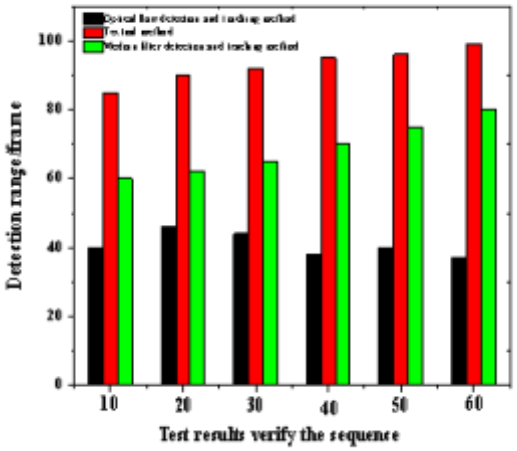

Fig. 4.1: Comparison of Detection Range Effects

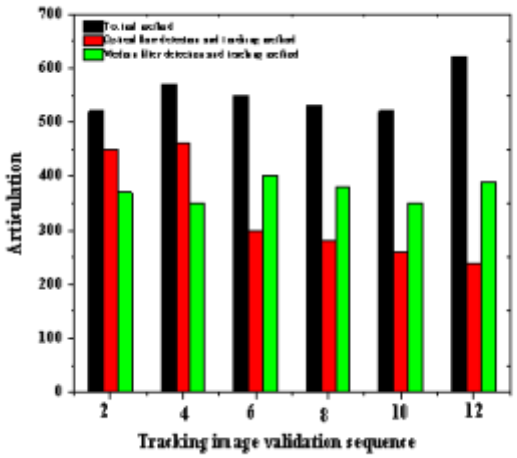

Fig. 4.2: Comparison of anti-interference ability results

good. From Figure 5, it can be seen that this method has the highest tracking clarity, can effectively handle interference, and has a good tracking effect [18].

According to the experimental comparison of the detection accuracy and error rate of the three methods, the results are shown in Table 4.1.

From Table 4.1, it can be seen that the accuracy of this method has been maintained within the 99% range, with an error rate controlled at 3%. The accuracy of the optical flow field detection and tracking method and the median filter detection and tracking method is less than 91%, with an error rate above 11%. This proves that the performance of this method is superior and more suitable for the detection and tracking of moving targets [19,20].

Table 4.1: Performance Comparison (%)

Experimental content	test method	accuracy	error rate
Scenario 1	Optical flow detection and tracking method	79	21
	Median filtering detection and tracking method	88	15
	Author's Method	99	3
Scenario 2	Optical flow detection and tracking method	78	22
	Median filtering detection and tracking method	87	13
	Author's Method	99	3

5. Conclusion. In traditional research, the foreground model generated by foreground matching failure in Gaussian models has not received academic attention, but it is precisely the foreground object information contained in this long neglected foreground model that is the key to moving object detection and tracking. The author uses the foreground model generated by matching failure and stability indicators to comprehensively detect and track moving targets on the basis of traditional models, and obtains a new improved Gaussian model that overcomes various influencing factors to obtain accurate moving target detection and tracking results. On the basis of the original Learning rate, the mean and variance are given different weights, and the median filter and object space connectivity are used for post-processing. Finally, the moving target detection is completed. The experimental results show that compared with traditional methods, this method can detect moving targets more effectively and has strong robustness. Eliminate shadow interference from moving targets to achieve more accurate detection and tracking results.

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RESEARCH ON SURVEYING AND MAPPING DATA PROCESSING BASED ON NONLINEAR MATHEMATICAL MODELS AND DEEP LEARNING OPTIMIZATION

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Abstract. In order to deeply understand the mapping data processing of nonlinear mathematical model optimization, this paper uses nonlinear model optimization theory to process mapping data. When the precision of parameter approximation is high, the calculation results of each algorithm are the same, and the iteration times of the fastest descent method and simplex method are significantly increased compared with the other three algorithms. Therefore $x_{01} = 5.42$ in the parameter is kept unchanged near the truth value, and the convergence range of Newton method, the fastest descent method, conjugate gradient method and simplex method away from the truth value of parameter $x_{02} = -0.25$ is investigated. When the approximate value of undetermined parameters is high, the results of Newton algorithm and simplex algorithm are consistent, but the Newton iterative algorithm has faster convergence speed and higher computational efficiency than the simplex algorithm. Lower value when the undetermined parameter approximation precision, namely the undetermined parameter approximation and its true value is far off, may complete failure type Newton iteration algorithm, the simplex algorithm can be a supplement of the Newton method for the most part, the simplex method significantly reduces the requirements for initial value of parameters, data calculation efficiency has improved significantly.

Key words: Nonlinear, Mathematical model optimization, Surveying data processing

1. Introduction. With the development of data processing technology and ability unceasing enhancement, the computer in many industrial control occasions, there is a kind of such variables: they are closely related to the quality of the product, should be strictly controlled, but because of economic or technology (such as online measuring instrument is expensive, or not work) in a poor working environment, are hard to measure online, analytical values can only be obtained through off-line laboratory analysis [1]. However, offline laboratory analysis often has the problem of long time lag, which cannot meet the requirements of online real-time control and optimization operation [2].

In recent years, surveying and mapping techniques have made significant advances in order to solve the estimation and control problems of such variables. The basic point of surveying and mapping technology is to select the secondary variables that are closely related to the primary variables and easy to measure, such as temperature, pressure and flow, etc., according to some optimal criteria. Use computer software to estimate the dominant variables. In the control system that takes the estimated value of surveying sensor as the feedback signal, the controller and estimator are separated, thus bringing great convenience to the design of both the controller and (Soft Sensor) [3]. In addition to "measuring" the leading variables, the soft sensor can also estimate the process parameters of some reaction process characteristics, overcoming the problems of offline analysis lag and large sampling interval. At present, mapping technology has become one of the key research directions in the field of engineering control [4].Linear principal component analysis (LPCA) is mainly aimed at steady-state data with high dimension, noise and collinearity between variables. However, many systems in the real society are often not stable systems, such as a financial decision-making system and many real-time industrial process systems. In addition to the above characteristics, the data generated during the operation of these systems often have time series relationship. At this time, the traditional principal component analysis is used to extract the features of these systems, but the principal component can not reflect the changing characteristics of the data. Aiming at this kind of problem, the theory of dynamic principal component analysis method is to obtain the augmented matrix by using the sampling data of the past time to the current analysis

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data matrix. Based on the augmented matrix, the traditional principal component analysis is carried out, and the method to determine the number of the augmented sequence vector is further proposed. Linear principal component analysis is generally used to extract linear relationships of systems or variables, which is a linear dimension reduction technique in essence. Principal component analysis has been successfully applied in many fields, such as chemical industry, finance, biology and so on, and has achieved good research results. But for the actual industrial process, its nature is nonlinear. At this point, there will be some problems if linear principal component analysis is used to extract the features of nonlinear processes.

On the one hand, since linear principal elements only reflect the linear characteristics of the system, in order to reflect as much information as possible, the number of principal elements will increase, thus losing the role of principal component analysis dimension reduction. On the other hand, after the nonlinear system is analyzed by linear principal component analysis method, the residual matrix often contains nonlinear information, rather than invalid information such as noise as the linear principal component thought. Therefore, it is often inappropriate to use linear principal component analysis to analyze nonlinear systems. Nonlinear principal component analysis is an extension of linear principal component analysis, which can more effectively complete the extraction of information with nonlinear relationship [5].

2. Literature review. Nonlinear principal component analysis is a hot and difficult research topic in recent years. In view of this research problem, Mirzaei, F. et al. proposed a mapping model based on DPCA-RBF network for industrial data featuring nonlinear, noisy, collinearity and dynamic strength. Firstly, the dynamic PCA method was used to preprocess the industrial modeling data to obtain the principal components, and then the RBF network model of the principal components and key quality variables was established. This model effectively reduces the number of model variables, removes noise and dynamic information, and reduces the number of parameters of RBF network training, thus improving the accuracy of the model [6].

Su, Y. T. et al. proposed a nonlinear regression model based on master curve for industrial process data with high dimension, data coupling and strong nonlinearity. This model draws on the basic idea of PLS, and takes into account the correlation between independent variables and dependent variables while extracting implicit variable information by using the master curve. In the space of hidden variables, polynomial function is used to fit the nonlinear relation between hidden variables. In the case study, pure function data and real-time operation data of vinyl chloride distillation tower were used to verify the model [7].

Cai, L. et al. made a pioneering study on the application of principal component analysis method in the field of fault diagnosis and monitoring of chemical process, and determined whether there were faults or anomalies by testing the statistics of data. With the development of large-scale database systems, algorithms based on data analysis have been greatly developed [8].

On the basis of the current study, this article for the study of surveying and mapping data processing based on nonlinear mathematical model of optimization, optimization theory and typical optimization algorithm for nonlinear model characteristic analysis, substitution analysis model of nonlinear optimization theory to deal with the data of surveying and mapping, when parameter approximation precision, the algorithm of calculation result is the same.

The number of iteration of the steepest descent method and simplex method increases obviously compared with the other three algorithms. When the parameter approximation value is taken, Newton method, quasi-Newton method, Gauss-Newton method, trust region method and other solutions do not converge. In this case, the norm of parameter error at this point indicates that the iterative algorithm based on Newton algorithm is highly dependent on the parameter approximation value. Therefore, the convergence range of Newton method, fastest descent method, conjugate gradient method and simplex method away from the parameter truth value is investigated by keeping the parameters near the truth value unchanged. When the accurate approximation value of parameters cannot be obtained, the efficiency of surveying and mapping data processing results can be effectively improved [9].

3. Methods.

3.1. Nonlinear model optimization theory and typical optimization algorithm characteristics.

(1) Nonlinear model optimization theory. The unconstrained nonlinear model is optimized, as shown in Equation 3.1.

$$minf_{x\epsilon R^N}(x) \tag{3.1}$$

where $f(x) = f(x_1, x_2, ..., x_n)$ is the n-element nonlinear real-valued function defined in R^n, $x = (x_1, x_2, ..., x_n)^T$.

Nonlinear model optimization iterative algorithm, that is, step size factor α_k is determined through some search method, as shown in Equation 3.2.

$$f(x_k + \alpha_k d_k) < f(x_k) \tag{3.2}$$

That is, move the objective function $f(x)$ in a specified direction until Equation 3.1 is satisfied. Different displacement (different selection of search direction d_k and step factor α_k) results in different iterative algorithms. In order to ensure the convergence of the algorithm, the search direction is required to be the downward direction. The direct optimization algorithm of nonlinear model represented by simplex algorithm only needs to calculate the value of the function without calculating the derivative of the objective function, which is also the most effective method to search for the minimum value. It is suitable for situations where the expression of the objective function is very complex and it is difficult to calculate the derivative [10].

(2) Characteristic analysis of typical optimization algorithms for nonlinear models. The fastest descent method is one of the simplest and oldest methods for solving nonlinear least squares problems. It is the basis of other unconstrained algorithms. It is based on the first approximation of the function and uses the negative gradient direction $d_k = -\nabla f(x)$ as the search direction. Because the steepest descent method in the direction of the adjacent two iterations perpendicular, convergence path appear jagged, thus began a few steps of step length is longer, the approximate solution and the change of the objective function value is bigger, but when close to convergence, step size is small, the approximate solution and the change of the objective function values are also small, thus greatly affect the convergence rate of the steepest descent method.

Newton's method is a classical unconstrained algorithm, which uses the first derivative (gradient) and second derivative (Hesse matrix) at the iterative point X to perform quadratic function approximation to the objective function, and then takes the minimum point of the quadratic function as the new iterative point, and repeats this process until the approximate minimum point satisfying the accuracy requirement is obtained.

Conjugate gradient method is an optimization algorithm based on conjugate direction method. Conjugate direction is in solving n positive definite quadratic objective function is minimum point to produce a set of conjugate direction as gradient direction, under the condition of exact line search algorithm at most iterative step n minimum point can be obtained, because the general objective function approximation of near the minimum point in quadratic function, so you can imagine an algorithm for quadratic function is more effective. It is expected to have a good effect on general functions. The conjugate gradient method is to generate the conjugate direction of Hesse matrix of convex quadratic function $f(x)$ in each iteration step without using the fastest descending direction at the current point. Each conjugate vector depends on the negative gradient at the iteration point, so as to establish the minimum point of not $f(x)$[11].

Trust region method first given the trust region radius as the upper bound of the length of the displacement, and in the current iteration point as the center, to the upper bound for the radius of trust region area, by solving the region's "letter Lai Yu subproblems" (objective function of the quadratic approximation model) of optimal point to determine the displacement of "candidate", if the candidate displacement can make the objective function values are fully drop, The candidate displacement is accepted as the new displacement, and the radius of trust region is maintained and expanded to continue the new iteration. Otherwise, it indicates that the approximation between the quadratic model and the objective function is not ideal, and the radius of the trust region needs to be reduced, and then the new candidate displacement is obtained by solving the sub-problem in the new trust region. The process is repeated until the iteration termination condition is satisfied.

Iterative algorithms need to calculate the derivative of the objective function, the solution directly without calculating the value of the objective function derivative calculation function and when the objective function

Table 4.1: Correlation observations and their truth values

i	1	2	3	4	5
The true value	4.202384	3.258924	2.527006	1.959459	1.519394
Observations	4.20	3.25	2.52	1.95	1.51

Table 4.2: Least-squares data processing results of nonlinear models under different calculation methods

The serial number	Equalization method	computing result	Error norm	iterations
1	steepest descent method	5.421940625 -0.255618484	0.00219887	121
2	Newton method	5.422744582 -0.255672087	0.00291896	6
3	conjugate gradient method	5.422159251 -0.255670512	0.00238897	20
4	Trust domain method	5.422748251 -0.255670512	0.00291233	6
5	simplex method	5.422748251 -0.255674147	0.00292317	64

or analytical expression is complex, calculating derivative difficulty, represented by the simplex algorithm of the simplex method is one of the most effective method of searching the minimum of the objective function of analyticity did not demand, wide applicable [12].

4. Results and analysis.

4.1. Analysis of surveying and mapping data case by nonlinear model optimization theory. It is known that the nonlinear model is $L_i = x_1 e^{ix2}$, and the truth values of x_1 and x_2 are expressed as vectors, that is, the five truth values of $X = (5.420136187 - 0.25436189)^T$, L_i and the corresponding five independent observations with the same accuracy are listed in Table 4.1.

When the approximate value of the parameter is $X_0 = (x_{01}, x_{02})^T = (5.4, -0.3)^T$, the error norm of the parameter is $||X - X_0||_2 = 0.0499$. On this basis, combined with MATLAB software programming technology, the data processing results of the above typical optimization algorithm are obtained, as shown in Table 4.2.

As can be seen from the calculation results in Table 4.2, when the parameter approximation value is of high accuracy, the calculation results of all algorithms are the same, and the number of iterations of the fastest descent method and simplex method increases significantly compared with the other three algorithms [13].

When the parameter approximation value is $X_0 = (x_{01}, x_{02})^T = (3.4, -0.8)^T$, Newton method, quasi-Newton method, Gauss-Newton method, trust region method and other solutions do not converge, and the norm of parameter error at this point is $||X - X_0||_2 = 2.0925$, indicating that the iterative algorithm based on Newton algorithm has a high dependence on parameter approximation value. Existing research shows that the nonlinear model parameters of the optimal value affected by the intensity of nonlinear function of nonlinear circle, in this case, the main factors influencing the size of the model of nonlinear strength index, in order to further parameter approximation accuracy values of different algorithms are dependent, so keep parameters in $x_{01} = 5.42$ near the true value of the same, The convergence range of Newton method, steepest descent method, conjugate gradient method and simplex method beyond the truth value of parameter $x_{02} = -0.25$ is investigated. By changing the parameter value according to $X = (x_{01}, x_{02})^T = (5.42 - 0.25 \pm k \times 0.1)^T k = 0, 1, 2, ..., n$, the convergence boundary of the corresponding algorithm and corresponding calculation results can be obtained, as shown in Table 4.3. The comparison of parameter approximations of corresponding algorithms is shown in Figure 4.1.

The calculation shows that similar data processing results can be obtained by changing the initial values of parameters in other ways. As shown in Table 4.3:

Table 4.3: Convergence boundary and corresponding calculation results under different algorithms

Algorithm	Parameter approximation	Parameter error norm	parametric solution	Parametric solution error norm
	5.42,-0.25	0.0044		
Newton method	5.42,1.45	1.7044	5.4227 -0.2557	0.0029
	5.42,-0.85	0.2956		
Steepest	5.42,-0.25	0.0044	5.4227,-0.2557	0.0029
descent	5.42,22.95	23.2044	5.4223,-0.2556	0.0026
method	5.42,-0.45	0.1956	5.4232,-0.2556	0.0034
Conjugate	5.42,-0.25	0.0044	5.4230,-0.2557	0.0032
gradient	5.42,0.15	75.5044	5.4227,-0.2557	0.0021
method	5.42,-12.95	38.6956	5.4228,-0.2557	0.0041
	5.42,-0.25	0.0044	5.4230,-0.2557	0.0029
Simplex method	5.42,74.25	75.5044	5.4227,-0.2557	0.0029
	5.42,-38.95	38.6956	5.4228,-0.2557	0.0030

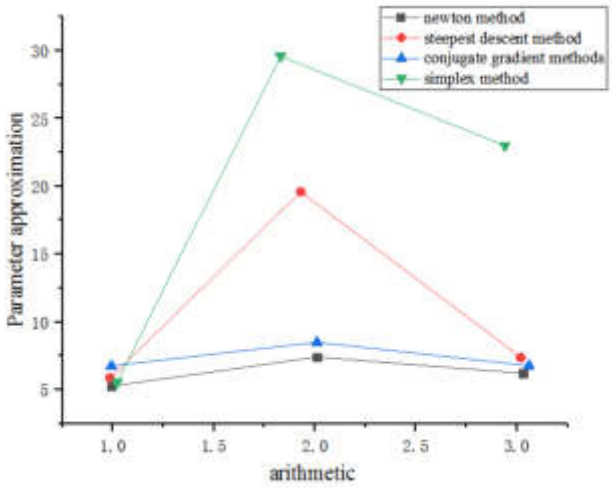

Fig. 4.1: Comparison of parameter approximations of corresponding algorithms

1. When the initial parameter value is within the parameter convergence region of the respective algorithms, Newton algorithm has the highest computational efficiency and the least number of iterations in the calculation process, but Newton algorithm has higher requirements on the accuracy of the initial parameter value, and the convergence region of the initial parameter value is the smallest compared with other types of algorithms [14].
2. Compared with the iterative calculation method, the simplex method has the lowest requirement on the accuracy of initial parameter value, although the calculation efficiency is relatively lower. Compared with the Newton algorithm, the simplex method significantly reduces the requirement on the accuracy of initial parameter value of the iterative algorithm. For general surveying and mapping data processing problems, when high precision initial values of undetermined parameters cannot be obtained, simplex method will undoubtedly be a good supplement to Newtonian algorithm [15].

5. Conclusions and prospects. In this paper, based on the nonlinear mathematical model for optimization of surveying and mapping data processing research, introduces the model of the nonlinear optimization theory and analysis of typical optimization algorithm features, analysis of nonlinear optimization theory model the surveying and mapping data instance when parameter approximation precision, the algorithm calculation result is the same, the steepest descent method and simplex method relative to the other three kinds of iteration algorithm is significantly increased. When the parameter approximation value is $X_0 = (x_{01}, x_{02})^T = (3.4, -0.8)^T$, Newton method, quasi-Newton method, Gauss-Newton method, trust region method and other solutions do not converge, and the norm of parameter error at this point is 001, indicating that the iterative algorithm based on Newton algorithm has a high degree of dependence on parameter approximation value. Therefore, keep $x_{01} = 5.42$ in the parameter unchanged near the truth value, and investigate the convergence range of Newton method, fastest descent method, conjugate gradient method and simplex method away from the truth value of parameter $x_{02} = -0.25$. The efficiency of surveying and mapping data processing can be improved effectively when the accurate approximation value of parameters cannot be obtained.

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APPLICATION OF IMPROVED GENETIC ALGORITHM AND DEEP LEARNING IN COLD CHAIN LOGISTICS DISTRIBUTION DEMAND PREDICTION

HAILONG LI* AND GUANGYAO LU

Abstract. In order to solve the problem of inaccurate prediction results caused by the excessive impact of downstream on upstream suppliers in the process of cold chain logistics transportation demand prediction, the author proposes a demand prediction system Multi agent based on improved genetic algorithm and deep learning. The system will improve genetic algorithm, combine deep learning with practical problems in cold chain logistics supply chain, and evaluate the improved model through instance simulation. The results are as follows: After optimization, the order quantity of each stratum reduces the influence of retailers on upstream suppliers by more than 70%; As for the overall transportation cost, it shows a continuous upward trend within 20 cycles, while the total cost of each cycle fluctuates in a lower range after optimization, reducing the overall total cost by about 50%. It shows the reliability of the improved demand forecasting system in this study to greatly reduce storage and transportation costs.

Key words: Cold chain logistics, Demand forecasting, Deep Learning, Improved genetic algorithm

1. Introduction. As a complex service industry, the logistics industry integrates transportation, storage, freight forwarding, information and other industries, and is also a basic and strategic industry supporting the development of the national economy, the state attaches great importance to its development, thus issuing a series of policies to support and guide the development of high-quality green logistics and achieve cost reduction and efficiency increase in the logistics industry. For example, the "green logistics index composition and accounting method" released in 2018 is used to solve the problems of resource waste, high energy consumption, high emission and so on in the development of logistics in China, in order to promote the sustainable development of modern logistics; In 2019, the National Development and Reform Commission issued the Opinions on Promoting High-quality Development of Logistics and Forming a Strong Domestic Market, in order to promote high-quality development of logistics and solve the problems of high cost and low efficiency of logistics in some fields. In 2020, the Implementation Opinions on Further Reducing Logistics Costs issued by the National Development and Reform Commission and the Ministry of Transport proposed to actively accelerate the development of smart logistics, actively promote logistics to reduce costs and increase efficiency to adapt to the construction of a modern economic system [1].

Nowadays, logistics has been integrated into every link of economic production and has played a great role in fighting against the COVID-19 epidemic [2]. As an important part of the logistics industry, cold chain logistics plays an important role in ensuring food safety of urban and rural residents, improving the quality of life of urban and rural residents, promoting rural revitalization and high-quality development of agriculture, and meeting diversified consumer demands in the market.

The core purpose of cold chain logistics is to ensure the safety of food and drugs in the cold chain process, reduce the cost of the cold chain, and improve the added value of the cold chain, which is the basic link in the production and circulation of fresh agricultural, food and medicine, biological products and other enterprises [3].

At present, there are many problems in cold chain transportation, such as high transportation cost and poor professionalism, large market gap, strong demand for cold chain transportation, unbalanced supply chain, disorderly competition and internal friction. In the 2019 logistics industry report, it was shown that the annual transportation cost accounted for 51.91% of the total social logistics cost in 2018, accounting for the largest proportion, the specific data is shown in Figure 1.1.

In short, with the promotion of fresh e-commerce, the cold chain logistics in the logistics industry has risen sharply from its affiliated status to the focus and hot spot of all walks of life, and moved to the front of

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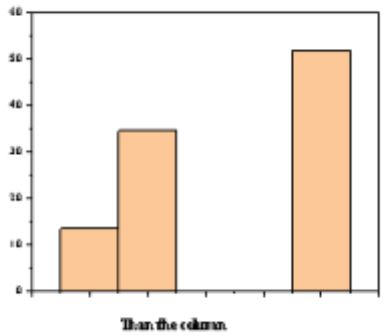

Fig. 1.1: Proportion of logistics expenses in 2018

the logistics industry. And the cold chain logistics industry also needs to accelerate the transformation and upgrading, the first is to improve the efficiency and benefit of cold chain distribution and distribution center.

2. Literature Review. The particularity of cold chain logistics makes it a complex system engineering: It covers a cross-field integrated system of modern technologies such as food and pharmaceutical engineering, biopharmaceutical engineering, packaging, storage and transportation technology, preservation and refrigeration technology, circulation and processing technology, and refrigeration technology [4]. At the micro level, the quality of cold chain logistics is related to the food safety of every household. From a macro perspective, the development of cold chain logistics industry has become increasingly important in the development of national economy and society.

Therefore, it is urgent to improve the efficiency and benefit of cold chain logistics. Although the cold chain logistics started late in China, the degree of organization, specialization, marketization and information of the industry is low, however, from 2014 to 2015, domestic e-commerce involved in fresh agricultural products and food, so cold chain logistics was pushed to the forefront of the market, and became a touchstone of fresh e-commerce, the cold chain industry thus set off a wave of investment, cold chain IT (information technology), cold chain real estate, cold chain equipment, cold chain exhibition, cold chain agent, cold chain express transport, cold chain information, cold chain finance and other sectors. Due to the continuous innovation of fresh e-commerce B2B, B2C, C2B, 020 and other marketing and cold chain modes, the field of cold chain logistics has undoubtedly accelerated into an unprecedented period of rapid development. Accompanied by it is the urgent need for the continuous improvement of the efficiency of cold chain logistics distribution and the efficiency of distribution center, which is also the key to the better and faster development of fresh agricultural products market and cold chain logistics industry.

However, when the well-known domestic e-commerce companies like tea land investment and operation of fresh agricultural products online sales and offline cold chain logistics and distribution, industry analysis results are that more than 95% of fresh e-commerce operations serious losses, goods wear or decay rate is high. The reasons are as follows: First, cold chain logistics itself is a field with high technology and information content, and the ability of domestic cold chain logistics to effectively integrate social resources is very low; Secondly, there is a shortage of professionals in cold chain logistics of fresh products, resulting in the interruption of operation from time to time; Finally, the lack of standardization system of cold chain logistics is serious, and the benefits and efficiency of cold chain logistics are not satisfactory.

The distribution of cold chain logistics covers fresh agricultural products or other goods that need the cold chain, the whole process from the cold chain logistics distribution center to the production place (supplier) and the sales place (demand supplier) should be properly arranged in the process, so that when the distribution cold chain vehicles pass through these distribution nodes in a planned way, it can also meet certain constraints (including vehicle mileage limit, delivery time, distribution vehicle capacity limit, cargo demand requirements,

etc.), so as to optimize the whole cold chain logistics distribution system (such as shortest distribution time, shortest distance, lowest cost, least number of vehicles, etc.).

Regarding demand forecasting, He, B. points out that demand forecasting is the basis of all management decisions in logistics and supply chain management. Demand forecasting is the starting point of all planning activities and execution processes, whether the supply chain system is push or pull. Considering the push process executed in anticipation of customer demand, procurement, production, transportation, operational activities and actions all require demand prediction as data input, and the same is true for the push process [5].

For research on demand forecasting, Xing and X. H. combined artificial neural networks and simple statistical methods to establish a hybrid modeling method to predict one-hour urban traffic flow [6]. Xu, X. used the neural network model to predict the oil demand of automobile and industrial lubricating oil manufacturing companies, and the prediction results were in good agreement with the actual demand [7]. Li, B. Using grey model and parameter optimization through Fourier series and Markov chain, a prediction system for end-of-life vehicles is developed to predict the number of end-of-life vehicles that will be generated in the future. However, compared to existing products, it is challenging to predict the demand for new products, because historical sales data cannot be used as indicators of future sales, and few scholars have studied quantitative methods for new product prediction in existing studies, especially the quantification of demand uncertainty [8]. Yu, N., proposed a new demand forecasting method, which combined K-means, random forest and quantile regression forest [9].

About the forecast of logistics demand, many scholars use different methods to forecast. Wang, H. established the autoregressive integral moving average model (ARIMA) for the short-term prediction of postal logistics in B city [10]. Chai, X. applied the combined prediction model of GM(1, 1) and BP neural network to predict the cold chain logistics demand of aquatic products in Dalian [11]. Zhang, Y. Applied fuzzy cognitive map to comprehensively consider the influence of various economic factors on social logistics demand, and determined the influence weight for prediction [12]. Wei, C. Based on the gravity model, forecast regional logistics demand by combining relevant economic theories, mathematical modeling methods, samples, attributes and existing specific problems of regional economic development [13].

In conclusion, the green development of cold chain logistics to achieve cost reduction and efficiency improvement is the driving force and direction of its long-term development, in order to further improve transportation efficiency and reduce costs, distribution links need to be strictly controlled, reasonable planning of distribution vehicle transportation path. Optimization of vehicle transportation routes can not only reduce product loss but also reduce costs, this study is based on artificial neural network to study the demand prediction of cold chain logistics.

3. Research methods.

3.1. Logistics demand forecast. Logistics demand refers to the demands of various enterprises, institutions and consumers in the process of social and economic activities, accompanied by logistics activities such as transportation, storage, loading, unloading, handling and distribution. The complete forecasting process should firstly clarify the requirements of the prediction object, the time limit of the prediction and the accuracy of the prediction results [14]. Secondly, relevant data are collected and processed, and then appropriate prediction methods are selected according to the characteristics of the predicted objects [15]. Finally, the accuracy and reliability of the prediction results are analyzed and evaluated. Therefore, logistics demand forecasting uses historical data and market information to scientifically analyze, assess and infer the future status of logistics demand. The general steps are shown in Figure 3.1.

3.2. Multi agent model. It is assumed that there is only one enterprise at each level of the supply chain, and each enterprise is willing to communicate and share demand information, and each enterprise's manager is willing to share real information. The supply chain model is shown in Figure 3.2.

In this study, Multi-Agent intelligent system is used to control the demand of each level in the supply chain, reduce the total cost of the entire supply chain, the structural model of the system is shown in Figure 3.3.

The system can be divided into two parts: Hierarchical Agent and demand forecasting Agent, the information exchange between them is timely and sufficient, and they can respond quickly to the information of various changes of supply chain enterprises [16].

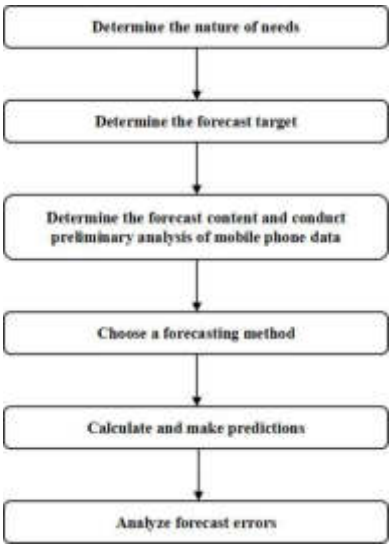

Fig. 3.1: Logistics demand forecasting process

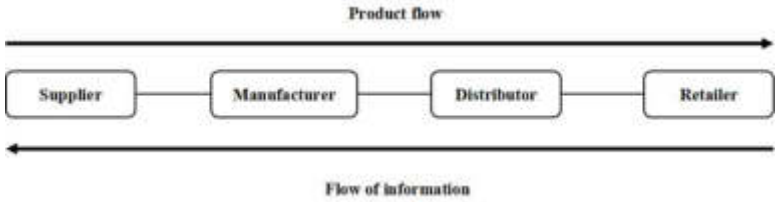

Fig. 3.2: assumes a supply chain model

3.3. Artificial neural network design. Genetic algorithm (GA) is a kind of adaptive global optimization probabilistic search algorithm which simulates the biological evolution process in natural environment. This algorithm is simple, practical, robust and suitable for parallel processing. The calculation steps of genetic algorithm: First, the computer randomly determines an initial population, and then selects individuals in the population according to the fitness value or some competition rules, the next generation population is generated by various genetic operators, until the termination condition is met to stop the operation, otherwise it will continue to evolve in this way. The specific optimization steps are as follows:

1.The encoding: When genetic algorithms are used to solve optimization problems, the solution data of the understanding space are not directly processed, but are represented as the genotype string structure data of the genetic space by coding. Choosing different encoding schemes will have a great impact on the optimization performance (quality and efficiency) of the algorithm[17].

2.Initialize: According to the given system parameters, the computer randomly generates a certain size of initial population.

3.Calculate fitness: The objective function is taken as the overall operation cost of the supply chain, in order to minimize it, the inverse of the objective function is taken as the fitness function of each individual.

4.Selection operator: In order to ensure that the genetic algorithm converges to the global optimum, the selection operator adopts the optimal preservation strategy, so that the optimal individual directly enters the next generation, and other individuals select and copy according to the size of their fitness by using the roulette method.

5.Crossover operator: In order to ensure the diversity of individuals, the overall crossover strategy is adopted

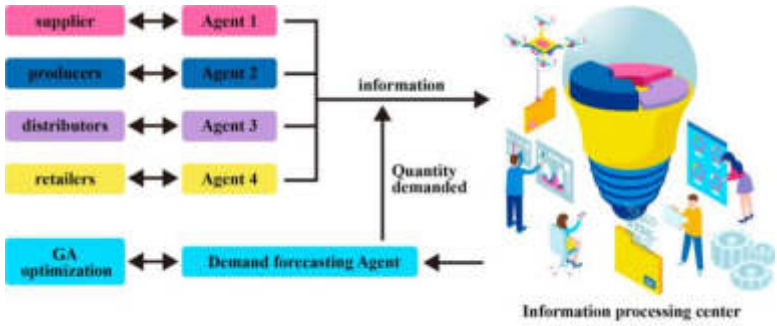

Fig. 3.3: Model of Multi agent system

here. As shown in Equations 3.1 and 3.2:

$$x_{oi} = \alpha_i + (1-\alpha)y_i \tag{3.1}$$

$$y_{oi} = \alpha y_i + (1-\alpha)x_i \tag{3.2}$$

where, x_{oi} and y_{oi} are offspring individuals, x_i and y_i are previous generation individuals, α is a randomnumber in [0,1].

6.Mutation operator: The inversion mutation operator is adopted, and the operation method is as follows: Let x_i be the parent individual executing mutation, where component gray mutates and $x_k \epsilon [a_k, b_k]$, then the offspring individual y_k generated by inversion mutation is

$$y_k = \frac{(x_k - a_k)a_k + (b_k - x_k)b_k}{b_k - a_k} \tag{3.3}$$

7.Stop criterion inheritance: After the algorithm runs to the maximum number of evolutionary generations, it stops and outputs the best individual in the current generation as the optimal solution. Otherwise, go to Step 3.

4. Result Analysis.

4.1. Case Analysis. Taking the process of a certain fruit from harvesting to storage, midway cold chain transportation, and finally sold to consumers as an example, according to the established model, the computer was used to simulate the optimization before and after the optimization, and the results were analyzed.

In the optimization system design, the population number of genetic algorithm is set as 60, the maximum evolutionary algebra is 80 generations, the crossover probability is 0.9 and the variation probability is 0.01, the daily scale function is taken as the minimum sum of total costs, and the design variable is taken as the order quantity of suppliers, manufacturers, distributors and retailers in the first week[18].

In the supply chain model, the mixed ordering strategy is adopted, and the manufacturer is set to adopt the continuous inventory checking strategy, suppliers and distributors adopt a periodic inventory check strategy, while retailers adopt a discretionary strategy.

Assume that the unit costs at each level of the supply chain are shown in Table 4.1.

Customer demand is randomly generated by the computer in the range of [5,15].

20 ordering cycles were randomly generated to simulate, and the results before and after optimization with the artificial neural network were shown in Figure 4.1, 4.2 and 4.3.

As can be seen from the above Figure, when the retailer's order quantity changes slightly, the order quantity of its upstream strata changes significantly, especially the most upstream supplier, whose order quantity changes by more than 5 times in some periods. This change will also cause a significant increase in the overall cost of the supply chain.

Table 4.1: Unit cost of each member in the supply chain

	Unit inventory cost	Cost per order	Single transport cost	Single backorder cost
supplier	4	2	2	6
producers	4	2	3	5
distributors	3	3	3	6
retailers	2	2	2	4

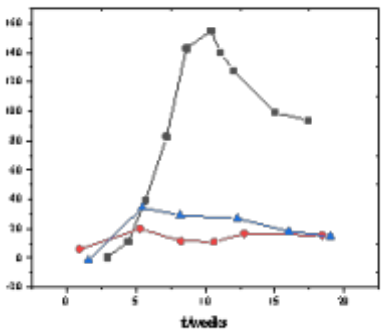

Fig. 4.1: Change of order quantity before optimization

After the artificial neural network is used to predict the demand, the order quantity changes of each member are shown in Figure 4.2.

As can be seen from Figure 4.2, after optimization, the order quantity of each stratum is relatively close to the customer demand, and the curve is relatively stable, this method effectively reduces the influence of retailers on upstream suppliers by more than 70%[19,20].

The operation cost of supply chain cycle before and after optimization is calculated and compared, and the result is shown in Figure 4.3.

As can be seen from Figure 4.3, when customer demand changes before optimization, the total cost of each cycle increases rapidly to a higher level, after optimization, the total cost of each cycle fluctuates within a low range, and the overall total cost is reduced by about 50%, this indicates that the optimization of the artificial neural network can effectively reduce the total cost of the supply chain.

5. Conclusion. In order to reduce the overall operation cost of supply chain, a reasonable demand prediction model is formulated, based on the integration of computer information, a Multagent model of multi-level supply chain is constructed, the artificial neural network is integrated into it, and the optimization model of multilevel supply chain demand forecasting based on genetic algorithm is put forward, and the example is analyzed by computer simulation.

The conclusions are as follows:

1. After optimization, the order quantity of each stratum is close to the customer demand, which reduces the influence of retailers on upstream suppliers by more than 70%, indicating that the optimized model can effectively reduce the disturbance of the market.
2. The cycle total cost of the example increases rapidly to a higher level and shows a continuous upward trend within 20 cycles, after optimization, the total cost of each cycle fluctuates within a lower range, and the overall total cost is reduced by about 50%.

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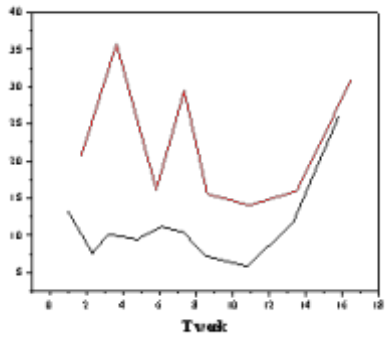

Fig. 4.2: Change of order quantity after optimization

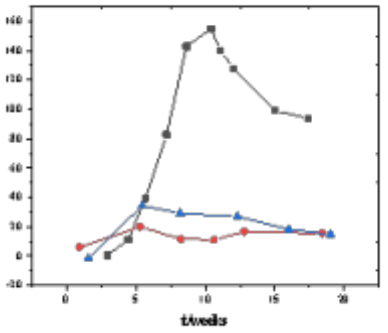

Fig. 4.3: Comparison of overall cycle cost before and after optimization

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THE APPLICATION OF IOT TECHNOLOGY AND DEEP LEARNING IN AUTOMATED INTELLIGENT CONTROL SYSTEMS

CHUNHUA HE* AND LIJUAN KANG

Abstract. In order to accurately monitor the environmental information of agricultural greenhouses, achieve remote automatic control, and improve crop yield, the author proposes an application method of Internet of Things technology in automatic intelligent control systems. This method utilizes IoT technologies such as WSN, Android, and cloud platforms to design an intelligent agricultural greenhouse monitoring system, taking sensors such as soil moisture, lighting, temperature and humidity as examples, and using shading, water spraying, fans, and fill lights as control devices. Design from aspects such as system architecture, perception control system, cloud database, and mobile terminal management system to achieve automatic monitoring of agricultural greenhouse environmental information.Experimental results show that: The data collected by the sensor is compared with the actual monitoring data of the instrument, taking temperature as an example, the errors are all within $\pm 0.5^{\circ}C$ of multiple measurements. Conclusion: The system has the advantages of good scalability, convenient networking, and high cost performance, which makes up for the difficulties in wiring and inconvenient use of the traditional agricultural greenhouse monitoring system, and has high practical value.

Key words: Internet of things technology, smart agriculture, cloud database, automatic detection, ZigBee communication

1. Introduction. With the proposal of the sustainable development goals of agriculture, the basic position of agriculture has been maintained, promoting the increase of agricultural production and income is an important topic that needs to be studied in depth. However, there is a problem with the traditional agricultural greenhouse planting method in my country, that is, the level of automation is relatively low, the labor demand is large, and the acquisition of crop information and environmental parameters is relatively backward, which is not conducive to expanding the scale of production. With the rapid development of agricultural science and technology, agricultural modernization requires the support of a variety of emerging technologies, the Internet of Things technology emerged in this era of rapid technological development, providing unprecedented opportunities for the development of agricultural modernization [1].

The combination of Internet of Things technology and agricultural technology has made smart agriculture a bright spot for people, the level of agricultural modernization has been significantly improved, and the growth information of crops can be obtained conveniently and accurately, so as to ensure the healthy growth of crops and the improvement of output. Smart agriculture applies sensor technology, Internet of Things technology, communication technology and expert decision-making system to agricultural system solutions, and uses relevant sensors and information management systems to monitor crop growth environment information in agricultural greenhouses, making agricultural greenhouses "smart" , which can realize accurate monitoring and intelligent management of crop growth process. In this era of rapid development, smart agriculture has very broad prospects for development under the advancement of cutting-edge technologies such as the Internet, Internet of Things, and big data [2].

Smart agriculture is the direction of my country's agricultural development, and more advanced technologies will be applied to the agricultural production process in the future [3]. Therefore, combined with the development of modern agriculture, the author designs and implements a complete agricultural greenhouse control system. The system applies advanced Internet of Things technology, sensor technology, wireless communication technology and information management system to agricultural greenhouses, which can manage agricultural greenhouses more conveniently and accurately, it is of great significance to improve the production efficiency and quality of agricultural products and the level of agricultural modernization.

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2. Literature Review . There is still a significant gap between China and developed countries in the construction of agricultural greenhouses. However, China attaches great importance to the development of the field of agricultural modernization, especially since the beginning of the 21st century, it has entered a new stage in the construction of agricultural modernization, the investment in agricultural construction has increased year by year, accelerated the upgrading and transformation of the agricultural industrial structure, developed facility agriculture in some areas, and applied modern advanced technologies to modern agricultural construction. At first, China's development of smart agriculture mainly relied on equipment and technologies imported from abroad, however, due to the high cost, most of the results were difficult to meet the needs of agricultural development, and it was difficult for them to be popularized in agricultural planting. In the late 1980s, China began to introduce greenhouse planting technology into agricultural production, and in-depth research on the intelligent control technology of agricultural greenhouses began in China, under the dual drive of national policies and the general environment, a series of achievements have been made in the research of smart agriculture, and the technology has continued to mature. Mohammadian, A. applied the industrial control computer in the greenhouse, mainly using the industrial computer as the core controller, responsible for the collection of environmental parameters and the control of the actuator [4]. The system has problems such as high overall construction and maintenance costs, complicated wiring, and huge volume. Chuang, J. H. Aiming at the complexity of agriculture, in order to solve the bottleneck problem of agricultural network communication, GPRS technology is applied to remote data collection [5].

Ramasubramanian, M. applied wireless sensor network and other technologies to orchard irrigation to realize the collection of greenhouse environmental parameters, and at the same time upload the collected data to the database on the PC side to complete storage [6]. Shafique, K. designed a distributed environment monitoring system by combining ZigBee technology and 3G/4G communication technology to realize data collection and transmission [7]. Umashankar combines CAN bus and wireless sensor network to realize a temperature and humidity monitoring system applied in agricultural greenhouses [8]. Yu, M. used LoRa and MSP430 microcontroller to design a farmland information monitoring system based on Internet of Things technology, and conducted in-depth research on the application of LoRa technology in farmland [9].

The monitoring system of traditional agricultural greenhouses has unfavorable factors such as complex wiring, high construction and maintenance costs, and poor expansion performance, and can no longer meet the development needs of modern agricultural greenhouses. Wireless technologies that can be used for smart agricultural greenhouse solutions include NB-IoT, ZigBee, WIFI, 4G, etc., each technical solution has its own characteristics, for example, WIFI technology has the advantages of convenient networking, stable communication, and high speed, but it has disadvantages such as small coverage radius and poor network expansion. This study uses ZigBee technology, which has the advantages of ad hoc networking, low power consumption, and scalability, combined with sensors such as light, soil humidity, temperature and humidity, CC2530 is used as the controller, and relays are used to control ventilation, watering, lighting, induction doors and other devices, and a smart agricultural greenhouse monitoring system is designed and implemented.

3. Methods.

3.1. System Architecture Design. The architecture of the smart agricultural greenhouse monitoring system based on the Internet of Things technology is shown in Figure 3.1. The system can be simply divided into three parts: One is the sensing control system, ZigBee nodes are connected with sensors to form sensing nodes, ZigBee nodes are combined with control devices to form control nodes, ZigBee sensing nodes, the control node and the coordinator are self-organized as a WSN (a ZigBee node can be both a sensing node and a control node). The second is the cloud platform, which is used for data storage and access, the system rents the Alibaba Cloud platform, creates a cloud server of the Linux system, and installs and configures services such as Tomcat and VSFTP, select MYSQL version database, use HTTP protocol to communicate with the lower computer gateway, realize the storage of ZigBee perception data and the forwarding of control instructions. The third is the user's remote management system, such as PC monitoring management system or mobile APP, connected to the cloud platform, connect to the cloud MYSQL database, read and display the environmental information collected by various sensors, and remotely control the corresponding control equipment automatically or manually [10].

ZigBee network has three topological structures: Star (star), cluster-tree (tree) and Mesh (mesh network), among them, the tree structure takes "coordinator (coordinator)" as the root node, combined with "end device

Fig. 3.1: Architecture diagram of smart agricultural greenhouse monitoring system based on Internet of Things technology

(terminal)" and "outer (router)" nodes, it can quickly form a multi-layer network and has the advantages of easy expansion, high reliability and wide application, therefore, the system is designed as a tree network. The ZigBee node takes CC2530 as the core, the coordinator is not connected to sensing or control equipment, but is connected to the gateway, the collected data is stored in the cloud server with the help of the Internet, and the mobile terminal can remotely monitor the agricultural greenhouse [11]. This research focuses on the software and hardware design of perception control system, cloud database design, mobile terminal monitoring APP system design, etc. The perception control system is automatically associated, and corresponding thresholds are set according to the needs of crop growth, realizing the intelligent management of agricultural greenhouses, and verifying the safety and stability of the system in the experimental link, which has certain promotion and application value.

3.2. Design of Perceptual Control System. The perception control system is mainly to realize the collection of agricultural greenhouse environmental information, device control and wireless communication functions of the sensor network. The perception control node is mainly composed of power supply module, ZigBee communication module, data acquisition module and relay control module, the hardware structure is shown in Figure 3.2.

(1) Power module. The power supply is the power supply guarantee for each functional module of the system, because the agricultural greenhouse is unattended, the environment is complex and the wiring is difficult, considering that data acquisition and stepper motor circuits all require 5V power supply, the system selects 2 AA batteries to provide 5V input power, and outputs 3.3 V through the LM1117 voltage regulator chip for CC2530, relay and other modules supply power [12].

(2) Data acquisition module. The system air temperature and humidity acquisition uses DHT11 (digital sensor), which has the characteristics of small size, fast processing speed and high cost performance. Its humidity range is 20% $\sim$ 90%RH, and the accuracy is $\pm$5% RH; Temperature range 0 to 50$^{\circ}C$, accuracy $\pm 2^{\circ}C$. Its temperature sensing uses an internal NTC element, and a resistive humidity sensing element is used to measure humidity, and its signal pin is connected to the P1.5 port of CC2530. Light intensity acquisition uses BH1750FVI sensor, which uses 16-bit AD conversion internally, uses IIC serial communication, and SDA and SCL are connected to P1.6 and P1.7 interfaces respectively [13]. Human body induction adopts HC-SR501 sensor, there is a person, keep high level output, no one, keep low level output, its signal pin is connected with P0.7. Soil moisture acquisition uses YL-69 sensor, analog output, using humidity sensitive capacitor, the output voltage increases with the increase of soil moisture, connected with the P0.2 interface, through AD conversion, the output voltage value.

(3) Equipment control module. The sunshade shutter, automatic door and other modules are controlled by two four-wire stepping motors, the basic step angle is 1.8°, and 200 pulses make one revolution. Modify the "M_Spend" value in the program to adjust the number of pulses to control the speed and number of turns of the motor, after debugging, the automatic door is set to 400 pulses/revolution, and it needs to turn 5.36 turns to close the door. Control the high and low levels of the corresponding pins to control the forward and

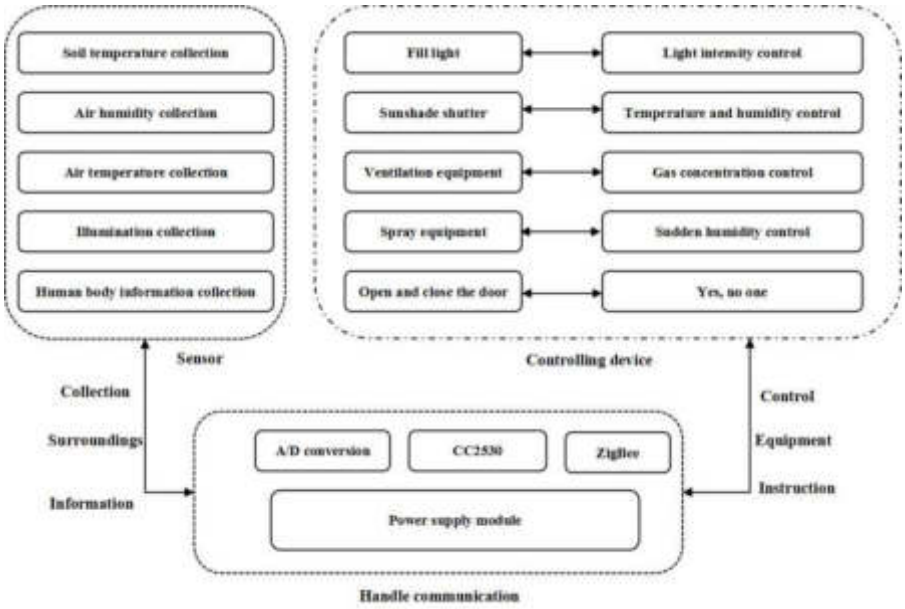

Fig. 3.2: Block diagram of the hardware structure of the sensing control node

reverse rotation of the motor, when Q2 and Q6 are disconnected, and Q4 and Q5 are connected, the motor is conducting forward; When Q4 and Q5 are disconnected, and Q2 and Q6 are connected, the motor is turned on in the reverse direction, and the sunshade roller blind in the system is to control the two stepping motors to synchronize forward and reverse rotation to realize the function of the roller blind. The relay controls the modules such as water pump spray irrigation, fan ventilation, and light supplementation.

(4) ZigBee node programming. ZigBee node programming is based on IAR Embedded Workbench as the development environment, using C programming language, for ZigBee networking, sensor information collection, device control and early warning functions, program design is carried out with the help of TI's Z-Stack [14]. Because the ZigBee protocol has problems such as nodes leaving the network or network broadcast blocking, take the advantages of AODVjr (on-demand distance vector routing) and Cluster-Tree (tree routing) algorithms, the parent and child nodes use the Cluster-Tree algorithm to reduce energy consumption and improve communication performance. Non-parent and child nodes use the AODVjr algorithm, set the Flag tag in the RREQ group, and limit the broadcast range to no greater than the maximum depth of the network, the broadcast storm suppression coordinator node initiates network formation, is responsible for the collection and forwarding of node data, and communicates with the WIFI module in the gateway [15]. Routing nodes maintain routing tables to forward data. The terminal node uses the system interrupt to collect data using digital-to-analog conversion, and different channels correspond to the collection of different environmental information. Part of the code for collecting the air temperature and humidity of the terminal node is as follows:

```
while (1) { THRH(); // call temperature and humidity reading subroutine
//Serial display program
Str_1 [0] = U8_RH_data_H;
Str_1 [1] = U8_RH_data_L;
Str_1 [2] = U8_T_data_H;
Str_1 [3] = U8_T_data_L;
Str_1 [4] = U8_check_data;
S_Data(str_1);//Send to serial port
Delay(20000); //Delay}
```

Table 3.1: Unit cost of each member in the supply chain

Field Name	type of data	Data length	name	Remark
device_mac	Int	16	Device MAC address	primary key
device_name	varchar	32	device name	
light	double	64	light intensity	lx
Soil_temperature	double	64	soil temperature	$^{\circ}C$
air_humidity	double	64	Air humidity	%
air_temperature	double	64	air temperature	$^{\circ}C$
up_time	datetime	64	update time	
Video_url	varchar	200	Video URL	

3.3. Cloud database design. The cloud database provides storage services for monitoring data of smart agricultural greenhouses, and provides users with remote access data interfaces to realize data additions, deletions, revisions, and historical tracking and real-time access. Choose the relational MYSQL database, which has the characteristics of open source, simple operation, fast running speed, strong portability, and supports java, Python and other languages [16]. The database mainly designs user Table, equipment Table, control instruction Table and storage data Table.

1. The t_user Table is used to store login user information, including user_id (user ID), user_name (user name), user_psd (user password), user_level (user level), user_tel (user phone number) and user_status (user status) and other fields, user_id is the primary key, two permission levels are designed for users, namely the common user user and the administrator admin, common users can obtain perception information, and administrators can issue control commands.
2. t_device Table, used to store monitoring system device information, mainly including device_id (device ID), device_name (device name), device_mac (device MAC address), device_c_time (device creation time), and device_status (device status) and other fields , device_id is a unique identifier that can accurately identify the device in the system.
3. The t_command Table is used to store the control commands for sensing and controlling the device, mainly including command (control command), device_name (device name), device_mac (device MAC address), the primary key is device_mac, after receiving the new command information, the cloud database server will immediately send a command to the sensing or control unit of the corresponding device_mac.
4. The t_data Table is used to store the environmental information collected by various sensors. The data list is shown in Table 3.1.

3.4. Mobile software design. For the Android operating system, using the Android Studio development environment, using the JAVA language and MVC programming framework, a smart agricultural greenhouse management system is designed [17]. The APP uses the HttpClient and HttpURLConnection interfaces to connect with the cloud platform (MySQL database), the functions of remote query and equipment control of the growing environment information of greenhouse crops are realized, and the functions of receiving, storing, classifying and analyzing the system perception data are realized by the cloud platform . The main interface of the system includes three modules: "information display", "equipment control" and "equipment status", the program design process is shown in Figure 3.3. The system uses Grid Layout, Seek Bar, Text View and other classes for layout, and uses set Content View, etOnClickListener and other methods to display and monitor controls, rewrite the handle Message method to send messages to the UI thread, use UTF-8 encoding, exchange data with cloud databases in JSON format, and save data in Shared Preferences .

The software interface of the smart agricultural greenhouse monitoring system is friendly and easy to operate, it is connected to the cloud platform through 4G or WIFI network, after authentication and login, greenhouse users can intuitively understand the growth information of crops in the greenhouse in real time [18]. The mobile terminal software mainly realizes the following 4 functions: (1) Information query: The mobile terminal monitoring system reads different sensors from the cloud platform to collect information in

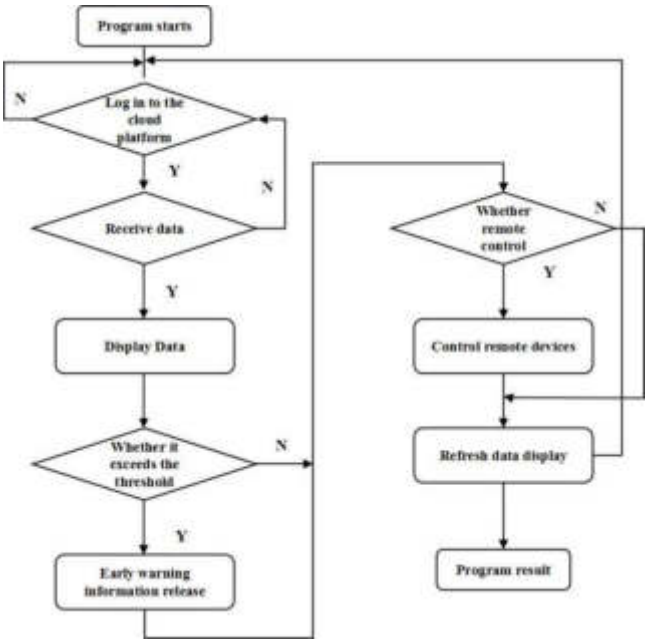

Fig. 3.3: Flow chart of smart agricultural greenhouse APP system

real time and display it, and multiple sensors of the same type are randomly read. (2) Node management: Greenhouse users can automatically or manually remotely control the doors and windows, lighting, ventilation, shading, irrigation and other equipment in the greenhouse according to early warning or needs. (3) Threshold management: For different seasons and different crop growth needs, according to the corresponding perception information, the user can move the "drag bar" to set the threshold, when the monitoring result exceeds the optimal threshold range, the system will send corresponding warning information, and farmers will take action according to the situation. The system can also set the automatic association of thresholds and corresponding control equipment to realize automatic response. (4) Video monitoring: The system realizes the function of video remote monitoring, and the camera button can be dragged to remotely control the camera, view the situation in the agricultural greenhouse from multiple angles.

4. Results and Discussion. The software and hardware function modules of the system are tested in a simulated greenhouse experimental environment, the simulated greenhouse is equipped with 3 soil temperature and humidity sensors, 4 temperature and humidity sensors, 2 illuminance sensors, 1 human body sensor and other sensors, sprinkler pumps, roller shades, fill lights, fans and automatic doors are installed. After the system has been powered on for more than 30 times, the indicator lights of each ZigBee communication and sensor module are normal, and the system has been running for 120 hours without interruption, Sensor Monitor tests that the network topology is stable, and Packet Sniffer captures real-time communication packets with a very low packet loss rate. The mobile APP can be connected to the cloud platform normally, and the data of each sensor can be displayed normally in real time. Comparing the data collected by the sensor with the monitoring data of the actual instrument, taking temperature as an example, the errors are all within $\pm 0.5^{\circ}C$ of multiple measurements, as shown in Table 4.1. The data collected by the sensor was recorded and observed for 12 hours, taking soil moisture as an example, the results are shown in Figure 4.1, during the period of 10:00-11:00, the window of the greenhouse was opened for ventilation, and the humidifier was turned on in the laboratory, and the data increased significantly, after the window was closed, the data was relatively stable, and the soil moisture was collected normally. The mobile terminal repeatedly sends control commands at a frequency of 20 and 30 seconds, and equipment such as shading, lighting, irrigation, fans, and gates can respond normally. The thresholds such as temperature, humidity, and illuminance are moved and set, and the corresponding control

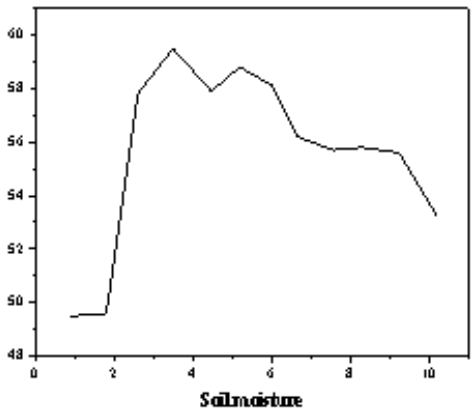

Fig. 4.1: Soil moisture value

Table 4.1: Comparison table of instrument monitoring and display data

Monitoring data/$^{\circ}C$					
DHT11 acquisition temperature	29.1	32.1	36.6	38.8	39.5
Temperature instrument value	29.3	33.4	36.8	38.5	29.1
difference	-0.2	-0.3	-0.2	+0.3	+0.4

equipment responds automatically and sensitively, and the early warning function is normal[19,20]. The camera can be dragged and moved to view the images in the greenhouse in real time. Sensing someone, the lights and the gate will automatically open, if no one is there, it will automatically close after a delay of 30s, people entering the greenhouse can use the gate control button to close the door. After repeated tests, the mobile terminal system runs stably, has good performance, high reliability and is easy to use.

5. Conclusion. The author proposes a method for the application of Internet of Things technology in automated intelligent control systems, and provides a solution for a smart agricultural greenhouse monitoring system by using the Internet of Things technology. Design and verify the perception control system, cloud database and mobile APP. The system enables users to remotely monitor the environmental information of agricultural greenhouses in real time, according to the needs of the growing environment of crops, set corresponding thresholds to realize automatic control of temperature, humidity, lighting and other information, which can better manage crops, achieve the purpose of increasing production and income. The system has the advantages of good scalability, convenient networking, and high cost performance, which makes up for the difficulties in wiring and inconvenient use of the traditional agricultural greenhouse monitoring system, and has high practical value. In the later stage of the system, a big data analysis model can be added, a comprehensive platform for smart agriculture can be built, more types of sensors and control devices can be added, and the application can be extended to a wider field of smart agriculture.

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RBF NEURAL NETWORK FOR CHAOTIC MOTION CONTROL OF COLLISION VIBRATION SYSTEM

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Abstract. Aiming at the control problem of chaotic motion of a kind of collision vibration system with gap, a chaotic motion control of collision vibration system based on RBF neural network is proposed. Firstly, the system mechanical model and chaotic motion are introduced, and then a chaotic controller based on RBFNN is designed to control and simulate the chaotic attractor. The model information of the system is not used in the control method. In this paper, the model of the system is used only to generate the input / output data of the system, and it is not used for the design of the controller. The parameters of AHGSA algorithm are set as follows: the population size is 30, the maximum number of iterations is 100,G_0, a = 18, and the proportional coefficient P = 0.96. Small disturbances are applied to the controllable parameter $\omega$of the system to suppress the chaotic motion of the system and make the system tend to stable periodic motion. In order to more clearly show the control effect of chaotic motion, the chaotic motion is controlled when the system iterates 400 times. The results show that the chaotic motion can be quickly controlled to periodic 1-1 motion, the phase diagram is a closed curve, and there is a peak in the spectrum diagram. Chaotic motion can be quickly controlled as periodic 2-2 motion, the phase diagram is two closed curves, and two obvious peaks appear in the spectrum diagram. The proposed method can effectively control the chaotic motion of the system, and the expected target can be not only the fixed point of period 1, but also other periodic orbits.

Key words: collision vibration, chaotic motion control, RBF neural network, Chaos controller

1. Introduction. Collision vibration system with gap widely exists in practical engineering systems such as locomotives, vehicles and mechanical equipment. Its dynamic behavior is rich and complex (including bifurcation and chaos). Effectively controlling the chaotic behavior of this kind of system has important theoretical significance and engineering application value to ensure the safe service of the system [1]. However, due to the existence of collision behavior, the system speed will jump before and after collision, resulting in continuous but not smooth system displacement. This kind of system has non smooth nonlinear characteristics. Therefore, some dynamic theories and control methods suitable for smooth systems are difficult to be directly applied to such systems. The compliance control framework of teleoperation system based on RBF neural network is shown in Figure 1.1 [2]. In order to optimize the working effect, it is necessary to study the theory and method of chaotic motion control for collision vibration system [3]. In practical application, due to design, manufacturing or assembly errors and other factors, there will be gaps between parts in the mechanical system, resulting in collision and vibration between parts under external incentives [4].

2. Literature review. In view of this problem, Huynh, T. T. et al. firstly from the viewpoint of modern dynamical system, studied a unilateral constrained oscillator, analyzed the local bifurcation of periodic motion by using the central manifold theorem, and analyzed its chaotic motion by using the homoclinic phase cut condition [5]. Burdukovsky, I. et al. studied the two degree of freedom collision vibration system excited by simple harmonic force by numerical simulation method, and confirmed that it leads to chaos through period doubling waterfall [6]. Jaddi, N. S. et al. first proposed a strategy to control chaos, the famous 0GY method, by using the sensitivity of chaotic system to parameter changes and the density of unstable periodic orbits of chaotic attractors [7]. Xu, Z. et al. proposed different improvement measures and further developed the 0GY method [8]. Lian, HH et al. proposed the idea of state delay feedback control to control chaos. Due to non-smooth factors such as collision, impact and dry friction, the vector field will be non-differentiable or discontinuous, so that the traditional theory of smooth dynamical system cannot be directly used in non-smooth dynamical system, and some control methods for smooth dynamical system are no longer applicable in non-

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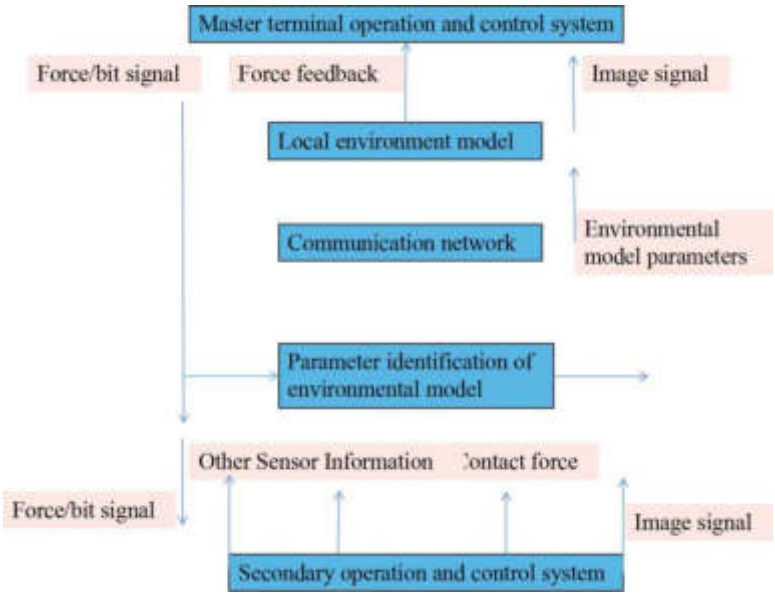

Fig. 1.1: Compliance control of teleoperation system based on RBF neural network

smooth dynamical system [9]. Due to the existence of collisions, the collision vibration system has non-smooth and strong nonlinear characteristics. Its complex and unstable dynamic behavior (such as chaotic behavior) will not only cause noise or wear of mechanical parts, but even endanger the safety of the system. For example, due to the existence of wheel rail gap, when the running speed of locomotive and vehicle is higher than the critical speed of locomotive and vehicle hunting motion, with the increase of running speed, the hunting motion will gradually deteriorate, the vibration displacement of each rigid body will become larger and larger, and finally there will be bifurcation phenomenon and chaotic operation state. Violent collision between wheel and rail will lead to the deterioration of locomotive and vehicle running performance. It may not only damage wheel sets and lines, but also cause derailment accidents. The flow of the vehicle collision vibration system is shown in Figure 2.1. Muthukumar, P. et al. proposed the control strategy of fitting Poincare map by experimental data and pole assignment by partition [10]. Congxu et al. localized the rub-collision mapping of the rotor near the rubbing track, and fitted the local mapping through experimental data, and controlled the chaotic motion of the rub- collision rotor system by variable delay feedback control method [11]. Qi, G. et al. proposed a new feedback control method that uses a small amplitude control signal to change the energy of a chaotic system to achieve the purpose of controlling chaos [12]. Wang, H. et al. used a piecewise linear absolute value function to obtain the control signal. In the actual control process, chaos control was performed by changing the damping coefficient [13]. Fan, J. et al. applied this method to a single-degree-of-freedom collision vibration system to control chaos [14]. Zotos et al. proposed a kind of single-degree-of-freedom collision oscillator position control strategy based on the feedback control idea [15]. E K ö se et al. Proposed chaos control strategy based on state variable predictive feedback and nonlinear delay feedback chaos control strategy for a class of single degree of freedom collision vibration system, and proposed parameter self-adjusting chaos control strategy for a class of two degree of freedom collision vibration system [16]. Zeng, H. B. et al. realized the control of chaotic motion of a class of single degree of freedom collision vibration system by 0GY method [17]. Kong, L. et al. realized the position control of a two-degree-of-freedom collision vibration system under asymmetric bilateral constraints based on feedback control ideas [18]. Zeng, Z. P. et al. realized the control of chaotic motion by changing the damping coefficient of a single degree of freedom collision vibration system. Most of the existing control methods for the chaotic motion of collision vibration systems require knowledge of the controlled system model. However, it is not easy to accurately model the actual engineering system. Unmodeled dynamics are always difficult to avoid, which makes it difficult to optimize the traditional control methods. The control performance

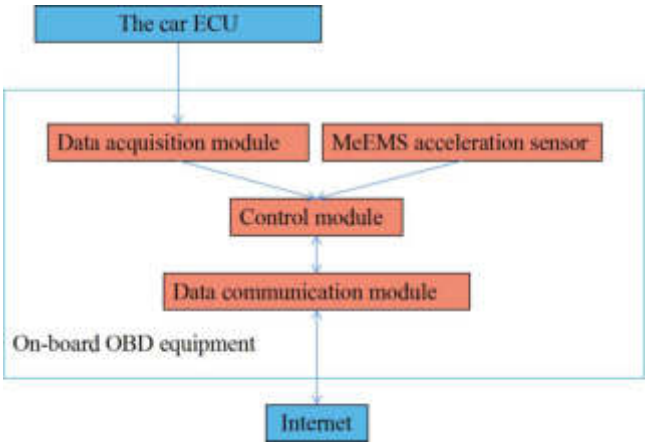

Fig. 2.1: Process of car collision vibration system

[19]. On the basis of the current research, the chaotic motion control of the collision vibration system based on the RBF neural network is proposed. First, the system mechanics model and chaotic motion are introduced, and then the chaos controller based on RBFNN is designed, and the chaotic attractor is controlled and simulated. The model information of the system is not used in the control method. In this paper, the model of the system is used only to generate the input / output data of the system, and it is not used for the design of the controller.

The parameters of the AHGSA algorithm are set as follows: the population size is 30, the maximum number of iterations is 100, G_0=130, a=18, and the proportional coefficient p=0.96. A small disturbance is applied to the controllable parameter of the system ω to suppress the chaotic motion of the system and make the system tend to a stable periodic motion. In order to show the effect of chaotic motion control more clearly, the chaotic motion is controlled when the system is iterated 400 times. The results show that chaotic motion can be quickly controlled to a period of 1-1 motion, the phase diagram is a closed curve, and a peak appears in the spectrogram. The chaotic motion can be quickly controlled to a period of 2-2 motion, the phase diagram is two closed curves, and the spectrogram shows two obvious peaks. Simulation analysis shows that effective chaos control cannot be completed.

And when the number of hidden layer nodes increases, the nonlinear mapping ability of the controller is enhanced, and the intelligent algorithm optimizes the appropriate controller parameters, the control effect becomes better.

3. Methods.

3.1. System mechanics and chaotic motion. The control of chaotic motion of a collision vibration system with gap and a class of single degree of freedom collision vibration system with gap are studied. The mass is denoted by M, and its displacement is denoted by X. The mass and the left rigid constraint are connected by a linear spring with a stiffness of K and a linear damper with a damping coefficient of C. When the mass M is in the equilibrium position, the gap between it and the right rigid constraint is B. The simple harmonic incentive force acting on the mass is $Fsin(\Omega T + \tau)$.

If the collision duration is negligible, the differential equation of system motion is:

$$\begin{cases} M\ddot{X} + C\dot{X} + KX = Fsin(\Omega T + \tau), X < B \\ \dot{X_+} = -R\dot{X_-}, X = B \end{cases} \tag{3.1}$$

where $\ddot{X}, \dot{X}$ and X are the acceleration, velocity and displacement of the mass M. M, C, K are the mass of M, the damping of the linear damper and the stiffness of the linear spring respectively. $\ddot{X}, \dot{X}$ is the instantaneous velocities before and after the collision between mass M and the right rigid constraint, respectively. R is the coefficient of restitution. Without loss of generality, introduce the dimensionless quantity $x = \frac{XK}{F}, \zeta =$

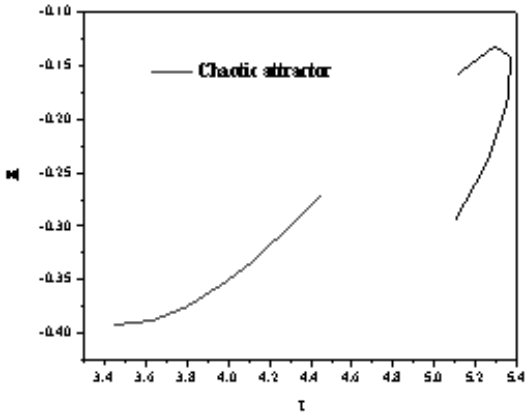

Fig. 3.1: Chaotic attractor

$\frac{C}{\sqrt{MK}}, \omega = \Omega\sqrt{\frac{M}{K}}, t = T\sqrt{\frac{K}{M}}, b = \frac{BK}{F}$ and carry on the dimensionless transformation to the Equation 3.1, and get:

$$\begin{cases} \ddot{x} + 2\zeta\dot{x} = x = sin(\omega t + \tau), x < b \\ \dot{x_+} = -R\dot{x_-}, x = b \end{cases} \tag{3.2}$$

where $\dot{x_-}, \dot{x_+}$ are the instantaneous velocities before and after the collision between the mass M and the right rigid constraint.

In order to study the evolution mechanism of system dynamics, the instantaneous cross-section σ after collision is selected, $\sigma = \{(x, \dot{x}, \theta) \in R^2 \times S^1 | x = b, \dot{x} = \dot{x_+}\}$, where $\theta = \omega t mod 2n\pi$ is the Poincare cross-section, and the parameter that affects the system dynamics—the frequency of the simple resonance excitation force ω is the bifurcation parameter, set $\zeta = 0.2$ and R=0.8, b=0.05, numerical simulation of the bifurcation phenomenon caused by the change of the system state with the frequency of the simple harmonic incentive force $\dot{x}$.

When the frequency of the harmonic incentive force $\dot{x}$ changes within a certain range, the system has a stable period n-1 motion. However, as ω increases, the system will undergo period-doubling bifurcation, and eventually evolve into chaotic motion. And there are some period windows in the chaotic motion process, which is one of the typical characteristics of chaotic motion of nonlinear systems. With the further increase of ω, chaotic motion will degenerate into periodic motion [20]. When c=2.65, as shown in Figures 3.1 and 3.2, the phase plan of the system is not repeated but chaotic. At the same time, the irregular scattered point set in the Poincare cross section and the continuum in the spectrogram also indicate that the system is in chaotic motion. Figure 3 shows the chaotic attractor of the system on the Poincare section.

3.2. Design of chaos controller based on RBFNN. Since the chaotic motion is caused by the changes of some key parameters of the nonlinear dynamic system, based on this, this paper controls the chaotic motion based on the principle of the parameter feedback chaos control method. That is, the RBF neural network chaos controller outputs a small disturbance to the controllable parameters of the system, and the chaotic motion is controlled to the desired regular motion by dynamically adjusting the controllable parameters of the system [21]. When designing a chaos controller, the RBF neural network has a three-layer structure, including an input layer, a hidden layer and an output layer. According to the chaotic motion control target, two distances are taken as the inputs of the controller. One is the distance between the projection point on the Poincare section after K iterations, which can reflect the movement trend of the system approaching a stable period 1-1, and the projection point on the Poincare section after k-1 iterations. The other is the distance between the

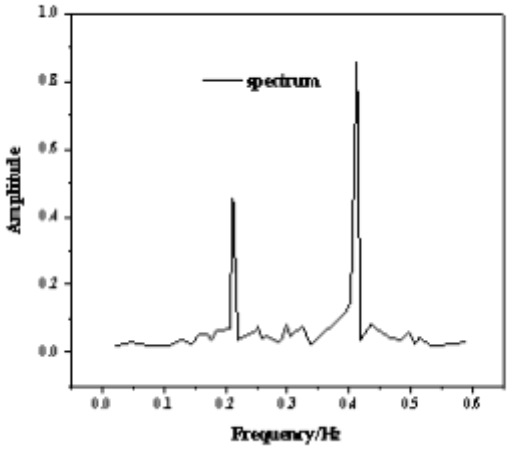

Fig. 3.2: Spectrogram of $\dot{x}$

projection point on the Poincare section after k-1 iterations and the projection point on the Poincare section after k-2 iterations. The output of the controller is defined as the slight adjustment of the excitation frequency or damping coefficient of the system (that is, the small disturbance of the controller output is a controllable parameter applied to the system). Therefore, it is determined that the input layer of the RBF neural network has 2 nodes and the output layer is 1 node [22].

4. Results and analysis. The chaos control method proposed in this paper is used to control and simulate the chaotic attractor shown in Figure 3.1. The control method does not use the model information of the system. The model of the system is used in this paper to generate the input/output data of the system, and it is not used for the design of the controller [23].

The Gaussian RBF neural network is selected for chaos controller design, and after comparative analysis, it is found that when there are less than 5 hidden layer nodes, the simulation analysis finds that effective chaos control cannot be completed due to the weak nonlinear mapping ability of the controller. And when the hidden layer nodes increase, the nonlinear mapping ability of the controller will be enhanced, and the intelligent algorithm will be optimized to the appropriate controller parameters, and the control effect will become better [24].

However, with the further increase of hidden layer nodes, the control device structure will become more complicated, the controller parameters that need to be determined will also increase exponentially. It becomes more difficult for the intelligent algorithm to find the appropriate controller parameters, and the optimization efficiency of the algorithm decreases accordingly. According to the basic principle of determining the number of nodes in the hidden layer of the neural network (i.e., the network structure as compact as possible shall be selected under the premise of meeting the performance requirements of the control system, that is, the number of hidden layer nodes should be as few as possible), choose the least number of hidden layer nodes that can complete effective chaos control, that is, select 5 hidden layer nodes in the network. The parameters of the AHGSA algorithm are set as follows: the population size is 30, the maximum number of iterations is 100, $G_0 = 130$, a=18, and the proportional coefficient p=0.96. A small disturbance is applied to the controllable parameters of the system ω to suppress the chaotic motion of the system and make the system tend to a stable periodic motion [25]. In order to show the effect of chaotic motion control more clearly, the chaotic motion is controlled when the system is iterated for 400 times [26].

Figure 4.1 is a simulation result diagram of controlling chaotic motion into period 1-1 motion, showing the effect of chaotic motion control based on AHGSA-RBFNN. The parameters of the RBF neural network

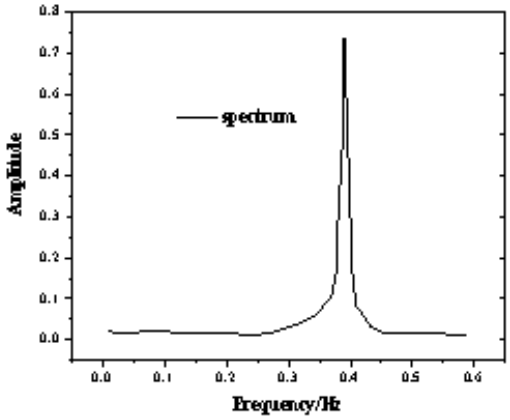

Fig. 4.1: Controlled period 1-1 motion of the system

Table 4.1: RBF neural network parameters (period 1-1)

Hidden layer node Center	Center width	Weights connecting hidden layer and output layer
-0.4644,0.0625	0.1552	-0. 1294
0.0144,0.4323	0.4958	0.6095
0.3885,-0.1883	0.5481	0.6571
-0.4652 ,0.9523	0.9752	1.8718
0.1788,-0.4594	0.4056	-0.7668

optimized by the AHGSA algorithm are shown in Table 4.1.

It can be seen from Figure 4.1 that the chaotic motion can be quickly controlled to a period of 1-1 motion, the phase diagram is a closed curve, and a peak appears in the spectrogram.

Figure 4.2 is the simulation result diagram of controlling chaotic motion into period 2-2 motion. The parameters of the RBF neural network optimized by the AHGSA algorithm are shown in Table 4.2.

It can be seen from Figure 4.3 that the chaotic motion can be quickly controlled to a period of 2-2 motion, the phase diagram is two closed curves, and the spectrogram shows two obvious peaks.

5. Conclusions. In this paper, RBF neural network for chaotic motion control of collision vibration system is proposed. The intelligent optimization control method based on RBF neural network is used to study the control of chaotic motion of a class of collision vibration system with gap. The Gaussian RBF neural network is selected for chaos controller design, and after comparative analysis, it is found that when there are less than 5 hidden layer nodes, due to the weak nonlinear mapping ability of the controller. Simulation analysis shows that effective chaos control cannot be completed. And when the hidden layer nodes increase, the nonlinear mapping ability of the controller is enhanced, and the intelligent algorithm is optimized to the appropriate controller parameters, and the control effect becomes better.

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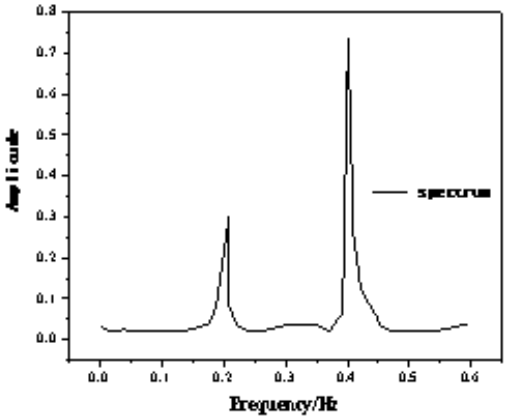

Fig. 4.2: RBF neural network parameters (period 2-2)

Table 4.2: RBF neural network parameters (period 1-1)

Hidden layer node Center	Center width	Weights connecting hidden layer and output layer
-0.5572,-0.0144	0.1552	- 0.4047
-0.4342,-0.2694	0.2271	1.4517
0.6567,- 0.2487	0.1656	1.1381
-0.4286 -0.0285	0.4051	0.1678
-0.3258,- 0.5973	0.3731	-1.1045

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THE IMPACT OF SIMILARITY FUSION BASED TRAVEL INTEREST POINT RECOMMENDATION ALGORITHM IN YOUTH USERS' STUDY TOURS

XINLI XING AND DAOJUN WANG*

Abstract. Study tours for adolescent users are somewhat contemporary and traditional methods, such as questionnaires cannot meet their psychological expectations. To bring a better experience to teenagers' study tour, a Latent Dirichlet Allocation (LDA) theme model was used to mine teenage users and their interest points, and then the similarity between LDA and the check-in matrix was calculated and fused. Based on this, an RT-CNN model was built for deep feature extraction of review information, and point-of-interest recommendation was performed by fusing similarity, check-in behavior, and geographic location. The RT-CNN model had an accuracy of 92.7%, a recall of 87.1%, a Mean Absolute Error (MAE) value of 4.2%, a Root Mean Square Error (RMSE) of 4.8%, and F1 values of 89.2% and 88.7% in the two datasets. The new model in this experiment has high accuracy in making interest point recommendations and has a good overall performance.

Key words: Similarity fusion; Dynamic prediction; RT-CNN; Interest points; LDA topic model

1. Introduction. More traditional methods such as questionnaires are generally used in the study of study tours for young users [1-2]. For young people nowadays, these travel recommendations are no longer representative. A point-of-interest recommendation is used to analyze teenage users' preferences through data mining of their personal information, browsing history, and location information, which can help teenage users to search for new locations of interest [3-5]. The point-of-interest recommendation for teenage users can help them to choose their favorite locations among countless locations, which improves the experience of teenage users and reduces the feeling of blindness and helplessness in unfamiliar locations [6]. Study tours are organized by schools based on regional characteristics, age of students, and teaching needs of various subjects to allow students to leave the campus through group trips and centralized accommodation and meals. Their experience of collective lifestyle and social public morality can be increased in this way. Therefore, it is very important to choose an appropriate research location and content. Dynamic and intelligent recommendations are proposed based on artificial intelligence to meet the psychological expectations of young users for sports research travel, combined with the emotional preferences and geographical location of young users. It is hoped to use intelligent recommendations to help students improve their experience and expectations of study tours. The LDA topic model is used to mine teenage users and their points of interest and topics on the text information of teenage users aggregated into different documents to improve the accuracy of the point-of-interest recommendation algorithm in the study tours of teenage users. Then the similarity between the check-in matrix and the LDA topic model is calculated and fused. An RT-CNN model is built to deeply extract content such as contextual sentiment and semantics from the comment information of teenage users. Travel interest point recommendations are achieved by mining the interest preferences, emotional tendency and location information of teenage users. Then the influence of similarity, teenage users' check-in behavior, and the geographic location factors they are located are fused. It is hoped to provide a practical travel interest point recommendation method for youth study tours in Qingdao.

The existing interest point recommendation algorithms have achieved good research results in mining the evaluation information, geographic location, and other information of adolescent users. However, these technologies still suffer from some issues, such as inaccurate check-in matrix information for teenage users. LDA topic model and RT-CNN are used to mine users and their interest points to improve the accuracy of interest point recommendation algorithms in sports research travel for adolescent users. It is hoped to provide a practical tourism interest point recommendation method for youth study tours in the Qingdao area.

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The article consists of four parts. The first part provides a review of the research on tourism interest point recommendation algorithms. Next a detailed explanation of the methods used is provided, and corresponding models are established. The third part is the validation of the established recommendation algorithm. Finally, there is a summary of the entire article and future prospects.

2. Related works. Data sparsity and cold start are the same problems that point-of-interest recommendation algorithms need to face as traditional recommendation algorithms. In addition, point-of-interest recommendation algorithms also have difficulties in using contextual information, such as the inability to analyze the geographic location of the movement [7-9]. Meanwhile, it is a difficult problem to mine the valid information in the sparse check-in data of teenage users and making recommendations for point-of-interest recommendation algorithms. The personalized recommendation has high academic research value and commercial value, so experts at home and abroad have conducted focused and in-depth research on personalized recommendation techniques. Most recommendation methods aim to improve the recommendation accuracy. Lin Y et al. proposed to design diversity recommendation methods using scenic features. This method could classify errors and optimize themes. The accuracy and diversity of this recommendation method were confirmed in real tourism datasets [10]. Apriori can be used to establish recommendation algorithms in the tourism industry. Yang S et al. designed an intelligent recommendation system based on the Internet and artificial intelligence. This system introduced Apriori for user behavior analysis, resulting in customized recommendation content. This system had been validated after method validation, which was better than traditional recommendation methods such as decision trees and linear regression [11]. Clustering algorithms can perform clustering analysis on textual information to provide users with decision-making. S Ding et al. confirmed that Peak Density Clustering (DPC) could effectively identify cluster centers. It could divide boundaries based on the relationship between cluster centers and surrounding points after the improvement of the method. The results on different datasets indicated that the improved method could effectively control runtime and improve clustering accuracy [12]. Context-aware methods based on knowledge graphs could be applied to recommend preference items to users, and the integration of auxiliary information and collaborative filtering techniques in the recommendation algorithm was a good improvement in the performance of the algorithm [13].

The performance of recommendation algorithms can be improved to some extent by text or rating information mining, but not by deep feature mining. So topic models or deep learning techniques are proposed to use for text mining, such as CNN, LDA, and Restricted Boltzmann Machine (RBM) and other topic models or deep learning techniques for deep mining of rating information and text documents of teenage users. The embedding models based on random forests and word vectors can achieve a rational use of point-of-interest data and can facilitate the improvement of urban functions [14]. Y Luo used the LDA model for sentiment analysis. Meanwhile, fuzzy algorithms were introduced for image mining and model analysis. Small samples were analyzed and the emotions and preferences of tourists were fully considered based on this model [15]. Xu Z constructed a recommendation model using differential privacy theory and clustering methods. This model could be used for analyzing user interests and preferences. The user's preferences formed a matrix model after training. After experimental verification, the generated comprehensive model could provide recommendations for tourism interest points with high accuracy and privacy protection capabilities [16]. In social networks, interest-based recommendations are of practical application value. Song R et al. were able to use this method to analyze user data from different dimensions. A new recommendation model was constructed to comprehensively analyze data with both temporal and spatial dimensions. In real datasets, this model outperformed existing methods [17]. Geographic information is the foundation of model application in interest point recommendation models. Vinodha R et al. integrated the obtained geographic information for analyzing user behavior patterns. Meanwhile, they fixed the missing data and displayed the areas of interest to the user. Recommendation calculation based on interest points was achieved after data processing [18].

In summary, existing interest point recommendation algorithms have achieved good research results in mining evaluation information, geographic location, and other information of adolescent users [19-20]. However, these techniques still suffer from some issues, such as inaccurate check-in matrix information for teenage users. In addition, these algorithms have not screened the comments of adolescent users, losing certain features of their comment information and a decrease in recommendation accuracy. The LDA topic model is used to mine users and their interest points to improve the accuracy of interest point recommendation algorithm in

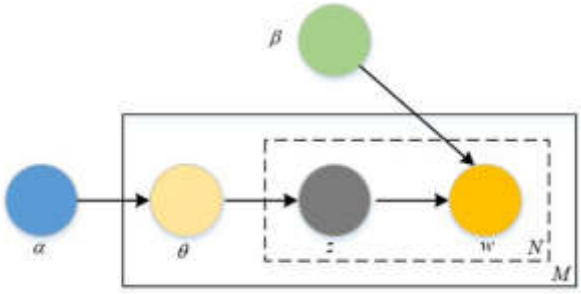


Fig. 3.1: Generation process of LDA theme model

sports research travel for adolescent users. Meanwhile, CNN is introduced into the model for value screening of user comment information, which can accurately reflect the characteristics of interest points. The proposed method aggregates all comment information related to the point of interest and distinguishes user comment information to a certain extent. It extracts some user comments during the information extraction to reflect the characteristics of the points of interest. The algorithm proposed in this experiment can effectively address the inaccurate feature extraction caused by the lack of importance differentiation for documents. It effectively addresses some of the shortcomings of the current approach and is superior.

3. The similarity fusion and CNN-based travel interest point recommendation algorithm in youth sports research trips.

3.1. The travel interest point recommendation algorithm based on similarity fusion. In the interest recommendation algorithm, text information related to interest points and teenage users is input into the LDA topic model for the point of interest and teenage users. Their latent topic topic features can be mined and represented by a topic vector. The method used in the LDA topic model is the bag-of-words method. A document (text) is composed of words (w) that have no sequential relationship, and these words are attributed to a topic (topic) in the document with a certain probability, while the topic in the document also has a certain probability to select a word. If a document is to be generated, then the probability of occurrence of words in it is given in equation (3.1).

$$p(w \mid text) = \sum_{topic} p(w \mid topic) \times p(topic \mid text) \tag{3.1}$$

In the same document that can contain more than one topic, the topics are output in a probability matrix of the LDA model. The topic distribution of words never can be obtained, and then the similarity of the document is calculated based on the topics. The model generation process is shown in Fig 3.1. First a random topic distribution θ is selected, then a random topic from z is selected, in the word probability based on the random topic z to generate words w. Word w is generated based on the probability of words in the random topic z.

In Fig. 3.1, α and β are corpus-level parameters, and θ denotes a topic vector of dimension$K$. Both the topic z and $word$ are word variables. The topic z is generated by the topic vectorθ. The word w is generated jointly by the topic z and the parameter β. Then the joint probability in equation (3.2) can be obtained.

$$p(\theta, z, w \,|\alpha, \beta\,) = p(\theta \,|\alpha\,) \prod_{n=1}^{N} p(z_n \,|\theta) p(w_\theta \,|z_\theta, \beta\,) \tag{3.2}$$

Combining Fig. 3.1 with equation (3.2) yields the probability generation for the LDA model in Fig 3.2.

In the LDA model, α and β need to be trained to obtain the parameters. α is used to represent the probability distribution of "document-topic". β is used to represent the probability distribution of "topic-word".

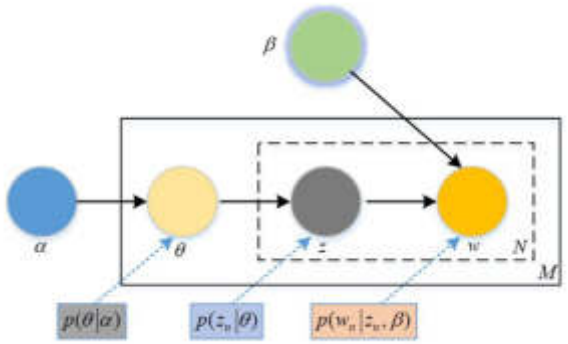


Fig. 3.2: Probability generation process of LDA model

For the training of the parameters α and β, the learning algorithm usually chosen is Gibbs sampling method, which first requires randomly setting the topics to which the words in the document belong. Then the probability of each word in the document belonging to the topic is updated according to equation (3.2), while satisfying the randomness of the word selection. Finally, the operations in equation (3.3) are continuously executed until the iteration condition is satisfied.

$$p(z_{i'} = k \,|z_{-i'}, w) \propto \frac{n^{(k)}_{m,_{-i'}} + \alpha_k}{n^{(.)}_{m,i'} + V\alpha_k} \times \frac{n^{(s)}_{m,-i'} + \theta_s}{\sum_{s=1}^{V}(n^{s}_{k,-i'} + \beta_s)} \tag{3.3}$$

In equation (3.3), z_{-i}¡ is the distribution of topics excluding subscript i. The word distribution under the topic can be obtained after the iterations in equation (3.3) based on equation (3.4).

$$\theta_{k,s} = \frac{n^{(s)}_{k} + \theta_s}{\sum_{s=1}^{V}(n^{(s)}_{k} + \beta_s)} \tag{3.4}$$

The topic distribution of the document can be obtained after the iterations in equation (3.3) based on equation (3.5).

$$\theta_{m,k} = \frac{n^{(k)}_{m} + \alpha_k}{n^{(.)}_{m} + V\alpha_k} \tag{3.5}$$

In the LDA-based phase-metric model, it is first necessary to aggregate the teenage users' comments and description information related to the same interest point into a single document. Next, all the labeled and commented information related to the interest point that has been checked in by the same teenage user is pooled into one document. Then a large collection of documents can be obtained, where one document corresponds to one teenage user or one point of interest. In this experiment, the number of interest points given and the topics implied in teenage users is K. Then the topic distribution of an interest point θ_p and the topic distribution of teenage users θ_u should be computed. θ_p and θ_u denote vectors of dimension K. Each dimension of the vector represents the probability size generated by the teenage user or interest point under the corresponding topic. The LDA model is used to train the topic features of each teenage user or point of interest. Equation (3.6) shows the process of solving the similarity of the teenage user's nearest neighboring topic features.

$$sim(\theta_{u_i}, \theta_{u_j}) = \frac{\sum_{m=1}^{K}(w_m^{(u_i)} \times w_m^{(u_j)})}{\sqrt{\sum_{m=1}^{K}((w_m^{(u_i)})^2 \times \sum_{m=1}^{K}((w_m^{(u_j)})^2)}} \tag{3.6}$$

In equation (3.6), θ_{u_i} is the topic vector of teenage user i. θ_{u_j} is the topic vector of interest point j. The probability that teenage user i and interest point j belong to topic m is denoted as $w_m^{(u_i)}$ and $w_m^{(u_j)}$, respectively. The similarity measure based on the teenage user check-in matrix and the LDA topic model is divided into the following steps. First, the information documents related to teenage users and points of interest are input. The teenage user documents or points of interest documents that need to be processed in the document set are word-sorted and the words are converted into word frequency vectors. Next, the relevant parameters of LDA are set, the processed documents are put into LDA for training, and the model output is transformed. For any teenage users u_i and u_j, the similarity is calculated using equation (3.6). Finally, the similarity matrix is output. It is supposed the set of teenage users recommended in the points of interest is denoted as $U_{POI} = \{u_1, u_2, ..., u_m\}$, the set of points of interest is denoted as $V_{POI} = \{u_1, u_2, ..., u_n\}$, a check-in matrix of size $N \times M$ is denoted as R, and the check-in term is $r_{i,j}$. In equation (3.7), the cosine similarity formula is used to carry out the similarity measure of the teenage users obtained based on the check-in matrix.

$$sim(x_a, x_b) = \frac{\sum_{i \in N(a) \cap N(b)} n_{a,i} \cdot n_{b,i}}{\sqrt{\sum_{i \in N(a)} (n_{a,i})^2 \cdot \sum_{i \in N(b)} (n_{b,i})^2}} \tag{3.7}$$

In equation (3.7), $n_{a,i}$ is the check-in frequency of teenage user a to interest point i and $n_{b,i}$ is the check-in frequency of teenage user b to interest point i. The set of nearest neighbors of teenage users can be obtained at $U_l = \{u_{l_1}, u_{l_2}, ..., u_{l_m}\}$ after the similarity is calculated using the LDA model. The set of nearest neighbors of teenage users based on the check-in data similarity measure is $U_t = \{u_{t_1}, u_{t_2}, ..., u_{t_n}\}$. The final set of nearest neighbors is $U_b = U_t \cup U_l$. The set of nearest neighbors that can be derived by both methods is denoted as $U_j = U_t \cap U_l$ and its weight value will be increased when performing the calculation of predicted visit probability. In equation (3.8), the similarity of teenage users can be set.

$$sim(u_a, u_b) = \mu sim_l(u_a, u_b) + (1 - \mu) sim_t(u_a, u_b) \tag{3.8}$$

In equation (3.8),$sim_l(u_a, u_b)$ is the similarity calculated using the LDA model, $sim_t(u_a, u_b)$ is the similarity calculated based on the check-in data similarity measure, and μ is the parameter of size 0.6. Dynamic prediction is introduced in this experiment to avoid the emergence of new errors, reduce the impact caused by data sparsity, and dynamically fill in the missing information for the current check-in of teenage users. The solution of the current interest point nearest neighbor set is performed using equation (3.6). The probability of access to the current missing interest point check-in information is predicted based on this nearest neighbor set. Then the probability of access is predicted. It is supposed that the current target teenage user is u, its interest point is p, M is denoted as the nearest neighbor set of the teenage user, and h denotes any teenage user of the nearest neighbor set M. Then the access prediction of h to the current interest point is denoted as $\hat{c}_{h,p}$ in equation (3.9).

$$\hat{c}_{h,p} = \begin{cases} c_{h,p} & c_{h,p} \neq 0 \\ \frac{\sum_{l \in N} sim(p,l) \cdot c_{h,l}}{\sum_{l \in N} sim(p,l)} & c_{h,p} = 0 \end{cases} \tag{3.9}$$

In equation (3.9), N is the set of h nearest neighbor interest points. $sim(p, l)$ is the similarity of interest point p to l. Then the access probability of the teenage user u to the current interest point in equation (3.10) can be obtained.

$$\hat{c}_{h,p} = \frac{\sum_{h \in v} w_{u,h} \cdot c_{h,p}}{\sum_{h \in v} w_{u,h}} \tag{3.10}$$

The v in equation (3.10) is the nearest neighbor set of teenage users, and $w_{u,h}$ is the similarity weight of u and h. The visit probability of teenage users can be predicted by using equation (3.10), and the top N interest points with the highest visit probability are selected according to the calculated visit probability size, thus generating a recommendation list of top-N for the target teenage users.

3.2. The travel interest point recommendation algorithm based on similarity fusion and CNN. In the previous study, the similarity fusion-based interest point recommendation algorithm has good recommendation interpretation, but it needs to continue to improve in terms of accuracy. CNN has better performance advantages in natural language and text processing and can be used for text or image feature extraction. Therefore, it is chosen for the optimization of the above interest point recommendation algorithm in this experiment. In general, teenage users tend to prefer interest points that are closer to their geographical location. This model can be optimized by equation (3.11). to predict the check-in interest of teenage users u_i to the geographic location l_j where no check-in is performed.

$$\min \frac{1}{2}(H \odot (R - UL^T))^2 \tag{3.11}$$

H is the check-in weight matrix, $H \in R^{M \times N}$, whose value of 1 indicates check-in and whose value of 0 indicates no check-in in equation (3.11). The regularization terms of the parameters U and L are added to the value equation (3.11) to obtain equation (3.12) to prevent the occurrence of overfitting.

$$\min \frac{1}{2} \left\| H \odot (R - UL^T) \right\|_F^2 + \frac{\lambda_u}{2} \|U\|_F^2 + \frac{\lambda_l}{2} \|L\|_F^2 \tag{3.12}$$

λ_u and λ_l are the regularization terms of parameters U and L respectively. $\|\cdot\|_F^2$ is the Frobenius parametrization, which is optimized using the gradient descent method to obtain the local optimal solution in equation (3.12). There is a correlation rule between things. If a teenage user is interested in the neighboring locations around a geographic location, then the teenage user is more likely to be interested in that geographic location. Therefore, the neighboring location weighting method can be used to fill in the corresponding vacant geographic locations in the matrix decomposition model, and equation (3.13) is the minimization of the objective function.

$$\min_{U,L} \frac{1}{2}(H \odot (R - UBL^T)^2) \tag{3.13}$$

In equation (3.13), $B = \gamma UL^T + (1 - \gamma)A^T, A \in R^{n \times n}$. γ denotes the parameter of the neighborhood location weight. The sparse data can be mitigated by fully mining the review information of teenage users. CNN can extract the latent features from the document information in the previous paper and incorporate them in the point-of-interest recommendation. In CNN, the input data is a word vector and the output data is sentiment tendency, the model contains 4 main layers, as shown in Fig. 3.3.

First of all, the first layer is the embedding layer, which can merge words from all evaluation information of a particular teenage user to form a single document. Then the corresponding word vector mapping is performed by the word vector model in the order of word occurrence to generate a word vector matrix with constant word order, as shown in equation (3.14).

$$M_i = (w_0) : (w_1) : ...(w_p) : ... : (w_{n-1}) \tag{3.14}$$

w_p is the word vector of word p in equation (3.14). The second layer is the convolution layer, which can be used to extract new features from the input M_i by convolution operations. The new features generated by each convolution are shown in equation (3.15).

$$T_y = f(M_i \otimes F_q + b_q) \tag{3.15}$$

f is the activation function, $\otimes$ is the convolution operation, F_q denotes the filter, and b_q is the bias term of F_q in equation (3.15). The third layer is the pooling layer, which can be used to generate new features by extracting the maximum contextual feature vector via max pooling operation. This operation can effectively handle evaluation texts of different lengths and can compress features to reduce their size and ensure that only the main features are extracted. It can downgrade the complexity of the computation and avoid overfitting of the model. The representation of pooled features is shown in equation (3.16).

$$D_j = T_y(Max(allfeature) \tag{3.16}$$

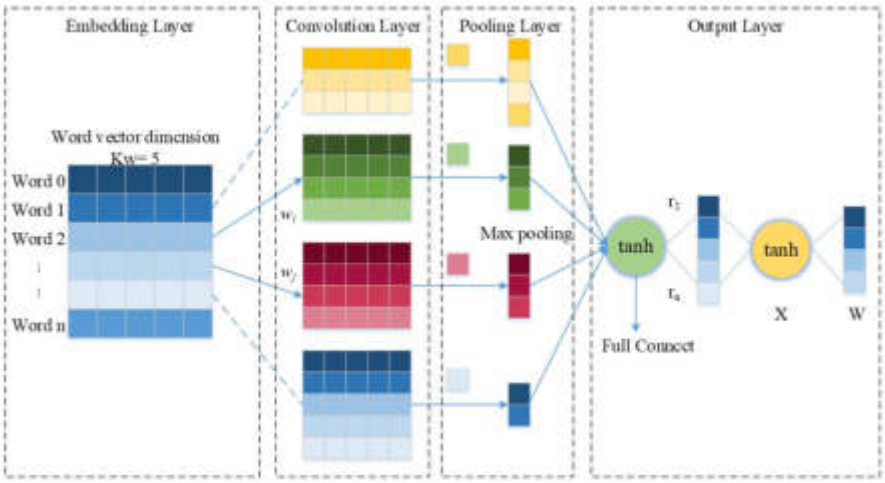


Fig. 3.3: Structure of CNN

The fourth layer is the output layer, which can input the sentiment feature vector extracted in the third layer to the Softmax function for the calculation of sentiment prediction probability. It is compared with the standard experimental data to get the error. The error is passed through the method of back propagation and gradient descent to update the parameters. In equation (3.17), CNN can deeply extract the latent features of the location interest point evaluation text and the probability of the teenage user posting the evaluation is defined using the Softmax function.

$$P(\varphi_{il} = 1 \,|u_{\,i}\,, c_l) = \frac{e^{(u_i^T \cdot C \cdot CNN(W, C_l))}}{\sum_{C_q \in C} e^{(u_i^T \cdot C \cdot CNN(W, C_q))}} \tag{3.17}$$

In equation (3.17), φ_{il} is whether the teenage user has published a rating, c_l denotes the set of documents evaluated, C means the interaction matrix used to analyze whether the teenage user has published a rating, $CNN(W, C_l)$ is the features of the evaluation text extracted by the CNN, and W refers to the internal weight of the CNN. There is a correlation between the output values of the Softmax logistic regression function, and the sum of their probabilities is equal to 1. It is necessary to transform equation (3.17) into the objective function in equation (3.18) to obtain the teenage user's potential feature vector.

$$\sum_{i=1}^{n} \sum_{c_q \in C_{ui}} \log P(\varphi_{iq} = 1 \,|u_{\,i}\,, c_q) \tag{3.18}$$

Similarly, the probability function for the correlation between geographic location and evaluation is given in equation (3.19).

$$P(\varphi_{jk} = 1 \,|l_{\,j}\,, c_k) = \frac{e^{(l_j^T \cdot P \cdot CNN(W, C_k))}}{\sum_{C_q \in C} e^{(l_j^T \cdot P \cdot CNN(W, C_q))}} \tag{3.19}$$

If the potential eigenvectors of locations are to be obtained, it is necessary to transform equation (3.19) into the objective function in equation (3.20).

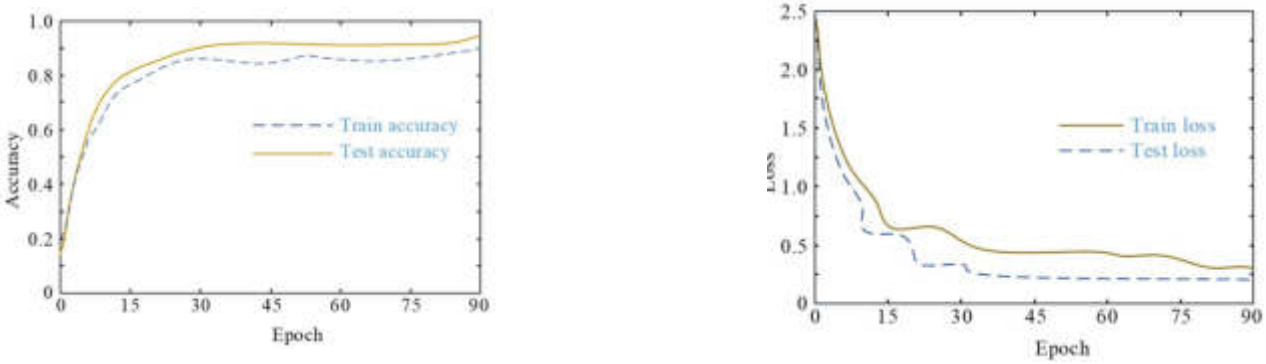
$$\sum_{j=1}^{m} \sum_{c_q \in C_{lj}} \log P(\varphi_{jq} = 1 \,|l_{\,j}\,, c_q) \tag{3.20}$$

The RT-CNN model incorporates the similarity SIM, geolocation influence B, location latent features L, check-in behavior R, teenage user sentiment tendency S, and teenage user latent features U. The location latent features L, teenage user sentiment tendency S, and teenage user latent features U are learned from CNN. The implementation steps of the RT-CNN model include the following process. First, $R, C_{u_i}, u_i \in U, C_{l_j}, l_k \in L$ are input in the model. Then SIM, W, U, L, P, C are randomly initialized. Next, CNN is used to obtain the S value, and the geographic location influence B is calculated by U, L. It is judged whether the function reaches the convergence state, otherwise parameters are updated and adjusted by back propagation method until the requirement is satisfied. Finally, top-N interest points are generated. Because this experiment is aimed at the youth sports research tourism in the Qingdao area, the potential features of geographic location and location in the model are chosen to analyze the tourist attractions in the Qingdao area.

4. Simulation analysis of travel interest point recommendation model. The similarity fusion-based travel interest point recommendation algorithm was trained in the LDA model into the parameters. The dataset chosen was Yelp to evaluate the effect of the training of the method. The dataset provided by the 6th Yelp Challenge launched by the Yelp website in 2015 was used. The dataset file used in this article contains three JSON format documents, which are about users, points of interest, and comment information. The information contained in the document includes the user's ID, rating, comment text, category of points of interest, latitude and longitude, etc. A preprocessing method similar to ConvMF was adopted for the original dataset. Users who had accessed information less than 5 times and interest points that had been visited less than 5 times were removed in this article due to the extreme sparsity of the Yelp dataset. The maximum length of a text document with user and interest points set should not exceed 300. All stop words were deleted. TF-IDF was used to calculate the weight of each word in the document, and words with weights not exceeding 0.5 were deleted. The top 8000 words with weight values were selected as the final vocabulary. The ratio of training set to test set was 7:3. The model was put into the training set and the test set for training, respectively. The training results of the travel interest point recommendation algorithm based on similarity fusion are shown in Fig. 4.1. The parameters of the comparison algorithm were set to achieve the best algorithm recommendation effect to demonstrate the effectiveness of the algorithm in this article. In this experiment, the dimensionality of the potential user and interest point matrices in matrix factorization was set to 50, and random initialization was performed. The regularization parameters α_U and α_V of the recommendation algorithm were set to 0.002 and 100, respectively. The word vector dimension kw of the LDA topic model was set to 200. The user and interest point text documents were set to a maximum length of 300 in this experiment to better train the CNN model. The dimension of word embedding was set to 200 in the experiment. The windows in the convolutional layer were set to 3, 4, and 5, respectively, to better extract document features. The number of windows of each width was 100. Dropout was used for mapping in the experiment to prevent overfitting, with a loss rate of 0.3. Accuracy is the proportion of all correctly predicted (including positive and negative classes) to the total, used to evaluate the generalization ability of a model, that is, the performance of the model. The higher the accuracy, the stronger the generalization ability of the model, indicating better performance. The accuracy of the similarity fusion-based recommendation algorithm in the test set was 93.7%, which was higher than the value in the training set. The loss function value of the method was 0.48 in the test set, which was lower than the value in the training set. The method could get better parameter optimization in the test set after learning from the training set.

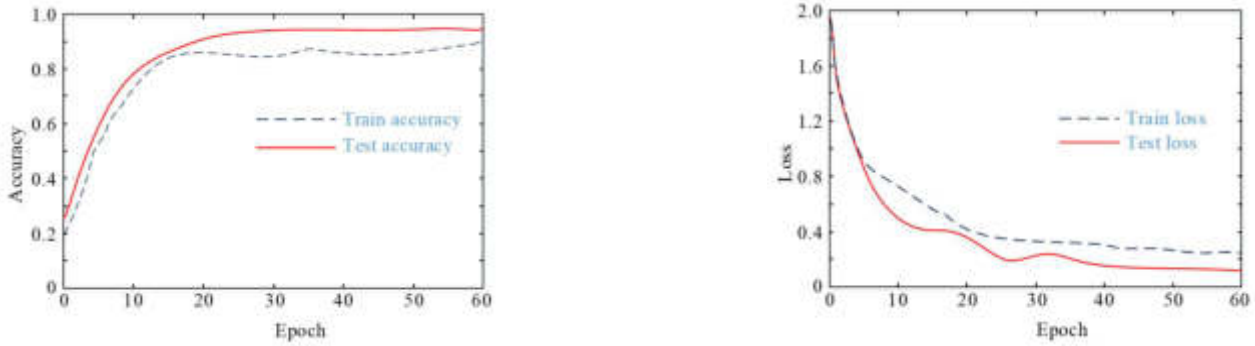
The RT-CNN model was also trained on both training and test sets in Fig. 4.2 to validate the similarity fusion and CNN-based travel interest point recommendation algorithm. The accuracy of the CNN-based recommendation algorithm in the test set was 94.8%, which was higher than the value in the training set. The loss function value of the method was 0.13 in the test set, which was lower than the value in the training set. The method could get better parameter optimization in the test set after learning from the training set.

The accuracy of the RT-CNN model might be affected by the word vector dimension and the number of convolutional kernels. Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were used to verify the influence of word vector dimension and the number of convolutional kernels to improve the application of the mode in Fig. 4.3. MAE is the average absolute value of the deviation between all individual observations and the arithmetic mean, which can better reflect the actual situation of prediction error. The smaller the MSE, the better performance of the model. RMSE represents the sample standard deviation of the difference



(a) Accuracy (b) Loss Value

Fig. 4.1: Accuracy and loss results

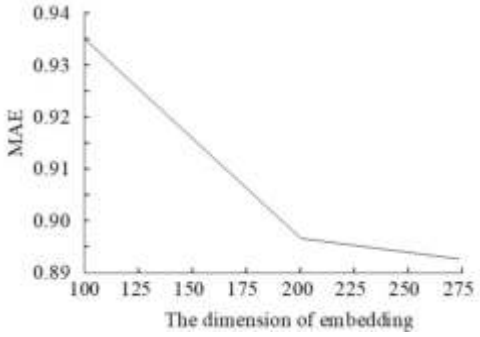


(a) Accuracy (b) Loss Value

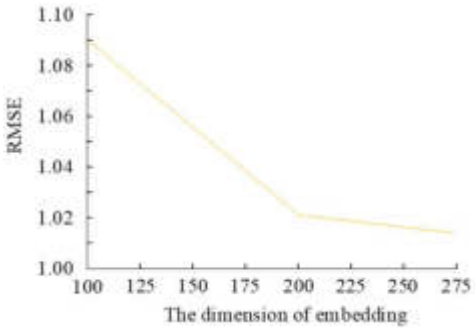
Fig. 4.2: Accuracy and loss results of RT-CNN

between predicted and observed values. RMSE can indicate the dispersion of the sample. When dealing with non-linear fitting, the smaller the RMSE, the better performance of the model. When the size of the word vector dimension was 200, the model's MAE and RMSE values were 0.897 and 1.021, while the model synthesis effect and complexity were the best. When the number of convolutional kernels was greater than 250, the MAE and RMSE values of the model gradually increased. At this point, it might be due to too much feature selection, which led to the occurrence of an overfitting phenomenon, resulting in a decrease in the comprehensive effect of the model. Therefore, the size of the word vector dimension was set to 200 and the number of convolutional kernels was set to 250 in the subsequent experiments.

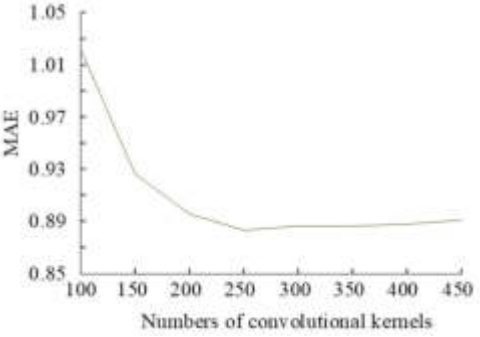
Regarding the performance evaluation of the above point-of-interest recommendation algorithm, the more widely used evaluation metrics were selected, which included the Precision (P), Recall (R), and the ratio of the two (F1). P is the proportion of correctly predicted positive classes to all predicted positive classes. A high P means that it is definitely positive as long as it is recognized as positive. It focuses on dividing indistinguishable samples into negative samples, examining whether the identified positive samples are reliable. R is the proportion of correctly predicted positive classes to all actually positive classes. A high R means that it can be recognized as long as it is positive. It focuses on dividing indistinguishable samples into positive samples, examining whether they are sensitive to positive samples. The F1 value is a measure of the classification problem



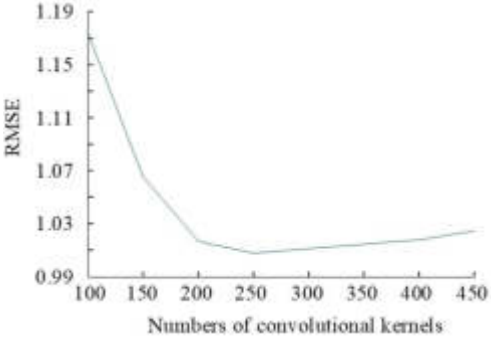
(a) MAE of different dimenssion of word embedding



(b) RMSE of different dimenssion of word embedding



(c) MAE of different number of convolutional kernels

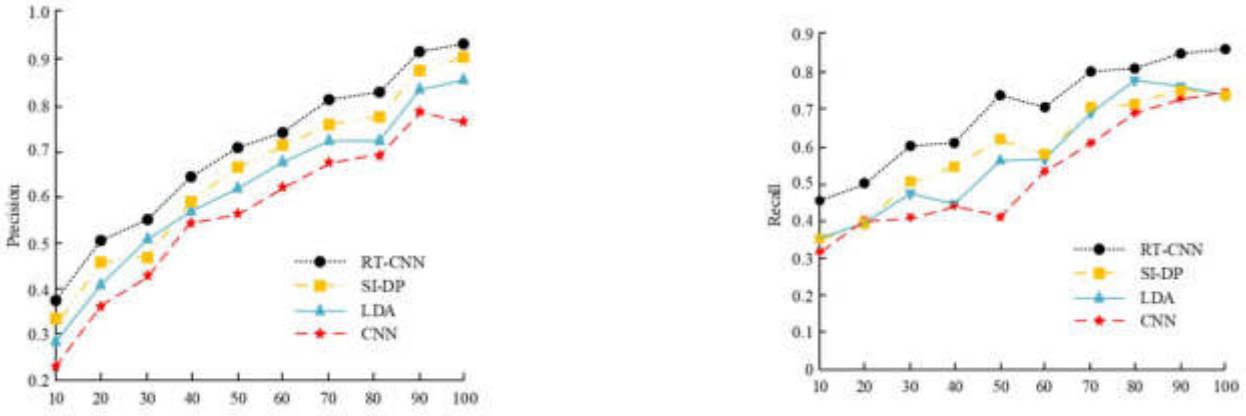


(d) RMSE of different number of convolutional kernels

Fig. 4.3: Accuracy and loss results of RT-CNN

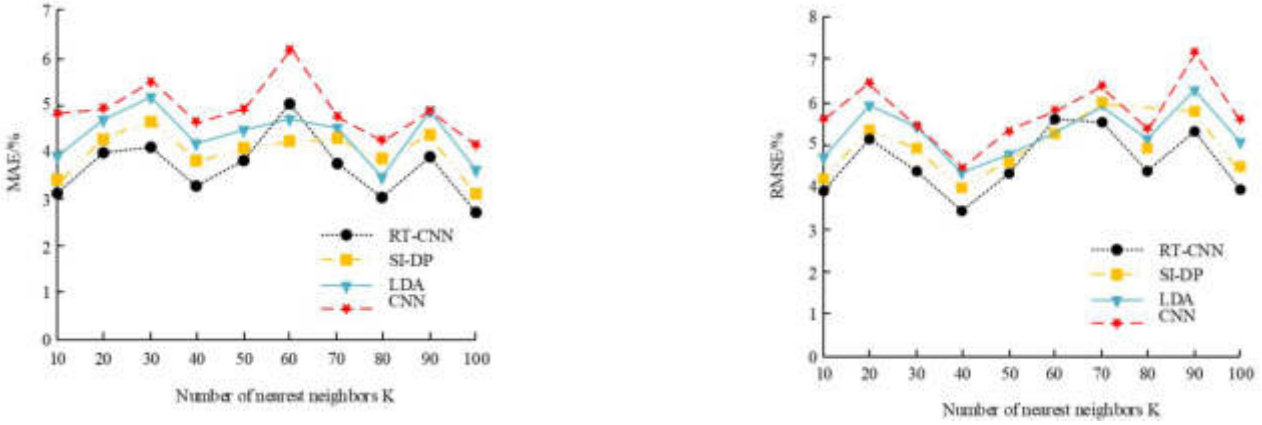
and can be used to evaluate the quality of a model. It is the harmonic mean of P and R, with a maximum of 1 and a minimum of 0. The higher the F1 value, the better the performance of the model. The difference in the metrics between the RT-CNN model, literature model [21], LDA model, and traditional CNN model were compared in Fig. 4.4. The R of the RT-CNN model was 92.7%, which was higher than the other models. The R of this model was 87.1%, which was the highest among all models, indicating the superior performance of the RT-CNN model. The MAE and RMSE metrics could be used to validate the P and R metrics with confidence in Fig. 4.5. The average MAE value of the RT-CNN model was 4.2% and its average RMSE value was 4.8%, which were lower than the literature model, LDA, and the traditional CNN, proving the results were accurate. The reason was that the LDA topic model was utilized to mine users and their interests. Then the similarity between LDA and check-in matrix was calculated and fused. On this basis, an RT-CNN model was established to extract deep features from comment information, and interest point recommendations were made by integrating factors such as similarity, check-in behavior, and geographic location. This effectively improved the accuracy of the model and was superior to existing methods.

To further verify the effect of RT-CNN model P and R, some data in Yelp dataset were selected as datasets 1 and 2 to verify whether the F1 value of the model was consistent with the results of P and R in Fig. 4.6. The F1 values of the RT-CNN model were 89.2% and 88.7%, which were higher than other algorithms and consistent with the above results of P and R metrics, which further verified the accuracy of the experimental results. The reason was that the CNN was introduced into the model for value filtering of user comment information, which could accurately reflect the characteristics of interest points. The proposed method aggregated all comment



(a) Precision (b) Recall

Fig. 4.4: Precision and recall results of RT-CNN

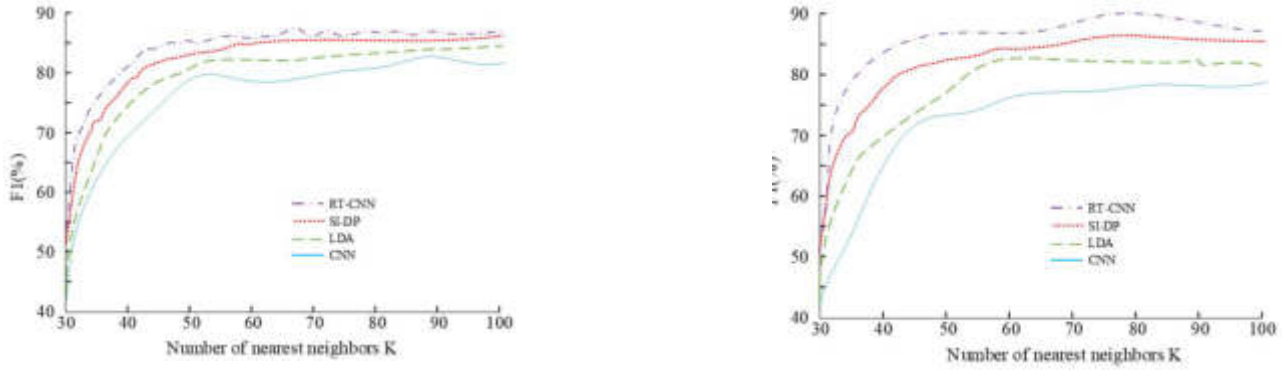


(a) MAE (b) RMSE

Fig. 4.5: Comparison of MAE and RMSE

information related to interest points and distinguished user comment information to a certain extent. This was beneficial for improving the recommendation accuracy of the model and fully reflecting limited data information.

Precision-Recall (PR) curve is a comprehensive judgment of precision and recall. This study compared the performance of the RT-CNN model, literature model, LDA, and traditional CNN in Fig. 4.7. PR comprehensively considers the situations of correct classification and incorrect classification. It has high practicality in extremely imbalanced data. But when the proportion of positive and negative samples is different, it will show significant differences. Therefore, PR can serve as a reference for model performance evaluation. The area under the PR curve of the RT-CNN model were higher than that of literature model, LDA, and traditional CNN, which proved that the travel interest point recommendation algorithm in this experiment had better accuracy. The reason was that the algorithm proposed in the experiment extracted some user comments during the information extraction, which were used to reflect the characteristics of the points of interest. This algorithm could effectively solve the inaccurate feature extraction caused by the lack of importance differentiation for



(a) Dataset1

(b) Dataset2

Fig. 4.6: F1 value of RT-CNN

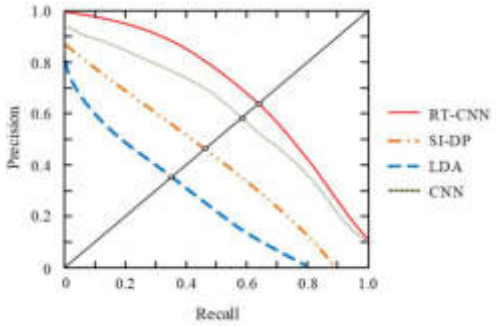
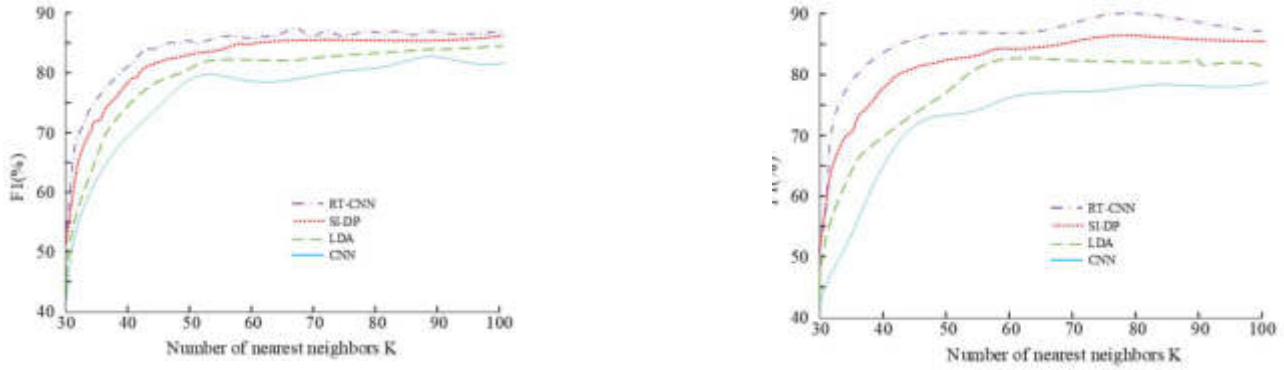


Fig. 4.7: Comparison of PR curves of different algorithms

documents. Meanwhile, it only filled in nearest neighbor access when the user's nearest neighbor had missing access to a certain point-of-interest, effectively improving the execution efficiency of the algorithm.

At the same time, the Receiver Operator Characteristic (ROC) curves of the RT-CNN model, literature model, LDA, and traditional CNN were compared in Fig. 4.8. ROC is an integrated metric that reflects the sensitivity and specificity of continuous variables, and each point on the ROC curve reflects the sensitivity to the same signal stimulus. The steeper the ROC curve, the better the performance of the model. The larger the area between the curve and the horizontal axis, the better the performance of the classifier. The ROC curve can be used to determine which of the two classification methods is better, or to evaluate different parameters of the same classification method and select the best parameters. Fig. 4.8a shows the validation ROC curve plot and Fig. 4.8b shows the recognition ROC curve plot. The area under both the validation and recognition ROC curves of the RT-CNN model was higher than that of the literature model, LDA, and the traditional CNN, indicating that the RT-CNN model proposed in this experiment achieved better results.

In summary, the proposed model achieved good results in all indicators. This article studied the extraction of word features from text information in algorithms to improve the accuracy of latent representation of interest points. However, the emotional factors contained in the textual information were not explored to better fit user preferences. In addition, the features extracted by the CNN model could not be artificially interpreted, so the interpretability of the recommendation results was poor. Therefore, the performance of the model still needed further improvement. The user-interest point check-in matrix and text information to model user preferences



(a) Verification of ROC Curve

(b) Detection and Identification of ROC Curve

Fig. 4.8: ROC curve

were utilized and the interest point feature information was extracted. There was a possibility of overfitting in the proposed model. The reason was that the criteria used to select a model were different from those used to determine its applicability. Therefore, the model could be selected by maximizing its performance on certain training datasets. In future work, it needs to consider incorporating factors such as geographic location, time, popularity, and user friendly relationships from check-in data into the algorithm, and combining them with matrix decomposition to alleviate data sparsity issues.

5. Conclusion. In this study, a travel interest point recommendation algorithm was built based on similarity fusion, and this recommendation algorithm was optimized using CNN to improve the performance of the model such as accuracy. Finally, an RT-CNN travel interest point recommendation model was generated. In the experimental results, the size of the word vector dimension of the model was set to 200 and the number of convolutional kernels was set to 250. The P of the RT-CNN model was 92.7%, which was higher than other models. The R value of this model was 87.1%, which was the highest among all models. The average MAE value was 4.2% and the average RMSE value was 4.8%, both lower than the literature model, LDA, and the traditional CNN. The F1 values in both datasets were 89.2% and 88.7%. The PR and ROC curves of the model were also plotted both agree with the results in P and R. The similarity fusion-based travel interest point recommendation algorithm proposed in this experiment had better performance and better overall results after combining with CNN. Although the recommendation model in the experiment has achieved good application results, there are still some shortcomings. For example, the feasibility, innovation, and spatial complexity of recommendation algorithms are considered in reality. But the time complexity in recommendation algorithms is less considered. In the next research work, more consideration will be given to the time complexity of the algorithm. This paper will explore the emotional factors contained in textual information to better fit user preferences and further improve algorithm performance. In future work, it is necessary to consider incorporating factors such as geographical location, time, popularity, and friend relationships among users into the algorithm based on check-in data. Meanwhile, it is necessary to combine it with matrix factorization to alleviate the problem of data sparsity. It is hoped that further optimization of the algorithm can be effectively used in travel interest point recommendations for different populations.

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RESEARCH ON THE TEACHING MODEL OF ENGLISH TEACHING QUALITY EVALUATION UNDER THE BACKGROUND OF MOOC

XIAO QIN*

Abstract. In the context of informatization, online teaching is increasingly favored by people for its convenience and resource richness. Through the Open CourseWar (MOOC) platform, people can easily access learning resources and achieve efficient line length learning. However, currently MOOC online learning cannot provide targeted evaluation for the learning effectiveness of English learners, and there is relatively little research on online English quality assessment. Propose an intelligent MOOC online English teaching evaluation technology. Firstly, analyze the existing English teaching factors and construct a quality evaluation system for online English teaching using Principal Component Analysis (PCA) and expert evaluation method. Considering that the quality of English teaching is influenced by many factors, the evaluation of English teaching quality belongs to a complex nonlinear solving problem. Therefore, the advanced GA-RBF (Genetic Algorithm Radial Basis Function Neural Network, GA-RBF) model is adopted to solve the English teaching quality evaluation model. In teaching quality evaluation, BP and RBF are selected to participate in comparative testing of teaching quality evaluation. In the training loss test of multiple models, the GA-RBF model has the best convergence speed and training performance in the oral sample test, tends to converge after 270 iterations, with a loss value of 0.24. In the evaluation of English proficiency indicators, the BP model has a significant error in testing, with an error of 13 in the evaluation of reading ability scores. The error of RBF in reading ability score evaluation is 4, and the GA-RBF model performs the best. The reading ability evaluation error is 1, and the overall evaluation performance is the best. Through the above research, an intelligent method for evaluating the quality of English teaching is proposed, which will provide important technical references for MOOC online education evaluation and English teaching improvement.

Key words: MOOC; English teaching; PCA; GA-RBF; Quality evaluation

1. Introduction. In the context of informatization, online teaching is increasingly favored by more and more people due to its convenience and abundant resources. Through the Open CourseWar (MOOC) platform, people can easily access learning resources and achieve efficient online learning. MOOC English plays an important role in English teaching. MOOC English teaching provides learners with a comprehensive learning experience through online videos, interactive discussions, online quizzes, and other functions. Learners can learn English listening and speaking skills by watching professional teaching videos [1]. Online lectures provide deeper knowledge learning, allowing learners to understand more English grammar and vocabulary. Forum discussions provide a platform for learners to interact and exchange ideas, allowing them to share their learning experiences and solve problems with other learners [2].

Online assignments and quizzes are used to help learners verify their learning outcomes and deepen their understanding of knowledge. However, there are some shortcomings in the current MOOC online learning. Especially in terms of evaluating the learning outcomes of English learners, targeted evaluations cannot be conducted, and the evaluation results cannot meet the learning requirements of learners [3].

To address the aforementioned issues, a research proposes an intelligent method for evaluating the quality of English teaching. This technology combines expert method and principal component analysis to explore learner influencing factors and construct a teaching quality evaluation system. At the same time, a fusion GA-RBF (Genetic Algorithm Radial Basis Function Neural Network) learning model is introduced to analyze and evaluate data, thereby achieving effective evaluation of MOOC online English teaching. The innovation of this study mainly includes two aspects. Firstly, a quality evaluation system suitable for MOOC English teaching was constructed through principal component analysis and expert evaluation, providing a targeted method for evaluating English learning effectiveness. Secondly, the study adopted the GA-RBF model to solve the English teaching quality evaluation model, achieving personalized evaluation of learners and improving

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accuracy. The significance of this research lies in the proposal of intelligent MOOC online English teaching evaluation technology, which can improve the learning effectiveness and self-learning ability of English learners. Secondly, this study can promote the development and improvement of MOOC English teaching, providing high-quality online learning resources for more learners.

2. Related Work. Good education analysis is the essential to ensure the effective implementation of education. Through effective education and teaching evaluation, it can provide important reference for the optimization and Improving classroom quality. Educators at home and abroad have carried out in-depth research on this. A study on the association between teacher mobility and headmaster effectiveness was conducted by Grissom JA et al. The study found that in actual teaching activities, teachers do not need to be retained equally. On the contrary, more powerful principals will try their best to retain excellent teachers and build a more comprehensive teacher team. Through the analysis and evaluation of the ability system of teachers, it will be found that teachers with high ability have better classroom teaching effect and lower turnover rate. And this study can also provide valuable advice for the evolution of modern education and improve the current educational effect. The research content will significantly improve the teaching quality of the teacher team, optimize the teaching structure, and promote the comprehensive development of education [4].

Han et al. conducted research on the existing education quality evaluation. Due to the imperfect system, classroom teaching evaluation faces many problems. To improve the quality of classroom education, the AHP is used to analyze the physical education in in higher education. to clarify the relevant factors affecting teaching and to build a teaching model. Through specific case analysis, the quality evaluation model constructed according to the existing teaching Can be effectively applied in a sports education environment and improve the teaching effect [5].

Close et al. conducted a study on a student bill promulgated by the US government, which removed the government's assessment of teacher competence. According to various survey data, different regions adopt different evaluation methods to evaluate teachers and students, and gradually reduce the evaluation of student violence. The teacher observation method is used to assess student development, and Meanwhile, it pays attention to the completion of the student's Learning Goals and uses it as the standard for evaluating student development. And this research will strengthen the management of teaching and improve the current teaching environment [6].

Nazari-Shirkouhi et al. analyzed the current teaching management in colleges and universities and found that using performance to adjust teaching functions is conducive to solving teaching problems and implementing more efficient teaching content. Therefore, the existing university management is analyzed, the balanced scorecard is used to determine the university services and activities, and the fuzzy decision-making scheme is used to realize the performance evaluation of the existing university teaching management. Meanwhile, an effective index is put forward as the weight of performance evaluation, which is linked with the cost and policy of education. Through this evaluation model, it can better reflect the management effect of colleges and universities, and help higher education to customize more effective teaching management policies and improve the quality of coursest of higher education [7].

Artificial intelligence and other technologies have been actively used in teaching management and teaching evaluation. Lino A and others found that virtual digital technology has achieved effective results in education and teaching, but due to the influence of teaching characteristics and factors of teaching itself, the existing teaching evaluation methods are facing accuracy problems. To this end, the teaching factors and inferred variable relationships are analyzed, and a new evaluation model is proposed, which uses neural networks to diagnose factor problems. Finally, the proposed evaluation model is applied to a specific teaching scenario. The proposed scheme the influence of complex factors on the evaluation of teaching and learning can be stopped in prediction and evaluation. and Meanwhile greatly Improving productivity [8].

Qianna and others conducted research on the existing intelligent teaching, and the evaluation of the quality of intelligent curriculum Education is the key to improving the quality of current education. However, at present, some intelligent education evaluation models are facing the problem of inaccurate predictions, mainly due to the influence of teaching environment factors, which cannot accurately evaluate the teaching status. Aiming at improving the accuracy of Subject Effectiveness Evaluation, the teaching feature information is extracted based on intelligent learning algorithms, and a classroom quality assessment model is constructed based on intelligent

algorithms. Applying the proposed scheme to a specific teaching environment, the quality assessment model introduced has good predictive performance and meets the relevant requirements of teaching development [9].

De-kun et al. studied the existing intelligent sports evaluation scheme and found that it ignored the labeling of key teaching tasks, resulting in large errors in the teaching evaluation of the algorithm and a long time-consuming. Therefore, the existing physical education teaching tasks are analyzed, and a brand-new intelligent evaluation scheme is designed, which uses an advanced learning model to mark the teaching objectives and tasks. Meanwhile, through the analysis of relevant factors of sports management, the weight of key factors in teaching is clarified, and a quantitative evaluation model is constructed. Finally, the optimized genetic model is used to solve the question. The final test shows that the proposed solution model has the best performance and is suitable for the current teaching quality requirements [10].

Goli A et al. conducted a study exploring the possibility of achieving educational democratization by increasing enrollment rates. This study investigated the impact of paid certificate purchase options on course content engagement, considering two aspects: certificate effect and sunk cost effect. The study used data from over 70 courses on the Coursera platform and analyzed the participation of individual participants at different milestones. Research has found that the certificate effect and sunk cost effect increase user engagement by approximately 8% -9% and 17% -20%, respectively. The sunk cost effect is short-lived, lasting only a few weeks after payment, while the certificate effect persists until participants reach the level required to qualify for the certificate. This study reveals the important role of price and payment in realizing the potential of MOOC, providing important references for further research and optimization of MOOC education. Compared with the technology studied, this study mainly focuses on the payment preferences of learners and does not fully consider the impact of personalized teaching. Therefore, further research will be conducted on the evaluation of MOOC online education [11].

Luo R et al. conducted a qualitative study aimed at investigating the quality assurance issues of large-scale open online language courses (LMOOC). They adopted a grounded theory approach and analyzed the evaluation of LMOOC quality from the learner's perspective. The study collected evaluation data from 1000 English as a Second Language (ESL) learners on iCourse, the largest MOOC platform in China, and examined the cognitive and perceptual influencing factors of learners towards LMOOC. Based on the research findings, they identified specific quality standards for five types of LMOOC courses, including ESL courses for oral, reading, writing, cultural research, and comprehensive skills. This study provides a foundation for establishing a quality standard framework for LMOOC and designing effective online language courses to meet the needs of different language learners. However, the aforementioned study did not fully consider the impact of English teaching on personalized assessment of learners, and further research will be conducted in the future [12].

Ren et al. proposed a theoretical based method for evaluating the quality of English MOOCs to address the issue of unreasonable weight distribution in existing evaluation indicators. This method constructs a framework for evaluating the quality of English MOOCs and determines the overall teaching objectives. On the basis of selecting MOOC quality evaluation indicators, Analytic Hierarchy Process (AHP) is used to determine the weight values of each evaluation indicator, and fuzzy algorithm is used to evaluate the comprehensive evaluation indicators of each level. Obtain the quality evaluation results of English MOOCs through comprehensive calculation. The quality evaluation method of English MOOC based on grounded theory can provide a reasonable weight distribution and evaluate the quality effect of MOOC. This study provides a feasible and effective method for evaluating the quality of English MOOC, which can help measure and improve the teaching quality of MOOC, thereby providing a better learning experience and outcomes. This study did not fully consider the impact of various factors on learners, and future research will add expert knowledge base to further improve the research [13].

A good teaching assessment will not only clarify the focus and difficulties of teaching. but also provide effective reference for teaching management and teaching planning. Online teaching such as MOOC has been facing problems such as inaccurate teaching evaluation. Innovations in modern educational technology and the spread of smart technology in teaching and learning scenarios are important in improving online English language teaching.

3. Construction of English teaching quality evaluation model under the background of MOOC. With the advent of the information network era, the existing English education is undergoing earth-shaking

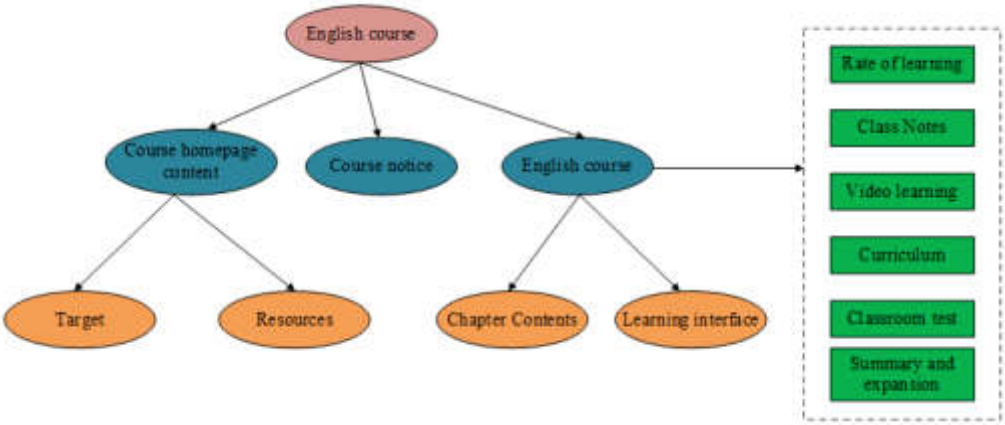


Fig. 3.1: Functional structure of the MOOC English teaching platform

changes, and the open network MOOC education provides an important technical reference for modern English teaching. Using big data mining technology and intelligent management technology, students and teachers can complete a series of English teaching tasks in MOOC. The functional structure of the open MOOC English teaching platform can be seen in Figure 3.1 [14].

Under the MOOC English platform, students can purposefully log in to the MOOC learning interface based on teaching tasks and course arrangements, and complete teaching tasks such as English online teaching and academic testing. However, in the current online MOOC teaching, teaching quality evaluation still faces problems. Traditional evaluation systems cannot adapt to different types of scholars and have poor accuracy in evaluation. Propose an intelligent online English evaluation technology for this [15]. This technology will analyze the factors of online English learning and use PCA method to screen the main influencing factors, thereby constructing an English teaching quality evaluation system. Principal component analysis (PCA) is a technique for simplifying datasets. It maps high-dimensional data to low dimensional space through linear transformation, reducing the dimensionality of the data while preserving as much information as possible, and mining useful data information [16]. PCA is an analytical method that transforms a set of variables into another set of variables through orthogonal transformation, thereby achieving dimensionality reduction of data. The principle is shown in Figure 3.2.

The PCA method is based on the concept of dimensional processing, and the teaching evaluation index is used as the dimension reduction data. For evaluation indicators that are not strongly related to teaching quality, through PCA dimension reduction processing, redundant and overlapping teaching indicator information can be removed, and the most critical indicator data can be retained [17]. Then define the MOOC English teaching index set as X, as shown in formula (3.1).

$$X = (X_1, X_2, ..., X_p) \tag{3.1}$$

In formula (3.1), $X_1, X_2, ..., X_p$ both represent the English teaching index factor and $p$represent the quantity of English teaching index. Due to the large differences in the various evaluation index factors in MOOC English teaching, the accuracy of the final teaching quality evaluation. Therefore, PCA is used to perform dimensionality reduction operations on all English teaching indicators, as seen in formula (3.2).

$$\bar{x}_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j} \tag{3.2}$$

In formula (3.2), the $\bar{x}_j$ expression is as seen in formula (3.3).

$$\bar{x}_j = \frac{1}{n} \sum_{i=1}^{n} x_{ij} \tag{3.3}$$

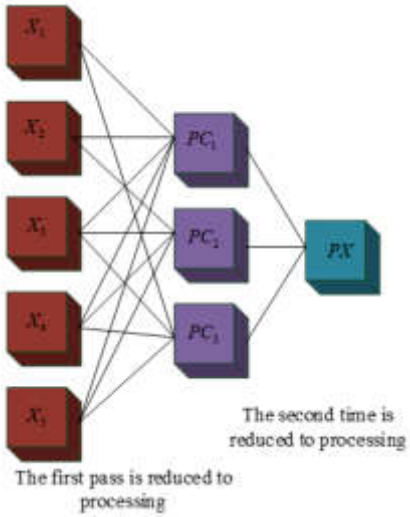


Fig. 3.2: Schematic diagram of PCA dimensionality reduction processing

In formula (3.3), it x_{ij} represents the ith teaching index factor of the jth teaching and the s_j expression is as seen in formula (3.4).

$$s_j = \frac{1}{n-1}\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2 \tag{3.4}$$

After standardizing the complex index factors of English teaching, the correlation coefficient matrix between the index and quality is calculated, as shown in formula (3.5).

$$R = (r_{ij})_{p \cdot p} \tag{3.5}$$

In Equation (3.5), it r_{ij} represents the correlation coefficient i of the jth teaching index factor of the th teaching, and the r_{ij} calculation is as seen in Equation (3.6).

$$r_{ij} = \frac{1}{n-1}\sum_{k=1}^{n}\bar{x}_{ki}\bar{x}_{kj} \tag{3.6}$$

In formula (3.6), $\bar{x}_{ki}$ represents the kth i teaching index factor of the th teaching, and $\bar{x}_{kj}$ represents the kth index factor of the th teaching j. After the incidence matrix is solved, the characteristic equation needs to be constructed, as seen in Equation (3.7).

$$\lambda u = Ru \tag{3.7}$$

In formula (3.7), λ denotes the eigenvalue and $u$denotes the eigenvector, then the calculation of the index eigenvalue is as seen in formula (3.8).

$$\lambda = (\lambda_1, \lambda_2, \lambda_3, ..., \lambda_p), \lambda_1 \geq \lambda_2 \geq \lambda_3 \geq ... \geq \lambda_p \geq 0 \tag{3.8}$$

The calculation of index feature vector is seen in formula (3.9).

$$u = (u_1, u_2, u_3, ..., u_p) \tag{3.9}$$

Table 3.1: Evaluation model of Teaching Effectiveness

Evaluation target	Level 1 evaluation index	Secondary evaluation index
MOOC Teaching Effectiveness evaluation	Teaching content	Contact actual
		Full of content
		Depth of knowledge
		Accuracy of theoretical concepts
	Teaching method	Way diversity
		Focus on personality
		Cultivation of innovation consciousness
		Good at inspiring
	Teacher's comprehensive ability	Teacher teaching level
		Professional level
		Teaching objectives are clear
	Teaching effect	Comprehensive quality
		Problem solving ability
		Depth of knowledge
		learning interest

After constructing the characteristic equation, it is necessary to calculate the contribution of the main components of the MOOC English teaching index factor, as seen in formula (3.10).

$$\xi = \sum_{i=1}^{p} a_i \tag{3.10}$$

In formula (3.10), it a_iRepresentative contribution rate. iIn the actual MOOC English education, the selected teaching index factors will be as many as possible, but it will affect the teaching quality evaluation when constructing the teaching evaluation index system [18]. To evaluate the effect of students' Teaching effectiveness more accurately, it is necessary to select the most representative main indicators among the constructed teaching index factors. If the contribution of the sum of the first main components in the $m$construction of the teaching index system is higher than 85%, it can be explained that the selected first $m$index can be used as an evaluation index of teaching quality. After PCA dimensionality reduction, the index factors are more closely related to the teaching quality and can better reflect the actual teaching quality. The MOOC teaching effectiveness evaluation system is shown in Table 3.1.

3.1. GA - RBF solution model construction. The solution of the MOOC English teaching quality evaluation model belongs to a complex nonlinear solving problem. In order to more accurately evaluate the effectiveness of MOOC English teaching quality, the RBF model is adopted to solve the teaching quality evaluation problem [19]. Among them, RBF has the ability of nonlinear mapping, which can map the input space to high-dimensional feature space by introducing nonlinear functions, making linearly inseparable problems linearly separable in high-dimensional space. However, RBF faces parameter configuration issues when dealing with complex data problems. Therefore, the GA algorithm is used to optimize the RBF model and construct the GA-RBF solution model. The RBF model belongs to a type of feedforward deep learning network, which has good non-linear fitting ability and can effectively map complex non-linear relationships in English teaching. At the same time, the model also has good global approximation and generalization ability, which can predict and evaluate the situation of English teaching well [20]. The topology of the RBF model is shown in Figure 3.3.

RBF model consists of input, hidden and output three-layer network structure, and the hidden layer is connected by radial basis function. In the test, the English teaching evaluation index data is standardized, and the processed evaluation vector is input into the RBF model And the teaching quality evaluation results are obtained through model training. Define the input vector as X_i, and the output vector as Y_i, as seen in

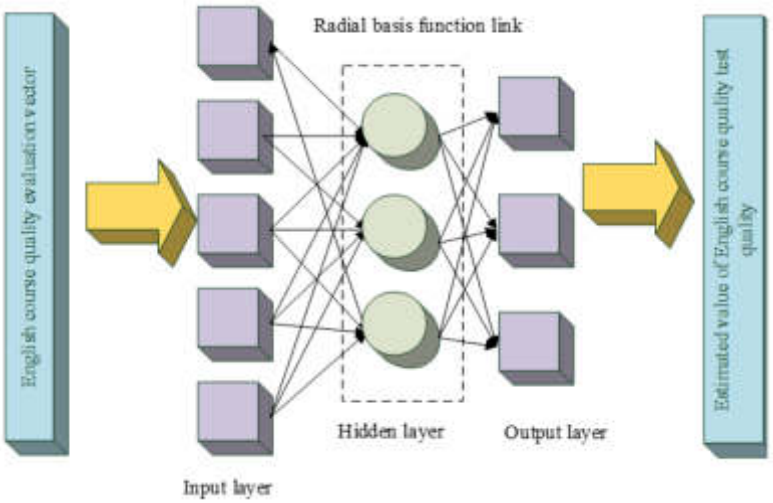


Fig. 3.3: RBF model topology schematic diagram

formula (3.11).

$$\begin{cases} X_i = (x_{i1}, x_{i2}, ..., x_{iN}) \\ Y_i = (Y_{i1}, Y_{i2}, ..., Y_{iN}) \end{cases} \tag{3.11}$$

Gaussian function is chosen as the activation function in RBF model training, as seen in Equation (3.12).

$$\Phi_i(t) = e^{-t^2/\delta_t^2} \tag{3.12}$$

In formula (3.12), δ_t^2 represents the basis function width, then the first output of the RBF model is $k$as seen in formula (3.14).

$$y_{ik} = \sum_{i=0}^{h} w_{ik}\Phi_i(\|X_j - C_i\|) + b_k \tag{3.13}$$

In formula (3.14), w_{ik} represents the weight of the basis function of the hidden layer, represents b_k the offset of the h model corresponding to the first output, and k represents the number of nodes in the hidden layer. In model training, the number of nodes should be selected to meet the learning rate and model accuracy requirements. In the initial training, select a smaller number of nodes and gradually increase them, and then compare the mean square error between the model output value and the expected value to select the hidden layer. Number of nodes [21]. Then the mean square error is calculated as shown in formula (3.14).

$$fStop = \frac{1}{N.m}\sum_{i=1}^{N}\sum_{j=1}^{m}(Y_{i,j} - y_{i,j})^2 \tag{3.14}$$

In formula (3.14), N represents the number of model training samples, Y_{ij} and y_{ij} respectively represents the i expected value and actual value m after the fitting operation of the first sample, and represents the $j$total number of nodes in the output layer.

RBF model faces the problem of model parameter setting during training, so the GA algorithm is used to optimize the RBF model. The GA algorithm is a kind of heuristic algorithm. The principle is to simulate the rules of biological evolution, and find the optimal solution from the population through the population's

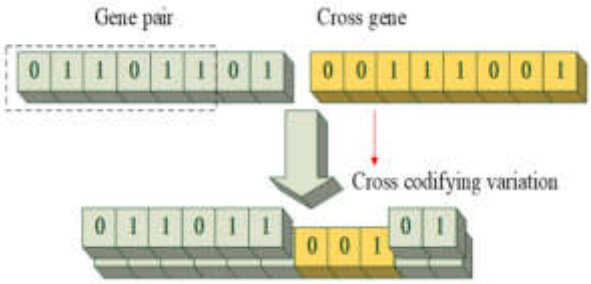


Fig. 3.4: Cross process of GA algorithm

selection, crossover and mutation of chromosomes. In the study, the common roulette method was chosen to calculate the total chromosome fitness of the genetic population, and the proportion of the fitness of a single chromosome was calculated as the probability of chromosome selection, and finally the algorithm operation was completed by using roulette. Since RBF model parameter setting is a continuous parameter optimization problem, floating-point encoding is used to ensure the accuracy of model training, so as to avoid decoding problems in the GA algorithm selection operation. The expression is as seen in formula (3.15).

$$E = 1/\sum_{Kl=1}^{N}(T_l - Y_l) \tag{3.15}$$

In formula (3.15), Trepresents the expected output value of the Y model, represents the actual output value of the model, and N is the total number of chromosomes. Using roulette to calculate and sort the fitness of a single chromosome, the probability of a single chromosome being selected is shown in formula (3.16).

$$p(b_i) = E_{bi}/E \tag{3.16}$$

In formula (3.16), it E_{bi} represents when chromosome fitness. According to the probability of each chromosome being selected, the chromosome with a higher probability of being selected is subjected to evolutionary operation. The crossover operation is to exchange some genes of two chromosome pairs, and a new chromosome pair appears. The principle is shown in Figure 3.4.

In the population crossover operation, the population is selected for crossover operation many times during the evolution, resulting in a larger chromosome fitness value. Therefore, To improve the optimization effect of the algorithm, it is necessary to reconfigure the crossover rate, and increase the probability of chromosome crossover with a small probability after the number of iterations increases. After completing the crossover operation, carry out the genetic variation operation [22]. The mutation operation is a mutation of a certain gene position of a chromosome to generate a new chromosome, as shown in Figure 3.5.

The population generates new chromosomes through mutation operations, which is one of the important processes of GA model optimization. Meanwhile, in the mutation operation, it is necessary to set an appropriate mutation rate. When the mutation rate is large, it can expand the optimization range of the model and enhance the global optimization effect of the model [23]. However, if the mutation rate is too large, it will affect the effect of chromosome selection and crossover, while a small mutation rate is conducive to retaining excellent chromosomes. Therefore, the mutation rate is dynamically set between 0.001 and 0.1, and when the chromosome fitness value is smaller than the average value in the early stage, the mutation rate takes a smaller value. When the chromosome fitness value is higher than the average value, the model mutation rate is gradually increased to ensure the optimization effect of the model. Then the working principle of the whole GA - RBF model can be seen in Figure 3.6.

4. Algorithm model simulation test and analysis. To test the performance effect of the proposed GA - RBF algorithm model, the traditional BP (back propa GA tion, BP) algorithm model and the traditional

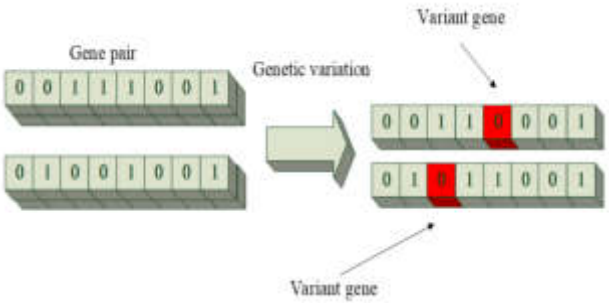


Fig. 3.5: Variation process of population

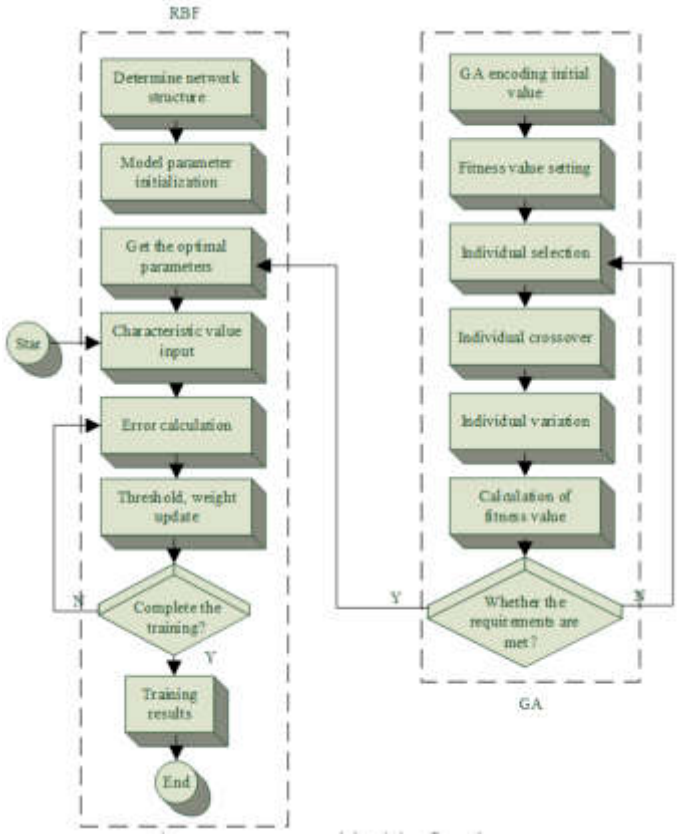


Fig. 3.6: GA - RBF model training flow chart

RBF model will be selected to participate in the performance comparison. The test platform is win10 64-bit system, memory 64g, processor is intel i7. GA - RBF test model parameters are seen in Table 4.1.

The MOOC Teaching Effectiveness evaluation data is selected as the model test data, and the main 15 teaching evaluation index factors are obtained on the basis of the PCA method. Choose 10 for experts in the field of education to score the Teaching Effectiveness index system, and get the weight of each index system, as shown in Table 4.3.

To further evaluate the quality and effect of MOOC English teaching, the MOOC English teaching in a

Table 4.1: GA - RBF model initial parameter values

Model initialization parameters	Parameter value
GA population size	30
Mutation probability	0.4
Number of evolution iterations	10
Crossover probability	0.6
Training step length	1500
learning rate	0.2

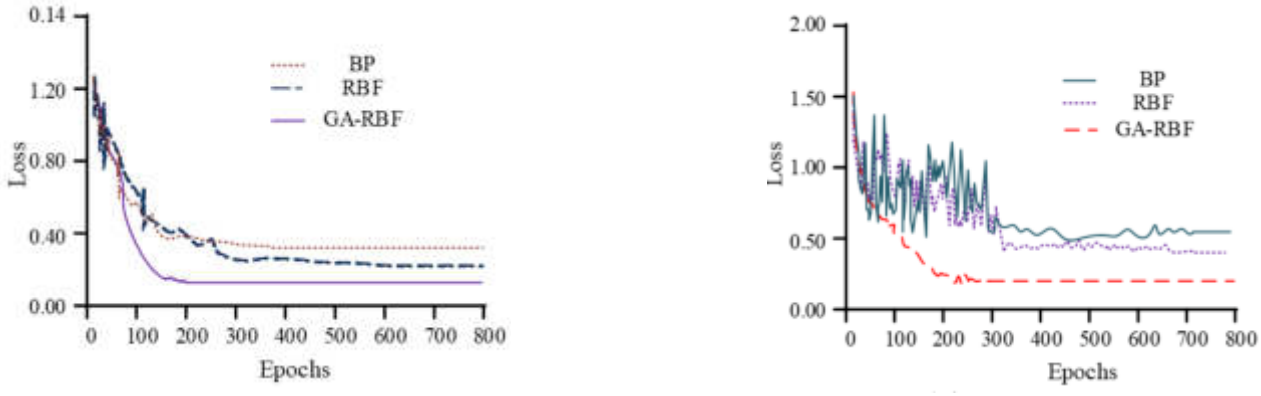
Table 4.2: MOOC English teaching weight index system

Level 1 evaluation index	Secondary evaluation index	Indicator weight score
teaching content	Contact actual	0.08
	Full of content	0.05
	Depth of knowledge	0.06
	Accuracy of theoretical concepts	0.04
Teaching method	Way diversity	0.04
	Focus on personality	0.05
	Cultivation of innovation consciousness	0.06
	Good at inspiring	0.04
Teacher's comprehensive ability	Teacher teaching level	0.05
	Professional level	0.08
	Teaching objectives are clear	0.05
Teaching effect	Comprehensive quality	0.08
	Problem solving ability	0.12
	Depth of knowledge	0.12
	learning interest	0.08

university is selected as the research object, the relevant quality evaluation data are collected from the 15 indicators in Table 3, and 200 English teaching test samples are obtained by scoring by experts. All test sample data are normalized to obtain the model training loss results, as shown in Figure 4.1.

Figure 4.1a Loss test results of multiple models trained on English grammar samples. Formthe graph data that different models have different loss performance in the English grammar sample test. The BP model tends to converge after 400 iterations, and the loss value at this moment is 0.39. The RBF model tends to converge after 600 iterations, and the loss value at this moment is 0.32. The best performance is the GA - RBF model, which tends to converge after 200 iterations, and the loss loss value at this moment is 0.23. From a comprehensive comparison, the BP model has more advantages in the convergence speed than the RBF model, but the accuracy is not as good as the RBF model. Figure 4.1b Loss test results of multi-model training on spoken English samples. Since the characteristic data of spoken language samples are more complex, the effect of the model on data processing is tested. Formthe data in the figure that the test results of the BP model are the worst in terms of convergence speed and model training accuracy. Compared with the BP model, the RBF model has more advantages in the convergence speed, tends to converge after 700 iterations, and the loss loss value at this moment is 0.47. The proposed GA - RBF model has the best comprehensive performance in the oral English sample test, and tends to converge after 270 iterations, and the loss value at this moment is 0.24. It can be seen that the GA - RBF model has the best comprehensive performance in the English sample test. Still choose English grammar and spoken English samples to test the teaching quality evaluation accuracy of each model, with a total of 10 sample data in each group, the results are shown in Figure 4.2.

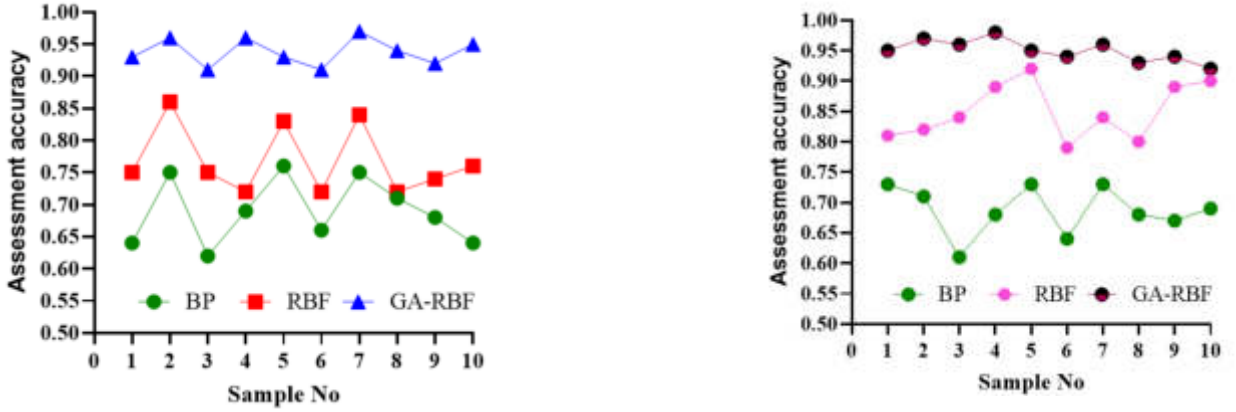
Figure 4.2a Quality evaluation results of multiple models on English grammar samples. According to the data, the three quality evaluation models have large accuracy differences in the quality evaluation of different samples. The BP model has low accuracy in evaluating the quality of a single English grammar sample, for



(a) English Grammar Teaching Test

(b) Oral English Teaching Test

Fig. 4.1: Model training loss test results



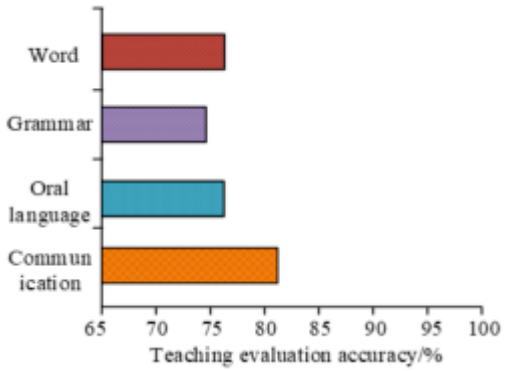
(a) English Grammar

(b) Oral English

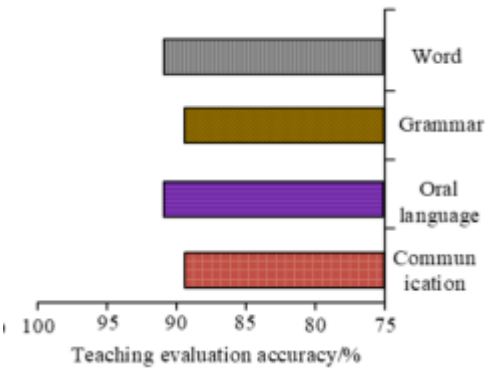
Fig. 4.2: Evaluation accuracy tests

example, the quality evaluation accuracy of sample 3 and sample 10 are 0.61 and 0.64 respectively. Compared with the BP model, the overall quality evaluation accuracy of the RBF model is higher. In the quality evaluation of sample 3 and sample 10, the evaluation accuracy is 0.74 and 0.76, respectively. The proposed GA - RBF model has the best performance in English grammar quality evaluation, and the quality evaluation accuracy is above 0.90. Figure 4.2b Quality evaluation results of multi-model in spoken English samples. The quality evaluation accuracies of BP model in sample 3, sample 6, and sample 9 are 0.61, 0.64, and 0.67, respectively. The quality evaluation accuracies of RBF model in sample 3, sample 6, and sample 9 are 0.84, 0.78, and 0.90, respectively. The quality evaluation accuracies of GA - RBF model in sample 3, sample 6, and sample 9 are 0.96, 0.94, and 0.91, respectively. It can be seen that the GA - RBF model has excellent evaluation accuracy in English quality evaluation. The teaching content of the four aspects of MOOC English teaching, vocabulary teaching, grammar teaching, oral language teaching and social environment, is selected for testing, and the results are shown in Figure 4.3.

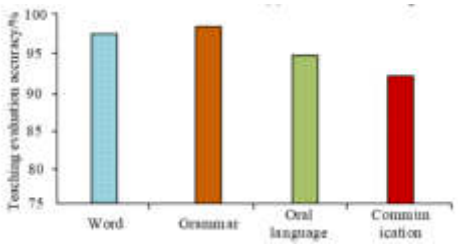
Figure 4.3a BP model Teaching Effectiveness evaluation results. Formthe figure data that in vocabulary



(a) BP model teaching evaluation accuracy



(b) RBF model teaching evaluation accuracy



(c) GA-RBF model teaching evaluation accuracys

Fig. 4.3: Evaluation accuracy results of MOOC English content

teaching, grammar teaching, oral language teaching and social environment, the quality evaluation accuracy of BP model is 77%, 75%, 73% and 81% respectively. Figure 4.3b RBF model Teaching Effectiveness evaluation results. Formthe figure data that in word teaching, grammar teaching, oral language teaching and social environment, the quality evaluation accuracy of BP model is 92%, 88%, 92% and 89% respectively. Figure 4.3c GA - RBF model Teaching Effectiveness evaluation results. Formthe figure data that in word teaching, grammar teaching, oral language teaching and social environment, the quality evaluation accuracy of GA - RBF model is 97%, 98%, 94% and 93%, respectively. Formthe data results that the GA - RBF model has more accurate evaluation accuracy in English content evaluation. Finally, the seven ability indicators in English teaching are selected for prediction, and the average scores are taken. The results are shown in Table 4.3.

Form the test results in Table 3 that the BP model performed worst in the performance prediction of English proficiency indicators, and there was a large error between the predicted performance and the actual performance. For example, in the reading ability test, the predicted score is 85, the actual score is 98, and the error is 13. The best performing model is the GA - RBF model, which has excellent performance in speaking ability, reading ability, and comprehensive ability prediction. It can be seen that the GA - RBF model has excellent performance in the evaluation of MOOC Teaching Effectiveness and meets the development requirements of English education.

5. Discussion. MOOC (Massive Open Online Courses) is an emerging educational model that provides open and free online courses through the internet, providing people with convenient learning opportunities. With the popularization and development of MOOC, the evaluation of its teaching quality has become particularly important. Educational evaluation can help research and understand teaching effectiveness, optimize curriculum design, and improve teaching quality, thereby providing better learning experiences and outcomes. In the past, traditional educational evaluation methods mainly relied on the subjective evaluation of teachers

Table 4.3: Evaluation results of English teaching ability indicators

Evaluation model	Test capacity	Predicted grades	Actual performance	difference
BP	Speaking ability	84	89	5
	Basic ability	94	90	4
	Problem solving ability	84	88	4
	Reading ability	85	98	13
	Writing ability	72	80	8
	Word memory ability	86	80	6
	Comprehensive ability	83	88	5
RBF	Speaking ability	86	89	3
	Basic ability	87	90	3
	Problem solving ability	90	88	2
	Reading ability	94	98	4
	Writing ability	79	80	1
	Word memory ability	82	80	2
	Comprehensive ability	90	88	2
GA-RBF	Speaking ability	90	89	1
	Basic ability	90	90	0
	Problem solving ability	90	88	2
	Reading ability	97	98	1
	Writing ability	82	80	2
	Word memory ability	82	80	2
	Comprehensive ability	87	88	1

and the academic performance of students for evaluation. However, this evaluation method has issues such as strong subjectivity and inconsistent evaluation standards. With the continuous development of technology, evaluation methods based on data analysis are gradually being applied. MOOC English teaching quality assessment is no exception. By collecting and analyzing learner data, teaching effectiveness can be more objectively evaluated, providing accurate feedback and improvement suggestions. This study is based on the Principal Component Analysis (PCA) method, selecting 15 main teaching evaluation indicators in the evaluation of MOOC English teaching quality, and determining the weight indicators through expert scoring. After normalization, model training and loss testing were conducted on 200 English teaching samples.

In this study, the GA-RBF model was chosen as the main evaluation model. Compared with traditional BP models, the GA-RBF model has advantages in convergence speed and accuracy. In English grammar sample training, the GA-RBF model tends to converge after 200 iterations, while the BP model requires 400 iterations to converge. In English speaking sample training, the GA-RBF model converges after 270 iterations, while the BP model requires 700 iterations to converge. This indicates that the GA-RBF model has a faster convergence speed. Secondly, the study also compared the differences in the accuracy of English teaching content evaluation among different models. The results show that the GA-RBF model has higher accuracy than the BP and RBF models in word teaching, grammar teaching, oral teaching, and social environment evaluation. This indicates that the GA-RBF model is more accurate in evaluating MOOC English teaching content. Finally, the study also used a model to predict the scores of English teaching ability indicators. The results showed that the GA-RBF model performed the best in predicting performance indicators, with a small error between the predicted results and actual scores. In contrast, the prediction accuracy of the BP model is lower.

Finally, the proposed technology was compared with literature [12] and literature [13]. Compared with previous research, this study introduced PCA and expert methods in the evaluation of MOOC English teaching quality, and selected the main teaching evaluation index factors. The weight index was determined through expert scoring. Compared with other technologies, it has stronger targeting and is suitable for English learners in more fields. At the same time, the GA-BP model was introduced to optimize the linear data, further improving the overall evaluation of the model. Compared to references [12] and [13], there is a significant improvement in the accuracy of the target audience and evaluation quality.

In summary, MOOC English teaching quality assessment is crucial for improving teaching quality and learning outcomes. This study provides an effective evaluation method by introducing PCA method and GA-RBF model, and has achieved excellent performance in experiments. However, further research and improvement are needed, such as the evaluation model only targeting online English learners, and an offline evaluation system can be added in the future. Strengthening consideration of learner emotions and other factors can further enhance the evaluation effectiveness of the model.

6. Conclusion. Network teaching has become an important development direction of modern education. Taking MOOC English teaching as the research background, a more comprehensive quality evaluation of MOOC English teaching is carried out. Therefore, this paper studies the current situation of MOOC English teaching using the PCA method to reduce the dimensionality of the existing Teaching Effectiveness factors, selects the main English quality evaluation index factors, and constructs the Teaching Effectiveness evaluation system. Considering the complexity of English quality evaluation, the GA-RBF model is used to solve the Teaching Effectiveness evaluation model. In the multi-model quality evaluation accuracy test, the GA-RBF model has the best evaluation accuracy in the oral English quality evaluation, and the quality evaluation accuracy in sample 3, sample 6, and sample 9 are 0.96, 0.94, and 0.91, respectively, which are better than BP model and RBF model. In the MOOC English content evaluation accuracy test, the quality evaluation accuracy of the BP model in vocabulary teaching, grammar teaching, oral language teaching, and social environment is 77%, 75%, 73%, and 81%, respectively. The RBF model is 92%, 88% respectively, and the GA-RBF model is 97%, 98%, 94%, 93%, respectively. It can be seen that the GA-RBF model has an excellent performance in quality assessment. Compared with BP and RBF, GA-RBF is more accurate in predicting the performance of English indicators in the evaluation test of teaching ability indicators. For example, in the reading ability test of BP, the predicted score is 85, the actual score is 98, and the error is 13. The GA-RBF estimated score is 97, the actual score is 98, and the error is 1. It can be seen that the proposed GA-RBF model performs the best in MOOC teaching effectiveness evaluation. Compared with similar evaluation models, it has higher accuracy and better adaptability, which meets the requirements of English teaching. However, there are also shortcomings in the research. The evaluation of English teaching quality mainly relies on algorithmic model solving, and the preset parameters of the model have a significant impact on the evaluation of teaching quality. It is necessary to choose training parameters reasonably to meet the requirements of model training. Meanwhile, in the future, offline evaluation systems can be added. Strengthening consideration of learner emotions and other factors can further enhance the evaluation effectiveness of the model.

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STUDYING THE INFLUENCE OF SCHOOL CULTURE ON HEALTH-RELATED KNOWLEDGE, ATTITUDES AND PRACTICES OF TRADITIONAL CHINESE MEDICINE

BIN LI*

Abstract. With the development of the mobile internet and the intensification of the differentiated behaviour of communication audiences, there are many challenges and difficulties in content dissemination to younger generations about promoting Traditional Chinese Medicine (TCM) and improving health-related behaviour. Current literature lacks information on the association between knowledge, attitude, practice, and campus culture construction. This article investigates the relationship between traditional Chinese medicine (TCM) campus culture construction and health-related knowledge, attitudes, and practices (KAP) among primary campus students in China. It employed structural equation modelling (SEM) to analyze the data. For this study, the data was collected through an online questionnaire from a group of students. Exploratory factor analysis (EFA) and Confirmatory Factor Analysis (CFA) was conducted on data for validation and reliability. The study contributes to the existing literature by providing empirical evidence on the influence of TCM campus culture construction on health-related KAP among primary campus students.

Key words: Structural equation modelling (SEM), knowledge-attitude-practice (KAP), TCM On Campus Campaign (TCMOCC), Campus culture construction

1. Introduction. Traditional Chinese medicine (TCM) culture has a deep heritage, a rich humanistic spirit, and philosophical ideas and is the treasure of traditional culture in China's long history. It is the sum of spiritual and material civilization reflecting the essence and characteristics of TCM in the excellent traditional culture of China [72].

The concept of "diagnosis and treatment" and the cultural connotation of "the harmony of heaven and human" have been positively disseminated worldwide. With the emphasis on holistic and integrated care, TCM's unique clinical efficacy and healthcare philosophy are more readily accepted and sought after by people worldwide. TCM mainly includes acupuncture, herbal medicine, moxibustion, massage and chiropractic [7,10,35].

Since 2016, China has started the "TCM on-campus campaign" (TCMOCC) in different provinces. Some scholars point out that promoting TCM culture on campuses can help enhance the knowledge of TCM culture among adolescents and improve their cultural confidence, a significant event of outstanding merit and benefit for the present generation [77]. Research shows that early exposure of primary and secondary campus students to TCM cultural knowledge is of profound significance in fostering cultural identity, better shaping their worldview and values, and laying the foundation for the cultivation and reserve of talents for the TCM industry [67].

TCMOCCs are mainly distributed in primary and secondary campuses and some colleges and universities. Specific achievements have been made after several years of practice [9,28,76]. Students who have participated in TCMOCC have improved their TCM culture knowledge, positive TCM attitude, and healthy living literacy. They have adopted healthier living behaviours and actively participated in physical exercise [44].

Some studies have shown that the attitude and identification with TCM are closely related to adopting TCM treatment. For example, in mainland China, people have a high level of TCM identity, and their adoption of TCM treatment is 32%, which is much higher than that in Hong Kong [3,6]. Influences on TCM adoption behaviour include self-perceptions of treatment effectiveness, recovery time [39], recommendations from friends [37], the strength of healthy living perceptions [69], and identification with Chinese values and recognition of Confucianism [55].

Numerous studies in different disciplines have found that knowledge has a positive impact on attitudes

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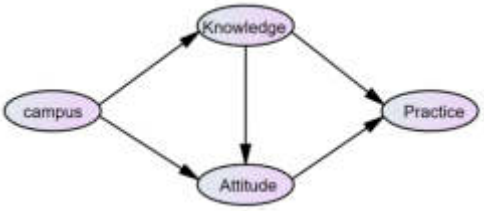

Fig. 2.1: Conceptual Model

and behaviours [45,48,50,55]. Under the knowledge-attitude-practice theory (KAP), health knowledge and information are necessary for belief generation, health attitudes, and health behaviour [13,42].

TCMOCC is essentially an act of communication. According to communication theory [29], the effectiveness of a campaign should focus on five dimensions: communicator, content, medium, audience, and effect. Combining the characteristics of TCM culture, the content of communication should reflect the core values of TCM culture, such as natural view, life view, disease view, medical ethics view, health view, and elephant thinking; expand the communication media, combining traditional gong Fu methods such as taijiquan to spread, using cultural activities to apply at a high level, making full use of traditional media, social media and self-media, etc.; establish feedback and communication effect evaluation system; for the student's attitude towards the adoption of TCM culture, it is related to their campus's support [33,51]. With the development of the mobile internet and the intensification of the differentiated behaviour of communication audiences, there are many challenges and difficulties in content dissemination to younger generations [1,46,65].

Though there is recent literature to provide behavioural analysis and relationships between KAP of TCM and different human groups [32,48,68], the research gap that can be identified from the literature review is the lack of studies that specifically examine the impact of the TCM on-campus campaign on the knowledge, attitudes, and behaviours of students towards TCM. There is a need for more research to establish a causal relationship between TCMOCC participation and changes in knowledge, attitudes, and behaviours towards TCM. It will help policymakers and stakeholders promote TCM culture to younger generations.

This study's main contribution is evaluating the relationship between Chinese primary campus students' knowledge, attitudes, and practices (KAP) regarding health and traditional Chinese medicine (TCM) campus culture construction. The study examines how the TCMOCC has affected students' health-related behaviour and attitudes towards TCM. To analyze the correlation between the study variables and provide insight into the KAP theoretical model, the study used structural equation modelling (SEM).

The organization of the study is as follows: a literature review related to KAP of TCM and various influencing factors is provided in section 2. It gives a comprehensive guide to derive a hypothesis for finding a relationship between TCM KAP and campus culture construction. Section 3 provides information about the sample collection, measurement instrument and statistical modelling required for this study. Various test methodology results are discussed in section 4. Finally, section 5 provides the conclusion of the study.

2. Literature review and theoretical hypothesis. This study aimed to test a conceptual model of the relationship between TCM knowledge, attitudes, behaviours, and campus culture construction, as shown in Figure 2.1. The model demonstrates the importance of knowledge and attitudes in endorsing practice and the influence of campus culture construction on knowledge and attitudes.

Some health research scholars have found that food hygiene habits can be improved if knowledge is provided to consumers; this will lead to increased food safety awareness when shopping and preparing food at home if positive attitudes are adopted towards food safety, food quality, or food integrity [74]. Although it has been proposed that the model is based only on the assumption that knowledge is the primary precursor to behavioural change and does not take into account cultural, social, and environmental influences [52,53], recent studies have shown its importance in pre-planning as well as in shaping behaviour [4,17,41,74].

2.1. The influence of TCM culture knowledge on TCM attitudes. Knowledge is interpreted as understanding what an individual experiences or knows. In contrast, attitude is interpreted as a belief or feeling about something, which can also be defined as "a mental disposition expressed in terms of how good or bad an entity is" [19]. In this study, TCM behaviours can be understood as the choice of TCM treatment, the acceptance of TCM inspections, and the adoption of health life behaviours [10,40,70].

Regarding knowledge-attitude-behaviour theory, knowledge positively affects attitudes and influences behaviour. Mainland TCM students highly identify with TCM culture [14], and over 20% of pharmacy students in Hong Kong express positive attitudes toward using TCM [30]. Knowledge of TCM may generate favourable perceptions of TCM healing behaviours and promote individual recognition of healthy living behaviours. For example, some scholars have found that knowledge of the effectiveness of acupuncture has a positive impact on attitudes towards acupuncture [66]. However, some studies give the opposite conclusion. Some scholars have found in studying food safety cases that even though a person may know what to do, they may not always be willing to do it [16,18].

Based on the literature provided, the following hypothesis was proposed.

1. **Hypothesis 1 (H1)**: Knowledge of TCM positively correlates with attitudes. The influence of TCM cultural knowledge on TCM treatment and Health Life behaviour adoption. The health life behaviours referred to in this study are expressions of what individuals consider desirable and what they think they should or should not do; they belong to the category of individual values [54]. Specifically, health life behaviour refers to the adoption of TCM concepts of disease prevention, treatment, adoption of a healthy lifestyle, and adherence to physical exercise as guiding ideas for daily life. It adopts thinking patterns and behaviours shaped by individual psychological behaviours and influenced by specific cultures [54]. Related studies have pointed out that TCM is not only a resource for disease management but also the incorporation of TCM into the health practices of individuals who can express their cultural identity and transmit their cultural heritage [36]. Various studies have concluded that health literacy may have a positive impact on health behaviours, such as behaviour change in preparation for pregnancy, better oral care, and diabetes management [23,26,59]. In hygienic food handling studies, knowledge is a significant predictor of engaging adolescents in hygiene procedures [47]. There are gender differences [56]; females with higher levels of knowledge exhibit better food safety practices [15,62]. For the influence of TCM knowledge, studies have found that those who have participated in education or training are more motivated to recommend TCM to their peers [9,31]. Younger people with more knowledge of TCM use TCM more frequently than older people [61]; patients' knowledge of TCM can also influence their decision to use TCM [24]. These studies have shown that respondents' high levels of health knowledge can lead them to consider changes in their health behaviours. In this study, the hypothesis that knowledge of TCM culture has a direct impact on self-reported TCM treatment adoption and health and wellness practices was assessed. Therefore, the following hypothesis was formulated.
2. **Hypothesis 2 (H2): knowledge of TCM is positively associated with the adoption of TCM treatment as well as health life practices Influence of attitudes toward TCM on TCM treatment adoption and health life behaviours** In recent research on attitudes toward smoking and behaviour change, mothers decided to raise their infants in smoke-free homes out of worry for their infant's health and the impacts of secondhand smoke inhalation [2]. A study in food health research [58] has shown that consumers with positive attitudes can positively influence their hygiene and cooking habits. A similar study by [64] revealed that consumers who have a positive attitude toward food safety when purchasing food can maintain hygienic behaviour when preparing ingredients for cooking. This practice lowers the risk of disease caused by contaminated food. Another study in the domain of personal health and safety presented by [13] demonstrated that healthy sexual attitudes can influence teenagers' safe sexual activities. According to studies, shared attitudes, values, and beliefs developed via continual learning are crucial for sanitary behaviour [25]. Similarly, attitudes toward TCM are critical in adopting healthy life behaviours. The study found that people with positive attitudes toward herbal medicine had more chance of using TCM [57]. Older adults are far more familiar with and dependent on TCM than adolescents [8]. The elderly group believes that TCM is

more effective than Western medicine. They have a stronger sense of superiority and pride in adopting TCM treatment [55]. Although TCM relies mainly on the accumulation of experience to form the logic of cure, it emphasizes the enhancement of individual immunity and aims to cure the root cause. While Western medicine over-emphasizes the treatment or is known as a cure for the symptoms, and Western medicine may be harmful to the body [63], it is one of the key factors being identified with TCM by older people. Therefore, the following hypothesis was formulated in this study.

3. **Hypothesis 3**(H3): The attitudes toward TCM are positively related to the adoption of TCM treatment as well as health life practices The influence of campus culture construction on knowledge and attitude towards TCM culture Campus culture construction refers to a TCM cultural atmosphere, which can be in the form of guiding individuals to receive TCM education, reading TCM books, conducting TCM cultural forums, TCM lectures, and practising TCM. Campuses are the primary place for cultural education; campus culture is the result of the joint creation of all teachers and students, covering three aspects: material, spiritual and institutional culture; campus culture is one of the main influencing factors of campus identity [71,73,79,80]. It has been pointed out that there are two essential functions in campus culture, value orientation and educational communication, which can influence students' value judgment, behaviour and mindset [71]. The TCMOCC is a vital push to fully form the cultural support of campuses. Therefore, it can be inferred that campus education for primary and secondary campus students with TCM culture courses, TCM culture practices, organization of club activities, and TCM culture lectures. Campus culture construction positively impacts the knowledge, attitudes, and cultural identity construction of TCM culture among adolescents. Therefore, the following hypotheses were formulated in this study.
4. **Hypothesis 4 (H4): Campus culture construction is positively related to knowledge of TCM culture**
5. **Hypothesis 5 (H5): Campus culture construction is positively correlated with attitude of TCM culture** The literature suggests that cultural transmission's effectiveness in TCM represents a niche field with limited correlation between campus culture construction and TCM Knowledge, Attitudes and practices. Various hypotheses from the literature survey validate the conceptual model shown in Figure 2.1. This study not only evaluates educational outcomes regarding knowledge, attitudes, and behaviours but also introduces the dimension of campus cultural support, which enhances the verification of the impact of TCM cultural activities in educational institutions. These activities have only recently been extensively promoted in various provinces in China over the past two to three years. Therefore, it is crucial to ascertain their actual effects by applying appropriate models. This study presents suitable evaluation methods at a reasonable time..

3. Methods. This section details the sample and data collection method, information about measurement instruments and the process of statistical analysis used in this study.

3.1. Sample and data collection. A quantitative survey method was adopted to address the research question. An online-based questionnaire using convenience sampling, using a professional survey provider WenJuanXing (https://www.wjx.cn/), was distributed to Students from participating camps in the TCM on Campus Campaign. The respondents completed the questionnaire in approximately 8–10 min by mobile or desktop computer. The survey was conducted between March 2022 to May 2022, and 329 respondents completed the survey. Data screening and cleaning yielded 309 valid responses and 93.9% reasonable responses. No financial incentives were given after the completion of the questionnaire.

3.2. Sample Selection. The study employed a quantitative survey method, utilizing convenience sampling for participant selection. This non-probability approach was based on the availability and willingness of students to participate, focusing on those enrolled in campuses engaged in the Traditional Chinese Medicine (TCM) on Campus Campaign. The survey, conducted via WenJuanXing, an online platform, facilitated the distribution and collection of responses, highlighting the study's modern data-gathering approach. Inclusion in the study was primarily contingent upon a student at a campus participating in the TCM program without explicit exclusion criteria outlined. However, it can be inferred that non-participants in the TCM program or those unable to consent were likely excluded. The survey garnered responses from 329 students initially, even-

tually narrowing down to 309 valid responses, marking a substantial response rate of 93.9%. The demographic makeup of the respondents, including a mix of male and female students, was noted, although specific details like age range or grade were not provided.

The data collection involved a thorough screening and cleaning phase to ensure response validity, a critical step in maintaining data integrity. Notably, the study did not provide financial incentives for survey participation, a factor that could potentially influence response behaviour. While the pasted text did not explicitly detail ethical considerations, standard practices in research involving minors, such as obtaining informed consent from parents or guardians and ensuring participant confidentiality, are typically expected in such studies. This approach underscores the study's commitment to ethical research practices, which is especially relevant given the involvement of a younger demographic.

3.3. Questionnaire Design. The online questionnaire design for the Traditional Chinese Medicine (TCM) campus culture study was carefully crafted to measure the health-related Knowledge, Attitudes, and Practices (KAP) among primary campus students. The questionnaire was structured into five sections, each targeting a different aspect of the study's focus.

Firstly, the questionnaire included items to measure students' knowledge about TCM. These questions were developed to assess the extent of students' understanding and awareness of TCM concepts and practices. The items for this section were adapted from existing scales in the literature, ensuring they were grounded in prior research and theoretically sound. The second section of the questionnaire focused on students' attitudes towards TCM. This part aimed to capture students' perceptions, beliefs, and feelings about TCM, including its relevance and importance in their lives. The attitude items were also adapted from relevant studies, ensuring they were appropriate for the target age group and educational context. The third section dealt with students' practices related to TCM. This included questions about students' engagement with TCM activities, such as using TCM methods for health and wellness, participation in TCM-related campus programs, and other health-related behaviours influenced by TCM teachings.

Additionally, the questionnaire covered aspects of campus culture construction related to TCM. This part aimed to understand the campus environment and the extent to which it supports and promotes TCM culture, including the availability of TCM resources and activities on the campus. Finally, demographic data, including age, gender, educational attainment, and personal media usage habits, were collected to provide context for the responses and to allow for demographic-based analysis.

For validation, the questionnaire items underwent a rigorous process. This likely included pilot testing with a small group of students to ensure the clarity and relevance of the questions. Feedback from the pilot test would have been used to refine the questions, ensuring they were understandable and appropriate for the age group. Moreover, the reliability and validity of the questionnaire were assessed using statistical methods such as calculating Cronbach's alpha coefficient, which indicated good internal consistency among the variables. This thorough design and validation process ensured that the questionnaire was a reliable and effective for measuring health-related KAP in the context of TCM campus culture.

3.4. Measurement instrument. The questionnaire consisted of five sections to collect the data regarding knowledge (4 items), attitude (4 items), practice (4 items), campus culture construction (4 items) and demographics. The questions for each of the four constructs were appropriately adapted to the scales available in the literature [33,42,48,51,66]. The survey also included additional modules on satisfaction, the Influence of fellow students and partners, and the Influence of family and social environment, which are not reported here. The demographic data, such as age, gender, highest educational attainment, and personal media usage habits, were collected in the first part of the questionnaire.

The knowledge construct, with four items, was adopted from the study of Wang [66], for the attitude construct with four items was adopted from the study of Jian [33], in the practice construct, with four items was adopted from the study of Wang [67], in campus culture construction with four items was adopted from the study of Jian and Pan [33,51]. The measurement of knowledge, attitude, practice, and campus culture construction used the five-point Likert scale (1 = strongly disagree to 5 = strongly agree.). The Cronbach's alpha coefficient showed fair construct reliability for TCM cultural knowledge (= 0.75) and TCM practices (= 0.786), showed good reliability for TCM cultural attitude (= 0.863) and Campus culture construction (= 0.863), suggesting good internal consistency among these variables.

3.5. Statistical analysis. To examine the conceptual framework in this study, Structural equation modeling (SEM) was adopted. SEM is a multivariate analysis technique that incorporates standard methods and extends them. These methods include regression techniques, factor analysis, correlation analysis and path coefficients. The internal consistency and convergent validity were examined to evaluate the reliability and validity of this study. In addition, the path coefficients were assessed in a structural model.

This study used SPSS 22 for descriptive statistics and IBM Amos 21.0 for SEM analysis. ANOVA compared each item among the different age groups. A t-test was used to determine whether there was a gender difference in each measurement item. A chi-square test was used to determine whether there was a difference in gender and some items.

3.6. Exploratory Factor Analysis. EFA was performed to reveal the underlying structure of the data set. It can provide factor loadings, variance explained by each construct, total variance explained, Kaiser-Meyer-Olkin (KMO) coefficient and Bartlett's test of sphericity, as well as the reliability of the data set.

3.7. Confirmative Factor Analysis. Confirmative Factor Analysis (CFA) was performed to assess the correlations between investigated variables and confirm the factor structure extracted in EFA.

4. Result.

4.1. Descriptive Analysis of Data. The study on Traditional Chinese Medicine (TCM) among students provides a detailed insight into their demographics, learning preferences, and attitudes towards TCM. The survey sample consisted of 309 participants, fairly distributed between males and females, with a higher representation of sixth graders. A dual approach was observed regarding learning preferences: traditional media sources for 'knowledge learning' and experiential methods like tasting medicinal cuisine for 'experience'. This diversity underscores a balanced interest in both theoretical and practical aspects of TCM among students.

A notable gender disparity emerged in learning preferences, with female students significantly favouring experiential learning methods, mainly through tasting medicinal food. This indicates a distinct gender-based difference in learning styles. The t-test results revealed significant gender differences in attitude and practice towards TCM, though not in knowledge or campus support. This suggests that while both genders possess similar levels of TCM knowledge, their attitudes and engagement in TCM practices vary.

The Exploratory Factor Analysis (EFA) indicated a well-structured factor model with good convergent and discriminant validity, reinforced by satisfactory composite reliability and Cronbach's alpha values. The Structural Equation Modeling (SEM) analysis revealed positive correlations between TCM knowledge, attitudes, and practices. The data supports the hypotheses that increased TCM knowledge and supportive campus culture positively influence students' attitudes and practices regarding TCM.

Campus culture emerged as a pivotal factor in shaping students' approach to TCM. Educators' promotion of TCM knowledge and healthy living concepts is crucial for cultivating a strong TCM cultural identity among students. The findings suggest that educational strategies should integrate theoretical and practical elements to enhance TCM learning effectively. The study highlights the importance of considering gender differences and the role of experiential learning in fostering a comprehensive understanding and practice of TCM among students.

4.2. Sample characteristics. Of the 309 participants who completed the survey, 157 (50.8% were male, and 152 (49.2%) were female. 116 (37.5%) are now in fifth grade, and 190 (61.5%) are in sixth grade, as shown in Table 4.1.

Regarding preferred channels and pathways for learning about Chinese medicine, the two main dimensions are subdivided into knowledge learning and experience. Knowledge learning includes media information (newspapers and magazines (21.7%), television (21%), lectures (21.7%) and basic courses (15.5%)); experience is mainly of willingness to taste medicinal cuisine (20.1%).

Regarding the preferred mode of learning TCM, more female students wanted to choose experience, that is, to gain knowledge by tasting medicinal food. ρ=0.000<0.01, the difference between male and female students was significant; see Table 4.2 for details.

The t-test of gender in their attitude practice showed a significant difference ($\rho < 0.05$) and no significant difference in their knowledge, TCMOCC ($\rho > 0.05$). See Table 4.3 for details.

Table 4.1: Sample characteristics

	Frequency	(%)
Gender		
Male	157	50.8
Female	152	49.2
Education level		
fifth grade (Form 5)	117	37.9
Sixth grade (Form 6)	192	62.1
Sources of TCM information		
Newspaper & Magazine	67	21.7
Watch the TCM TV program	65	21.0
TCM Lectures	67	21.7
Tasting of medicinal food	62	20.1
Learn the Foundation course of TCM	48	15.5

Table 4.2: A chi-square test for gender differences in learning TCM

	Learning	experience	Pearson Chi-Square	P
Male	139	18	14.72	0.00
	88.5%	11.5%		
Female	108	44		
	71.1%	4.20±0.62		

The t-test of the means of Different grades showed no significant difference in their knowledge, attitude, practice and campus support ($p > 0.05$). The t-test of the means of Different grades showed no significant difference in their knowledge, attitude, practice and campus support ($p > 0.05$).

4.3. Primary campus culture. The commentary on the preliminary study of Traditional Chinese Medicine on Campus Cultural Construction (TCMOCCC) in primary schools highlights a notable gap: the impact of locality (rural, urban, semi-urban) on TCM school culture and learning preferences. This aspect is vital in understanding how students engage with TCM, as their access to resources and learning opportunities can vastly differ based on their geographical location. The study reveals students' diverse learning preferences, including traditional media and experiential methods such as tasting medicinal food. The students' locality could significantly influence this diversity in learning preferences. For instance, urban students might have better access to various media and experiential learning opportunities than their rural counterparts. This difference in access could lead to varied exposure and attitudes towards TCM, potentially affecting the study's generalizability across different locales.

Gender differences in learning preferences, particularly the female students' inclination towards experiential learning, might also be impacted by locality. Urban environments, offering a more comprehensive range of learning experiences, could influence these preferences differently than rural settings.

The study did not find significant differences in TCM knowledge and campus support across educational levels. However, when considering the impact of locality, this uniformity might not hold. Schools in various localities might differ in resources and emphasis on TCM education, influencing students' knowledge and attitudes.

The effectiveness of TCMOCCC, as analyzed through Exploratory Factor Analysis (EFA) and Structural Equation Modeling (SEM), might not fully account for the variations brought about by locality. Factors like community beliefs, accessibility to TCM resources, and regional educational policies could play a crucial role in shaping the outcomes of TCMOCCC.

The study underscores the role of campus culture in shaping students' knowledge and attitudes towards TCM, suggesting that locality-specific strategies might be essential, especially in rural schools where resources

Table 4.3: Gender difference in knowledge, attitude, practice and campus support

	Male	**Female**	**p**
Knowledge	3.97±0.75	3.84±0.61	0.091
Attitude	3.47±1.02	3.15±0.97	0.006
Practice	4.10±0.76	4.20±0.62	0.009
Campus support	2.90±1.17	3.86±0.83	0.149

Table 4.4: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.868
Bartlett's Test of Sphericity	Approx. Chi-Square	2207.286
	df	120
	Sig.	.000

might be limited.

In conclusion, while the study provides valuable insights into students' engagement with TCM, incorporating locality as a variable could enhance the understanding of TCM learning preferences and the effectiveness of TCMOCCC. Future research could benefit from exploring how TCM learning preferences and the success of TCMOCCC vary across different localities, leading to more customized and effective educational strategies.

4.4. Exploratory Factor Analysis. The appropriateness of data was measured by the KMO coefficient, which proved to be meritorious (0.868); Bartlett's test of sphericity was found significant ($p < 0.001$), suggesting patterned relationships among variables and resulting in a meaningful EFA [22]. See Table 4.4 for details.

The Kaiser criterion identified eight factors to retain with eigenvalue > 1, which explained a cumulative variance of 66.187% of the variables in the data. See Table 4.5 for details.

Table 4.6 shows the EFA with a rotated component matrix for this study.

The factor loadings were > 0.5, indicating that convergent validity is present. The rule assessed discriminant validity and stated that items should relate strongly to one extracted component. There were no cross-loadings in EFA, suggesting that discriminant validity existed among the observed variables; see Table 4.7 for details.

4.5. Measurement Model and Confirmative Factor Analysis. In the previous EFA, two items of knowledge, three items of attitude, two items of practice and two items of campus had to be deleted because their loadings were < 0.5. All remaining items had outer loadings of > 0.6 [34]. Therefore, the four-construct had four items for each.

The reliability and validity of the measurement model are summarized in Table 4.8. To examine the reliability and validity of each study construct, the outer loadings were assessed.

The square root of AVE is shown in bold on the diagonal. CR - Composite reliability, AVE is the average variance extracted, and MSV is the maximum squared variance.

The composite reliability of attitude and TCM on campus are over 0.86, which is regarded as satisfactory. Although the Cronbach's alpha of the model was not greater than 0.7, the value of 0.6 was acceptable and indicated that the constructs were reliable [27].

The Cronbach's alpha was higher than 0.7 for the knowledge and practice construct, indicating reliability [27]. Although the Average Variance Extracted (AVE) is lower than 0.5 but higher than 0.4, that can be accepted. Because Fornell and Larcker said that if AVE is less than 0.5 but composite reliability is higher than 0.6, the convergent validity of the construct is still adequate [21,38]. So convergent validity was established in this study.

The final measurement model gained an adequate fit ($\gamma 2/df = 2.003$, CFI = 0.953, GFI = 0.930, AGFI = 0.904, RMSEA = 0.057, SRMR = 0.052, all the latent factors have demonstrated discriminant validity.

Table 4.5: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	5.837	36.478	36.478	5.837	36.478	36.478	2.954	18.461	18.461
2	2.260	14.128	50.606	2.260	14.128	50.606	2.755	17.218	35.678
3	1.410	8.814	59.420	1.410	8.814	59.420	2.503	15.643	51.322
4	1.083	6.767	66.187	1.083	6.767	66.187	2.378	14.866	66.187

Table 4.6: Rotated Component Matrix

	Component			
	1	2	3	4
Campus1	.777			
Campus2	.798			
Campus3	.838			
Campus4	.833			
Attitude1		.783		
Attitude2		.732		
Attitude3		.773		
Attitude4		.752		
Practice1			.739	
Practice2			.765	
Practice3			.761	
Practice4			.707	
Knowledge1				.749
Knowledge2				.635
Knowledge3				.741
Knowledge4				.733

4.6. Structural equation model. The structural equation model (SEM) shown in Fig. 4.1 is based on the conceptual model shown in Fig. 2.1. The questionnaire had four sections that collected data on knowledge (4 items), attitude (4 items), practice (4 items), and campus culture construction (4 items). The structural equation model represents the relationship between each item in each category. Fig. 2 displays the KAP structural equation model with the factor loadings, the standardized path coefficients and the total variance of the practices explained by its predictors. As acknowledged by previous research, self-assessment bias is often present in self-reported practices due to the influence of cognitive biases mediated by judgmental heuristics and their habitus [17]. If in other KAP studies, the nonspecific scale of the variables varies from "Strongly disagree "to "Strongly agree", in this case, the 5-point Likert scale offered a reasonable range of responses [17,75].

This study shows a positive significant correlation between TCM cultural knowledge and TCM attitude ($\beta = 0.493$; $\rho < 0.001$) among students with knowledge related to the relevant information gained through learning and experience. At the same time, practice implies the recurrent actions someone conducts based on their knowledge regarding a particular event, situation, or subject. An increased knowledge of TCM will lead to more responsible health practices.

This hypothesis has been confirmed in different domains, such as in the field of health, where good health knowledge helps to establish hygienic kitchen behaviours [45], safe health knowledge circumvents risky eating behaviours [43,70], healthy general life knowledge leads to a stable and adequate drinking process [11,78], healthy knowledge of sexual behaviour leads to safe sexual practices [13,60]. This suggests that when adolescents' knowledge of TCM culture increases, their adoption of TCM treatment and healthy life behavioural practices also increase.

A positive significant correlation between TCM cultural knowledge and TCM attitude ($\beta = 0.357$; ρ

Table 4.7: EFA with factor loadings, validity and reliability

Constructs and items	Mean	SD	Loadings	Variance, %	AVE	Composite reliability	Cronbach's alpha
Knowledge				6.767%	0.448	0.762	0.758
Knowledge1	4.13	0.887	0.749				
Knowledge2	3.45	1.033	0.635				
Knowledge3	4.10	0.798	0.741				
Knowledge4	3.95	0.880	0.733				
Attitude				14.128%	0.616	0.865	0.864
Attitude_1	3.26	1.188	0.783				
Attitude_2	3.39	1.181	0.732				
Attitude_3	3.24	1.270	0.773				
Attitude_4	3.36	1.155	0.752				
practice				8.814%	0.487	0.791	0.790
Practice_1	4.00	0.989	0.739				
Practice_2	3.75	1.179	0.765				
Practice_3	4.17	0.961	0.761				
Practice_4	3.99	0.975	0.707				
Campus				36.478%	0.615	0.864	0.862
Campus_1	2.86	1.316	0.777				
Campus_2	3.17	1.270	0.798				
Campus_3	2.54	1.352	0.838				
Campus_4	2.68	1.393	0.833				
Total variance explained (%) =				66.187%			

Table 4.8: Model validity and reliability

	CR	AVE	MSV	Knowledge	Attitude	Practices	Campus
Knowledge	0.762	0.448	0.360	0.669			
Attitude	0.865	0.616	0.360	0.600***	0.785		
Practices	0.791	0.487	0.327	0.571***	0.561***	0.698	
Campus	0.864	0.615	0.331	0.224**	0.576***	0.327***	0.784

< 0.001) among students that have TCMOCC, thus supporting hypothesis H2. This indicates that when students' Knowledge of TCM improves, their attitude regarding TCM culture becomes appropriate and vice versa, meaning that students have a positive attitude toward TCM culture if the TCMOCC is more frequent.

Hypothesis 3 suggests that TCM attitude has a significant positive effect on practices (TCM adoption and health life behaviour) ($\beta = 0.352$; $\rho < 0.001$) with a statistically significant difference. This hypothesis indicates that their healthy behaviour will also improve with a more TCM attitude of the students. Students will develop good habits in their daily lives, eat on time, rest on time, and exercise consistently to achieve a healthy body, and they will be more willing to accept the diagnosis and treatment of TCM. This suggests that when student's Knowledge of TCM improves, their healthy activity practices also ameliorate.

A positive significant correlation between campus culture construction and TCM cultural knowledge ($\beta = 0.229$; $\rho < 0.001$) among students that have TCMOCC, thus supporting hypothesis H4.

A positive significant correlation between campus culture construction and TCM cultural knowledge ($\beta = 0.462$; $\rho < 0.001$) among students that have TCMOCC, thus supporting hypothesis H5.

TCM culture is based on unique Eastern philosophical thinking and has special characteristics. TCM cultural mindset is formed implicitly over a long period and requires guidance and education starting from adolescence. The influence of TCM books, TCM forums and TCM extracurricular practical activities can positively affect the enhancement of TCM cultural literacy among adolescents, so campus cultural support is

Table 4.9: Results of structural modelling

Hypotheses	Path coefficient	p	
The knowledge of TCM is positively related to the attitude.	0.493	0.001	Yes
The knowledge of TCM is positively related to the practice.	0.357	0.000	Yes
The attitude of TCM is positively related to the practice.	0.352	0.000	Yes
The campus support is positively related to the knowledge of TCM.	0.229	0.000	Yes
The campus support is positively related to the attitude of TCM.	0.462	0.000	Yes

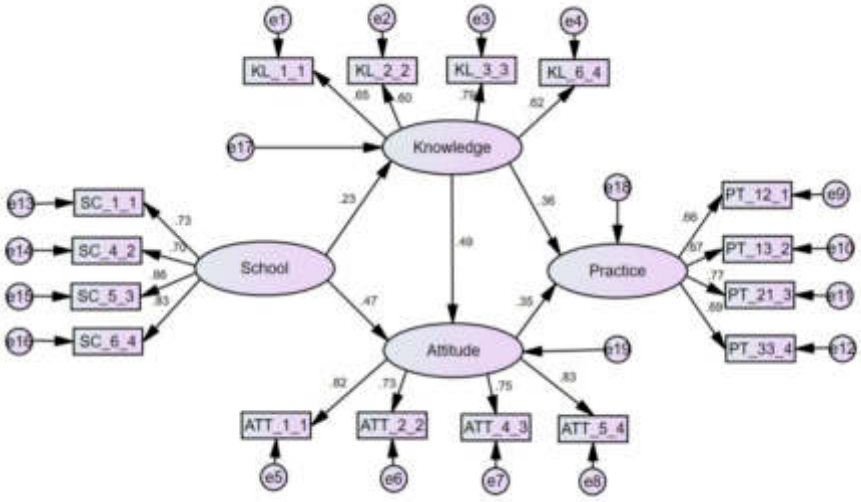

Fig. 4.1: Structural model with the relationships between TCM knowledge, attitude, practices and TCM on-campus campaign

significant. A multifaceted and multileveled interaction results in the formation and strengthening of good knowledge and positive attitudes. All teachers should be encouraged to actively promote TCM knowledge, help students establish healthy living concepts, encourage students to adopt healthy lifestyles, and continuously build and consolidate the cultural identity of TCM among youth. The evaluation results of the structure model are summarized in Table 4.9.

Applying the KAP SEM model in the current survey confirms that probable knowledge of TCM correlated with a wide-awake attitude regarding TCM benefit for a healthy life positively influences TCM adoption and healthy life behaviour. Campus culture construction is essential for building the knowledge of TCM and attitude.

5. Measurement of the Fitness Index in the Study. The measurement of the fitness index in the study was carried out through a well-structured process. The sample was collected using an online-based questionnaire distributed to students participating in the Traditional Chinese Medicine (TCM) on Campus Campaign, with 329 initial respondents. Data screening and cleaning were performed to ensure validity, resulting in 309 valid responses. The questionnaire was carefully designed and structured into five sections to measure health-related Knowledge, Attitudes, and Practices (KAP) among primary campus students, with questions adapted from existing scales in the literature to ensure theoretical soundness. The measurement instrument had four constructs: knowledge, attitude, practice, and campus culture construction, with items adapted from relevant studies. Reliability analysis using Cronbach's alpha coefficient indicated good internal consistency among these variables. Statistical analysis, including Structural Equation Modeling (SEM), examined the relationships between these constructs. The results supported hypotheses regarding the positive

relationships between TCM knowledge and attitude, knowledge and practice, attitude and practice, campus culture construction and knowledge, and campus culture construction and attitude. The study provided valuable insights into the influence of TCM campus culture on health-related KAP among primary campus students. It highlighted the role of education and the campus environment in shaping perceptions and behaviours related to TCM and health practices.

6. Discussion. The findings from the study on Traditional Chinese Medicine (TCM) campus culture and its influence on health-related Knowledge, Attitudes, and Practices (KAP) among primary campus students have several important implications, both with the research objectives and within the broader context of existing literature.

Firstly, the significant correlation found between TCM cultural knowledge and positive attitudes towards TCM among students reinforces the crucial role of education in shaping perceptions and receptiveness towards traditional medicine practices. This aligns with the research objectives and supports existing literature, which suggests that increased awareness and understanding of health practices can lead to more favourable attitudes towards them. The study contributes to this body of knowledge by explicitly focusing on TCM, a less-explored area in the context of primary education. Regarding practical significance, the study's findings highlight the potential of TCM campus culture initiatives in fostering positive health-related behaviours among young students. The positive relationship between TCM knowledge and practices suggests that integrating TCM into the campus curriculum could effectively promote healthier lifestyles and choices among children. This is particularly relevant given the increasing global interest in holistic and integrative health approaches.

Furthermore, the study underscores the importance of the campus environment and culture in health education. The fact that TCM cultural knowledge and attitudes were positively influenced by campus culture construction implies that campuses play a crucial role in promoting and disseminating health-related knowledge. This insight is valuable for educators and policymakers who are tasked with developing and implementing health education programs. In light of these findings, efforts to promote TCM knowledge and health-related behaviour on campuses could involve a more integrated approach, combining traditional educational methods with experiential learning opportunities, such as TCM-related activities and campus-wide campaigns. Additionally, the study suggests the need for teacher training and resource development to deliver TCM education effectively and to foster a supportive learning environment.

Overall, the study contributes to understanding how TCM can be effectively incorporated into primary education to enhance students' health-related knowledge, attitudes, and practices. It provides a foundation for future research in this area. It offers practical insights for developing campus health education programs, particularly those aimed at promoting traditional and holistic health practices.

The study has several limitations. First, the sample size is small for the representativeness and generalizability of the results. It is helpful to compare results between campuses that participate in TCMOCC and those that do not compare the differences in knowledge, attitude, and practice with the construction of campus culture. The study's second limitation is that it relies on self-reported data and is prone to recall or social desirability biases. As a result, the outcomes might not accurately reflect the participants' actual behaviours and attitudes. Third, the study only examines the relationships between traditional Chinese medicine (TCM) campus culture construction and health-related knowledge, attitudes, and practices (KAP). The scope of this article does not include additional variables like socioeconomic status, family history, or peer pressure that may affect students' behaviour on primary campuses. The study only considers how TCM campus culture construction affects students' health-related behaviour on primary campuses. It does not consider how it might affect other areas of their lives, like their achievement on campuses or mental health. Future research ought to collect and compare data on healthy living behaviours to determine the essential components that influence campus culture and suggest strategies and initiatives for the wide-scale promotion of the behaviours. A more extensive and varied sample of primary campus students from various parts of China can be added to the study. Future research can also examine the relationships between the three constructs—knowledge, attitude, and practice—and the factors that influence them [5,20,49]. Theoretical implications of the study include offering empirical evidence that campus culture construction in traditional Chinese medicine (TCM) influences health-related knowledge, attitudes, and practices (KAP) among primary campus students. The findings of the study have several managerial implications. To improve health-related KAP among primary campus students,

it emphasizes the necessity of promoting TCM culture in educational institutions. The study also suggests that TCM campus culture construction should focus on the communicator, content, medium, audience, and effect to ensure the campaign's effectiveness. The study's practical implications include showing how TCM campus culture construction can influence primary campus students' health-related KAP positively. The study's social implications include promoting the importance of TCM culture in China's long history and its potential role in improving health-related behaviour among primary campus students. Overall, the study's findings contribute to promoting TCM culture and improving health-related behaviour among primary campus students in China.

7. Summary of the Study findings. To summarize the main findings of this study and their significance. We have decided to conclude with statements about the broader implications of your research.

The study on Traditional Chinese Medicine (TCM) campus culture's influence on primary campus students' health-related Knowledge, Attitudes, and Practices (KAP) yielded several significant findings. First and foremost, the research established a positive correlation between exposure to TCM culture on campuses and enhanced knowledge and attitudes towards TCM among students. Specifically, students who were part of the TCM campus culture demonstrated a greater understanding of TCM concepts and practices, alongside more favourable attitudes toward TCM.

Moreover, the study found that this increased knowledge and positive attitude towards TCM translated into healthier practices. Students exposed to TCM culture were more likely to engage in health behaviours influenced by TCM teachings, suggesting a direct impact of educational exposure on student behaviour. This result is particularly noteworthy, highlighting the practical benefits of integrating traditional medicine and holistic health concepts into campus curricula.

Another critical finding was the role of the campus environment in fostering an appreciation and understanding of TCM. The study underscores the importance of campus culture construction in promoting TCM, suggesting that a supportive and resource-rich educational setting is crucial for effective health education.

The broader implications of this research are multifaceted. Firstly, it contributes to the growing body of evidence supporting the integration of traditional health knowledge into modern educational settings. By demonstrating the positive impact of TCM exposure on young students' health-related knowledge, attitudes, and practices, the study provides a compelling argument for incorporating TCM into campus curricula, not just in China but potentially in other cultural contexts.

Secondly, the findings have practical implications for educators and policymakers. The clear link between campus-based TCM programs and improved health-related outcomes among students suggests that such initiatives can effectively promote holistic health and wellness in young populations. It also opens opportunities for developing similar programs based on other traditional health practices.

Lastly, the study contributes to a broader understanding of how cultural practices and knowledge can be harnessed in educational settings to promote overall health and well-being. It underscores the potential of traditional knowledge systems in enriching modern education and healthcare practices, encouraging a more integrative approach to health education.

In conclusion, this research not only sheds light on the positive impact of TCM campus culture on students' health-related KAP but also paves the way for further exploration and integration of traditional health knowledge in education, with far-reaching implications for health promotion and cultural education.

8. Conclusion. This study evaluated the associations among health-related knowledge, attitudes, practice (KAP), and traditional Chinese medicine (TCM) campus culture construction among Chinese primary campus students. It was found from the results that factor loadings that are used to measure convergent validity were more significant than 0.5, which indicates a positive correlation among the TCM campus culture construction on knowledge, attitudes, and practices among the students. The study contributes to the existing literature by providing empirical evidence on the influence of TCM campus culture construction on health-related KAP among primary campus students. The findings have important implications for the ongoing efforts to promote TCM on campuses and enhance health-related KAP among students. Future research could further explore the impact of TCM campus culture construction on other aspects of campuses' lives and examine the effectiveness of different strategies for promoting TCM culture on campuses.

9. Future works. The study examining the impact of Traditional Chinese Medicine (TCM) campus culture on primary campus students' health-related Knowledge, Attitudes, and Practices (KAP) suggests several avenues for future research and methodological enhancements. Expanding the sample size and diversity is recommended to improve the generalizability of findings and to understand TCM's impact across varied student demographics. Incorporating a control group not exposed to TCM culture is crucial for establishing a more precise cause-and-effect relationship. Adopting a longitudinal study design would provide insight into the long-term effects of TCM exposure. Integrating qualitative methods like interviews or focus groups would offer deeper insights into student perceptions of TCM. Exploring additional variables such as family influences, peer interactions, and societal attitudes towards TCM could provide a more holistic view of factors affecting student engagement with TCM. Investigating specific TCM interventions within campuses could help identify the most compelling aspects of TCM culture in influencing KAP. Advanced statistical techniques could refine the analysis and address potential biases, while ethical and cultural considerations are essential, particularly in studies involving traditional practices and young students. The future research directions also aim to enhance the study of Traditional Chinese Medicine (TCM) in the context of campus culture and its impact on students' health-related knowledge, attitudes, and practices (KAP). Other suggested areas for future research include expanding the sample to encompass diverse demographics, utilizing diverse data collection methods such as in-person surveys, and incorporating qualitative methods like interviews or focus groups to gain deeper insights into student perspectives on TCM. These approaches aim to improve the generalizability and comprehensiveness of the findings.

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THE RELATIONSHIP BETWEEN FAMILY FUNCTIONING AND ACADEMIC BURNOUT OF COLLEGE STUDENTS: THE MEDIATING ROLE OF CORE SELF-EVALUATION AND COPYING STYLE

HAIXIANG YU*

Abstract. Family is of paramount importance in individual growth and has significant impact on individual academic burnout. Despite of the importance of family functioning, the impact mechanism of overall family functioning on students academic burnout remains unclear. Therefore, this paper examined the mediating role of core self-evaluation and coping style between family functioning and academic burnout. In this study, 314 Chinese college students from different universities were investigated with the family functioning evaluation scale, core self-evaluations scale, simplified coping style scale, and academic burnout scale. The findings showed that family functioning, core self-evaluation, and coping style were significantly and positively correlated with each other. All three variables were significantly and negatively correlated with academic burnout. As expected, core self-evaluation and coping style play a full mediating role between family functioning and academic burnout. This research reveals the impact mechanism between family functioning and academic burnout among Chinese college students, providing effective intervention strategies focusing on students' core self-evaluation and coping style.

Key words: Family functioning, core self-evaluation, coping style, academic burnout, China

1. Introduction. Family is a microsystem that influences individual growth, providing different conditions for the development of individuals' cognitive, psychological, and social aspects [10]. According to previous studies, family environment has a significant impact on students' academic burnout [32]. Academic burnout refers to the phenomenon that students become exhausted due to the pressure of long-term schoolwork, losing enthusiasm for schoolwork activities, becoming indifferent to classmates, and have negative attitudes towards schoolwork because their performance is not as good as expected [35]. Academic burnout reflects students' learning motivation and attitudes and can have a negative impact on their academic performance and efficiency [37]. Long-term academic burnout may also lead to decreases in happiness [27]. Therefore, it is crucial to study the impact mechanism of academic burnout, which can provide insights for improving academic burnout status and students' physical and mental health. Although previous studies explored the correlation between family factors and academic burnout, to my best knowledge, there is no study to clarify the mechanism of overall family functioning's impact on academic burnout. To fill the literature gap, this study explored the impact of family functioning on academic burnout and the role of core self-evaluation and coping style.

1.1. The relationship between family functioning and academic burnout. Family functioning is a comprehensive variable that measures the overall operational quality of a family [9]. It includes specific behavioral characteristics in family environment, such as communication, behavioral control, etc. [14]. Different factors in family environment can have impacts on academic burnout and its related factors. For example, parental involvement can effectively promote children's academic engagement and academic performance [11]. A recent meta-analysis also showed a significant and positive correlation between parental engagement and student performance [26]. In addition, individuals who grow up in a positive parenting style full of emotional warmth rather than a negative parenting style of punishment and rejection are less likely to suffer from learning disabilities [6]. A positive parenting style also makes students more confident and less likely to suffer from academic burnout [45]. A highly controlled family atmosphere can create higher academic pressure on children, thereby undermining their desire for autonomous learning [15]. In terms of family conflicts, parental marital conflicts are also an important reason for students' academic burnout [5]. This may be because parents will focus on marriage issues and pay less attention to children, or even refuse to communicate with children. In order to

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attract the parents' attention, neglected children may occasionally learn to gain the parents' attention through their problematic behaviors, and in turn such parents' attention strengthens their problematic behaviors [39].

It is worth noting that there are separate studies that have looked at the independent effects of various factors in the family environment on academic burnout. However, in real life circumstances, various factors in the family environment coexist and have a joint impact on academic burnout. Therefore, it is of paramount importance to conduct a study on the impact of various factors in the family environment, namely family functioning, on academic burnout. In addition, previous studies mostly focused on the impact of family functioning or resources obtained from the overall family on academic-related factors rather than academic burnout per se. For example, good family functioning has positive effect on children's self-regulated learning and academic achievement [7, 46], and the support obtained in the overall family is effective in preventing academic failure [3]. However, little consideration has been given to the impact and mechanism of overall family functioning on academic burnout. The current research concentrates on the impact mechanism of family functioning on academic burnou. Specifically, this study tests the mediating role of core self-evaluation and coping style between overall family functioning and academic burnout. This mediation model has not been studied and will be introduced below.

1.2. The mediating role of core self-evaluation. Core self-evaluation is considered to be the most core assessment of an individual's own ability and value, containing four factors: generalized self-efficacy, self-esteem, neuroticism, and locus of control [22]. Research shows that various factors in family functioning will have an impact on individual core self-evaluation. For example, higher parental involvement can help children build a higher sense of academic efficacy [1]. Parenting style, parent-child relationship, and core self-evaluation are closely related [34]. Positive family resources can also improve the individuals' core self-evaluation [18]. Research on overall family functioning also shows that the better the family functioning, the higher the core self-evaluation level [41].

In addition, students with high levels of core self-evaluation have low levels of academic burnout [38]. As a sub-dimension of core self-evaluation, self-esteem [31] and self-efficacy [12] can significantly and negatively predict academic burnout, and neuroticism [47] and external locus of control [24] also have a significant and positive correlation with academic burnout. Therefore, this study hypothesizes that family functioning has an impact on academic burnout through the mediating effect of core self-evaluation.

1.3. The mediating role of coping style. Coping style refers to individuals' cognitive or behavioral strategies when internal or external demands exceed their own resources [30]. There are two types of coping style: positive coping and negative coping [53]. Positive coping often focuses on problem-solving, and reflect individuals' effort to make changes. In contrast, negative coping often focuses more on emotions, and means individuals' try to reduce their bad emotions through avoidance, venting, fantasy, and other strategies.

Family functioning, as a resource that provides conditions for development, is also significantly correlated with coping style [33]. Good intimacy and adaptability in families are associated with higher levels of positive coping [4], while arbitrary and negative parent-child interactions in families increase the use of negative coping [25].

In addition, positive coping can reduce academic burnout [36,52]. When facing stressful events, college students who tend to actively respond are less prone to suffer from academic burnout [2]. Thompson et al. [49] have also found in their research on medical students that the more frequent use of method-oriented coping style, compared to avoidance coping style, can significantly reduce the risk of burnout. Therefore, this study hypothesizes that family functioning has an impact on academic burnout through the mediating effect of coping style.

1.4. The chain mediating effect of core self-evaluation and coping style. Both high core self-evaluation and positive coping contribute to reducing academic burnout, and research has shown a close relationship between the two. Individuals with higher core self-evaluation adopt more problem-solving coping style and fewer avoidance coping style [20]. This can be explained by the "evaluation-coping" theory, which argues that individuals' cognition and evaluation of themselves will affect their attitudes and methods of coping when facing problems. Individuals with higher levels of core self-evaluation tend to adopt positive coping when facing difficulties, while individuals with lower core self-evaluation are more inclined to adopt negative coping style

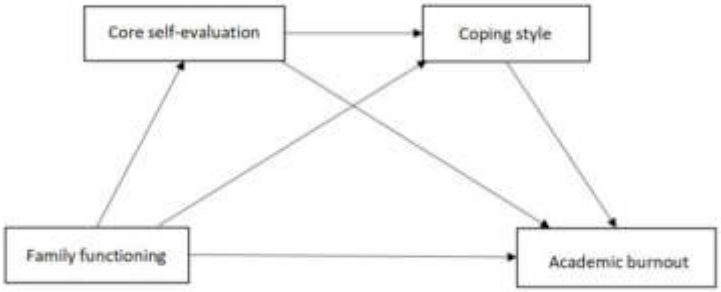

Fig. 1.1: The mediating model hypothesis of core self-evaluation and coping style between family functioning and academic burnout

such as avoiding problems [29].

In the sub-dimensions of core self-evaluation, it can also be seen that self-efficacy affects individuals' sensory responses and thinking patterns [8]. Students with high self-efficacy are usually able to select appropriate strategies when facing failure or academic stress, thereby decreasing the intensity of any symptom of academic burnout [28]. Therefore, this study hypothesizes that core self-evaluation and coping style play a chain mediating role between family functioning and academic burnout (Figure 1.1).

2. Methods.

2.1. Participants. This study adopted the questionnaire method. In the study of mediating effects, the sample size should reach 250 [17]. This study collected 314 valid questionnaires. The participants were all college students aged 17 to 26 from various regions in China ($M = 20.09$, $SD = 1.31$), of which 123 were males and 182 were females (9 of whom did not want to disclose their gender).

2.2. Measures.

2.2.1. Family functioning. A Family Functioning Evaluation Scale suitable for Chinese cultural background was developed by [58] for adolescent participants, consisting of 33 questions, including five dimensions: mutuality, conflict and harmony, communication, parental concern, and parental control. The scale adopted a 5-point scoring system, ranging from 1 "*completely dissimilar*" to 5 "*completely similar*". Nine items were reverse coded, because the lower the scores on these items, the higher the degree of the characteristic measured by this questionnaire. The average score of all items was calculated. The higher the score, the better the participants' family functioning. The Cronbach alpha coefficient for Family Functioning Evaluation Scale in this study was 0.96.

2.2.2. Core self-evaluation. This research adopted the adjusted version of the Core Self-Evaluations Scale established by [22]. The original scale contained 12 questions and was a single-dimensional tool for directly measuring core self-evaluation. A confirmative factor analysis with Chinese sample showed that only after deleting 2 of the questions could the remaining 10 questions be classified into the same underlying factor [13]. The scale adopted a 5-point scoring system, ranging from 1 "*completely disagree*" to 5 "*completely agree*". Six items were reverse coded. The average score of all items was calculated. The higher the score, the higher the participants' core self-evaluation. The Cronbach alpha coefficient for Core Self-Evaluations Scale in this study was 0.91.

2.2.3. Coping style. This research employed the Simplified Coping Style Scale developed by [53]. The scale consisted of 20 questions, including two subscales: positive coping and negative coping. The scale adopted a 4-point scoring system, which ranges from 1 "*never use*", 2 "*occasionally use*", 3 "*sometimes use*" to 4 "*frequently use*". After the negative coping dimension items were scored reversely, the average score of all items was calculated. The higher the score, the more active the participants' coping style was when facing difficulties

Table 3.1: Mean, standard deviation, and correlation coefficient between variables

Variable	M ± SD	Family functioning	Core self-evaluation	Coping style	Academic burnout
Family functioning	3.917±0.620	1			
Core self-evaluation	3.439±0.707	0.423**	1		
Coping style	2.861±0.322	0.360**	0.574**	1	
Academic burnout	3.586±1.101	-0.370**	-0.737**	-0.617**	1

Note: **p<0.01

and problems. The Cronbach alpha coefficient for Simplified Coping Style Scale in this study was 0.68, which was greater than 0.6 and within the acceptable range [48].

2.2.4. Academic burnout. This research adopted the Academic Burnout Scale (MBI-SS) established by [42]. It consisted of 15 questions and included three dimensions: exhaustion, cynicism, professional efficacy. The scale adopted a 7-point scoring system, ranging from 1 "*completely non-compliant*" to 7 "*completely compliant*". Six items were reversely coded. The average score of all items were calculated. The higher the score, the more severe the academic burnout of the participants. The Cronbach alpha coefficient for Academic Burnout Scale in this study was 0.94.

2.3. Testing procedures and data analysis. The present research utilized the online questionnaire platform "Wenjuanxing" to create and distribute questionnaires. 517 copies of questionnaires were distributed. Participants saw questionnaire information in WeChat groups of college students across China. After the selection by quality screening questions (For example: Please select "completely agree" for this question), 314 valid questionnaires were left (Participants who did not select the specified option would be excluded). All participants were given 3 yuan (roughly equal to 0.42 dollars) as a token of appreciation. Participants were told that the questionnaire was anonymous and would only be used for scientific research purposes. After completing the questionnaire, all participants were informed of the research purpose.

SPSS 23 was employed for descriptive statistical analysis and correlation analysis, and its plug-in process 4.0 was utilized to test the mediating effect. The Bootstrap mediating test method [17] was employed to test the mediating effect.

3. Results.

3.1. Common method bias control. The utilization of self-reported data collection could result in common method bias. This study adopted the Harman single-factor test [54], revealing that 17 factors had a characteristic value greater than 1. The variance elucidated by the first factor was 26.7%, lower than 40% (the critical value). Thus, no obvious common method bias was found in the current research.

3.2. Descriptive analysis and correlation analysis. From Table 3.1, it could be seen that family functioning had positive correlations with core self-evaluation and coping style. Core self-evaluation had a positive correlation with coping style. Family functioning, core self-evaluation, and coping style were negatively correlated with academic burnout.

3.3. Mediation Analysis. The findings of the testing of the mediation model were reported in Table 3.2 (the values between variables in the table were non-standardized regression coefficients, and the values in parentheses were standardized regression coefficients). The control variables are gender and age. According to the results in Table 3.2, family functioning significantly and negatively affected academic burnout among college students, with a total effect of -0.632.

Further analysis and summary of the effects were shown in Table 3.3. Family functioning significantly and positively affected core self-evaluation (r = 0.477, $p < 0.001$) and coping style (r =0.077, p = 0.004). Core self-evaluation significantly and positively affected coping style (r = 0.233, $p < 0.001$), and negatively affected academic burnout (r = -0.854, $p < 0.001$). Coping style significantly and negatively affected academic burnout (r = -0.966, $p < 0.001$). After adding two mediating variables, the direct effect was not significant anymore,

Table 3.2: Mediating effect model test (n=314)

	Core self-evaluation	Coping style	Academic burnout	Academic burnout
Constant	1.395**	1.621**	7.603**	10.674**
Gender	-0.085(-0.059)	0.006(0.009)	0.382**(0.171)	0.296**(0.132)
Age	0.015(0.027)	0.006(0.025)	-0.107*(-0.121)	-0.084**(-0.095)
Family functioning	0.477** 0.418	0.077** 0.148	-0.632** -0.356	-0.042 -0.024
Core self-evaluation		0.233** 0.511		-0.854** -0.549
coping style				-0.966** -0.282
R2	0.183	0.349	0.185	0.629
Adjusted R2	0.175	0.340	0.177	0.623
F-value	F (3,310)=23.195**	F (4,309)=41.361**	F (3,310)=23.399**	F (5,308)=104.295**

Note: **p<0.01

Table 3.3: Summary of the effect analysis process

	Functional relationship	Effect	SE	t	p	LLCI	ULCI
Direct effect	Family functioning→Academic burnout	-0.042	0.069	-0.614	0.540	-0.178	0.093
Indirect effect	Family functioning→Core self-evaluation	0.477	0.059	8.134	0.000	0.362	0.592
	Family functioning→Coping style	0.077	0.026	2.928	0.004	0.025	0.129
	Core self-evaluation→Coping style	0.233	0.023	10.064	0.000	0.187	0.278
	Core self-evaluation→Academic burnout	-0.854	0.069	-12.390	0.000	-0.989	-0.719
	Coping style→Academic burnout	-0.966	0.147	-6.564	0.000	-1.254	-0.677
Total effect	Family functioning→Academic burnout	-0.632	0.091	-6.920	0.000	-0.810	-0.453

Note: LLCI represents the lower limit of the 95% interval of the estimated value, while ULCI represents the upper limit of the 95% interval of the estimated value.

indicating that core self-evaluation and coping style played a full mediating role between family functioning and academic burnout.

The Bootstrap mediating test method (repeated sampling 5,000 times) was employed to further test the mediating effect, and the findings were depicted in Table 3.3.

The confidence interval of the mediating effect test of core self-evaluation between family functioning and academic burnout was [-0.295, -0.164], excluding 0. 64.46% of the total effect resulted from this mediating effect. Thus, family functioning can affect academic burnout by influencing core self-evaluation. The confidence interval of the mediating effect test of coping style between family functioning and academic burnout was [-0.073, -0.015], excluding 0. 11.77% of the total effect resulted from this mediating effect. Thus, family functioning can affect academic burnout by influencing coping style. The confidence interval of the chain mediating effect path was [-0.086, -0.037], excluding 0. Thus, the chain mediating effect path existed, and 16.99% of the total effect resulted from this chain mediating effect. Thus, family functioning can affect academic burnout by influencing core self-evaluation and subsequently influencing coping style. This study took the standard regression coefficient to draw the model diagram, as depicted in Figure 3.1.

4. Discussion. This study examined the mediating role of core self-evaluation and coping style between family functioning and academic burnout. In the area of research on academic burnout, previous studies mostly focused on how separate factors in the family environment affected academic burnout, while lacking research on overall family functioning. This study focused on the impact of overall family functioning on academic burnout, using a chain mediation model to demonstrate its influencing mechanism, providing more insights to research in this field.

This study showed that good family functioning could reduce academic burnout, which was in line with previous studies. For example, family environment could significantly and negatively predict academic burnout [32], and support from the family had an important role in preventing academic failure [3], and family functioning could promote self-regulated learning and academic achievement [46]. In addition, the current research

Table 3.4: Mediating effect analysis

Functional relationship	Effect	Boot SE	BootLLCI	BootULCI	z	p
Family functioning→ →Core self-evaluation→ →Academic burnout	-0.407	0.034	-0.295	-0.164	-12.152	0.000
Family functioning→ →Coping style→ →Academic burnout	-0.074	0.015	-0.073	-0.015	-4.897	0.000
Family functioning→ →Core self-evaluation→ →Coping style→Academic burnout	-0.107	0.012	-0.086	-0.037	-8.697	0.000

Note: BootLLCI represents the lower limit of the 95% interval for Bootstrap sampling, and BootULCI represents the upper limit of the 95% interval for Bootstrap sampling.

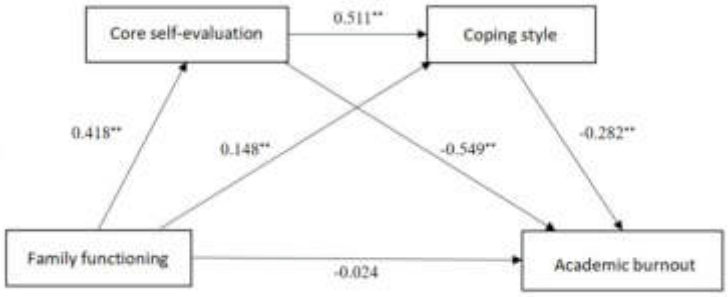

Fig. 3.1: The mediation model of family functioning, core self-evaluation, coping style, and academic burnout (Note: **p <0.01)

found that core self-evaluation played a mediating role between family functioning and academic burnout. This was consistent with previous theoretical mechanisms, where factors in the family, such as parents' attitudes and specific behaviors, were further internalized into children's own beliefs (cognition and evaluation of themselves). For example, the care given and expectations showed by parents to children, could be transformed into children's more positive learning attitudes and stimulate their learning motivation, thereby decreasing the possibility of academic burnout [40].

Moreover, the current research found that coping style played a mediating role between family functioning and academic burnout. This could be because an individual's coping style played an important mediating role between the stress situation and the individuals' short-term or long-term mental health problems (i.e., academic burnout in this study) it led to [44]. For instance, when the family functioning was poor, this could lead to some stress situations (such as parental conflicts), which could affect children's coping style and lead to psychological problems such as emotional exhaustion (a sub-dimension of academic burnout). Similarly, more stressful life events directly led to more avoidance coping style, rather than problem-solving coping style. This also indicated that when poor family functioning caused stress, children were more prone to develop negative coping style, thus being more likely to suffer from academic burnout [2]. Moreover, On the basis of the conservation of resources theory, individuals with more resources would adopt more positive coping styles when faced with problems, thereby they can obtain more resources. On the contrary, the fewer resources they had, the more likely they would adopt more negative coping styles, and this would result in fewer resources [19]. Family functioning is a resource that provides conditions for individuals' development, and when it was well functioning, individuals could adopt more positive coping styles and obtain more resources to invest in learning, which also made individuals less prone to academic burnout. Lastly, this study found for the first time that core self-evaluation and coping style played a chain mediating role between family functioning and academic

burnout, revealing a more complete mechanism of the impact of family functioning on academic burnout. This chain mediation also conformed to the "evaluation-coping" theory proposed by previous scholars, which stated that individuals' core self-evaluation affected their coping style when facing problems [30].

The chain mediation model also provided new insights for designing effective interventions in students' academic burnout problems. Family functioning is relatively difficult to regulate and intervene effectively, as it is a complex variable involving multiple individual members in the family. Comparably, core self-evaluation and coping style are more prone to be intervened through relevant methods, thereby reducing students' academic burnout. For example, research showed that personality advantage based mental health treatment methods (which made people aware of their positive qualities or advantages) had a continuous improvement in self-esteem and self-efficacy (sub-dimensions of core self-evaluation) [50]. Additionally, the research by [21] also demonstrated that six-week occupational interventions (including adaptability, self-concept, decision-making, *etc.*) showed strong effects in addressing negatively coping style. Due to the full mediating effect of core self-evaluation and coping style, educators can use these therapies to improve core self-evaluation and coping style to effectively improve academic burnout. At the same time, educators or therapists using these therapies should undergo rigorous ethical review, and there could also be policies in place to support the improvement of academic burnout with these therapies.

Finally, there are also some shortcomings and limitations in this study. First of all, the participants in this study were selected only from Chinese college students, and future studies may consider selecting participants from different cultural backgrounds. Secondly, the research method was a cross-sectional study. The analysis of the mediation effect may not indicate causal relationships. The longitudinal design can be used in the future to discuss this issue more deeply. Thirdly, the questionnaire of this study adopted self-report method, and the responses of the participants may not be entirely accurate, and may also be influenced by external factors. Future research could consider combining the reported results of others (such as parents, teachers, and friends), or use methods such as interviews and senarios. Lastly, some variables may moderate the impact of family functioning on academic burnout. Future research could study potential moderators, and this will provide meaningful insights for designing effective interventions, too. For example, emotional intelligence may moderate the impact of family functioning on academic burnout. Thus, individuals with high emotional intelligence are less prone to suffer from academic burnout [51], which means they may be less susceptible to external stress events and may still be able to maintain a good state of learning engagement even when family functioning is poor. This possibility can be explored in the future.

5. Conclusion. In summary, this article investigates for the first time the chain mediating effect of core self-evaluation and coping style between family functioning and academic burnout. This research draws the following crucial conclusions:

1. Family functioning, core self-evaluation, and coping style are all significantly and positively correlated with each other. All three variables are significantly and negatively correlated with academic burnout;
2. Core self-evaluation and coping style play a full mediating role between family functioning and academic burnout. The findings of this research also inspire relevant researchers to design interventions based on students' core self-evaluation and coping style, in order to improve students' academic burnout.

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APPLICATION OF CNN BASED REGOGNITION TECHNOLOGY IN PUBLIC ENGLISH TEACHING IN COLLEGE INTELLIGENT CLASSROOM

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Abstract. With the advancement of intelligent technology, CNN-based recognition technology has been integrated into public English teaching in universities. This implementation contributes to enhancing teaching quality, nurturing students' English proficiency, and holds significant educational and practical value. To address the issue of low traditional attendance efficiency in intelligent classrooms for public English teaching, a face recognition model based on CNN recognition technology has been developed. R-CNN is utilized for object detection, along with pyramid pooling and non-maximum suppression to acquire the optimal candidate region for face detection. Furthermore, K-Means clustering is combined to enhance Fast R-CNN, thereby improving detection accuracy. Experimental results demonstrated that among the three networks—Fast R-CNN, Faster R-CNN, and CNN—Faster R-CNN maintained a high recognition rate and exhibited faster convergence speed, showcasing superior overall performance. Specifically, at 500 iterations, the three networks require 23.7 seconds, 26.8 seconds, and 34.2 seconds, respectively. For facial expression recognition, Faster R-CNN achieved the highest recognition rate, indicating its exceptional detection efficiency and potential for aiding teaching management. This study offers novel technical support for public English teaching in intelligent university classrooms, effectively enhancing teaching efficacy and learning experiences. Its practical significance extends to promoting educational reform and improvement.

Key words: CNN; Faster R-CNN; Face recognition; Public English teaching; Class attendance

1. Introduction. With the rapid development of technology, artificial intelligence technology has gradually penetrated into the field of education. In recent years, with the implementation of the enrollment expansion policy, the scale of universities has become increasingly large, and there are more and more college students. Teaching management has become a major challenge [1]. As an important basic education course, public English teaching in universities has always been the focus of attention for education workers in terms of teaching effectiveness and learning experience. Intelligent classroom public English teaching in universities is an important aspect of teaching. In order to strengthen its teaching management level and improve the teaching environment, attention should be paid to classroom attendance to facilitate the smooth implementation of teaching. Classroom attendance is an important link in teaching and is generally used as one of the criteria for teachers to evaluate students' grades [2]. Intelligent technology offers a solution to the limitations of traditional teaching methods by enabling personalized and targeted approaches tailored to diverse student needs. In the context of public English teaching in universities, existing models face challenges including low student participation, inadequate assessment of learning outcomes, and a lack of personalized teaching processes. To enhance the objectivity and efficiency of classroom management in this setting, facial recognition technology is being implemented for attendance tracking in intelligent classrooms. Convolutional Neural Networks (CNN) have strong feature learning capabilities and have been widely used in fields such as computer vision and pattern recognition [3]. Therefore, leveraging CNN-based recognition technology in intelligent classrooms allows for accurate identification of students' emotions, expressions, and interactive behavior, enabling educators to make timely teaching adjustments and create a more personalized learning environment. This will help improve students' learning motivation and interest, thereby improving teaching effectiveness. CNN-based recognition technology can monitor and analyze students' expressions, postures, etc. in real time. By identifying students' emotions and interactive behaviors, it can help teachers better understand their learning status. For example, when the system detects that students have low emotions or difficult learning situations, teachers can provide timely attention and assistance. In addition, an intelligent classroom monitoring system based on this technology can also provide teachers with data such as student participation and interest levels, helping

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with personalized teaching. Therefore, the application of CNN-based recognition technology in public English teaching in intelligent classrooms in universities has important practical significance and potential application prospects, which involves important ethical, social, and educational considerations. The facial data of students belongs to personal sensitive information and must be appropriately protected. To ensure the responsible use of data, strict data protection policies should be established, with clear communication and consent from students regarding the usage, storage, and processing of their personal information. Robust encryption and security measures must be implemented to prevent unauthorized access or misuse of stored data. Facial recognition technology should be implemented in a fair and unbiased manner, ensuring equal treatment for all students. By utilizing facial recognition for attendance tracking, teachers can effectively monitor student engagement. This data can also provide insights into students' learning habits and needs, facilitating personalized teaching support. Leveraging CNN for facial recognition and addressing its limitations will enhance the efficiency of attendance management in public English teaching in intelligent university classrooms, promoting scientific and standardized approaches to education.

2. Related works. Intelligent recognition is an important content in many fields at present, and recognition efficiency and accuracy make a big difference in the final result. Face recognition technology based on CNN can improve the accuracy of face recognition, it has been applied to many fields by many scholars and achieved many research results.

For the purpose of improving the teaching efficiency of multimedia English, Hao K put forward an intelligent network teaching system model, which used deep learning speech enhancement and facial expression recognition technology to judge students' understanding of emotions. The result showed a good detection effect [4]. Duan R and other scholars established an AI speech recognition correction model based on AI speech recognition technology to solve the problem of limited oral English pronunciation correction. The test results showed that the model effectively assisted teachers in correcting students' spoken English pronunciation [5]. In view of the shortcomings of intelligent speech recognition, Dong S established an intelligent English recognition and prediction system based on support vector machine and combined with wavelet packet analysis to extract features of EEG signals. The result showed that the system built by the research improved the speech recognition rate [6]. For the purpose of improving the efficiency of cross-cultural English teaching, Zhang M and other scholars established a cultural O2O English teaching system that supported cross-intelligent recognition and management to detect and recognize students' emotions. Combined with the neural network algorithm optimization system, the result showed that the system built by the research had a nice performance [7]. Li A and other researchers built an English intelligent online teaching model to solve the problem that the traditional English online teaching mode was limited by the location and used the improved deep belief network to identify the students' status and locate the location. The result showed that the model effectively enhanced the monitoring and recognition of students' online learning status, and had a good performance [8].

Yu J, for the purpose of achieving task recognition in English classroom teaching, used improved CNN to recognize images and combined GPU to solve the problem that data training took a long time. The result showed that the way proposed in the study validly perceived the results according to the target location, which was conducive to task recognition in English teaching [9]. Chen X, for the purpose of enhancing the recognition of English speech emotion, established a training strategy based on transfer learning and CNN. The result showed that the proposed method had a good performance in English speech emotion recognition [10]. For the purpose of improving the efficiency of face recognition, Karkal G and other researchers built a non-invasive attendance system, which used CNN to detect faces and a neural network to recognize faces. The result showed that the system realized automatic detection of face recognition and improved the efficiency of attendance [11]. For the purpose of improving the efficiency of classroom attendance, Seelam V and others proposed an intelligent classroom attendance management system based on face recognition by using the principles of deep learning and computer vision. The result showed that compared with traditional manual attendance, the former improved the efficiency of attendance [12]. Shah V and other scholars established a recognition model based on machine learning and depth learning algorithms to improve the accuracy of emotional state recognition. The result showed that the model effectively processed text data and had a high accuracy in emotional state recognition [13].

Shen Y and other researchers built an intelligent assessment system for autistic children in view of the lack of

professional evaluators for autistic children's painting. They developed an assessment model for autistic children by utilizing LSTM and CNN to segment and identify the components of portrait sketches. The result showed that this model validly judged children's autistic tendencies [14]. Lan C and other scholars, in order to enhance the recognition rate of speaker recognition system, constructed a model combining the additive Margin Softmax loss function, which combined CNN with gated recursive units. The speaker model was trained using the data enhancement method. The result showed that compared with other models, the equal error rate of this model was reduced, the recognition rate was greatly enhanced, and it had good robustness [15]. Chen Z and other scholars proposed a lightweight real-time facial recognition algorithm based on CNN to improve the accuracy of facial recognition, therefore reducing the parameters and computational complexity of facial feature extraction networks. The research results indicated that this method improved the accuracy of facial recognition and the recognition time was shorter than the current recognition methods [16]. Rao T et al. designed a multi-scale graph CNN-based facial expression recognition method to improve the accuracy of facial expression recognition. The experimental results showed that this method had a more stable performance and improved the accuracy of facial expression recognition [17]. Xianzhang P proposed a video facial expression recognition method based on CNNs and gradient direction histograms to address the low efficiency of facial expression recognition in videos. This method comprehensively extracted facial features from videos and recognized facial expressions. The research results indicated that this method effectively extracted facial expressions from videos, thereby improving the performance of facial expression recognition [18].

The above content is the intelligent recognition research conducted by scholars from different fields combined with CNN. Compared to traditional facial recognition methods, CNN technology has high accuracy and robustness in image recognition and can better recognize faces under different lighting, angles, and facial expressions. However, using CNN for facial recognition requires a large amount of labeled data and computational resources for training. In order to improve the efficiency of teacher attendance in public English teaching in intelligent classrooms in universities, this study will introduce Faster R-CNN, which can perform object detection faster, improve recognition speed and accuracy, and facilitate the smooth implementation of teacher teaching work.

3. Face recognition in public English teaching attendance for college intelligent classroom.

3.1. Research on face recognition and CNN optimization. Since the 1970s, face recognition technology has risen and developed rapidly. There are many excellent methods used in face recognition, including geometric feature matching, template matching, neural network, and other methods Among them, the matching method based on facial geometric features, as the most effective face matching method, has the advantage of simple recognition methods, but it mainly depends on the accuracy of facial organ feature localization algorithm, and the localization algorithm has a high complexity. At the same time, the accuracy of face recognition will be affected by occlusion and expression The detection method based on the feature face uses principal component analysis to project the face image into the feature face subspace, calculate the position and length of the projection point, and then recognize the face. This method has a simple calculation method and fast recognition speed, but it requires high image quality, and other external environmental factors also have a greater impact on the recognition results. The way based on template matching mainly uses coded matching to complete face recognition. Template matching can be divided into points, regions, and a mixture of the two according to the level. The calculation process of the first way is relatively complex, the calculation amount of the second method is reduced, and the matching method based on the combination of the two methods has more recognition efficiency. The recognition method based on the hidden Markov model has a high recognition rate, and can better realize the recognition of face images under different conditions. The method based on the neural network has stronger expression ability and adaptability, and the recognition efficiency is better. CNN is the representative network structure of the neural network and has made many breakthroughs in face recognition.

Face detection is a key step in face recognition. Its results have a great impact on the extraction of face features and the accuracy of face recognition. Conventional face detection mainly extracts features manually and then trains classifiers, but it has high requirements for the detection environment CNN can better extract facial features. CNN structures generally include an input layer, convolution layer, down-sampling layer, and output layer. The convolution layer and down-sampling layer appear alternately between the input layer and

the output layer and are important modules for feature extraction [19]. At the same time, activation functions are also an important part of CNN, which can increase the expression ability and learning ability of models. Common activation functions include the Sigmaid function, Tanh function, and ReLU function. Among them, Sigmoid function and Tanh function are continuously differentiable functions, monotonically increasing, which is convenient for forward propagation of the network and unfavorable for back propagation. The expressions of the two functions are shown in Formula 3.1.

$$\begin{cases} f(x) = \frac{1}{1+e^{-x}} \\ tanh(x) = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \end{cases} \tag{3.1}$$

The ReLU function generally outputs hidden neurons, and the expression is shown in Formula 3.2.

$$f(x) = max(0, x) \tag{3.2}$$

The expressions (2.1) and (2.2) show that the ReLU function requires less computation than the three functions. When $X < 0$, the occurrence rate of over fitting is greatly reduced, which is not conducive to back propagation. Therefore, it is improved to obtain the Leaky ReLU function. The expression is shown in Formula 3.3.

$$f(x) = \begin{cases} x, & \text{if } x \geq 0 \\ ax, & \text{if } x < 0 \end{cases} \tag{3.3}$$

The Leaky ReLU function is used as the activation function of CNN. Meanwhile, the loss function can improve the accuracy and stability of the model. Its expression is shown in Formula 3.4.

$$f(x) = -\log\left(\frac{e^{f_{yi}}}{\sum_{j} e^{f_j}}\right) \tag{3.4}$$

In formula 3.5, f_j represents the jth element in the classification score vector f [20]. The normalized exponential function also has a significant impact on most CNNs, and its expression is shown in formula 3.5.

$$f_j(z) = \frac{e^{z} j}{\sum k e^{z} k)} \tag{3.5}$$

The random gradient algorithm can decrease the difference between the real value and the predicted value when the parameters are updated, which is conducive to obtaining the optimal weight parameters. At the same time, CNN uses iterative training to improve its ability to extract features and combines gradient descent way to reverse adjust the weight parameters of the network layer by layer. CNN also has the function of multi-layer perception, which enables local receptive field, convolutional kernel weight sharing, and spatial subsampling. In turn, CNN has the advantages of lower network complexity, easier network tuning, and less risk of fitting Regions with convolutional neural network feature (R-CNN) have a better effect in target detection. The general steps of R-CNN are shown in Figure 3.1.

In Figure 3.1, R-CNN generates candidate regions for each image to be detected through the selective search (SS) algorithm. Among them, SS extracts the features of candidate regions by merging sub regions. First, the input image is divided into many small regions, and a hierarchical grouping algorithm is used in this process. After that, the regions are merged through the similarity between small regions, and iterative merging is performed. When all images are merged into a whole region, the iterative process is ended. A circumscribed rectangle is then made for the sub-regions merged in the iteration process, and the candidate regions are the circumscribed rectangles of the sub-regions. Finally, the candidate regions are output. Before feature extraction, it is necessary to normalize and unify the size of candidate regions, and then extract features using CNN to obtain feature vectors [21]. Then the classification processing is carried out. When it belongs to the corresponding category, the position coordinates of the candidate box to be corrected can be output after its position. It is worth noting that the detection effect of R-CNN is better than that of conventional detection

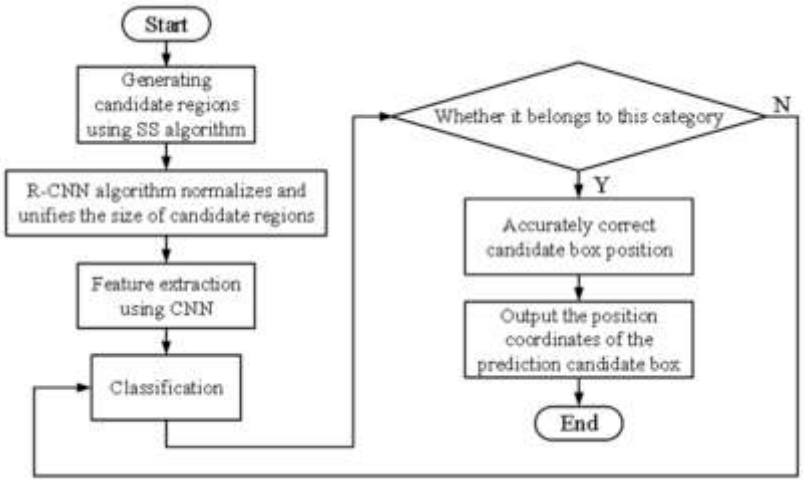


Fig. 3.1: R-CNN flow chart

methods, but there are also issues such as long training and testing time and large memory consumption in the process.

To address the issue of information loss and deformation caused by normalizing and unifying candidate regions in size, and to improve the accuracy of recognition results, Spatial Pyramid Pooling (SPP) can be employed as an intervention technique. As a multi-scale Pooling technology, image features can be extracted from more than one angle, and feature maps of different sizes can be converted into feature vectors of uniform size, thus improving the accuracy of image detection.

In addition, in the process of face target detection, since more than one target candidate box region will contain the same face, the candidate boxes will contain or cross each other At this time, the candidate region box can be filtered by using non-maximum suppression (NMS). NMS can suppress non-maximum elements, search for local maximum, eliminate overlapping windows, and then get the best candidate area for face detection

3.2. Face recognition based on improved Faster R-CNN algorithm. Fast R-CNN adopts the method of sharing the convolution layer. After a complete graph is input into the network, the operation of extracting the features of candidate regions is implemented on the final convolution layer, which can avoid repeated calculation of convolution. The overall framework of the Fast R-CNN algorithm is shown in Figure 3.2.

Due to some defects in the speed of Fast R-CNN, it takes more time to find all candidate regions using the SS algorithm, so Fast R-CNN uses the Region Proposal Network (RPN) instead of SS to improve the detection speed. Fast R-CNN represents the combination of Fast R-CNN and RPN. It mainly uses the CNN network to detect targets and uses RPN to generate candidate regions from the extracted feature map. In addition, since the area generation network and classification network use the same CNN to complete the weight sharing, the detection speed and accuracy can be improved. In view of the large number of RPNs generated by the Faster R-CNN algorithm, and in order to give consideration to the RPN size and the proportion of width and height and lose the pertinence, it is necessary to improve the face target search algorithm in Faster R-CNN, using RPN as the area search strategy. The RPN structure is shown in Figure 4.1.

RPN is a full convolutional network, and shares all convolutional features with all CNNs used for detection. It can extract high-quality detection areas and save area recommendation time. In Figure 3.3 , the output characteristic diagram of the last convolution layer of the shared convolution network uses a $\times$ 3. The window is fully connected. The feature is mapped to a low-dimensional vector and then sent to the parallel box classification layer (cls) and box regression layer (reg). The positions of the points of the convolved feature graph and the original graph are mapped, and every point on the former graph is mapped to the latter at the same time, the center of each sliding window has anchor points at the position corresponding to the original

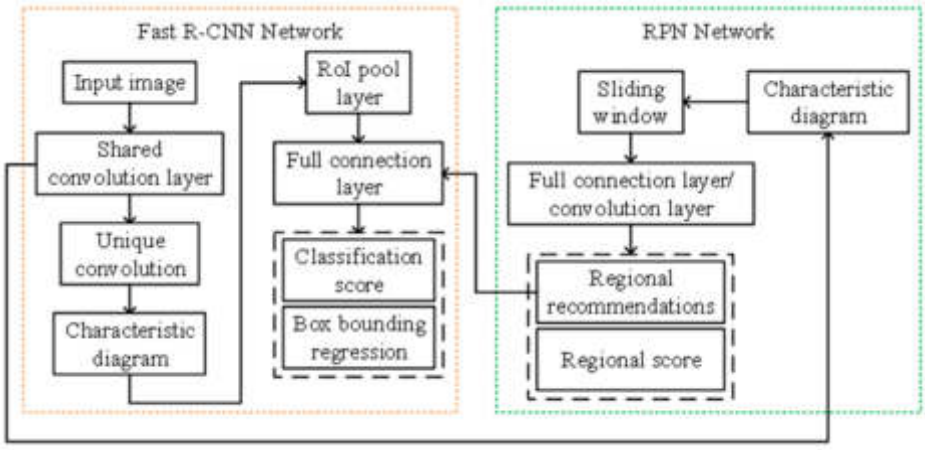


Fig. 3.2: Overall framework of Fast R-CNN algorithm

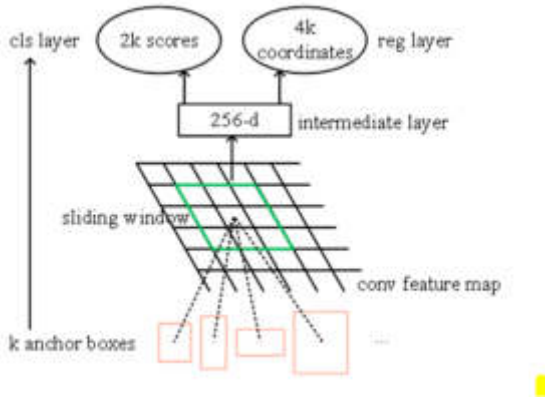


Fig. 3.3: RPN structure

drawing, and each anchor point corresponds to a size and aspect ratio [22]. RPN has three dimensions, length to width ratio, so each feature map element generates a total of 9 regional recommendations. When the RPN network is trained, the anchor points generate different anchor frames according to the corresponding rules due to the particularity of their positions. The Faster R-CNN algorithm takes each anchor point as the center and generates three anchor frames with different length-width ratios and pixel areas. Then all generated anchor frames are classified, including positive sample sets and negative sample sets, according to the Image Interaction Over Union (IoU) standard. The calculation way of training RPN. IoU is shown in Formula 3.6.

$$\mathrm{IoU} = \frac{\mathrm{area}(C) \cap \mathrm{area}(G)}{\mathrm{area}(C) \cup \mathrm{area}(G)} \tag{3.6}$$

At Formula 3.6, $area(C)$ expresses the generated Candidate bound,$area(G)$ expresses the original Ground truth bound, and IoU represents the overlap rate and the ratio of their intersection and union, which can indicate the accuracy of object detection in a specific data set. When $IoU = 1$, it means that they are all overlapped, indicating that the accuracy is the best.$IoU < 0.7$ divides the anchor frame into negative samples, and $IoU > 0.7$ or the value of the anchor frame and target into positive samples at most.

Given that the face target image typically contains a small number of pixels and the aspect ratio of the

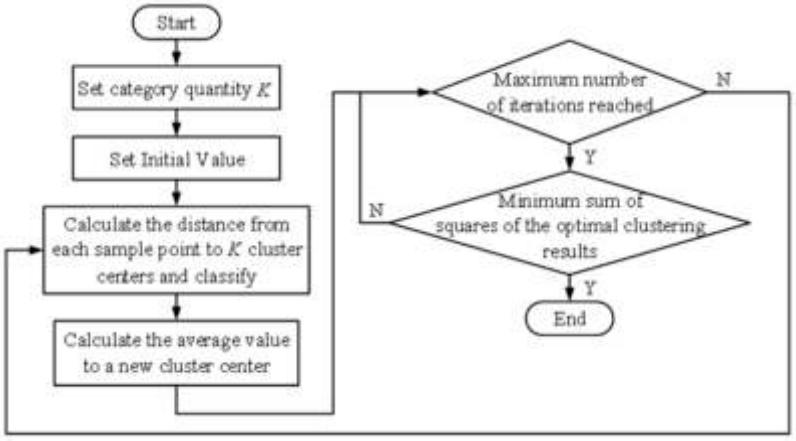


Fig. 3.4: Basic process of K-Means

face's bounding box is relatively small, utilizing the features of the bounding box as the face candidate area for the RPN network can enhance feature extraction and overall speed in face detection. In view of this, an unsupervised K-Means clustering way is used to learn the characteristics of face candidate regions from many labeled samples. First, the input sample set is $D = X_1, X_2, ...X_m$, the amount of clusters is K, n represents the maximum amount of iterations, $C = C_1, C_2, ...C_k$ describes that the output is cluster division, and the basic flow of K-Means clustering is shown in Figure 3.4.

The K-Means clustering method can be used to obtain candidate regions more suitable for the face dataset in this study for RPN, and the anchor size obtained is closer to the face bounding box of the dataset in this study, which can save training time, improve detection accuracy and speed up convergence. Among them, K-Means clustering uses the square of Euclid distance to calculate the distance, as shown in formula 3.7.

$$\text{dist}(x, y)^2 = \sum_{i=1}^{n}(x_i - y_i)^2 = \|x - y\|_2^2 \tag{3.7}$$

In formula 3.7,x and y are two different samples, and n is used to describe the sample dimension [23]. At the same time, the sum of the squared error (SSE) is used to judge the clustering results. When SSE is the minimum value, the best clustering result is obtained. The calculation way of SSE is shown in formula 3.8 .

$$\text{SSE} = \sum_{i=1}^{k}\sum_{x \in C_i} \text{dist}(x, c_i) \tag{3.8}$$

In formula 3.8,c_i represents the center of cluster C_i . Common evaluation indexes are cited to appraise the results, including precision, recall rate, false positive rate, PR curve, average accuracy (AP), and mean average precision (mAP). In addition, true positives (TP), false negatives (FN), false positives (FP), and true negatives (TN) are introduced into the calculation. The calculation method of accuracy is shown in Formula 3.9.

$$P = \frac{TP}{TP + FP} \tag{3.9}$$

In formula 3.9,P represents the precision,TP expresses the number of positive samples predicted to be positive samples, and $TP + FP$ represents the number of correct examples. The calculation way of the recall rate is shown in formula 3.10.

$$R = \frac{TP}{TP + FN} \tag{3.10}$$

Table 4.1: System parameter

Number	Project	Size	Unit
#1	Operating system	Windows 10	/
#2	Experimental platform	Tensor Flow	/
#3	GPU	GTX 1080Ti	SM
#4	Memory	1024	Mb
#5	Working voltage	220	V

In formula 3.10, R represents the recall rate and $TP+FN$ represents the number of correctly labeled instances. The calculation way of the FP rate is shown in formula 3.11.

$$F = \frac{FP}{TP + FN} \tag{3.11}$$

In formula 3.11,F is the FP rate, and is the amount of correct target instances predicted from the wrong target [24]. The calculation way of AP is shown in formula 3.12.

$$AP_C = \frac{1}{n}\sum_{i=1}^{n} P_{C,i} \tag{3.12}$$

In formula 3.12,AP_C is the AP of Category. The mAP is calculated as shown in formula 3.13.

$$mAP = \frac{1}{m}\sum_{i=1}^{m} AP_C \tag{3.13}$$

In formula 3.13,m represents the number of categories to be detected. Generally, the larger the mAP value is, the better the detection algorithm is.

4. Face recognition training experiment and result analysis.

4.1. Experimental analysis of face recognition model training. In the analysis of the application of CNN-based recognition technology [25, 26, 27] in public English teaching in intelligent classrooms in universities, a significant step was to gather a substantial amount of student face data within university classroom settings. Established facial recognition datasets like CASIA WebFace and LFW were utilized as a starting point. However, to enhance the effectiveness of the model in practical applications, data from specific classroom environments was incorporated. The data was appropriately annotated with student identity information, ensuring consistent distribution for training and testing purposes. The face recognition process was trained and a simulation model was created, facilitating the implementation of the model on the Tensor Flow platform. Leveraging the capabilities of Tensor Flow, the model could be automated for seamless operation. The platform also provided support for various algorithms such as CNN and RNN, ensuring a high degree of compatibility and assistance throughout the process. Other parameter settings of the simulation model are shown in Table 4.1.

The CNN excitation function was set as the Sigmaid function, Tanh function, ReLU function, and Leaky ReLU function respectively to learn face features and observe the performance of the CNN to obtain four different excitation function training networks. The results are shown in Figure 4.1.

In Figure 4.1, the horizontal axis expresses the number of iterations of the CNN network structure training, and the vertical axis expresses the convergence value of the loss function during training. Sigmoid function, Tanh function, ReLU function, and Leaky ReLU function are represented by red, purple, orange, and green lines respectively. In Figure 4.1, among the four excitation functions, the loss value of the last three functions was significantly lower than that of the first function, indicating that the last three functions had a high recognition rate. Among the three functions, the Leaky ReLU function had the fastest convergence speed at the same time, so the Leaky ReLU function was used as the excitation function of the model. Then the three networks were trained to get the training results, as shown in Figure 4.2.

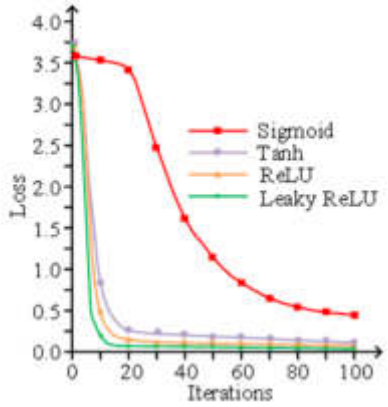


Fig. 4.1: Training of CNN by excitation function

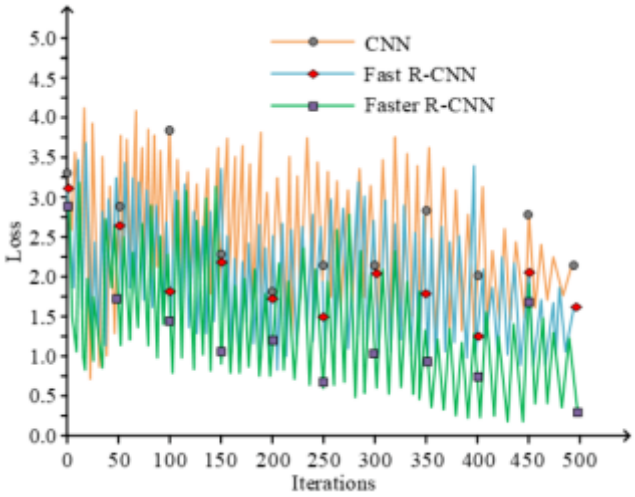


Fig. 4.2: Training of three networks

In Figure 4.2, the abscissa expresses the amount of training iterations, and the ordinate expresses the loss value of the loss function in the training process. The orange line expresses the training iteration of CNN, the blue line expresses the training iteration of Fast R-CNN, and the green line expresses the training iteration of Fast R-CNN. In Figure 6, the convergence rates of the three networks differed greatly. When the number of iterations was 250, the Loss values of CNN, Fast R-CNN, and Faster R-CNN were 2.19, 1.51, and 0.72 respectively. When the number of iterations was 500, the loss values of CNN, Fast R-CNN, and Faster R-CNN were 2.43, 1.67, and 0.27 respectively, that is, Faster R-CNN converged faster among the three networks, maintained a high level of recognition rate, and had a Faster convergence rate. The evaluation indicators mainly included precision, recall, AP, and mAP to analyze the proportion of correctly recognized faces to the total number of faces, as well as the accurate recognition of each student in public English teaching. Cross-validation methods were used to evaluate the stability and generalization ability of the method, tests were conducted in different classroom environments, and the adaptability of the method was analyzed. Three network structures were evaluated in combination with evaluation indicators, and the outcomes are shown in Table 4.2.

In Table 4.2, among various evaluation indicators, the precision, recall, AP, and mAP of the three networks

Table 4.2: Comparison of three network evaluation indicators (%)

Iterations	Index	CNN	Fast R-CNN	Faster R-CNN
100	Precision	66.3	68.2	88.1
	Recall	77.1	82.5	86.7
	AP	80.2	83.4	85.6
	mAP	79.7	82.1	83.4
200	Precision	72.5	82.3	91.4
	Recall	80.5	84.6	87.1
	AP	81.6	84.7	86.3
	mAP	80.1	82.9	83.7
300	Precision	73.6	83.8	93.7
	Recall	82.7	85.3	89.4
	AP	82.4	85.3	87.6
	mAP	83.6	83.9	84.3
400	Precision	77.1	86.3	94.5
	Recall	83.4	86.9	92.7
	AP	83.9	86.2	88.1
	mAP	84.1	85.2	86.4
500	Precision	82.5	93.4	96.2
	Recall	86.3	88.4	94.8
	AP	84.2	87.5	89.4
	mAP	82.9	85.7	87.2

Table 4.3: Recognition rate result of facial expression recognition (%)

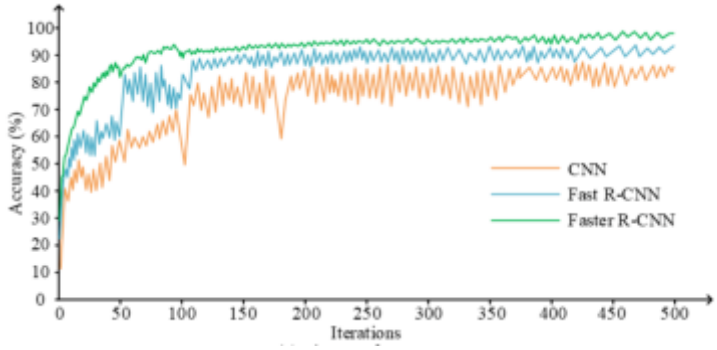
Number	Expression	CNN	Fast R-CNN	Faster R-CNN
#1	Smiling face	80.2	89.3	94.2
#2	Doubt	68.4	70.4	91.3
#3	Drowsiness	76.9	68.7	90.7

were Faster R-CNN, Fast R-CNN, and CNN in descending order. The improved Faster R-CNN had the strongest comprehensive performance and validly enhanced the detection efficiency.

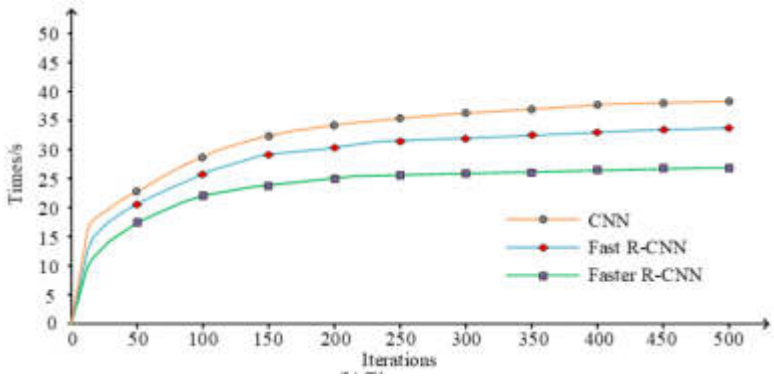
4.2. Analysis of face recognition results based on optimized CNN network structure. The change in recognition accuracy and training iteration time of the three network models in the face recognition iteration process were simulated, and the results are shown in Figure 4.3.

In Figure 4.3, the orange line, blue line, and green line respectively represent the accuracy and time use of CNN, Fast R-CNN, and Faster R-CNN in the training iteration process. Subgraph (a) represents the accuracy rate change, subgraph (b) represents the time use, and the abscissa of the two subgraphs shows the number of iterations. The ordinate of subgraph (a) represents the accuracy, in%. The ordinate of subgraph (b) represents the time, in seconds (s). In subgraph (a), the accuracy of the three network models from low to high was CNN, Fast R-CNN, Faster R-CNN, and the accuracy of Faster R-CNN tended to be stable first. In subgraph (b), when iteration was 500 times, the time of R-CNN, Fast R-CNN, and Faster R-CNN was 34.2s, 26.8s, and 23.7s respectively. That is, in terms of the accuracy and time of face recognition, Faster R-CNN had the highest accuracy and the shortest time, after that, three models were used to recognize facial expressions, and the outcomes are shown in Table 4.3.

Table 4.3 shows that Faster R-CNN still had the highest recognition rate for specific facial expression recognition. Faster R-CNN had 94.2%, 91.3%, and 90.7% recognition rates for smiling faces, doubts, and sleepiness, 89.3%, 70.4%, and 68.7% respectively for smiling faces, doubts, and sleepiness, and 80.2%, 68.4%, and 76.9% respectively for smiling faces, doubts, and sleepiness. Among the three models, smiling faces had the highest recognition rates for different facial expressions Therefore, Faster R-CNN was used to analyze students'



(a) Change of accuracy rate



(b) Time Usage

Fig. 4.3: Changes in recognition accuracy and time consumption during iteration

mental state and classroom performance on the basis of face recognition, which was beneficial for teachers to master students' learning in teaching.

In order to further analyze the research methods, the proposed model was compared with more advanced You Only Look Once (YOLO) and Single Shot Multibox Detector (SSD). These methods made significant breakthroughs in the field of object detection and recognition and were applied to public English teaching in intelligent classrooms in universities. The results are shown in Figure 4.4.

From Figure 4.4, the accuracy of the research method was comparable to other advanced methods. However, the research method had a higher recognition rate for different expressions in college intelligent classroom English teaching, indicating that the research method had good comprehensive performance and good application effects in public English teaching in college intelligent classrooms.

5. Conclusion. With the increasing number of students in school, teachers' classroom attendance will take more time, increase the difficulty of attendance and teachers' workload, and have some adverse effects on teachers' other teaching work. Public English teaching in intelligent classrooms in colleges and universities also faces this problem. As a required course for every student in colleges and universities, teachers will spend more energy on attendance. Therefore, it is urgent to improve the efficiency of attendance by using intelligent attendance methods. By using the CNN recognition technology and improving its shortcomings, Faster R-CNN is obtained. The experimental results showed that the Leaky ReLU function had the fastest convergence speed and was used as the excitation function of the network model. Faster R-CNN, Fast R-CNN, and CNN have the lowest loss value in the training process. When the number of iterations was 500, the loss values of the three networks were 2.43, 1.67, and 0.27 respectively. Based on the evaluation index, the three network structures

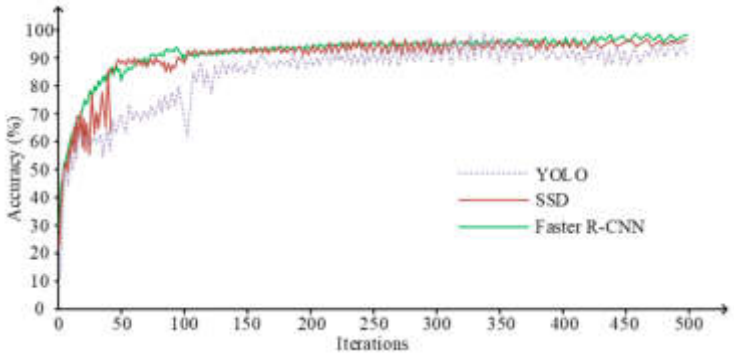


Fig. 4.4: Comparison between research methods and other advanced methods

were evaluated, and it was found that the precision, recall, AP, and mAP of Faster R-CNN were the best. In terms of accuracy and time of face recognition, Faster R-CNN had the highest accuracy, the shortest time, and tended to be stable first. In terms of specific facial expression recognition, Faster R-CNN still had the highest recognition rate. That is, Faster R-CNN maintained a high level of recognition rate and had faster convergence speed and better performance. It enhanced the efficiency of classroom attendance in teaching and promoted the development of intelligent attendance. At the same time, how to achieve intelligent attendance in the classroom on mobile devices is also the main research direction in the future. The advantages of Faster R-CNN include high accuracy, fast detection speed, and end-to-end training process, but there are complex network structures, weak target recognition ability, and complex training and parameter tuning problems. Efforts should be made to continuously enhance algorithms, minimizing false recognition rates. Facial recognition can be combined with other intelligent technologies to enrich classroom interaction. Additionally, regular evaluations of data management policies can be conducted to ensure compliance with the most recent ethical and legal standards. Students can be actively involved in the evaluation and improvement process, ensuring their needs and concerns are considered and addressed effectively. Overall, the use of this technology requires a balance between the benefits of technological progress and the accompanying ethical and social responsibilities. Through continuous technological improvement, policy formulation, and stakeholder engagement, the positive impact of these systems can be maximized while minimizing potential negative effects.

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BOOK CLASSIFICATION AND RECOMMENDATION FOR UNIVERSITY LIBRARIES USING GREY CORRELATION AND BAYESIAN PROBABILITY

FANG CUI* AND LIANG GAO†

Abstract. In today's information era, collaborative filtering algorithms are widely used and their distinct knowledge discovery techniques can effectively address numerous issues. However, conventional collaborative filtering algorithms encounter cold-start and data sparsity issues, which restrict their performance and accuracy. The study selected the multi-feature method to improve the traditional collaborative filtering algorithm, and introduced gray correlation calculation and Bayesian probability for user preference analysis. A learning resource recommendation model based on collaborative filtering was developed by comparing the target user's characteristics with those of other users, calculating their similarity, selecting users with high similarity to the target user and forming a neighbor set. Using Bayesian probability and grey correlation to analyze user preferences in library systems can be well applied in book classification and recommendation problems in university libraries. The computing layer, which includes the collaborative filtering calculation stage and the group recommendation calculation stage, is the model's main functional component. The smaller the value of mean absolute error, the higher the prediction accuracy of the model. The mean absolute error value of the multi-feature collaborative filtering algorithm was inferior to the traditional collaborative filtering algorithm, indicating that the classification accuracy of the former is higher than that of the latter. When the training set to test set ratio steadily became bigger, the mean absolute error value reached the lowest and smoothest point at 80%. In dataset A, the minimum mean absolute error values of multi-feature collaborative filtering and collaborative filtering were 0.765 and 0.809. Compared with traditional filtering algorithms, the mean absolute error value has decreased by 0.044. In dataset B, the mean absolute error values of multi-feature collaborative filtering and collaborative filtering were 0.796 and 0.836. Compared with traditional filtering algorithms, the mean absolute error value has decreased by 0.040. In dataset C, the minimum mean absolute error values of multi-feature collaborative filtering and collaborative filtering were 0.815 and 0.848. Compared with traditional filtering algorithms, the mean absolute error value has decreased by 0.033. When the accuracy was the highest; the mean absolute error value was the smallest at the grey correlation, which means that the technique improves the reliability of the recommendations compared with other methods. This means that the method has a positive impact on the accuracy of the recommendations compared to other methods. Grey correlation degree can comprehensively consider the interrelationships between multiple factors, handle uncertain and incomplete information, and explore potential user needs and behavior patterns. The implementation of the grey correlation degree has transformed the collaborative filtering algorithm into a group filtering algorithm, thereby enhancing its precision. The research on book classification and recommendation in university libraries, which enhances the group filtering algorithm, can address a range of issues such as improving classification accuracy, augmenting recommendation diversity, enhancing library management efficiency among others. This, in turn, enables more precise book recommendations to users.

Key words: Collaborative filtering system; Grey correlation; Multi-feature algorithm; Book recommendation

1. Introduction.

For libraries, museums and other databases with large volumes of books, accurate and precise classification and recommendation systems are necessary [1]. Collaborative filtering (CF) algorithms are widely used in many recommendation systems [2]. The unique knowledge discovery technology of resource recommendation can identify users with similar information by examining their past history, forming a group of similar neighbors. And based on the past data in the collection, customized suggestions can be provided to target users to solve problems such as information overload [3]. However, data sparsity is a challenge for the conventional CF method. As time passes and the number of users grows, the system accumulates more data, the computational workload increases in size and complexity, and the users' ratings of items decrease. Consequently, the system experiences greater sparsity, which significantly impacts its recommendation accuracy and performance. It is difficult to give accurate recommendations to new users with no or sparse rating data, which is a problem that is difficult to ignore [4, 5, 6]. To address the problem that data sparsity can lead to lower accuracy and diversity of collaborative filtering recommendation algorithms, Yan H et al. used a granularity computation model to achieve nearest neighbor clustering and proposed a coverage roughness

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granularity computation model for optimization of collaborative filtering recommendation algorithms to solve the problem [7]. Yang, Y et al. proposed the design and application of a handicraft recommendation system based on an improved hybrid algorithm. Based on the theory of e-commerce system, a personalized e-commerce system with hybrid algorithm is designed and analyzed by traditional user collaborative filtering algorithm. Further proposed a personalized recommendation system for e-commerce based on hybrid algorithm [8]. To enhance the constraints in the system, the paper adopted a multi-feature strategy to enhance the standard CF algorithm. It incorporated grey correlation into the recommendation system for computation and utilized Bayesian probability to analyze user preferences. The system obtained a set of neighbors with high similarity to the user to supplement the recommendation process, alongside constructing a CF-based learning resource recommendation model. Multi-feature collaborative filtering (MCF) calculation and group recommendation computation were applied to learning recommendation resources. Also for the problem of the accuracy of feature selection caused by data sparsity, the introduction of gray correlation computation and Bayesian probability to improve the user preference-based recommend system chosen in this paper has the advantage that: the gray correlation computation can excavate the regularity and characteristics of the data, and the Bayesian probability can provide a more accurate recommend result through the a priori knowledge and the user's feedback; both of these two methods have a certain degree of robustness, which can reduce the impact of external interference on the recommend result.

The innovation of the research on book classification and recommendation in university libraries based on group filtering algorithms lies in its ability to break through traditional methods, improve recommendation accuracy, promote interdisciplinary integration, and achieve dynamic recommendations. It can better meet the personalized needs of readers, improve the service quality and borrowing rate of libraries.

2. Related Works. To address the problems in using multiple types of representations in a knowledge graph recommendation scenario, Wu et al. suggested a new method, which combines the benefits of path-based and propagation-based approaches [9]. A method for classifying and retrieving items in hierarchy was designed by Li et al. A merchandise matching recommendation algorithm was proposed to analyze the research status of image retrieval method. Correspondence between various item visual characteristics was applied for item recommendation [10]. Li et al. proposed an algorithm for recommending explanation documents with questions and answers to alleviate the problem of CQA websites. The Q&A documents were modeled using a two-terms topic model and the Q&A documents were clustered using a growing neural gas algorithm [12]. Li et al. proposed a balanced resource recommendation engine to address the issues of resource imbalance and low trust in traditional sports online education resource recommendations. The sports network's instructional materials were first classified using the Support Vector Machine (SVM) method, and then any incorrect information was eliminated [12]. Liang et al. suggested an image recommendation algorithm in social networks. Deep neural networks showed a wide range of successful applications in various fields [13].

Deep networks have recently achieved good performance in classification tasks. When the training set is very small, the behaviour of this model diminishes significantly. Classifiers based on linear representations have been widely used in many fields. Building on these observations, Du et al. suggested a new competitive and categorization via cooperative representation that uses properties of training data with L2 parametric regularization to create a competitive environment that allows the correct class to contribute more to the encoding [14]. Chi et al. proposed a new CRC-based classifier utilizing class-mean weighted discriminative co-representation [15]. Currently, classification techniques have become increasingly important. Classifiers based on collaborative representation have been applied to many practical cognitive domains due to their advantages in terms of efficiency and effectiveness. A new neighbourhood prior constrained collaborative representation model was suggested by Gou et al. The guidance of the neighbourhood prior in the encoding process was emphasized [16]. Hyper-spectral pictures' extensive spectral data enabled several applications with tremendous advantages. The RPnet model overcame the redundant bands with a few training sample numbers [17]. Wu et al. proposed a weighted multi-view cooperative fuzzy C-mean clustering algorithm (DPSO-WCoFCM). The weighted clustering method's clustering centers were optimized using the common particle swarm optimization technique in conjunction with the WCoFCM algorithm [18].

In summary, many scholars are interested in recommendation and classification systems and combine various algorithms with them to optimize the efficiency and accuracy of system recommendation and classification.

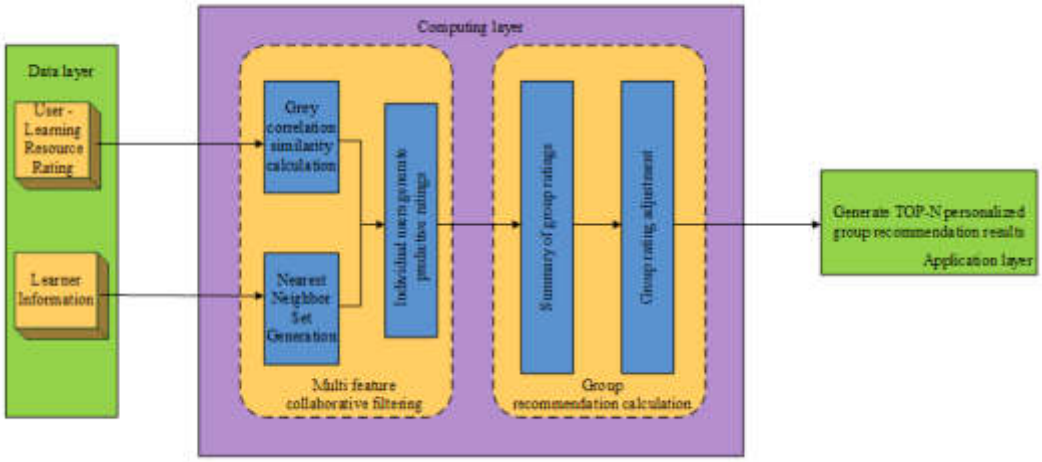


Fig. 3.1: The Group Recommendation Model for Learning Resources

There is relatively little research on combining collaborative algorithms with classification recommendation systems. Therefore, improving collaborative algorithms and combining them to recommend and classify library books is a worthwhile research direction. Based on the analysis of user attributes, the MCF algorithm has been improved through the optimization of feature selection and extraction to overcome the limitations of conventional group filtering algorithms. The benefit of the enhanced CF algorithm suggested in this study lies in its ability to contemplate the interaction between various features concurrently. This approach produces more comprehensive recommendation outcomes and caters to the assorted requirements of users. Nevertheless, a setback is that the dataset size employed in the experiment might contrast with the size of a real-world dataset, impeding full and precise simulation.

3. Collaborative population filtering algorithm for book recommendation model and classification in university libraries applications.

3.1. A CF-based book recommendation model for university libraries. The CF algorithm offers several benefits in recommendation models. However, with growing computational volume and increasing data complexity, the algorithm confronts limitations, particularly regarding cold starts and data sparsity [19]. The cold start problem pertains to the challenge of traditional recommendation algorithms in producing precise personalized recommendations for new users or projects in recommendation systems because of the lack of data and inadequate information. For new users, the system lacks sufficient personal preference data. The problem of data sparsity in recommendation systems is characterized by a large number of users and items, yet a relatively small amount of interaction data between them. This poses a challenge for accurately assessing similarity between users and items, thereby impacting recommendation accuracy. In the face of the problems of group recommendation and learning resource recommendation, CF algorithm is used to build a group recommendation model for learning resources based on the idea of hierarchical software engineering systems, as shown in Figure 3.1.

In Figure 3.1, the computational layer of the learning resource group recommendation model plays a key role. This layer comprises a CF computation phase and a group recommendation computation phase. The MCF calculation phase shown in Figure 3.1 is based on this algorithm and is calculated in three main steps: grey correlation, nearest neighbour generation, and prediction ratings generated by individual users. Within this model, there is a MCF of diverse recommendation lists with individuals as the focus, and the recommendation lists produced by the learning resource group recommendation model comprise solely of the predicted ratings of individual users that can be utilized as a group. The group suggestion framework generates a recommendation list solely based on the predicted ratings of individual users. This list can serve as input

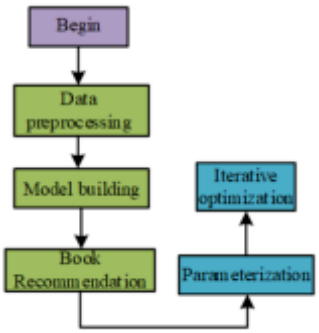


Fig. 3.2: Flow chart of MCF algorithm

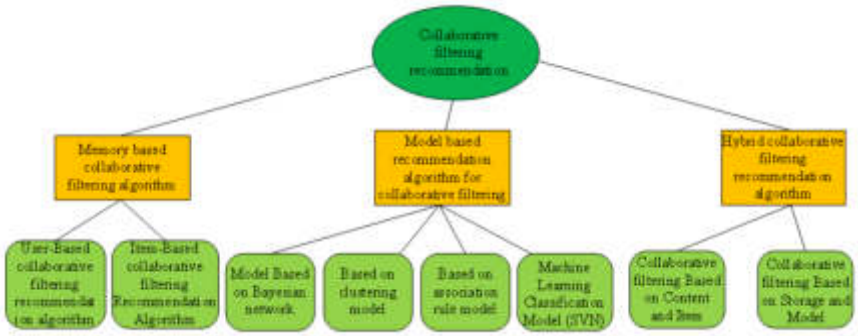


Fig. 3.3: Classification of CF algorithms

data for calculating group recommendations. The MCF algorithm is an enhancement of the CF algorithm, which possesses a succinct operational approach capable of remedying intricate and varied recommendation issues. The algorithm extensively utilizes multiple features and requires processing vast amounts of data and precise parameter tuning. In practical applications, it is essential to choose suitable multi-feature algorithms depending on specific tasks and data characteristics. Such algorithms have found widespread application in various internet products [20]. The flowchart of the MCF algorithm is shown in Figure 3.2.

In Figure 3.2, there are five steps: data preprocessing, model construction, book recommendation, parameter adjustment, and iterative optimization. Figure 3.3 shows the memory-based, model-based, and hybrid CF algorithms.

The memory-based recommendation algorithm offers several advantages over earlier similar systems. It is more widely used, efficient, and easier to implement in its application. The algorithm differs from earlier similar systems in that existing historical data on user ratings are collected together as a training set and a training model is built for predictive evaluation. The initial step in the data representation stage involves formalizing the recommendation problem by dichotomizing the recommendation system through a dichotomous network, as illustrated in Figure 3.4.

In the dichotomous network, the users of the personalized recommendation system are regarded as the set of user nodes U and the whole item as the set of item nodes O . The relationship between the U and O is a set of edges with weights. All the values taken by the item's user evaluation are represented by the set of weights of the edges between the item node set and the user node set by , as shown in equation 3.1.

$$U \times O \to \{R_{u_a}(o_k)\}_{m \times n} \tag{3.1}$$

In equation 3.1, $\{R_{u_a}(o_k)\}$ is the rating of the item by the user o_k and u_a. The nearest neighbor query

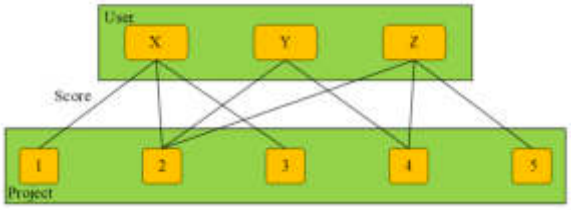


Fig. 3.4: Binary network of recommendation systems

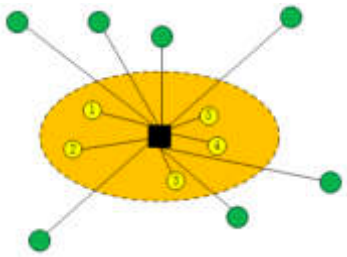


Fig. 3.5: An illustration of the closest neighbour set

constructs a set of nearest neighbors for the user and utilizes this information in the subsequent stage to generate recommendations. The diagram for constructing the set of users' neighbors is shown in Figure 3.5.

In Figure 3.5, the rectangle in the middle of the graph is the target user. The spheres at the end points of the line segment represent users with similarity to the target user. The similar users within the dashed box ellipse constitute the set of nearest neighbors U . Weighted similarity calculations are the typical calculation techniques, Pearson similarity calculation and cosine exponential similarity calculation. The formula for the weighted similarity calculation is shown in equation 3.2.

$$sim_{(u_\alpha,u_\beta)} = \frac{\sum_{o_k \in o(u_\alpha,u_\beta)} R_{u_a}(o_k) R_{u_\beta(o_k)}}{|o_k|_{o_k \in o(u_\alpha,u_\beta)}} \tag{3.2}$$

As shown in equation 3.2, $|o_k|_{o_k \in o(u_\alpha,u_\beta)}$ denotes the quantity of items for which the user u_α, u_β has a common rating on the item o_k. $o_k \in o(u_\alpha, u_\beta)$ denotes the set of items for which the user u_α, u_β has a ordinary rating. The technique for calculating Pearson similarity focuses on the correlation between vectors and is shown in equation 3.3.

$$sim_{(u_\alpha,u_\beta)} = \frac{\sum_{o_k \in o(u_\alpha,u_\beta)} (R_{u_\alpha}(o_k) - \overline{R_{u_\alpha}})(R_{u_\beta}(o_k) - \overline{R_{u_\beta}})}{\sqrt{\sum_{o_k \in o(u_\alpha,u_\beta)} (R_{u_\alpha}(o_k) - \overline{R_{u_\alpha}})^2} \sqrt{\sum_{o_k \in o(u_\alpha,u_\beta)} (R_{u_\beta}(o_k) - \overline{R_{u_\theta}})^2}} \tag{3.3}$$

As shown in equation 3.3, $\overline{R_{u_\alpha}}$ denotes the mean value of user u_α's rating and $\overline{R_{u_\beta}}$ is the mean value of user u_β's rating. The cosine index similarity calculation method uses the user vector as the unit of calculation by measuring the tutor cosine value between the user vectors, which is calculated as shown in equation 3.4.

$$sim_{(u_\alpha,u_\beta)} = \frac{\overline{R_{u_\alpha}} \cdot \overline{R_{u_\alpha}}}{\|R_{u_\alpha}\| \times \|R_{u_\alpha}\|} \tag{3.4}$$

In equation 3.4, R_{u_α} represents the rating vector of user u_α and R_{u_β} represents the rating vector of user u_β. The list of recommendation results is obtained in two ways, namely the weighted sum approach and the

Table 3.1: User Learning Resource Rating

Field name	Data type	Field Description
U-id	Int	User ID
I-id	Int	Learning Resource Number
U-Rate	Int	User Learning Resource Rating
G-Rate	Double	Group Learning Resource Rating
R-time	Datatimme	Scoring time

weighted average method. The formula for the weighted summation method of predicted ratings is shown in equation (5).

$$P_{u_\alpha}^{(o_k)} = R_{u_\alpha} \frac{\sum_{u_{\beta \in \alpha}} sim(u_\alpha, u_\beta) \times R_{u_\beta}(o_k) - \overline{R_{u_\beta}}}{\sum_{u_{\beta \in \alpha}} sim(u_\alpha, u_\beta)} \tag{3.5}$$

In equation 3.5, $sim(u_\alpha, u_\beta)$ denotes the similarity between user u_α to be recommended and user u_β in its neighbor set A. $\overline{R_{u_\alpha}}$ and $\overline{R_{u_\beta}}$ represent the average score of the project. The formula for calculating the weighted average of predicted scores is shown in equation (6).

$$P_{u_\alpha}^{(o_k)} = \frac{\sum_{u_{\beta \in A}} sim(u_\alpha, u_\beta) \times R_{u_\beta}(o_k)}{\sum_{u_{\beta \in \alpha}} sim(u_\alpha, u_\beta)} \tag{3.6}$$

The initial stage of incorporating the individual predicted scores of call signs from the multi-feature synergy phase into the group recommendation calculation is to amalgamate the group's scores. This calculation can be found in equation 3.7.

$$R_{G_i}(O_k) = \frac{1}{|G_i|} \sum_{j=1}^{|G_i|} R_{u_j}(O_k) \tag{3.7}$$

In equation 3.7, G_i represents the group of users in the learning resource recommendation. $R_{G_i}(O_k)$ represents the rating of the learning resource O_k by the group G_i. $|G_i|$ is the total number of users in the group for learning resource recommendations. $R_{G_i}(O_k)$ represents the rating of the item O_k by the individual user u_j. The second step in the recommendation calculation is the group rating adjustment, which is calculated as shown in equation (8).

$$d(G_i(O_k)) = \frac{\sum \sqrt{(R_{u_i}(O_k) - R_{u_j}(O_k))^2}}{|G_i|(|G_i| - 1)/2} \tag{3.8}$$

In equation 3.8, $d(G_i(O_k))$ represents the difference in the ratings of the learning resource recommendation group G_i against the learning resource O_k . The aggregated group ratings of the learning resources are then adjusted to give the final adjusted group ratings of against the learning resource, as shown in equation (9).

$$r_{G_i}(O_k) = w_1 \cdot R_{G_i}(O_k) + w_2 \cdot (1 \to d(G_i(O_k)) \tag{3.9}$$

In equation 3.9, w_1 is the percentage of aggregated ratings in the group ratings. w_2 is the percentage of variance accounted for in the group ratings, and $r_{G_i}(O_k)$ represents the adjusted ratings of G_i for the learning resources O_k in the group recommendations of learning resources. The computation is modular and divided into three computational layers. The input data in the data layer contains information on user-learning-resource ratings and learner characteristic attributes. Table 3.1 demonstrates the user-learning-resource table for the data layer.

The MCF learning resource recommendations initially score the computational layer. Subsequently, the group learning resource recommendations aggregate and adjust the scores of the user-learning resources. Finally, the resulting scores are incorporated into the learning resource scores in the data layer. The primary responsibility of the application layer is to present user and group data, and to arrange recommendations in a decreasing order based on adjusted group learning resources.

Fig. 4.1: Schematic diagram of user feature selection

4. Improved MCF algorithm design. CF algorithm has the limitations of difficulties with data sparsity and cold start. The problem with cold starts occurs in the system when recommending accurately becomes challenging with new users who lack rating data or have sparse data. This problem cannot be ignored during operation, making it a difficult issue to address [21] . The issue of data sparsity is predominantly a result of the increasing number of users and data stored over time. As a result, calculating and rating the items becomes more challenging, and the number of users contributing to these ratings decreases. This leads to greater sparsity, which directly impacts the accuracy and overall performance of the system [22] To address the common problems in CF algorithms, a fresh approach to calculating similarity was chosen to enhance the algorithm by incorporating user attribute analysis to reduce the impact of slow start and data shortage issues. The formula for calculating the grey correlation degree is shown in equation 4.1.

$$\gamma_{u_\alpha,u_\beta}^{o_k} = \frac{min_{o_k\in o(u_\alpha,u_\beta)}|R_{u_\alpha}(o_k) - R_{u_\beta}(o_k)| + \xi max_{o_k\in o(u_\alpha,u_\beta)}|R_{u_\alpha}(o_k) - R_{u_\beta}(o_k)|}{|R_{u_\alpha}(o_k) - R_{u_\beta}(o_k)| + \xi max_{o_k\in o(u_\alpha,u_\beta)}|R_{u_\alpha}(o_k) - R_{u_\beta}(o_k)|} \tag{4.1}$$

In equation 4.1, $\xi \in (0,1)$, and $o(u_\alpha, u_\beta)$ indicates the group of objects that the recommended users and peculiar users are rated by together. Finally, the grey correlation of users is calculated and its formula is shown in equation 4.2.

$$\gamma_{(u_\alpha,u_\beta)} = \frac{\sum_{o_k\in O(u_\alpha,u_\beta)} r_{(u_\alpha,u_\beta)}^{o_k}}{|o_k|_{o_k\in o(u_\alpha,u_\beta)}} \tag{4.2}$$

In equation 4.2, $r_{(u_\alpha,u_\beta)}$ is the number of grey associations of users u_α, u_β, about items o_k , and $|o_k|_{o_k\in o(u_\alpha,u_\beta)}$ is the number of items with common ratings of users u_α and u_β. The multi-feature closest neighbour set modifies the ranking based on similarity by include user multi-feature qualities in the similarity computation, and its calculation steps include: attribute extraction, pre-processing, and adjusting the nearest neighbour set selection. The user multi-feature attribute extraction includes many evaluation criteria, and the individual features and group features are extracted by hierarchical analysis, and the features are selected as shown in Figure 3.6.

User multi-trait attributes cannot be calculated directly, they should be converted into orders of magnitude before they can be calculated. Equation 4.3 illustrates the formula for determining a user's interest in a particular item.

$$p(u_\alpha, u_\beta) = \frac{\sum_{u_\beta\in U_{o_k}} \gamma(u_\alpha, u_\beta)}{|U_{o_k}|} \tag{4.3}$$

As shown in equation (12), $\gamma(u_\alpha, u_\beta)$ is the user's grey correlation similarity. $|U_{o_k}|$ is the set of users who have scored item o_k. $|U_{o_k}|$ is the number of users who have scored item o_k. From the Bayesian probability, the probability of a user liking an item when the user characteristic $c_m \in u_\alpha$ is shown in equation 4.4.

$$P_{o_k}^{u_\alpha}(M|c_m) = \frac{P_{o_k}(c_m|M)P_{o_k}(M)}{P_{o_k}(c_m|M)P_{o_k(M)} + P_{o_k}(c_m|N)P_{o_k(N)}} \tag{4.4}$$

In equation 4.4, $P_{o_k}(c_m|M)$ is the likelihood that an element will appear in the occurrence M and $P_{o_k}(M)$ is the likelihood that a consumer will like a product. The likelihood that a user would adore a product when the user features is shown in equation (14).

$$P_{o_k}^{u_\alpha}(M|C_a) = \frac{P_{o_k}^{u_\alpha}(M|C_1)P_{o_k}^{u_\alpha}(M|C_2)\dots P_{o_k}^{u_\alpha}(M|C_m)}{\prod_{i=1}^{m} P_{o_k}^{u_\alpha}(M|C_1) + \prod_{i=1}^{m}(1 - P_{o_k}^{u_\alpha}(M|C_i))} \tag{4.5}$$

The first task in adjusting the nearest neighbour set selection is to adjust the similarity of the users, based on the theory shown in equation 4.6.

$$nsim(u_\alpha, u_\beta) = \begin{cases} P_{o_k}^{u_\alpha} * \gamma(u_\alpha, u_\beta), u_\alpha \in U_{like} \\ (1 - P_{o_k}^{u_\alpha}(M|c_a)) * \gamma(u_\alpha, u_\beta), u_\alpha \in U_{unlike} \end{cases} \tag{4.6}$$

As shown in equation 4.6, $P_{o_k}^{u_\alpha}(M|c_a))$ is the likelihood that a user would adore a product when the user features and $\gamma(u_\alpha, u_\beta)$ is the grey correlation of the user. The list of recommendations is generated for the user and arranged in descending order of predicted value. The prediction score, calculated in accordance with equation 4.7, is based on grey correlation.

$$P_{o_k}^{u_\alpha} = \overline{R_{u_\alpha}} + \frac{\sum_{U_\beta \in A} nsim(u_\alpha, u_\beta) \times R_{u_\beta}(o_k - \overline{R_{u_\beta}})}{\sum_{U_\beta \in A} nsim(u_\alpha, u_\beta)} \tag{4.7}$$

In equation 4.7, $nsim(u_\alpha, u_\beta)$ is the adjusted similarity between the recommended users and the neighbouring users in the neighbourhood set. $\overline{R_{u_\alpha}}$ and $\overline{R_{u_\beta}}$ represent the mean item ratings of the two users in the user-item rating matrix, and $R_{u_\beta(o_k)}$ is the user ratings of the items in the user-item rating matrix.

5. Results of testing the recommendation capability of the multi-feature group filtering algorithm.

5.1. Effect of the ratio of dataset algorithm to training set on recommendation accuracy. Faced with cold start issues and data scarcity issues in CF algorithm, the study proposes a grey correlation similarity algorithm for improvement, conducts simulation experiments on the improved MCF algorithm, and analyzes the results. Common evaluation criteria used in recommendation engines to measure the precision of the system are selected for the experiments. To examine the impact of various datasets on the recommendation algorithm's accuracy, comparison experiments are conducted for each dataset. Therefore, data of the same size as the data set A was selected from the three data sets A, B and C. 940 data sets were selected from the user pool, while 1660 data sets were chosen from the item group to serve as the test data for this experiment. One-fifth of the test set was randomly chosen as the test set, while the remaining four-fifths of the data comprised the training set. The validity of the recommendation algorithm was tested on three different datasets. According to the aforementioned experimental criteria and different datasets, the experimental outcomes were segregated into three categories: groups A, B, and C. The validity of the algorithm was compared with the traditional CF algorithm and MCF algorithm, and the experimental results obtained are shown in Figure 5.1.

As depicted in Figure 5.1, the graph of experimental results with the data set as a variable demonstrates that the MCF algorithm has considerably higher accuracy compared to the traditional CF algorithm. It is verified that the recommendation accuracy of the MCF algorithm has been significantly improved compared with that of the traditional CF algorithm. To investigate the effect of different training set to test set ratios, i.e. data sparsity on performance, a comparative study of the recommendation accuracy obtained with different test set training set ratios was conducted. The experimental group's training set to test set ratio was increased from 0.1 to 0.9 to compare algorithmic recommendation accuracy with various data sparsity ratios. A dataset with 50 predetermined neighbors was utilized for experimentation purposes. The objective was to examine the impact of varying ratios between the training and testing sets on the performance of the recommendation algorithm. This allowed for the assessment of the algorithm's effectiveness with different levels of data sparsity. To test the validity of different sparsity of the data set on the recommendation accuracy, three test sets A, B and C were selected. The ratio of the training set to the test set was set to 0.1 as the initial ratio, and the

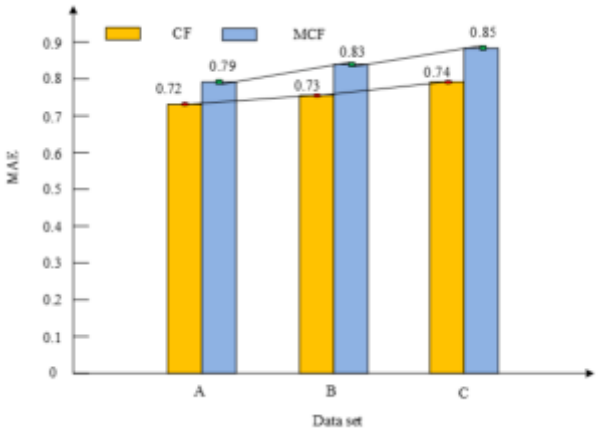
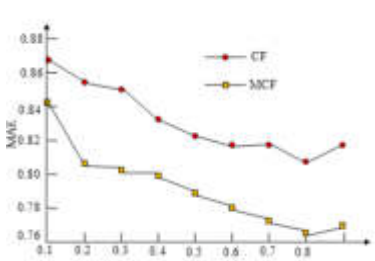
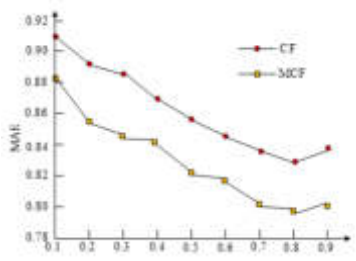


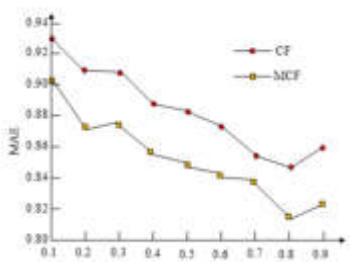
Fig. 5.1: Comparison of Algorithm Accuracy under Different Datasets



(a) Performance testing under different sparsities(Date A)



(b) Performance testing under different sparsities(Date B)



(c) Performance testing under different sparsities(Date C)

Fig. 5.2: Performance testing under different sparsities (Data A and B)

interval was set to 0.1, which was gradually increased until the data sparsity ended at 0.9. The accuracy of the recommendations and advice decreased as the average mistake value increased. The results of the Mean Absolute Error (MAE) values of the MCF and the traditional CF algorithms with different proportions of training sets in the A, B and C data sets are shown in Figure 5.2.

In Figure 5.2, the average error value of CF algorithm gradually leveled off as the ratio of the training set to the test set increased steadily for two different sized data sets A, B and C. The average error value of CF algorithm tended to be optimal when the training set was 0.8. The average error value is minimized when the training set is 0.8. In dataset A, the minimum MAE values of MCF and CF were 0.765 and 0.809. Compared with traditional filtering algorithms, the MAE value has decreased by 0.044. In dataset B, the MAE value of MCF and CF was 0.796 and 0.836. Compared with traditional filtering algorithms, the MAE value has decreased by 0.040. In dataset C, the minimum MAE values of MCF and CF were 0.815 and 0.848. Compared with traditional filtering algorithms, the MAE value has decreased by 0.033. The recommendation accuracy of the algorithm is at its highest point, and the performance of the MCF algorithm in terms of recommendation precision has considerably increased compared with the traditional CF algorithm. The number of neighbors is also a factor in the MAE, and the experimental comparison of the MAE data with different sets of neighbors is shown in Figure 5.3.

In Figure 5.3, the MAE value of the MCF algorithm is consistently lower than that of the traditional CF algorithm as the number of neighbourhood sets increases. Thus, the MCF algorithm can effectively enhance

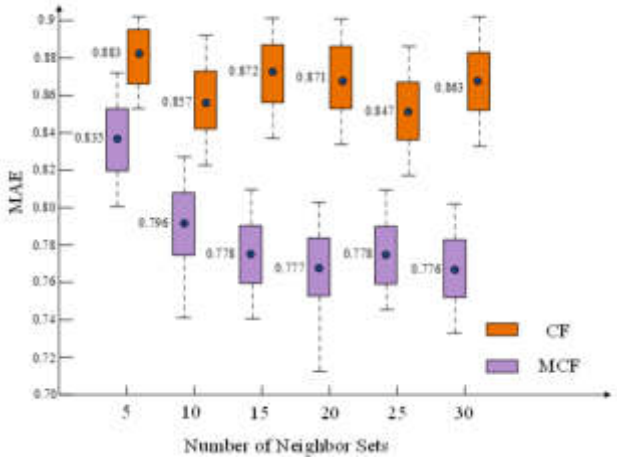


Fig. 5.3: MAE data values for different neighbor sets

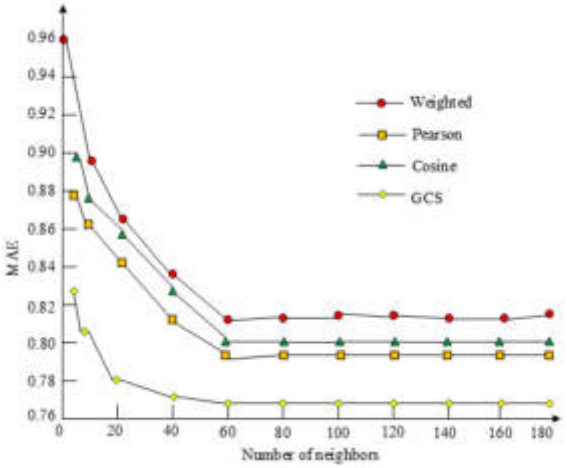


Fig. 5.4: The impact of the number of neighbors on MAE

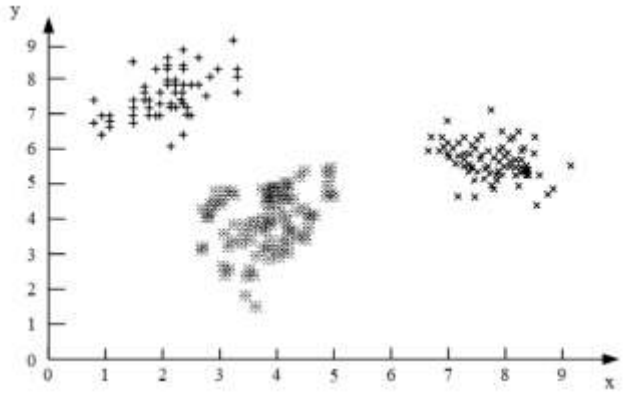
the recommendation quality of the recommendation system.

5.2. Impact of similarity measures on recommendation accuracy and optimization results of improved algorithms for book classification. To explore the impact of similarity measurement on the accuracy of recommendation systems, three commonly used similarity measures were selected: weighted similarity, Pearson, and cosine index calculation. The three indicators were compared with the grey correlation similarity selected in the MCF used in this study. 0.8 in the dataset is used as the training set and 0.2 as the test set to verify the effectiveness of grey correlation. To assess the effectiveness of grey correlation as a similarity calculation, this paper conducted experiments comparing it with three commonly used similarity calculations: weighted, Pearson, and cosine exponential similarity calculations. The data set used was B, and the training set was set at 80%. The results are displayed in Figure 10.

In Figure 5.4, under MCF, the minimum MAE value obtained by using grey correlation similarity as similarity indicates that using this method in recommendation algorithms can improve recommendation quality to a certain extent. It can be found that the recommendation accuracy of the MCF is higher when the choice of

Data set	Number of samples	Number of categories	Dimension
C dataset	153	3	2
Library dataset	2240	10	4

(a) Dataset Parameters



(b) Cluster Results of Library Datasets

Fig. 5.5: Dataset parameters and cluster results of library datasets

Table 5.1: Comparison of classification results of improved algorithms

Algorithm	F1-measure	Iterations
Traditional CF algorithm (Data A)	0.9752	12
MCF group algorithm (Data A)	0.9830	10
Traditional CF algorithm (Data B)	0.9734	12
MCF group algorithm (Data B)	0.9851	10
Traditional CF algorithm (Data C)	0.9721	12
MCF group algorithm (Data C)	0.9863	10

neighbors of the user is relatively large. However, when the number of neighbors is chosen to be relatively large, it will have an impact on the efficiency of the algorithm's execution. The MCF works better when the number of neighbors is in the interval of 50 to 70, when the number of neighbors is 60, the MAE value obtained by GCS calculation is the smallest, which is about 0.767; when the number of neighbors is 60, the MAE value obtained by all four algorithms is the smallest, which is 0.814 by weighted similarity calculation, 0.806 by Pearson's similarity calculation, and 0.795 by cosine similarity calculation method. The clustering effect of the improved system was explored, and the improved population filtering algorithm was used to cluster the library dataset and a dataset C. The clustering effect obtained experimentally on the two datasets is shown in Figure 5.5.

In Figure 5.5, the clustering results of the improved population filtering algorithm are excellent and the correct number of clusters can be obtained, verifying its feasibility. For the judgement of the classification effect, the common judgement criterion is F1-measure. The collection of a library was chosen as the database for the experiment, and the two algorithms were repeatedly run 10 times on the datasets A, B and C respectively to take the average value. Table 5.1 displays a comparison of the categorization outcomes produced by the algorithms.

In Table 5.1, with the improvement of the algorithm, the F1-measure in dataset A grew from 0.9752 to

0.9830, the F1-measure in dataset B grew from 0.9734 to 0.9851, and the F1-measure in dataset C grew from 0.9721 to 0.9863. The number of iterations increased from 12 to 10 on all three datasets reduced to 10 iterations. The experiments show that the improved population MCF algorithm classifies library books better than the traditional algorithm, with increased classification accuracy and better stability.

The research results show that introducing Bayesian probability and grey correlation to improve the collaborative filtering algorithm has better accuracy compared to traditional collaborative filtering algorithms. This is consistent with the research results obtained in Wang N's research on the ideological and political education recommendation system of the improved collaborative optimization algorithm. The personalized recommendation proposed in his study is feasible and has important accuracy and convergence [23].And it also matches with the findings of Sri S L R et al. Predicting user's preference for a specific item, collaborative filtering based on user clustering is used for venue recommendation, where clusters are formed by bio-inspired grey wolf optimization algorithm. The use of clustering eliminates the drawbacks of collaborative filtering in terms of scalability, sparsity and accuracy. In the study Sri S L R et al simulated and validated new mobile based recommendation application framework for developing urban venue recommendation in smart cities. The experimental and evaluation results demonstrate the utility of the newly generated recommendations and demonstrate user satisfaction with the suggested recommendation techniques [24, 25, 26, 27].

6. Conclusion. The classification and personalized recommendation of learning resources such as library books are necessary. The CF group algorithm has a good application environment for book classification and recommendation. However, traditional CF algorithms have issues with cold start and data sparsity, which can constrain the application of the algorithm and affect its recommendation accuracy. This study selected multiple feature methods to improve the traditional CF algorithm. By introducing grey correlation degree into the recommendation system for calculation, a neighbor set with high similarity to users was obtained, and the system's classification and recommendation were completed. In addition, a learning resource recommendation model based on the CF algorithm was constructed, which applies MCF calculation and group recommendation calculation. After several experiments the factors influencing the accuracy of the recommendation sessions were explored. It was verified that the improved MCF group algorithm classified library books better than the traditional algorithms. The MAE value was used as the evaluation criterion to measure the recommendation effectiveness of the system. The average error value of the MCF algorithm was inferior to the traditional CF algorithm, indicating that the classification accuracy of the former is higher than that of the latter. The sparsity of the data set was also an important influencing factor, with the ratio of the training set to the test set gradually increasing, the MAE value reached the lowest and smoothest point at 80%. Because of the improvement of the algorithm, the F1-measure value increased from 0.9752 to 0.9830 in dataset A, from 0.9734 to 0.9851 in dataset B and from 0.9721 to 0.9863 in dataset C. The number of iterations decreased from 12 to 10, suggesting that the enhanced population MCF algorithm performs better in classifying library books than the traditional algorithm. Moreover, the classification accuracy has increased and stability has improved. However, the paper still has some limitations, including the discrepancy in dataset size between the selected dataset in the experiment and the actual dataset, which cannot be simulated accurately. Moreover, although the model has been designed and the main system functions have been implemented, the effectiveness of the model's recommendations has not been practically verified. To further advance research efforts, the model should be applied to specific practical scenarios for verification.

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MOBILE USER ENGLISH LEARNING PATTERN RECOGNITION MODEL BASED ON INTEGRATED LEARNING

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Abstract. The research in the field of mobile assisted language learning has a long history. It basically follows the route from theory to application practice, but there are few process studies on learners' individual language skills learning behavior based on mobile platform data. This research takes vocabulary learning as the starting point, and constructs a mobile user English learning pattern recognition model with improved Stacking integration algorithm. The purpose of this study is to identify different learning modes by analyzing the learning behavior and learning data of mobile users, and to provide personalized learning suggestions for users. The evaluation goal of this study is the accuracy and robustness of the mobile users' English learning pattern recognition model, and the accuracy is the classification accuracy of the model for different learning patterns. Robustness is the stability and consistency of the model in different situations. In order to evaluate the integrated English learning mode of mobile users, the study first divides the collected learning data set into training set and test set. In this step, the method used in the study is cross-validation, which aims to reduce the difference of evaluation results caused by different data sets. For the relevant features in mobile users' learning data, the features extracted by the research include learning behavior and learning progress, which can accurately reflect the learning mode. Then, the integrated learning method is used to train the model, and the best parameter combination is selected through the training set. Finally, the study uses the test set to evaluate the trained model, and calculates the accuracy and recall index of the model on the test set. Through this evaluation method, the evaluation results of the integrated learning pattern recognition model in terms of accuracy and robustness are obtained, and reference is provided for the improvement of the model. The model proposed in this study is suitable for a large number of user data. Because the learning behavior of users is influenced by personal habits, there are limitations in obtaining enough high-quality data, so the labeling of data is subjective. It is still a challenge to select the most representative features of user learning behavior extracted from the model. The feature selection method can lead to different results, and the process requires a lot of human intervention. The experiment conducted mining and analysis on user learning behavior data of a domestic English vocabulary learning APP. Compared with the confusion matrix of the traditional Stacking model, the improved Stacking model has a stronger ability to distinguish user learning patterns. According to the formula, the accuracy of the improved Stacking model is 91.29%; The accuracy of traditional Stacking model is 90.71%. The ROC curve of the improved Stacking model is smoother than the three single models. Its AUC value is 0.85, which is the same as that of XGBoost. The function is also improved compared with the traditional Stacking model, Logistic Regression (LR) and Random Forest (RF) model. Therefore, the Stacking integrated model owns the best forecast performance and can accurately predict the long-term learning mode of users. In this study, the English learning patterns of mobile users are identified by the method of integrated learning, so that the prediction results of multiple basic learners can be integrated, and the complementarity between different learners can be effectively dealt with, thus improving the generalization ability of the model. This model aims at identifying the English learning patterns of mobile users, and can accurately identify the learning patterns of users by analyzing their learning behaviors on mobile devices. This is of great significance for personalized English learning recommendation. The English learning pattern recognition model for mobile users proposed in this study can identify users' learning patterns by analyzing their learning behaviors, thus providing personalized learning support and suggestions. In the process of digital manufacturing, they can learn from the idea of learning pattern recognition model and identify the patterns and laws in the production process by analyzing production data and process parameters, so as to optimize the production process and improve production efficiency.

Key words: Mobile assisted language learning; Learning behavior analysis; Integrated learning; Learning mode; Stacking

1. Introduction. Currently, under the advancement of mobile technique and the popularity of smart terminals, mobile devices such as mobile phones have become more widely applied in people's daily life. Meanwhile, the number of mobile phone holders has also continued to rise [1]. In this context, the popularization of smart phones in education means that the way of knowledge transmission and reception has undergone great changes. Mobile learning, born with the integration of technology and education, is characterized by personalization, interactivity and accessibility. Therefore, this way of learning is attracting much attention [2, 3]. At present,

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the research on mobile learning has covered many levels from theory to practice. It involves interactive technology, learning mode, and methods of integrating with traditional classroom teaching in mobile learning. Among them, language learning is one of the important fields in mobile learning research [4]. The academic research on the application of mobile technology in language learning has undergone nearly 20 years of development, and has formed a rich research content and relatively independent research field, namely, Mobile Assisted Language Learning (MALL) [5]. MALL has not only received widespread attention and attention in academic circles, but also aroused great interest in the commercial market. Major Internet and online education enterprises have launched a wide range of language learning applications, involving vocabulary, reading, listening, translation and other language skills, to satisfy the users' learning needs in all aspect [6]. Language APPs, especially word APPs, are at the top of the list of online education product traffic with tens of millions of independent users all year round [7]. Meanwhile, the user behavior data recorded by these applications can help academic researchers understand the learning status of learners in the process of using APP from an objective perspective and at a micro level [8]. However, researchers generally prefer to use questionnaires and experimental design to obtain data. This cannot mine more valuable information from the big data. In addition, there are few studies on the development characteristics and change rules of user's learning behavior at present [9]. Therefore, from the perspective of data mining, this study uses integrated learning technology to identify mobile users' English learning patterns. The proposed model can comprehensively consider the characteristics of users' behavior and learning content, and comprehensively analyze and learn these characteristics. Compared with the traditional learning mode based on desktop computer, this method has the characteristics of portability and personalization, and can better adapt to the learning habits of mobile users. Because the mobile users' English learning pattern recognition model performs well on the training set, and there are individual differences in users' learning patterns, it can be shown that the method has strong generalization ability. For the performance of users in the new learning scene, the generalization ability of the model is further improved. When the model is faced with other design methods other than the reference architecture, the model is a complex integrated model, so the explanation of the model is effectively discussed. In order to provide an effective design method of mobile users' English learning pattern recognition model, this paper studies the collection and extraction of relevant data generated by mobile users in the process of English learning, and then preprocesses the extracted features. For the specific learning needs, the model is trained by using the preprocessed data. After evaluating the trained model in an independent test data set, this paper studies the optimization of the model, and applies the optimized model to the actual English learning scene, so as to identify the user's learning mode in real time. In addition, the research also focuses on the privacy protection and data security of the mobile users' English learning pattern recognition model, so as to ensure that the users' personal information is reasonably protected.

2. Related work. Recently, integrated learning has received extensive attention in the data mining. Many researchers use it as a tool for disease prediction and detection. Pei et al. proposed a learning modeling framework integrating genetic information to predict early treatment reaction of antidepressants for severe depression at baseline. The results showed that the performance of the suggested method was improved compared with the single-level model; The accuracy of imaging data and genetic data was improved from 0.61 to 0.86. The integrated learning framework of genetic features increased the sensitivity from 0.78 to 0.87 [10]. Vogelstein et al. applied the integrated learning model to the early detection of Alzheimer's disease in the elderly. The results indicated that the detection accuracy was 94.64%; The comparison with other models also shows that the model are the best [11]. To achieve accurate classification of rock burst intensity, Zhang et al. suggested an integrated machine learning method. The results showed that the accuracy of rockburst classification obtained by the classifier set was improved by 15.4%. In addition, the importance of the prediction variables obtained from the classifier set showed that the most unstable variable for rock burst was elastic energy index [12]. Hong et al. paid attention to the process monitoring of industrial activities and proposed an integrated process monitoring method. The experiment proved the effectiveness of the method. The research compared the performance of this method with other methods, and the results also proved that this scheme had better performance [13]. Some researchers also noticed the use of integrated learning technology in education. Nuankaew et al. proposed a higher education curriculum recommendation model. The results showed that the accuracy of the model developed using majority voting technology is the highest, reaching 91.65% [14].

In addition, the Stacking integration algorithm is popular as well. Tan et al. focused on the development of power load forecasting technology. To carry out load forecasting, an experimental load forecasting method combining support vector regression and superposition is proposed. A series of comparison algorithms are introduced. The comparison results verify that the method has high prediction accuracy and generalization ability, and is superior to the comparison algorithm [15]. Meharie et al. applied Stacking integrated machine learning algorithm to predict highway construction cost. The results showed that the model could predict accurately. The comparison results of the models showed that the Stacking integrated model was superior to the single model in all performance indicators. For the RMSE value, the accuracy of the results produced by the Stacking integrated cost model was 86.8%, 87.8% and 5.6% higher than that of linear regression, vector machine support and neural network models respectively [16]. Acuna et al. proposed a genetic algorithm with improved efficiency. The research results showed that compared with several advanced genetic algorithms with multimodal functions, the convergence speed of this improved genetic algorithm performed better. The research results also tested the effectiveness of the model, which could be applied to the two-dimensional common reflector superposition problem [18]. Youssef et al. paid attention to the dropout of MOOC learners and developed a prediction model to classify them. This method applied feature selection method and integrated machine learning algorithm, and took several similar algorithms as the basis for comparison. Several performances of the method were evaluated by experiments. The comparison results demonstrated that this algorithm has excllent performance and its prediction accuracy reaches 98.6% [17].

To sum up, the integration algorithm, especially the Stacking integration algorithm, has been more and more widely used in many fields. However, the application of this kind of algorithm in the field of education is relatively limited, and few people pay attention to its application in data mining of language learning APP. In addition, the existing research mainly applies it to the fields of curriculum recommendation and performance prediction; However, there are few studies on the development characteristics and change rules of user's learning behavior. Therefore, the research starts with English vocabulary learning and uses Stacking integration algorithm to study mobile English learning APP. The experiment deeply digs and analyzes user learning behavior data. The purpose of this experiment is to mine the learning mode of user groups from the memorization data through clustering and modeling. The experiment takes the learning state representation attribute as the explanatory variable, and then realizes the prediction and recognition of the learning mode.

3. Mobile user English learning pattern recognition model based on integrated learning.

3.1. Establishment of mobile user English learning pattern recognition model. The English learning pattern recognition model built by the research institute consist of data preprocessing, feature screening, model training and output results, as shown in Figure 2.1. Before model training, data preprocessing and feature filtering are required. When obtaining data, due to various subjective and objective reasons, a large number of missing values and noise values may be generated; These data are very unfavorable to the training of the algorithm model [19]. Therefore, it is necessary to convert the data into standard data that can be recognized by the model in the data preprocessing stage. This can ensure the validity and precision of the model in the subsequent modeling process.

Data preprocessing includes missing values, outliers and data normalization. The missing value refers to the incomplete data caused by the lack of some data information in the original data [20]. Research the deletion of features with high and low missing values; For features with a moderate proportion of missing values, the missing feature is used as the target label; In this study, the RF model is trained by using non-missing features as variables. Abnormal value refers to the individual value in the sample that significantly deviates from its numerical range. In the study, the univariate outlier detection method is used to draw the boxplot of characteristic variables, as shown in Figure 3.2.

The distribution of variables can be intuitively understood according to the box diagram. The experiment can further deal with the abnormal value of the characteristic variable by combining the meaning and type of the variable. Data normalization is to accelerate the convergence. The Min-Max method is applied in the study to convert the original value of the variable into [0,1] standardized value, which is defined as formula 3.1.

$$x_j^i = \frac{v_j^i - \min_{1\le i\le M}(v_j^i)}{\max_{1\le i\le M}(v_j^i) - \min_{1\le i\le M}(v_j^i)} \tag{3.1}$$

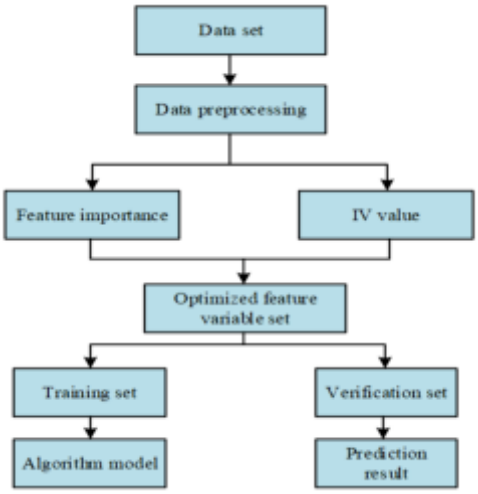


Fig. 3.1: Model building framework

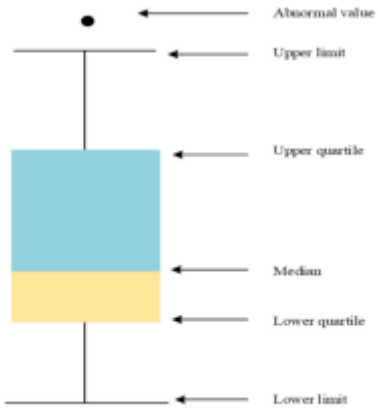


Fig. 3.2: Example of the Box-plot

In formula 3.1, suppose x_j^i denotes the normalized value of the i-th sample on the j-th characteristic variable; v_j^i indicates the value of the i-th user on the j -th characteristic variable; M indicates the total number of samples.

Feature selection is an essential part, whose purpose is to seek the optimal feature subset. On the one hand, feature selection reduces the dimension of features and enhances the training efficiency and accuracy of the model. On the other hand, it alleviates the problem of over-fitting and has a significant impact on advancing the generalization ability of the model. This study design a multi-dimensional feature selection method, which can comprehensively consider feature importance and IV value, and score feature variables from the perspective of model and statistics. Then weaken the influence of data distribution on feature selection, and select features with strong prediction ability. The research uses Gradient Lifting Decision Tree (GBDT) to calculate feature importance. Definition $X = \{x_1, x_2, x_3, , x_n\}$ is the set of characteristic variables after processing missing values and outliers. Input into the GBDT model to obtain the square loss caused by node splitting after fitting the data. Take the square loss value as the importance score of each feature $C_j, j \in \{1, 2, 3, , n\}$.

IV is applied to describe the significance contribution of each feature, and the feature set can be sorted

according to the importance of the feature. The calculation of IV value depends on WOE (Weight of Evidence) value. The calculation of WOE value needs to group the data to make the feature discrete. In the experiment, the strategy of frequency splitting is adopted for continuous variables; Specify the threshold for other variables to implement the unpacking policy. The WOE value of each group can be calculated after unpacking, and the formula definition is shown in formula 3.2

$$\mathrm{WOE} = \ln\left(\frac{\mathrm{Bad}_i}{\mathrm{Bad}_T} \div \frac{\mathrm{Good}_i}{\mathrm{Good}_T}\right) = \ln\left(\frac{\mathrm{Bad}_i}{\mathrm{Bad}_T}\right) - \ln\left(\frac{\mathrm{Good}_i}{\mathrm{Good}_T}\right) \tag{3.2}$$

In formula 3.2, taking the number of words memorized as an example, Bad_i indicates that the number of words memorized per day in the current variable group label is more than 50; iIndicates that the label is the total number of words recited per day that does not exceed 50. indicates that in group i , the label is the number of samples with total recited words exceeding 1000; $Good_T$ Indicates the total number of labels with more than 1000 samples. WOE transform makes the feature not only have numerical attributes, but also reflect the weight of grouping. After obtaining the WOE value of the sub-container, formula 3.3 indicates the calculation of IV value.

$$\mathrm{IV}_i = \left(\frac{\mathrm{Bad}_i}{\mathrm{Bad}_T} - \frac{\mathrm{Good}_i}{\mathrm{Good}_T}\right) \cdot \mathrm{WOE}_i = \left(\frac{\mathrm{Bad}_i}{\mathrm{Bad}_T} - \frac{\mathrm{Good}_i}{\mathrm{Good}_T}\right) \cdot \ln\left(\frac{\frac{\mathrm{Bad}_i}{\mathrm{Bad}_T}}{\frac{\mathrm{Good}_i}{\mathrm{Good}_T}}\right) \tag{3.3}$$

The IV value ensures that the result is non-negative based on the WOE value. According to the IV value of the variable in each group, the calculation of the IV value of the entire variable is shown in formula 3.4

$$\mathrm{IV} = \sum_{i=1}^{n} IV_i \tag{3.4}$$

The larger the IV value, the greater the role of this variable in distinguishing user learning patterns and the stronger the predictive ability. Calculate the IV value of each characteristic variable and define it as $D_j, j \in \{1, 2, 3, , n\}$. To eliminate the influence of numerical measurement, it is necessary to substitute the feature importance C_j and feature IV value D_j into formula (2.4) for Min-Max normalization. Get the feature importance score $S(C_j)$ and IV value score $S(D_j)$ of feature j. Add the two to get the comprehensive score F_j of the variable. The research adopts the cumulative contribution of comprehensive score greater than 85% as the feature screening criteria, that is, in the data set $X = x_1, x_2, x_3, , x_n$ composed of n features, there is a feature subset composed of k features. This subset makes F in X' formula 3.5(2.5) hold when it is greater than 85%; X' is the optimized feature variable set.

$$S(x_j) = \frac{x_j - \min_{1 \le j \le n}(x_j)}{\max_{1 \le j \le n}(x_j) - \min_{1 \le j \le n}(x_j)} \tag{3.5}$$

$$F = \frac{\sum_{j=1}^{k} F_j}{\sum_{j=1}^{n} F_j} \tag{3.6}$$

4. Stacking integration algorithm and its optimization. Stacking is an integrated learning algorithm that adopts a hierarchical model fusion strategy. It usually consists of a two-layer structure, as shown in Figure 4.1. The first layer consists of multiple base learners; The second layer consists of a meta-learner. The traditional Stacking algorithm fuses multiple weak learners through a two-layer layout to form a strong learner. However, the multiple base learners obtained by K-fold cross validation are different due to different training sets. There may be differences in the prediction performance, and it may make the base learners with good performance cover up the base learners with poor performance.

Under the current research background, when building the Stacking learning pattern recognition model, base learners' ability to distinguish data sets is particularly important. Therefore, higher weight should be given to the features produced by the base learners with stronger discrimination ability. This study uses KS

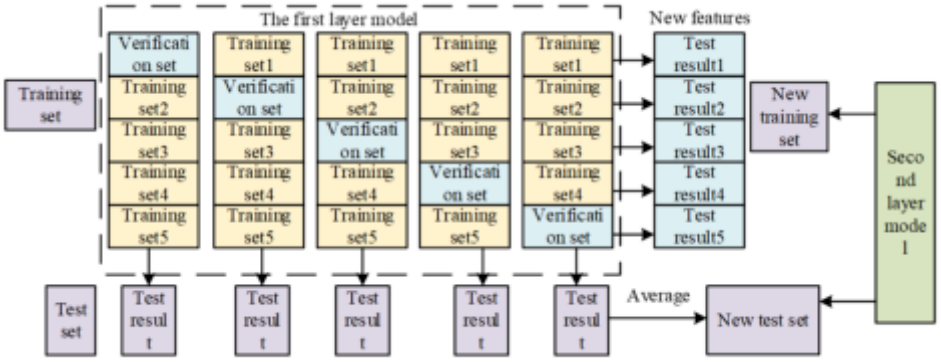


Fig. 4.1: Schematic diagram of traditional Stacking algorithm training

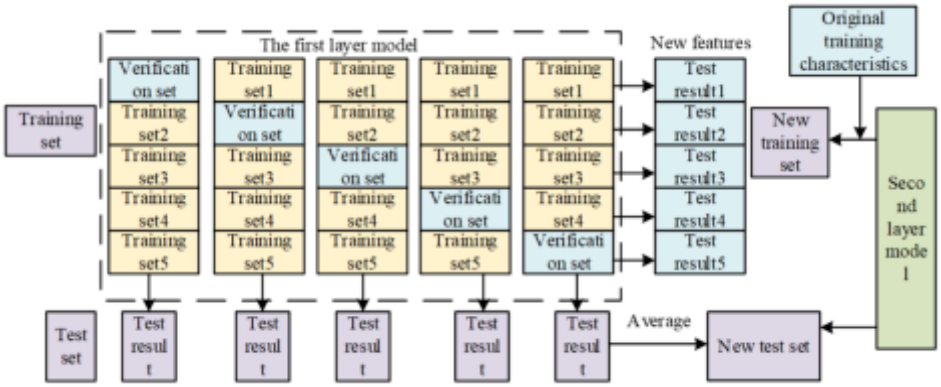


Fig. 4.2: Schematic diagram of traditional Stacking algorithm training

value measurement model to distinguish the strength of the ability. When generating the training set and test set of the second layer through K-fold cross validation of the first layer learner, the KS value of each fold model to the verification set is calculated; The KS value is used as the weight value to weight the prediction results of the verification set and the test set, and then form the second layer of data set that has been differentiated and weighted. Meanwhile, to prevent over-fitting, the experiment expanded the second layer input features, and combined the original features with the differentiated weighted features as the input of the second layer meta-learning machine. This method can also enhance the generalization ability. Its principle is displayed in Figure 4.2.

For the selection of improved Stacking integration algorithm model, the first-level base learner selects the integration model XGBoost and RF with strong prediction ability. The second layer selects the LR model with simple structure and strong explanatory power. Because the selected model has many super parameters, the above learner's parameters can be optimized by grid search. A set of parameter combinations with the highest AUC value of the above three models under the 50% cross-validation were determined. Figure 4.3 illustrates the total structure.

The research briefly introduces the specific methods used. XGBoost algorithm is an integrated tree model for distributed implementation. It owns the characteristics of fast running velocity, high prediction precision and not easy to over-fit. XGBoost is composed of multiple CART trees. The latter tree will fit the residuals of all the previous trees, and finally output the cumulative sum of the prediction results of all the trees. In the training stage, the latter CART tree completes the training based on the previous CART tree. Suppose the

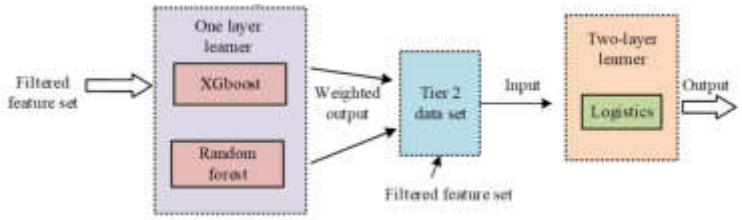


Fig. 4.3: Structure of the personal credit scoring model

sample data set is (x_i, y_j), where $xR^m, yR;;$ x belongs to feature vector; y belongs to the label value. Define XGBoost model as shown in formula 4.1.

$$\hat{y}_l = \sum_{k=1}^{K} f_k(x_i), \quad f_k \in F \tag{4.1}$$

In formula 4.2, $\widehat{y}_i$ represents the predicted value of the i sample; K indicates the number of current CART trees; x_i represents the characteristic vector of the i -th sample; f_k represents the predicted value of the i -th sample on the k-th tree. The current sample's output is the sum of all the predicted values of the CART tree. The weight vector w and mapping relationship q of leaf nodes in the CART tree are defined as formula 4.2 .

$$f_t(x) = w_q(x) \tag{4.2}$$

In formula 4.4, w denotes a one-dimensional vector with length T , representing the weight of each leaf node of the tree $q; q$ denotes the structure of a tree. The target function generated by each tree in XGBoost is defined as formula 4.3.

$$\text{Obj} = \sum_{i=1}^{n} l(y_i, \hat{y}_l) + \sum_{k=1}^{K} \Omega(f_k) \tag{4.3}$$

In formula 4.5, the former term denotes the loss function, and the latter term denotes the complexity of the tree. The number of current leaf nodes and L2 normal form constitute the complexity of the tree, as defined in formula 4.4.

$$\Omega(f_t) = \gamma T + \frac{1}{2}\lambda \sum_{j=1}^{T} w_j^2 \tag{4.4}$$

The objective function of the i-th tree is shown in formula 4.5.

$$\text{Obj}^{(t)} = \sum_{i=1}^{n} l(y_i, \hat{y}_l) + \sum_{k=1}^{K} \Omega(f_i) = \sum_{i=1}^{n} l(y_i, \hat{y}_l^{(t)} + f_t(x_i)) + \Omega(f_i) + \text{constant} \tag{4.5}$$

Split the regular items. Because the structure of the previous t tree has been decided, the complexity of the previous $t-1$ tree can be expressed as a constant *constant* ; So in the above formula, only $f_t(x_i)$ is a variable, and the rest are known quantities that can be calculated. Carry out second-order Taylor expansion of formula 4.5 to obtain the result as shown in formula 4.6.

$$\begin{cases} Obj^{(t)} \approx \sum_{i=1}^{n} [l(y_i, \hat{y}_l^{(t-1)}) + g_i f_t(x_i) + \frac{1}{2} h_i f_t^2(x_i)] + \Omega(f_i) + \text{constant} \\ g_i = \partial \hat{y}_{(t-1)} l(y_i, \hat{y}^{(t-1)}) \\ h_i = \partial^2_{\hat{y}_{(t-1)}} l(y_i, \hat{y}^{(t-1)}) \end{cases} \tag{4.6}$$

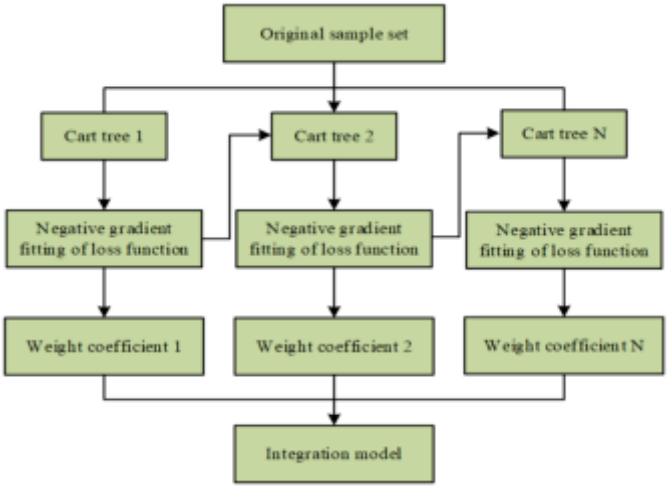


Fig. 4.4: Schematic diagram of GBDT

In formula 4.6, g_i and h_i are the first and second order partial derivatives of the loss function to $y^(t-1))$; Then divide all samples x_i with the same category as the x_i leaf node into the same sample set, and the mathematical expression is shown in formula 4.7.

$$I_j = \{i \mid q(x_i) = j\} \tag{4.7}$$

Substitute the definition formula and complexity formula of the above tree into formula 4.8 to obtain formula 4.8.

$$Obj^{(t)} \cong \sum_{i=1}^{n}[g_i f_t(x_i) + \frac{1}{2}h_i f_t^2(x_i)] + \Omega(f_i) = \sum_{j=1}^{T}[\sum_{i\in I_j} g_i w_i + \frac{1}{2}(\sum_{i\in I_j} h_i + \lambda)w_j^2] = \gamma T \tag{4.8}$$

In formula 4.8, $\sum_{i\in I_j} g_i$ and $\sum_{i\in I_j} h_i$ are equivalent to the total of the first and second partial derivatives of the samples contained in the leaf node j , which are two constants. Therefore, the above equation is a univariate quadratic equation. Wherein,) w_j is an independent variable; $Obj^(t)$ is a dependent variable. According to the maximum formula, the leaf node j is optimal w_j^* as shown in formula 4.9.

$$w_j^* = \frac{\sum_{i\in I_j} g_i}{-2 \times \frac{1}{2}\left(\sum_{i\in I_j} h_i + \lambda\right)} = -\frac{\sum_{i\in I_j} g_i}{\sum_{i\in I_j} h_i + \lambda} \tag{4.9}$$

After obtaining the optimal leaf node w_j^* , the optimal objective function can be obtained for the fixed tree structure, as shown in equation 4.10.

$$\mathrm{Obj}^{(s)} = -\frac{1}{2}\sum_{j=1}^{T}\left(\frac{\left(\sum_{i\in I_j} g_i\right)^2}{\sum_{i\in I_j} h_i + \lambda} + \right)\gamma T \tag{4.10}$$

The value of the above formula is negatively correlated with the prediction ability of the model; The smaller the value is, the stronger the prediction ability of the model is. GBDT is the representative model of integration method, and its principle is shown in Figure 4.4.

GBDT will sum the gain generated by node splitting of CART tree, calculate its maximum correlation and minimum redundancy, so as to filter features of features. Let the importance of feature j be J_j^2, , as shown in

formula 4.11.

$$\hat{J}_J^2 = \frac{1}{N}\sum_{n=1}^{N}\hat{J}_J^2(T_n) \tag{4.11}$$

In formula 4.11, N is the number of regression trees. Assuming $J_J^2(T_n)$ is the importance of the feature j in a tree, the calculation process is written in formula 4.12.

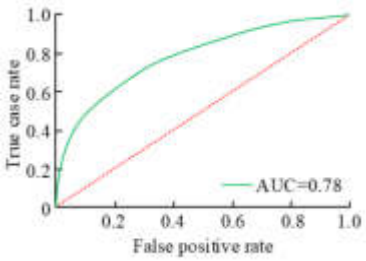
$$\hat{J}_J^2(T_n) = \sum_{t=1}^{L-1}\hat{h}_t^2 l(v_t = j) \tag{4.12}$$

In formula 4.12, $L-1$ is the number of non-leaf nodes contained in the CART tree; v_t and h_t^2 represent the characteristics associated with node t and the loss of the node in the splitting process.

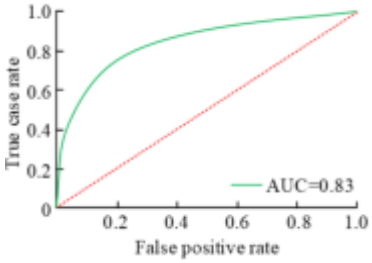
The RF uses the method of sampling back to randomly select data and features. It consist of multiple CART decision trees in structure. Each decision tree is regarded as a weak learner. Assume that the total number of samples in the original dataset D is n . It contains M characteristics. The number of decision trees needed to build a RF model is k. The calculation of RF contains the extraction of training subset, the decision tree's construction, the RF's generation, the classification and prediction test set and the output of final results. The prediction result is calculated as shown in formula 4.13

$$T(x) = \arg\max\sum_{i=1}^{k} I(t_i(x) = y) \tag{4.13}$$

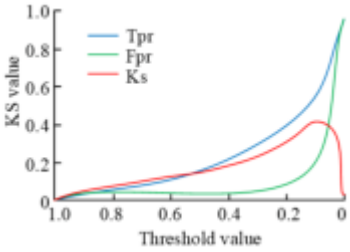
In formula 4.13,i is the predicted result of the $t_i(x)$ test set. The specific indicators used in this study include AUC value, ROC curve and accuracy. AUC measures the relationship between the sensitivity of mobile users' English learning and the false positive rate under different thresholds, and its value ranges from 0 to 1, and 0.5 indicates that the working state of the recognition model at this time is random guess. The closer the AUC value is to 1, the better the performance of the model, which is a commonly used index to evaluate the performance of the model. ROC curve is a graphical representation method to evaluate the performance of the model. It draws the curve by changing the threshold of mobile users' English learning status. On the ROC curve, each point represents a different point in a specific learning mode. Each point on the curve corresponds to a different performance of the English learning recognition model, and the area under the curve represents the overall performance of the model. By observing ROC curve, we can choose the best threshold to achieve the best performance of mobile users' English learning pattern recognition model. In order to evaluate the effectiveness of low-cost digital manufacturing system, this study first draws the cost-benefit of the traditional manufacturing system according to ROC curve, and compares the cost and return of the two systems; Then calculate their differences in production efficiency. At the same time, it is judged whether the production efficiency of the manufacturing system reaches the standard through the production capacity indexes of the two systems. For the effectiveness of low-cost digital manufacturing system in quality control, this paper compares the product quality and defects of the two systems, and then evaluates the control ability of low-cost digital manufacturing system. When the low-cost digital manufacturing system is superior to the traditional system in terms of production flexibility, it shows that the low-cost digital manufacturing system can provide higher degrees of freedom. In addition, the study also evaluates the environmental sustainability of low-cost digital manufacturing systems. In this step, the energy consumption difference between the two systems is compared.



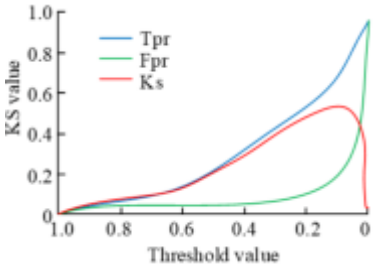
(a) The curve of Logistics Regression ROC



(b) The curve of Random Forest ROC



(c) The curve of Logistics Regression KS



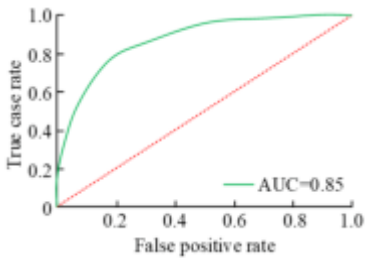
(d) The curve of Random Forest KS

Fig. 5.1: ROC, AUC and KS values of Logistics regression model and RF model

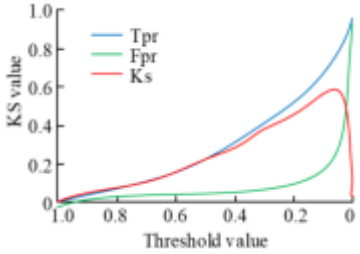
5. Result analysis.

5.1. Model prediction performance analysis. The research carries out experimental analysis on the learning recognition model. The experimental evaluation indexes include AUC value, KS value and accuracy. The optimized data set is divided into training set and test set. Wherein 70% as training set; 30% as test set. The training set is used as the input of LR model and RF model. In the training process, the grid search method is applied to adjust the parameters. In this study, the source of data is online learning platform. This data set contains various behaviors and interactive data of users in the process of learning English. The purpose of this study is to identify different learning modes by analyzing the learning behavior and learning data of mobile users. Firstly, the collected learning data set is divided into training set and test set, and then the integrated learning method is used to select the best parameter combination of training set. Finally, the test set is used to evaluate the trained model. Through this evaluation method, the experimental results of model improvement are obtained. Feature importance and IV value are commonly used feature selection methods to evaluate the predictive ability of user behavior characteristics to English learning patterns. The importance of features measures the contribution of features in the model, while the IV value measures the prediction ability of features to target variables. When using feature importance and IV value for feature selection, the study evaluates the predictive ability of user behavior characteristics to English learning patterns according to the size of feature importance and IV value.

In this study, the test set will be predicted, and the ROC curve, AUC value and KS curve of the Golden Sine (GS) model, Proportional Integral Derivative (PID) model, LR model and RF model will be compared with them, as shown in Figure 5.1. The AUC value of the model under the combination of the processed training set and the optimal parameters is 0.78. Figure 5.1b) shows that only when the test set threshold reaches 0.1 to 0.2 can the model have good discrimination; That is, within this range, KS value reaches the maximum value, which is 0.427. Combined with the confusion matrix data, the prediction result of LR model is low. The classification accuracy of the output results of a large number of samples is low. Therefore, when the threshold



(a) The curve of XG BoostROC



(b) The curve of XG BoostKS

Fig. 5.2: ROC, AUC and KS values of XGBoost

Table 5.1: Confusion matrix for Stacking

Model	Correctly predict the result											
	Login days			Daily average login times			Recitation amount			Daily average reciting vocabulary		
	<30	30-60	60<	<3	3-5	5<	<200	200-500	500<	<20	20-50	50<
Traditional Stacking	35657	52397	12508	65144	28779	9541	41212	58194	9629	71758	37697	5914
Improved Stacking	35897	52482	12585	65235	28946	9652	41256	58426	9714	71912	37764	5976

set by the model is greater than 0.2, the judgment result of the model is not reliable. ROC curve, AUC value and KS value after RF model test are shown in Fig. 5.1c and 5.1d. The model's AUC value after parameter adjustment and data processing is 0.83; The KS value is 0.534, and the probability threshold of the maximum KS is between 0.05 and 0.15. The ROC curve and KS value also show that the stochastic forest model performs better discrimination than the Logistic model.

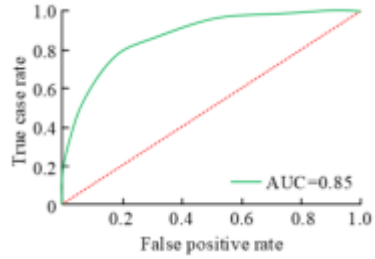
As shown in Figure 5.2, the model's AUC value is 0.85 and the KS value is 0.553. When the threshold reaches the range of 0 to 0.2, the KS value reaches the maximum. Compared with LR model and RF model, XGBoost model has better performance in classifying samples. In addition, the sample prediction probability distribution of XGBoost is more uniform than that of LR model. The distribution results are also more reasonable, indicating that the model has better discrimination.

Conduct grid search on the Stacking model, and input the training set into the two kinds of Stacking models for training. The experiment predicts the test set, and the resulting confusion matrix is shown in Table 5.1. In the improved Stacking model, 37764 samples were correctly identified on the samples with more than 20 but not more than 50 memorized words per day; In the case that the number of words recited per day is less than 20, 71912 samples were correctly identified; On the samples with more than 50 words memorized daily, it correctly identified 5976. Compared with the confusion matrix of the traditional Stacking model, the improved Stacking model has a stronger ability to distinguish user learning patterns. According to the formula, the accuracy of the improved Stacking model is 91.29%; The accuracy of traditional Stacking model is 90.71%.

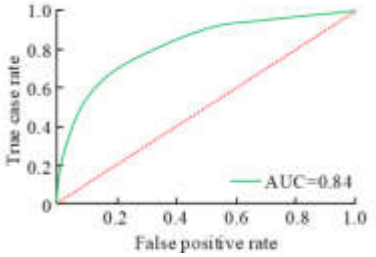
ROC curve and AUC value are shown in Figure 5.3. The ROC curve of the improved Stacking model is smoother than that of the three single models; Its AUC value is 0.85, which is the same as XGBoost; The improved Stacking model has better performance than the traditional Stacking model, LR and RF model. The KS value of the model is 0.583; When the threshold is about 0.1, KS gets the maximum value.

5.2. Comparative analysis of models. LR, RF, XGBoost and traditional Stacking models were selected as the baseline models for the performance evaluation of the optimization model; The indicators for comparison include AUC, KS and accuracy.

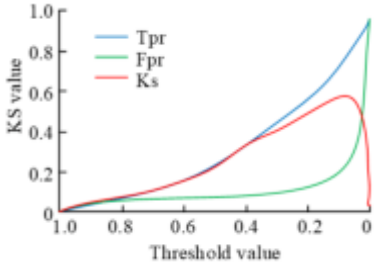
As shown in Table 5.2, the AUC value, KS value and precision of the improved Stacking model built in the study are 0.85, 0.582 and 91.29% respectively. The improved Stacking model has the highest prediction



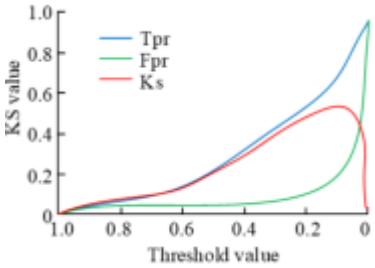
(a) Improved Stacking Model ROC'S



(b) Tradtional Stacking Model ROC'S curves



(c) Improved Stacking Model KS'S curves



(d) Traditionla Staking model KS's Curves

Fig. 5.3: Comparison between improved Stacking model and traditional Stacking model

Table 5.2: Comparison of integrated model evaluation indicators

Model	AUC	KS	Accuracy rate
LR	0.78	0.426	89.46%
RF	0.83	0.533	90.04%
XGBoost	0.85	0.553	90.11%
Traditional Stacking	0.84	0.556	90.71%
Improved Stacking	0.85	0.582	91.29%

accuracy; Compared with the single model, it has improved to different degrees. On the AUC value of the indicator, the improved Stacking model and XGBoost model are the same; Compared with traditional Stacking model, LR and RF model, it has been greatly improved. In terms of the key indicator KS value, the improved Stacking model also has a significant improvement compared with other models. From the comprehensive index data, compared with the traditional Stacking model and the single model, the improved Stacking model built for user learning mode has better discrimination and performance. This verifies the effectiveness of the model in the field of online English education APP user classification.

To verify the effectiveness of the multi-dimensional feature screening strategy, the experiment input the pre screening data into the single model, the traditional Stacking model and the improved Stacking model for training respectively. In the experiment, the AUC value, KS value and accuracy rate are also applied. Table 5.3 demonstrates the final results. From Table 5.3, the AUC, KS and precision of the data set before screening have decreased compared with the data after screening after training by inputting the data set before screening into Logistics, RF, XGBoost, Traditional Stacking Model and Improved Stacking Model. In particular, the key indicators KS value and AUC value have significantly decreased. This shows that the feature filtering strategy

Table 5.3: Pre-feature screening model indicators

Model	AUC	KS	Accuracy rate
LR	0.76	0.404	87.75%
RF	0.80	0.515	89.87%
XGBoost	0.81	0.534	89.16%
Traditional Stacking	0.81	0.530	89.71%
Improved Stacking	0.82	0.552	90.34%

proposed by the research can be used to optimize the recognition of user learning patterns [21, 22, 23], and it has a good effect on improving the model discrimination and accuracy.

6. Conclusion. Recently, learning behavior analysis based on mobile platform data has attracted more and more attention. This study uses feature importance and IV value to grade feature variables layer by layer. Meanwhile, the experiment adopts the integrated learning method, and improves the Stacking integration algorithm with the differentiation weighting and feature extension combined with the recognition of learning patterns. The experiment compared the effect of the model trained by the data set before and after screening, and found that the AUC value, KS value and prediction accuracy of the model built after the screening strategy designed by the research institute were improved. The results demonstrated that the strategy is efficient in improving the performance of the credit scoring model. The comprehensive experimental results indicate that compared with the single model and the traditional Stacking model, the improved Stacking model has advancement in AUC value, KS value and prediction accuracy; The AUC value is 0.85, the KS value is 0.582, and the accuracy rate is 91.29%. Therefore, this method is more effective than the previous methods and can provide reference for mobile users' English learning pattern recognition. However, there are few characteristic variables screened out in the current study. Further mining is needed in the future to obtain more accurate analysis models. This study is only aimed at online users' English learning pattern recognition, and the research on using social networks and social learning theory is still insufficient. Incorporating social factors into mobile users' English learning pattern recognition model can analyze users' interactive behavior in social networks and the influence of learning communities, so as to promote cooperative learning and knowledge sharing among users. This study is also of great significance to the study of mobile users' English learning mode, and will be carried out gradually in future research.

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APPLICATION OF FASHION ELEMENT TREND PREDICTION MODEL INTEGRATING AM AND EFFICIENTNET-B7 MODELS IN ART DESIGN

WEN YAN*, XIAOJING CAO†, AND PENG YE‡

Abstract. The poor application effect of traditional sports training methods and the difficulty of recording data due to the time and space constraints of sports make it difficult for trainers to improve their learning outcomes. Based on this, the study proposes to apply human posture recognition in sports teaching design, and use VGGNet-19 as a feature extractor and OpenCV open source software to capture posture movements, and introduce the concepts of joint angle and movement similarity to design a sports assessment system for physical education based on the geometric spatial feature variability analysis of posture based on limb angle information. The testing outcomes demonstrate that the study's improved gesture recognition algorithm has a recognition rate of more than 90% on gesture movements, and the maximum recognition error value (0.010) is smaller than that of the dynamic time-regularised gesture algorithm (0.014) and the convolutional neural network algorithm (0.017). The assessment system is also better able to improve students' professional performance and satisfaction, with its average professional score and satisfaction reaching 86 and 92%, which is significantly better than other comparative algorithms. The method is effective in providing trainers with data-based training scenarios and helping them to improve their learning in sport.

Key words: Joint angle; Movement similarity; Human posture recognition algorithm; Physical education; assessment system

1. Introduction. Movement as a dynamic body change is based on the movement of a few key parts to demonstrate different teaching movements, so the piecing together and tracking of joint parts is a good way to depict the general work [1]. The design of a movement system to aid training will therefore allow the trainer to learn independently with less time and space constraints, and the trainer will be able to adjust their training plan and intensity in real time based on the training data. [2-3]. The human eye is the most common method of recording, but it is less accurate and less realistic. As an important means of acquiring information, computer vision, as an important branch of information science, is able to extract important feature information from the original image data, which has an important role in object recognition and image reconstruction [4]. Additionally, due to the quick advancement of computer technology, it is now possible to use pertinent artificial intelligence techniques in sports training, where vision techniques can be used to accurately assess and calculate sports types, sports movements, and athlete tracking. Human Pose Estimation (HPE) is a computerised image processing technique that identifies and locates the human body and its articulation points and realises the skeleton of the articulation points [5]. Based on this, the study proposes to apply human posture recognition in sports evaluation and reduce the recognition errors caused by individual differences and difficulties in continuous frame extraction based on joint angles and movement similarity. A sports assessment system is also designed to help learners improve their quality and mastery of sports movements.This article mainly studies the cable current carrying capacity from four aspects. The first part is a summary and discussion of some current algorithms related to human posture recognition and related sports teaching and evaluation. The second part introduces joint angle and motion similarity on the basis of the original pose recognition algorithm, and uses VGGNet-19 feature network for feature extraction, and constructs an evaluation system that meets the needs of physical education teaching. The third step is organising the results after analysing the simulation results and evaluating the developed recognition model's algorithm performance. A summary of the full essay is in the last section.

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2. Literature review. For 2D image pose detection, Nasr M scholars implemented part confidence map detection with the help of part affinity fields associated with parts, and the architecture method showed good application performance and efficiency [6]. With the aid of a multi-way matching technique, dong J scholars clustered 2D poses, and they also developed a view matching approach based on convex optimisation and geometric appearance. The results revealed that the system performed well on the dataset. In order to forecast the network topology, Chen T provided a 3D approach for estimating human pose, and he also implemented a full convolutional propagation structure with long hop connections. Pagnon D proposed a markerless Pose2Sim to improve the recognition accuracy of athletes' movements in the field, which takes a multi-view OpenPose 2D pose as input to calibrate the camera for joint coordinate measurement. The results showed that the standard deviation and mean absolute error of the method were small under different environmental conditions [9]. Luvizon D C scholars proposed a multitasking framework combining monocular colour images and multi-dimensional human pose with decoupling to achieve prediction of key components. The results show that the method shows good effectiveness on the dataset and can be adapted to multi-target tasks [10]. Pan T Y scholars used Myo armband wearing to make judgments on sports game referee signals, and its final recognition results were obtained by recognising the referee signal gestures and feature extraction by deep belief networks. The experiments showed that the method could better achieve hierarchical processing and training of multimodal data features [11]. Bakshi A scholars proposed a yoga coach design based on pose estimation, and used body key points to achieve region vector mapping, and identified sliced key points with the help of cause estimation model, and applied the method to pose recognition and detection such as squatting and forward bending. The method is better able to recognise postures in different states [12].

Yi X proposed a DNN-based capture method that included global translation and body pose to address the drawbacks of inertial inertial sensing technology for motion capture. The quantitative results showed that the method has better accuracy and efficiency than the learning optimization-based method and expands the sensor's motion spatial environment scale [12]. To overcome the issue that 3D human pose recognition is impacted by high resolution when deep learning is used, Xu X proposed a combination of resolution-aware network, self-supervised loss, and learning scheme. This extended method can better process low-resolution image video, effectively enhance the consistency of deep features, and has better application in pedestrian recognition [13]. qiu Z scholars proposed dynamic graph convolution module (DGCM) to strengthen the connection of key points of multi-person pose estimation recognition. The relationship between all edges of the image and the pose is considered. The outcomes demonstrated that the method's value-added magnitude effect on the test data was greater than 3% [14]. Papic C scholars implemented the analysis of sports videos with the help of neural networks and found that the method could effectively achieve the recognition and detection of body marker positions and greatly reduce the motion analysis time [15]. Mujahid Researchers combined the YOLO v3 and DarkNet-53 networks to recognise gestures, and the findings revealed that the strategy had improved accuracy and recall while requiring less image pre-processing and filtering [16]. Su H proposed a gesture recognition method combining deep visual learning and EMG signal-based gesture recognition, which made its recognition method consider less motion order. And the outcomes demonstrated that the method had greater application efficacy and minimised the step of data pre-annotation [17]. Yan G et al. implemented the HSV space method to segment the frontal segmentation of instructional videos to achieve the extraction of video feature vectors. Shi X et al. used computer-aided methods and mobile intelligence to optimise the design of physical education teaching, which was effective in improving teaching efficiency and student motivation [18]. In physical education and motion analysis, feature extraction with the help of posture recognition can effectively achieve action recognition, so the study uses human posture recognition algorithm for the design of motion evaluation system to better improve the application of physical education.

3. Design of improved human posture recognition algorithm and research on sports evaluation system. Human posture recognition is an important premise and basic content of the research. First, the research improves the human posture recognition algorithm. With its application in sports, the research uses VGGNet-19 as the feature extractor to capture the posture algorithm, and introduces the concepts of joint angle and motion similarity to carry out limb angle information and geometric spatial analysis analysis. Subsequently, starting from the requirements of the sports evaluation system, a sports evaluation system is built based on human posture recognition algorithm and joint angle distance evaluation, in order to better design a evaluation

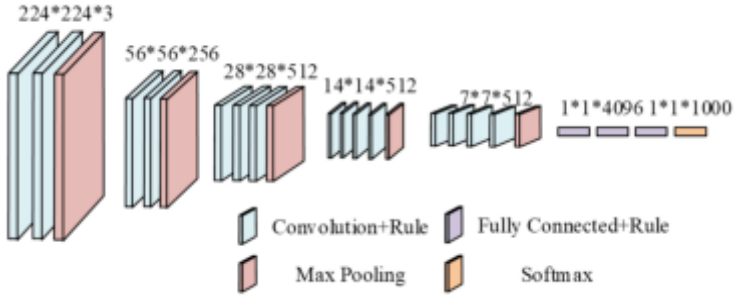


Fig. 3.1: Schematic diagram of VGGNet-19 network structure

system that meets the user's sports needs.

3.1. Application of human posture recognition algorithms in sports design. Conventional tools for human pose recognition are mainly analysed with the help of depth images or wearable device technology, but the costly nature of the research and the limited range of motion make it difficult to show good applicability in pose recognition. For acquiring key data for deep learning, open source software such as OpenCV is good for analysing the pose test module, but the effect of testing key points can be affected by environmental conditions, light sensitivity and other factors [19]. Therefore, the study applies OpenCV software with high robustness to the construction of human pose recognition system, and uses VGGNet-19, which can better adapt to different resolution image data, as the feature extractor. openPose extracts multiple key points from a single image frame simultaneously when performing human body recognition, and applies the affinity field method with real-time and targeting to the two-dimensional pose image of human body to The VGGNet-19 network is a deeper structured convolutional network, and its expansion of the network depth enables better network performance [21]. The VGGNet-19 network can be used to extract the image features and explore their depth of meaning. Figure 3.1 shows the structure of the VGGNet-19 network.

The VGGNet-19 network replaces the three fully-connected layers in the training process with three convolutional operations, making the final fully-convolutional network free from the limitation of fully-connectedness, so it is not limited by the width and height of the input data at the moment of input data.The VGGNet-19 can process input image data with different resolutions in Open Pose human pose recognition, and it mainly focuses on the confidence map feature of the key parts of the human body in the image. The confidence map features of the key parts of the human body are acquired.VGGNet-19 is used as a backbone feature extractor which is responsible for extracting the useful features from the input image.Passing the input image in the pre-trained VGGNet-19, different types of feature maps related to the gesture action can be acquired, which are convolved and downsampled to acquire the key points of the human body. The processed feature maps can generate Heatmap for pose estimation, the feature maps obtained in this processing stage can be lost to improve the convergence performance of the network, and the Heatmap predicted in the previous stage can provide rich spatial information, which plays an important role in the identification of joint points.When the system network performs body part location prediction, it forms a set of vector fields containing a combination of a confidence map and a partial affinity field, which effectively encodes the part association. The OpenPose network is trained using a multi-stage convolutional neural network structure, where the first ten layers of VGGNet-19 data are initialised to generate the input body feature map, and subsequent stages of images are cascaded with affinity fields and confidence map predictions. is shown in Figure 3.2.

In Figure 3.2, the first part of the OpenPose network structure, the network for key point detection first produces a part of the affinity field, and in each subsequent stage, the prediction results it produces will be associated with the fields produced in the first stage and the original graph features to improve the accuracy of its prediction.When key points are detected in the human pose recognition process, the subsequent predictions generated are linked to the affinity field generated in the first stage and the original graph features to improve

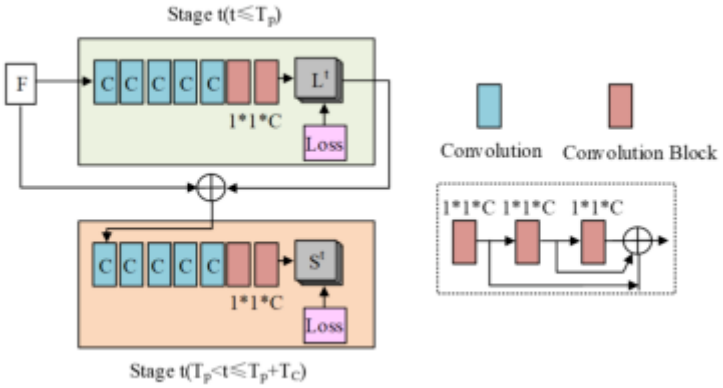


Fig. 3.2: OpenPose Network Structure

their prediction accuracy. The mathematical formulation of the affinity field is given in equation (3.1).

$$L^t = \phi(F, L^{t-1}), \forall 2 \leq t \leq Tp \tag{3.1}$$

In equation (3.1), ϕ represents the convolutional neural network for the prediction phase t, Tp is the total affinity field prediction, Tp is the number of iterations, F is the original graph feature, and ϕ is the set of vector fields for the prediction phase $t-1$. Repeating the prediction phase process requires the prediction of the confidence map, which is mathematically expressed in equation (3.2).

$$\begin{cases} S^{TP} = p^t(F, L^{TP}), \forall t = Tp \\ S^t = p^t(F, L^{TP}, S^{t-1}), \forall Tp < t \leq Tp + TC \end{cases} \tag{3.2}$$

OpenPose pose recognition itself contains occlusion problems and slow speed problems that can interfere with the recognition results. The common ideas for improvement are to reduce the model file by modifying the network model or to increase the number of processors by improving the hardware environment, but these two methods reduce the reliability of the motion evaluation system and consume more costs [22]. Therefore, the study started with the data to be measured and improved the fluency of the system by downsampling the images or data, i.e. setting the width and height in the feature extractor to 640 and 480 respectively, and compressing the images or videos in equal proportions. There are differences in the postures presented by the state changes of the joints during human movement, and the limb pinch features can also show similarities, which can easily lead to wrong judgement of movements. Therefore, the research is based on the limb angle information, with the addition of the centre of gravity vector information and the geometric spatial features of human posture for differential posture feature recognition. The flow of the feature extraction algorithm is shown in Figure 3.3.

In Fig. 3.3, after reviewing the video, detection is performed with the help of OpenPose pose recognition to determine whether there is an action pose, and if there is, then the skeletal point position information is extracted, the skeletal coordinate system is established in the unified coordinate system, the features of limb angle, axis, and limb direction are extracted and fused with the features, and the respective labels are created for the joint feature information of each pose, to complete the acquisition of the human body pose information. The human posture is extracted by first normalising the skeletal point position coordinate data to obtain the original sequence data, then using the human centre of gravity method, the limb angle calculation method and the skeletal point joint coordinate data calculation to obtain the feature vector data, and then fusing the three feature information to obtain the final human posture feature information. Equation (3.3) is the expression formula for the posture feature information.

$$F' = [G, V, O] \tag{3.3}$$

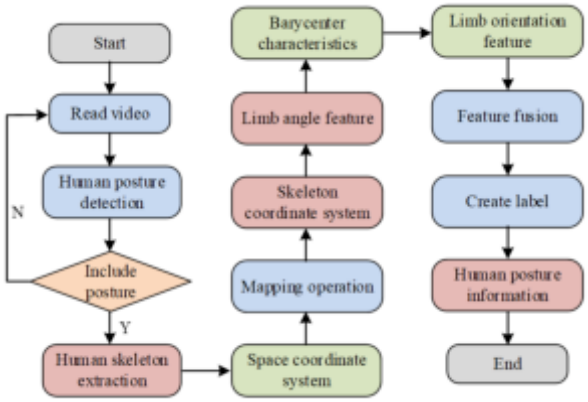


Fig. 3.3: Human pose feature extraction algorithm flow

In equation (3.3), G is the centre of gravity vector angle feature, V is the set of human limb angle features, and O is the set of limb orientation features. The formula for the skeletal point data conversion is shown in equation (3.4).

$$pi1 = pio - p10 = (xi0 - x10, yi0 - y10) = (xi1, yi1) \tag{3.4}$$

In equation (3.4), $pi0 = (xi0, yi0)$ represents the original coordinate data of the i joint point, and $pi1 = (xi1, yi1)$ is the coordinate data after the new coordinates. The moment synthesis method is used to transform the mechanical situation of the human centre of gravity into a combined moment of constant force, and the coordinates of the human centre of gravity are obtained according to the position and weight of each sub-extremity $(\frac{\sum Gi \cdot Xi}{G}, \frac{\sum Gi \cdot Yi}{G})$. The calculation is shown in equation (3.5).

$$\begin{cases} x = \sum ki \cdot Xi \\ y = \sum ki \cdot Yi \end{cases} \tag{3.5}$$

In equation (3.5), ki denotes the link correlation coefficient corresponding to each$i$ limb. When performing the calculation of limb angle pinch angles, the study was carried out with the vector inner product to obtain equation (3.6).

$$\theta = \arccos\left(\frac{\vec{G} \cdot \vec{M}}{|\vec{G}| \cdot |\vec{M}|}\right) \tag{3.6}$$

In equation (3.6), $\vec{G}$ and $\vec{M}$ represent the centre of gravity vector and the spine vector respectively, andθ represents the angle between the two. The principle is to operate on the direction vector with the help of the positive tangent function to obtain the radian information.

3.2. Design of recognition algorithm and evaluation system based on joint angle and movement similarity. The algorithm based on human pose recognition only locates the human joint points, but further extraction of the joint point coordinates is crucial. At the same time, due to the uncertainty of the human body in motion and the differences in its movement angles, the results of the two-dimensional action recognition images are also different and need to be analysed with the help of certain action description rules. The study introduces joint angle indicators and movement similarity for evaluation and analysis. The joint angle is the angle formed by the joint part adjacent to the front and back joints, which can be achieved by means of the cosine of the three-point coordinates, while the action similarity is used to identify the action by rule, which also enables the identification of continuous action sequences[23]. Action similarity is the core of

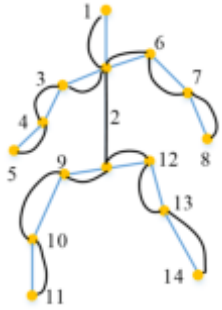


Fig. 3.4: Schematic diagram of human skeleton model labeling

describing action rules, which can be used to calculate the "distance" between two actions to identify individual actions, and can also be used to find out the "standard action" in a continuous action sequence. The calculation of the "distance" is still achieved by the joint angle data of the two actions, and the introduction of joint angle and motion similarity can be used for the evaluation of the action in human posture recognition to assist in judging the feature data extracted from the recognition image. The human posture recognition technology extracts the joints of the characters from the video or image containing the key actions, and calculates the respective joint angles, which are sorted and saved in the database according to the sequence of the actions, such as Action 1, Action 2, Action 3.... etc. Subsequently, the joint angle data of all the actions in the video are extracted and filtered with the joint angle data of the actions tested in the standard action database, which can be used for action evaluation. Setting the joint angles of the action to be measured and the template action to *Angle*, and *SAngle* respectively then the distance between the two vectors can be solved with the help of the Euclidean distance, whose mathematical expression is shown in equation (3.7).

$$\begin{aligned} D = ((SAngle1 - Angle1)^2 + (SAngle2 - Angle2)^2 + (SAngle3 - Angle3)^2 \\ + (SAngle4 - Angle4)^2 + (SAngle5 - Angle5)^2 + (SAngle6 - Angle6)^2 \\ + (SAngle7 - Angle7)^2 + (SAngle8 - Angle8)^2)^{0.5} \end{aligned} \tag{3.7}$$

The eight joint points are selected in equation (3.7). The smaller the Euclidean distance, the more similar the movements are and the better the joint angles are identified. Figure 3.4 shows a diagram of the human skeleton model markings.

The research was then based on the improved stance recognition algorithm proposed by the study to design a sports evaluation system a sports assistance evaluation system to help trainers to analyse their own sports state and process, and then improve their own deficiencies, so the research is based on OpenPose stance recognition and joint angle distance action evaluation, the design of the sports system, and in the process of system development and testing with a school secondary school students sports action as a test The object of the system development and testing is the sports movement of secondary school students. The functional design of the system is shown in Figure 3.5.

In the functional requirements design, the system establishes a standard action database based on key actions, so the evaluation focuses on the analysis of joint angle differences. Firstly the user needs to access the system window with the help of a password and user name, secondly the key movement images are captured in the movement database module and the system automatically implements the identification and saving of joint angles for key movements. Subsequently, in the assisted teaching module design, the user can practice the movements according to their situation and pause the exercises when the user's movements have a good resemblance to the movements captured by the system. The user can also analyse their own learning in the general assessment module, where the system will analyse the exercise work against key movements in the standard movement database for movement frame analysis, presented as Euclidean distance of the movement and joint angle data. The OpenCV 4.1.0 open source computer vision library enables the acquisition, loading, saving and transposition of images and videos. It has good image data processing capabilities as well as

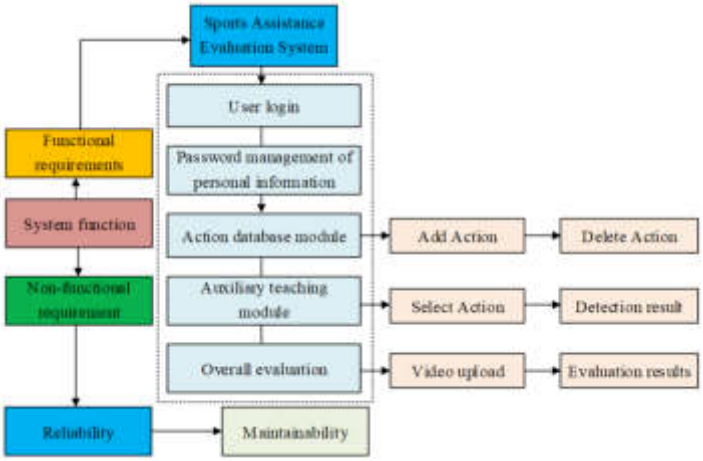
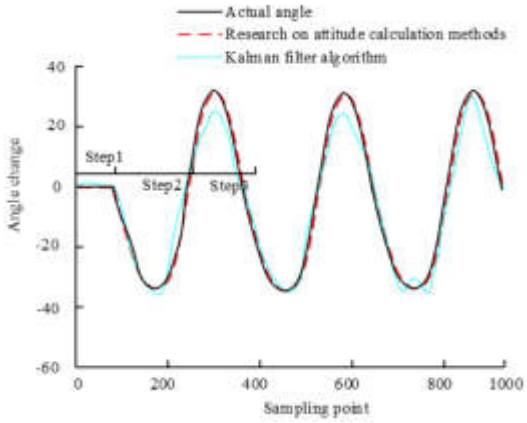


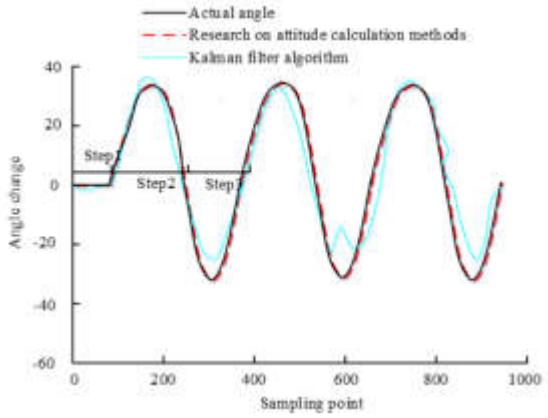
Fig. 3.5: Overall Design of System Functions

capture capabilities. In the data pre-processing part, OpenCV normalises the resolution of the input annoying image video to 480*360 and acquires the coordinates of the human skeletal points in the video. The obtained skeletal point coordinates are scaled isometrically to account for the effect of resolution changes on the skeletal information. In the feature extraction and pose matching section, the user's key movements are identified and similarity is calculated, thus enabling the user's movements to be scored to help them learn to correct their own movements.

4. Analysis of the results of sports evaluation applications with improved pose recognition algorithms. When designing the standard movement database, the collected movements are the key movements in sports, and the selection criteria and number of movements can be decided according to the norms of movement design and specific situations. The four pairs of movements that are prone to misjudgment in sports movement teaching are collected for analysis, i.e. leg raise, sideways, lift and lunge, and the video frames of each movement are taken as the collected data, which are captured by a camera shooting at 30 frames per second, obtaining the coordinates of the skeletal point data, marking the filenames, and distinguishing the movement data with the interference of the adjacent frames with the class sequence number. During the experiment, we design the relevant environment parameters, namely, the operating system is Windows10 64bit, the memory is DDR4 2400MHz 8GB, the CPU and GPU are Intel(R) Core(TM) i5-8300H 2.30GHz and NVIDIA GeForce GTX1050Ti 4G, and the software platforms include Qt5.9.0, VisualCon, and Qt4.1.0, and VisualCon. .0, Visual Studio 2015 and OpenCV.The resolution of the video file is 480p, and the frame rate is 30fps.During the experimental data acquisition process, the distance between the experimenter and the camera is designed to be 2-3 metres.The software platform is built in the Visual Studio 2015 environment, and the OpenCV computer vision inventory and C++ development are selected as the basic class library, which can process the involved data types as well as text information. Subsequently, the collected data were randomly divided into template set and test set according to the ratio of 6:4, and the similarity of pose calculation was used as the basis of judgement, and the threshold was set to 0.9 for the output of results.For the comparison of experimental results, the study compares the proposed improved gesture recognition algorithms, whose main evaluation metrics include Accuracy, Recall, and Teaching Evaluation Results, among others. Among them, Accuracy and Recall are commonly used metrics to evaluate the performance of classification models. Accuracy, defined as the number of samples correctly predicted divided by the total number of samples, measures the model's predictive accuracy across all samples and is a commonly used evaluation metric. Recall is defined as the number of positive samples correctly predicted by the model divided by the total number of true positive samples, which measures the model's ability to identify positive samples, and is an indicator for evaluating the sensitivity of the model and its ability to find true positive samples, and a higher recall indicates that the model



(a) Posture recognition results under a single action



(b) Posture recognition results under repeated actions

Fig. 4.1: Action posture curves of two algorithms

is better able to find positive samples. Accuracy emphasises the overall accuracy of the model's predictions, with higher values indicating that the model's predictions are more consistent with the true results. Mean Squared Error (MSE) and F1 value are mostly used to evaluate the performance of different types of tasks, MS is defined as the average of the squares of the difference between the predicted and true values, the smaller the MSE, the smaller the difference between the predicted results of the model and the true values, i.e., the better the model is fitted.The F1 value is a measure that combines both the accuracy and the recall, which combines the effects of accuracy and recall, especially more effective in the case of unbalanced categories.The value of F1 value ranges from 0 to 1, and the closer it is to 1 means the better the results predicted by the model. The main content of the study is the human posture recognition algorithm, so the analysis of the recognition of the posture and its accuracy with the standard movement, and the recall of the comparison algorithm can effectively assess the sensitivity of the algorithm to process the sample data. As for the evaluation of teaching movement, the study analyses the effectiveness of teaching with satisfaction, which can effectively analyse the practical ability of the application of the algorithm [26, 25, 24].

The pose solution method used for the study was compared with the pose Kalman filter algorithm for the analysis of the solution results and a simple kick action was used for the pose analysis. This leg lifting action can be divided into three steps of lift-kick-out-retract, and the action pose curves of both algorithms are obtained, as shown in Figure 4.1.

In Figure 4.1, the identification fit between the stance curve and the actual curve under the Kalman filter algorithm is above 90% under single action training, but it has significant nodal fluctuations at sample points 300, 600 and 750, with a maximum deviation rate of 4.17% from the extraction of the algorithm proposed in the study. The magnitude of the deviation of the posture curve between the two compared algorithms was extended to a maximum of 6.38% under repeated action testing, followed by joint angle calculation with the stance of standing on both feet and arms open, which is shown in Figure 4.2.

In Figure 4.2, the overall deviation of the proposed pose recognition algorithm from the real curve for joint point angle analysis does not exceed 2%. However, the Kalman filtering algorithm deviates from the real curve to varying degrees from one joint point to another. These results show that the proposed algorithm is able to recognise human movements well. The matching accuracy of the different algorithmic models for human pose recognition was then analysed and the comparison results are shown in Figure 8.

In Figure 4.3, the accuracy of the proposed pose recognition model in matching broad and detailed movements showed a more significant difference in accuracy with the Dynamic Time Warping (DTW) model and the Convolutional Neural Network (CNN) model. The improved pose recognition model achieved 94.8% and

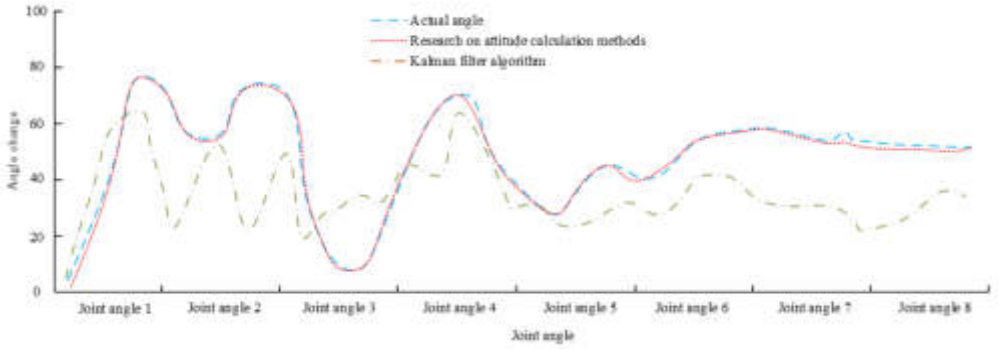


Fig. 4.2: Recognition Results of Two Algorithms under Joint Angle

93.4% action recognition accuracy on both data sets, with the highest matching accuracy (98.65%) for the lunge action. was less effective, with matching rates of 88.7% and 89.2% in datasets A and B, respectively, with a difference margin of 6.1% and 4.2% compared to the pose algorithm proposed in the study. The recall exhibited by the three algorithms was then analysed and the results are shown in Figure 4.3.

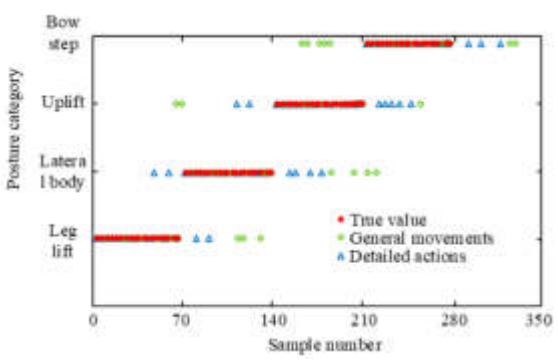
In Figure 4.4, the recall of the improved pose recognition algorithm model stays within the interval of [0.60, 0.67] and [0.68, 0.74] respectively during the training process on both datasets, and its overall recall changes at a more stable rate. The aforementioned findings demonstrate that the enhanced gesture recognition algorithm can successfully distinguish between positive and negative actions, and that the gesture actions are retrieved more effectively. The errors of the three algorithms in performing human action recognition are shown in Figure 4.5.

In Figure 4.5, the improved pose recognition algorithm's recognition error is shown to be substantially lower than that of the other two examined methods. Its maximum error value is 0.010, and it exhibits less overall variance. The maximum recognition error values for the DTW and CNN algorithms are 0.014 and 0.017, which are 0.004 and 0.007 higher than the algorithms proposed in the study, and the error curves for these two algorithms are less occurring in a numerical continuum. The results of the different algorithms for pose recognition were subsequently analysed with the help of ablation experiments, the results of which are shown in Fig. 4.6.

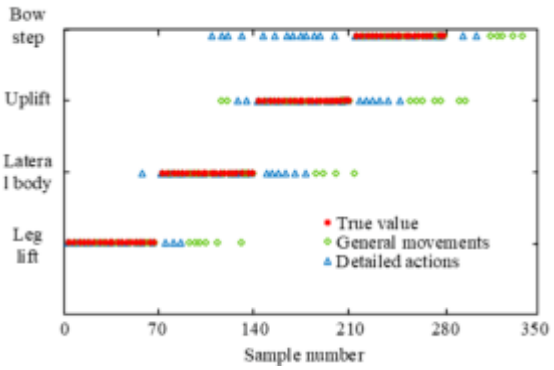
In Fig. 4.6, the MAE error value (0.1208) exhibited by the study's proposed algorithm is smaller than the DTW model (0.1742) and the CNN model (0.1503), and its F1 value (0.6923) is larger than that of the DTW model (0.6212) and the HRNet-w48 model (0.5849). The results of the teaching application of the system with this algorithm were analysed in terms of the users of the recognition algorithm in the assessment of physical education, which mainly reflected the effect of the teaching ratings and the satisfaction of the students' feedback, as shown in Figure 4.7.

In Figure 4.7, the improved posture recognition algorithm proposed in the study resulted in a mean score of 86 for the students in PE, followed by the better performing DTW and CNN models, which corresponded to mean grade scores of 76 and 68. The student satisfaction results showed that the improved posture recognition algorithm achieved 92% satisfaction, significantly higher than the DTW and CNN models with 78% and 64% satisfaction. These results show that the improved posture recognition can better assist the teaching of physical education and effectively improve the students' performance in physical education.

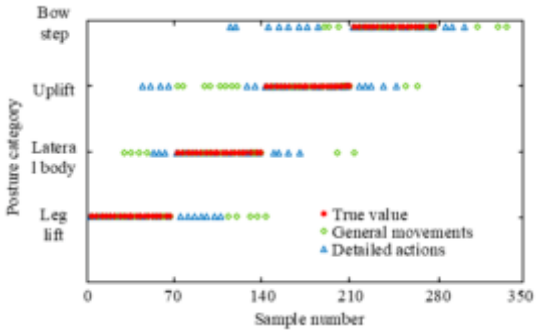
5. Conclusion. The application of human posture recognition algorithms to sports assessment systems can better capture and recognise sports movements, and effectively avoid the disadvantages of traditional training methods of data recording. The study proposes a stance recognition algorithm based on joint angle and movement similarity to design a sports assessment system for physical education. The results show that the stance curve of the kicking action obtained by the proposed stance solution method has a higher similarity to the actual situation, much higher than the comparative algorithm Kalman filter algorithm, and the maximum



(a) Research on Proposed ALgorithm

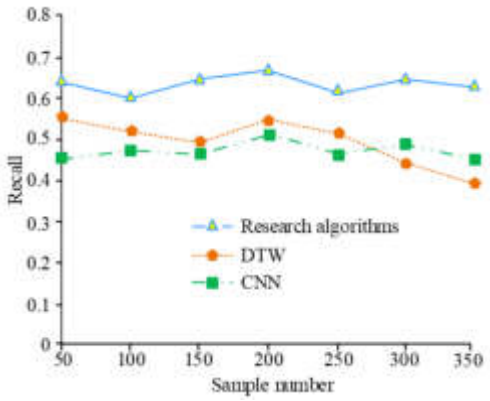


(b) DTW Model

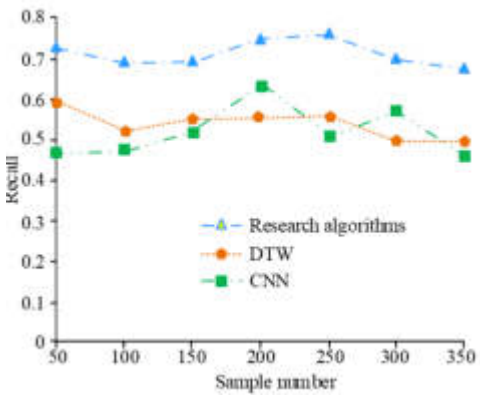


(c) CNN Model

Fig. 4.3: Comparison of matching accuracy under different algorithm models



(a) General Movement set



(b) Detailed Movement set

Fig. 4.4: Comparison of matching recall under different algorithm models

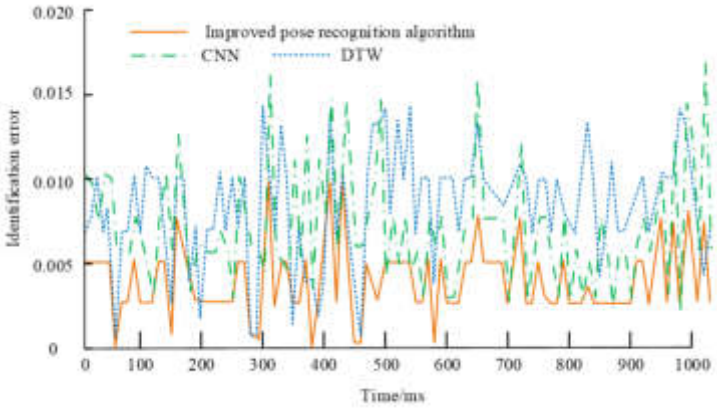


Fig. 4.5: Identification error of three models

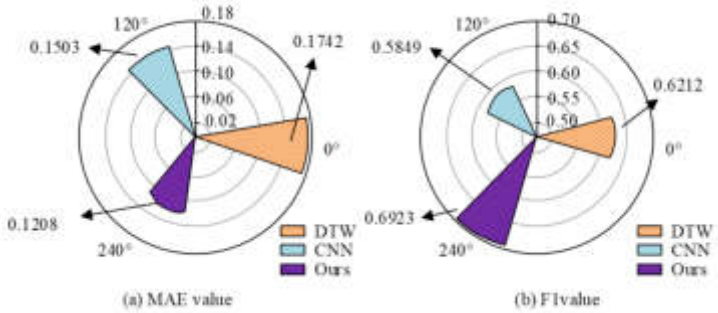
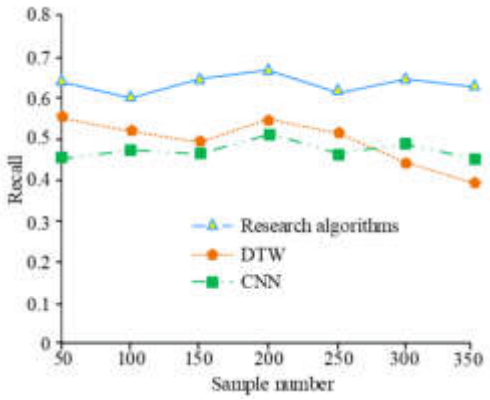
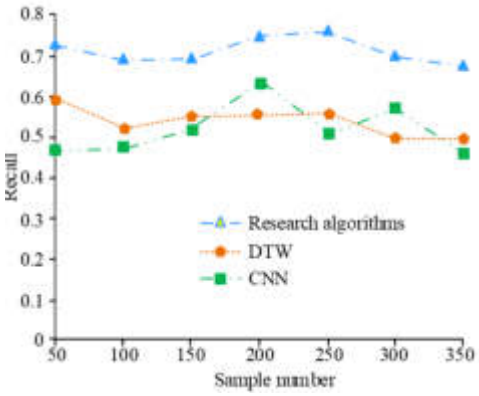


Fig. 4.6: Ablation results of different algorithms



(a) Evaluation scores of different algorithms in physical education teaching



(b) Student satisfaction with the effectiveness of physical education teaching under different algorithms

Fig. 4.7: Practical Application Results of Sports Evaluation System

deviation rate between them reaches 4.17%. The improved pose recognition algorithm has a deviation of less than 2% in the joint angle error, and the accuracy of matching the general and detailed movements is 94.8% and 93.4%, which is much higher than the 91.1% and 88.5% of the DTW model and 88.7% and 89.2% of the CNN model. And the recall of the improved pose recognition algorithm model remained within the interval of [0.60, 0.67] and [0.68, 0.74] respectively, which is higher than the range of [0.39, 0.58] and [0.48, 0.60] of the DTW model, and the overall discrimination of action recognition is better, and the maximum error value of human action recognition 0.0010 is smaller than that of the DTW algorithm and CNN algorithm The sports assessment system designed with the improved posture recognition algorithm was able to improve the students' professional rating results (86 points) and satisfaction (92%), better than the 76 and 78%, 68 and 64% scores of the DTW and CNN models. This sports assessment system is a good training aid, and consideration of upgrading the hardware configuration and adding factors influencing the assessment of movement standards is one of the elements that need to be further investigated in future studies.

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TEACHING OPTIMIZATION ALGORITHM AND SIMULATION ANALYSIS BASED ON SELF-LEARNING MECHANISM AND MULTI-CLASS INTERACTION

QIANLI MA*

Abstract. Teaching optimization algorithm is an intelligent optimization algorithm applied in the education. At the same time, it can solve complex optimization problems in other fields such as traffic flow optimization and logistics optimization. In response to the weak development ability, a teaching optimization algorithm based on self-learning mechanism is proposed by referring to general reverse learning methods. Meanwhile, a multi class interactive teaching optimization algorithm is proposed by combining clustering and partitioning methods based on Euclidean distance. By combining the two algorithms, a personalized and collaborative learning teaching environment is provided. When the function dimension is 30, the average function evaluations for the teaching optimization algorithm based on self-learning mechanism on unimodal function f_1 is only 3859. On the multimodal function f_2, the average function evaluations for this algorithm are only 4735, which is 2057 and 1367 less than the other two algorithms, respectively. Meanwhile, the success rates of this algorithm are all 100%. In addition, on the unconstrained function f_6, the multi class interactive teaching optimization algorithm tends to converge when the function evaluations are 0.1×10^4. Traditional teaching optimization algorithms tend to converge only at 1.0×10^4. The two improved algorithms proposed in the study have better solution accuracy and stability, providing a reliable method reference for solving modern complex engineering problems.

Key words: TLBO algorithm; Self study mechanism; Multi class interactive; Cluster partitioning

1. Introduction. Optimization problems are closely related to people's lives, mainly referring to finding the best solution to achieve one or more functional indicators from many different solutions on the basis of meeting certain conditions. The method used to solve optimization problems is called optimization method. As the name suggests, it is a type of method used to solve optimization problems based on various theories or principles. There are many optimization methods, all based on different theories and principles to solve optimization problems. In the context of the information age, many fields such as image processing, signal processing, production scheduling, pattern recognition, task allocation, mechanical design, and automatic control have developed rapidly. Optimization methods have played an irreplaceable role in solving optimization problems in various fields. From this, it can be seen that optimization methods are of great significance to people's lives. They can effectively plan and utilize existing resources on complex and large-scale problems, providing irreplaceable guidance value for people. Moreover, the larger the scale of the problem to be solved, the greater the contribution of optimization methods [1]. Since the introduction of intelligent optimization algorithms, they have solved significant challenges that were previously difficult to overcome in many fields such as industrial optimization design, electronics, and communication due to their simplicity, versatility, and ease of parallel processing. Among them, the Teaching-Learning-Based Optimization algorithm (TLBO) is a novel algorithm that compares student grades to fitness values based on school teaching principles. This algorithm imitates the way that schools improve students' grades, abstracting the teaching and learning processes of teachers and students into teaching and learning stages. However, the research on TLBO algorithm is still in the early stages. It has problems such as low accuracy and insufficient local search ability [2-3]. To address these issues, a teaching optimization algorithm based on the self-learning mechanism (SLTLBO) is introduced. On the basis of teacher self-learning and diversified learning methods for students, the aim is improve the convergence performance and search ability. A multi class interactive teaching optimization algorithm (MCITLBO) combining clustering partitioning method is proposed to improve the local search ability of the population and enhance population diversity. The main content includes four parts. The first part provides a review of the application and corresponding improvement methods of the TLBO algorithm. The second part provides a detailed introduction to the TLBO algorithm and the improved algorithms. The first section introduces the TLBO algorithm model and

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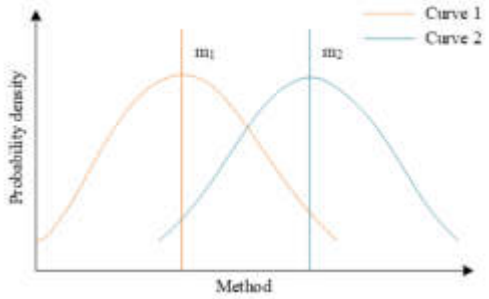
the complexity analysis. The second section proposes SLTLBO and provides detailed implementation steps of the algorithm. The third section proposes the MCITLBO algorithm and introduces the specific implementation steps. The third part mainly conducts simulation experiments and analysis on the two improved algorithms proposed in the research. The fourth part discusses the experimental results and proposes future prospects.

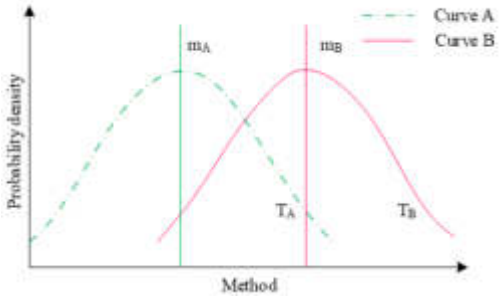
2. Related works. The TLBO algorithm is based on the principles of teaching by teachers and learning by students in schools. Starting from the reality of teaching, this algorithm has high solving accuracy and good convergence performance. Since its proposal, it has quickly attracted the interest of a large number of scientific researchers. Many scholars have conducted extensive research on this algorithm from multiple perspectives, proposing a large number of effective improvement algorithms, and applying them to many fields such as pattern recognition, function optimization, clustering problems, machine learning, scheduling problems, etc. Chen W et al. proposed the TLBO algorithm and the satin bowerbird optimization algorithm to optimize the adaptive neural fuzzy inference system model for landslide susceptibility evaluation. The proposed exhibited higher AUROC values and lower RMSE values [4]. Ghoneim S S M et al. proposed a new optimization method for transformer fault diagnosis. By using the TLBO algorithm to establish an optimization model, high-precision fault diagnosis is achieved. The results show that this method outperforms other existing DGA techniques in diagnostic accuracy [5]. Shukla A K et al. developed an algorithm using adaptive exponential distribution of inertia weights and changing position update equations to improve the TLBO algorithm with local optimal problems. The logistics map generates a uniformly distributed population, further improving the quality of the initial population. The results show that the method is superior in solution quality, convergence speed, and classification accuracy [6]. Gao N et al. proposed an embedding rib strategy to broaden the sound absorption region of porous materials. The results show that the composite element structure based on the TLBO algorithm has ultra wide high sound absorption characteristics. The average sound absorption coefficient in the range of 0-10 kHz is 0.937 [7]. Arashpour M et al. proposed a hybrid machine learning model and a teaching based optimizer approach for reliable prediction of individual learning performance. The results show that using the TLBO algorithm to perform feature selection and ANN structure determination can reliably predict students' exam scores [8].

Reverse learning is a machine learning method that learns optimal behavioral strategies through the interaction between intelligent agents and the environment. In reverse learning, intelligent agents continuously adjust their behavioral strategies by observing environmental conditions and receiving reward signals, in order to maximize long-term cumulative rewards. Clustering algorithm is an unsupervised learning method used to partition a set of data into different categories or clusters. The goal of clustering algorithms is to find intrinsic patterns and structures in data, group similar data points together, and maximize the differences between different groups. Currently, reverse learning and clustering algorithms are widely used in fields such as data mining and image analysis. Yildiz B S et al. proposed a grasshopper optimization method based on elite reverse learning for engineering design problems. It has significant performance advantages in engineering design problems such as welding beam design, car collision, and multi clutch discs [9]. Khishe M designed an improved chaotic ant colony algorithm to solve the slow convergence speed and low exploration ability. The results show that the algorithm ranks first among 27 numerical test functions. It achieves the fourth highest score in the percentile challenge [10]. Wang S et al. developed an improved ant lion optimization algorithm based on reverse learning for region analysis of complex images in image segmentation. This algorithm determines the optimal threshold by maximizing the objective function. The exponentially increasing time complexity when the number of thresholds increases is effectively addressed. The results show that the fitness value and peak signal-to-noise ratio of this algorithm are significantly better than other algorithms [11]. Ghazal T M found that the K-means clustering algorithm needs to be optimized in execution time. Therefore, different mathematical measurement methods are proposed to evaluate different datasets and cluster numbers. The results show that the Manhattan distance measurement method achieves the best execution time results [12]. Zhao P et al. introduced a clustering method relying on network distance and graph partitioning to better solve the detection problem of urban hotspots. The taxi unloading event is represented as a linear element in the spatial environment of the road network. The Jaccard distance is used to measure the similarity of road segments. The results show that this method has higher accuracy in identifying urban hotspots [13].

In summary, domestic and foreign researchers have conducted extensive research on reverse learning algo-



(a) Distribution of teaching effectiveness among different teachers



(b) Distribution of learning outcomes among different students

Fig. 3.1: Distribution of grades in different situations

rithms and clustering algorithms. However, few scholars have applied it to the optimization of TLBO algorithms. Therefore, the SLTLBO algorithm and MCITLBO algorithm are designed by combining general reverse learning methods and new clustering partitioning methods based on Euclidean distance (ED). It is expected to improve the solving ability of the TLBO.

3. Teaching optimization algorithm based on self-learning mechanism and multi class interaction. The TLBO algorithm has advantages such as fewer control parameters and ease of understanding. Currently, it is a research focus in the scientific research. However, it has premature convergence, low solving accuracy, and poor stability. This chapter first introduces a general reverse learning method. Then the SLTLBO algorithm is designed to address this issue. At the same time, a clustering partitioning method based on Euclidean distance is used to design the MCITLBO algorithm to improve the convergence performance and solving ability of the TLBO.

3.1. Model construction and complexity analysis of teaching optimization algorithms. The TLBO algorithm can be applied to optimize the teaching process. It can also solve complex optimization problems in other fields. In the TLBO algorithm, it is assumed that there are two teachers, Teacher 1 and Teacher 2, who respectively teach the same subject in two classes. The students in both classes have similar levels of proficiency. Student grades exhibit a normal distribution. After a period of teaching, the distribution of grades between the two classes is shown in Figure 3.1a. In the figure, curve 1 stands for the distribution of grades in the class taught by Teacher 1. Curve 2 stands for the distribution of grades in the classes taught by Teacher 2. m_1 and m_2 represent the average of the two, respectively. The grades of the classes taught by Teacher 2 are better, indicating that Teacher 2 has better teaching effectiveness. To play the guiding role of the optimal individual, the teacher with the best performance should be selected as the leader. That is, the individual with the best fitness value should be selected as the teacher [15].

The distribution of grades before and after the teaching and learning stages is shown in Figure 3.1b. In the figure, curve A represents the student's performance before learning. Curve B represents the student's academic performance after learning. m_A and m_B represent the average of the two, respectively. From the graph, through learning and teacher guidance, students' individual grades have also improved. Therefore, after learning, both the average grade of the class and the individual grades of the students have improved. The original teacher may not be competent for the teaching work of the class. A new teacher needs to be selected for the next round of teaching work. Through this cycle, the solution represented by each student will be continuously updated until the termination condition is met [16]. The optimization problems involved are represented in equation

(3.1).

$$\min imize\, f(X_i), X_i = (x_1, x_2, ..., x_D) \in S = \prod_{j=1}^{D} [L_j, U_j] \tag{3.1}$$

In equation (3.1), X_i represents the decision variable of the iF-th D dimension, that is, the i-th student. $f(X_i)$ represents the fitness value function, which is the student's score. S is the decision space. D represents the dimension. L_j and U_j represents the lower and upper bounds of the j-th dimensional variable. During the teaching phase, the average score of students is shown in equation (3.2).

$$M_k = \frac{(\sum_{i=1}^{NP} X_{i,1}, \sum_{i=1}^{NP} X_{i,2}, ..., \sum_{i=1}^{NP} X_{i,D})}{NP} \tag{3.2}$$

In equation (3.2), NP represents the number of students. The selected teacher is shown in equation (3.3).

$$T_k = \min \{ f(X_i) \,|i = 1, 2, ..., NP \} \tag{3.3}$$

In equation (3.3), k is the number of iterations. The basis for teachers to impart knowledge includes students' average grades and their own differences. The gap calculation is shown in equation (3.4).

$$Difference\_Mean_i = r_i(T_k - T_{F_i} M_k) \tag{3.4}$$

In equation (3.4), r_i is 0 or 1. $T_F$represents the teaching factor. T_{F_i} is shown in equation (3.5).

$$T_{F_i} = round\,[1 + rand(0, 1)] \tag{3.5}$$

The update calculation of individual is shown in equation (3.6).

$$X_{new} = X_{old} + Difference\_Mean \tag{3.6}$$

In equation (3.6), X_{old} and X_{new} represent individual students before and after the update, respectively. If X_{new} exceeds X_{old}, it is replaced. During the learning stage, student $X_j$is randomly selected. If there is $f(X_i) < f(X_j)$, it is calculated in equation (3.7).

$$X_{new,i} = X_{old,i} + r_k(X_i - X_j) \tag{3.7}$$

If there is $f(X_i) > f(X_j)$, the calculation is shown in equation (3.8).

$$X_{new,i} = X_{old,i} + r_k(X_j - X_i) \tag{3.8}$$

The population initialization is shown in equation (3.9).

$$P(t) = \{X_i(t) \,|x_{i,j}(t) = rand \cdot (U_j - L_j) + L_j, 1 \le i \le NP,\ 1 \le j \le D\} \tag{3.9}$$

Time complexity and spatial complexity are used to measure the execution efficiency of the TLBO algorithm. The time complexity calculation is shown in equation (3.10).

$$T(D) = O(\max\_iter \times 2 \times NP \times D) \tag{3.10}$$

In equation (3.10), $\max\_iter$ represents the maximum number of cycles. The spatial complexity is shown in equation (3.11).

$$S(D) = O((\max\_iter + 2 \times NP) \times D) \tag{3.11}$$

The time complexity and spatial complexity of the TLBO algorithm are linearly related to the size of the problem. As the scale of the problem increases, the execution time and required memory space of the algorithm can grow relatively quickly.

3.2. Teaching optimization algorithm based on self-learning mechanism. In traditional TLBO algorithms, students mainly improve themselves by learning from other students and retaining or updating individuals in a survival of the fittest manner. But it limits students' diversity and selectivity in learning methods, leading to a rapid decrease in population diversity. Therefore, the SLTLBO algorithm is proposed. In this algorithm, teachers act an important leading role in the evolution of the entire population. Excellent individual teachers can help the entire population approach the optimal solution faster. To more effectively utilize the guiding role of individual teachers in population evolution, a general reverse learning method is introduced to achieve individual teachers' self-learning [17-18]. Specifically, firstly, in the k-th iteration, the individual with the best fitness value is selected as the teacher individual T_k. Next, the general inverse solution $\overline{T}_k$ is calculated and evaluated. When $f(\overline{T}_k) < f(T_k)$ is met, replace T_k with $\overline{T}_k$ and teach. In the TLBO algorithm, after obtaining knowledge from teachers, students can not only learn from other students again, but also improve their academic performance through self-learning. As the iterations increases, the search area shrinks. The similarity of individuals in the population will gradually increase. However, this learning method has low efficiency, which is prone to trapping the population into local optima. To better simulate the learning process in real life, the learning stage is modified. Students engage in diversified learning through three methods, seeking advice from teachers in a probabilistic manner, learning from other classmates, and self-learning, thereby enhancing the diversity of the population. A random number between (0, 1) is generated during the learning phase. When $0 < rand < \frac{1}{3}$ is reached, students will seek advice from the teacher, as shown in equation (3.12).

$$X_{newi} = X_i + rand(T_k - X_i) \tag{3.12}$$

When $\frac{1}{3} \leq rand \leq \frac{2}{3}$ is reached, students seek advice from other students. When $\frac{2}{3} < rand < 1$ is reached, students adopt a general reverse learning method for self-learning. The specific calculation is shown in equation (3.13).

$$\overline{x_j} = \begin{cases} x_j^* + rand\left[(a+b)/2 - x_j^*\right], & if\,(a+b)/2 < x_j^* \\ (a+b)/2 + rand\left[x_j^* - (a+b)/2\right], & else \end{cases} \tag{3.13}$$

In equation (3.13), $X = (x_1, x_2, ..., x_D)$ represents a point in the D-dimensional space. $x_j \in [a_j, b_j], j = 1, 2, ..., D$. X^* represents the reverse point of X. The general reverse point definition of X is represented by equation (3.14).

$$\overline{X} = (\overline{x_1}, \overline{x_2}, ..., \overline{x_D}) \tag{3.14}$$

When $f(X_{newi}) < f(X)$ is reached, X is replaced with X_{newi}. In the proposed SLTLBO algorithm, the teacher who plays a dominant role in algorithm convergence no longer only selects the optimal population, but improves their own ability through general reverse learning methods, which can not only enhance the convergence performance of the algorithm, but also to a high extent avoid the population falling into local "valleys"; Students are no longer blindly learning from random individuals, with a single and inefficient learning method. Instead, they imitate the real teaching environment by establishing three learning methods: self-learning, learning from other classmates, and seeking advice from teachers. This diversifies the learning methods of students, increases the utilization of population neighborhood information, and enhances the development ability of algorithms. The SLTLBO algorithm is shown in Figure 3.2.

3.3. Teaching optimization algorithm based on multi class interaction. The TLBO algorithm is a method of improving students' academic performance by optimizing their learning process. It is mainly calculated based on two parameters, population size and iteration number. To effectively improve the stability performance and optimization accuracy of the TLBO algorithm, a MCITLBO algorithm is further proposed. Firstly, a new clustering method is adopted to divide the initial population into multiple subgroups based on ED to effectively utilize the neighborhood information and enhance the local search ability. Then, after the teaching stage, the school selects excellent teachers to guide students with poor grades. The worst individual (WI) in each subgroup learns from the best individual (BI) in that subgroup, accelerating the evolution of the WI towards the best direction. Finally, after the learning stage, based on the principle of student mobility, an

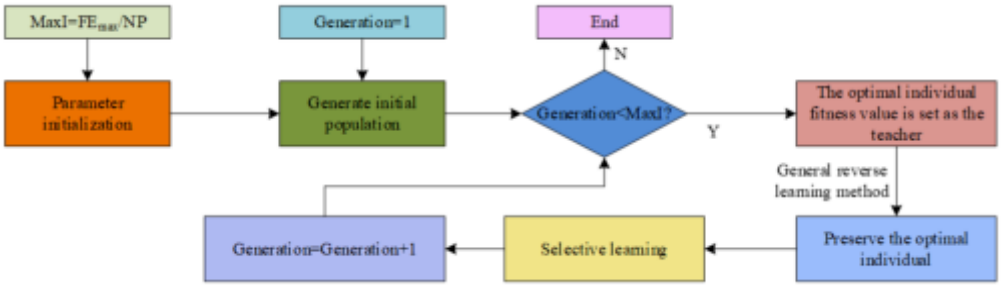


Fig. 3.2: SLTLBO The flow of the algorithm

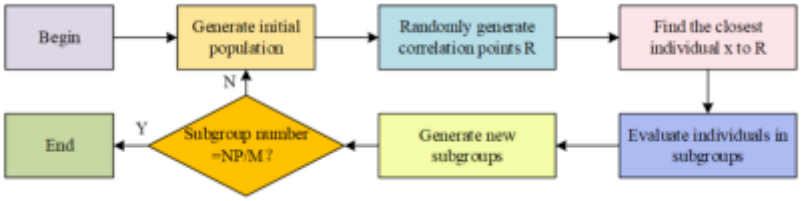


Fig. 3.3: Flowchart of a Novel Clustering and Partitioning Method Based on Euclidean Distance

individual is randomly generated for each subgroup to learn from two individuals in other subgroups, effectively maintaining population diversity [19]. The main implementation steps of the new clustering partitioning method based on ED are shown in Figure 3.3.

The advantages of clustering and partitioning methods based on ED are as follows. Firstly, compared to classical clustering and partitioning methods, it has lower complexity and shorter runtime. Secondly, the clustering partitioning method based on Euclidean distance can select individuals from each sub region during the learning stage, thereby better utilizing the local information of the population. The algorithm can more accurately find the optimal solution and converge more stably. In real life, schools will take measures to help poorer students improve their academic performance. One of them is to organize the best teachers to provide them with after-school tutoring. After the teaching stage, the worst performing students communicate with the best performing students in the entire class, thereby accelerating the improvement of their grades [20]. The WI learns from the BI as shown in equation (3.15).

$$x_{new,i} = x_{old,i} + rand(T_k - x_{old,i}) \tag{3.15}$$

When $x_{new,i}$ is superior to $x_{old,i}$, then $x_{new,i}$ is accepted. At the same time, to promote student interaction and information exchange between different classes and increase population diversity, a student x_{M1} is randomly selected from each class. It communicates with students from two other classes. The specific update method is shown in equation (3.16).

$$\begin{cases} x_{new,M_1} = x_{old,M_1} + rand(x_{M_2} - x_{M_3}), & if\ f(x_{M_2}) < f(x_{M_3}) \\ x_{new,M_1} = x_{old,M_1} + rand(x_{M_3} - x_{M_2}), & if\ f(x_{M_2}) > f(x_{M_3}) \end{cases} \tag{3.16}$$

MCITLBO When x_{new,M_1} is superior to x_{old,M_1}, x_{new,M_1} is accepted. In the early stages of algorithm iteration, the diversity of the algorithm population is good, and the establishment of information exchange between populations ensures that each class searches within the feasible domain under the guidance of the optimal teacher in the population. The algorithm has good exploration and development capabilities. As the number of iterations gradually increases, the population gradually approaches the optimal solution, individual differences gradually shrink, and population diversity gradually decreases. Population evolution puts higher

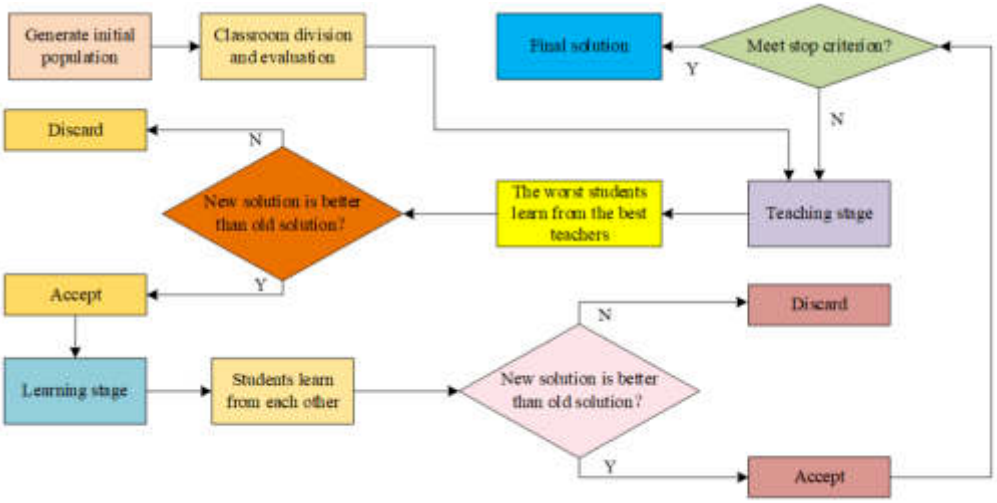


Fig. 3.4: Flowchart of MCITLBO algorithm

requirements on the algorithm's local search ability. Due to the delay in the evolution of each class in the multi class teaching mode and the learning method of random communication between students in each class, it can effectively enhance population diversity and improve the algorithm's optimization ability. Therefore, MCITLBO can fully maintain a balance between the two search abilities in evolution, improving the search performance of TLBO. According to the description of the multi class interactive TLBO, the flowchart of the MCITLBO is displayed in Figure 3.4.

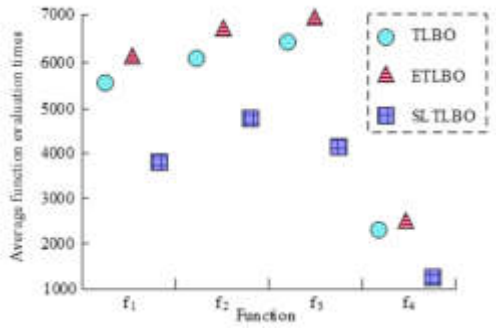
In the multi class teaching mode, there is random communication between students in each class, as well as enhanced population diversity, which can effectively improve the optimization ability. Therefore, the MCITLBO algorithm can balance the two search abilities, thereby improving the search performance. In addition, the SLTLBO algorithm focuses on the learning process of individual learners. It mainly adjusts the teaching content and learning path based on the individual learning characteristics and needs of students, so that each student can receive suitable learning support. In contrast, the MCITLBO algorithm fully considers the interaction and cooperation between different classes. By analyzing the learning situation and interactive behavior of multi class learners, the allocation of teaching resources and the organization of teaching activities are optimized. By combining the two, a personalized and collaborative learning teaching environment can be better provided.

4. Simulation analysis based on SLTLBO and MCITLBO algorithms. To verify the performance advantages of the optimized TLBO, this chapter conducts simulation experiments on the SLTLBO algorithm and the MCITLBO algorithm. In the experiment of SLTLBO algorithm, multiple test functions are used and performance simulation analysis is conducted from multiple dimensions. In the experiment to validate the MCITLBO algorithm, the performance simulation analysis is conducted using population distribution and experimental results on unconstrained functions.

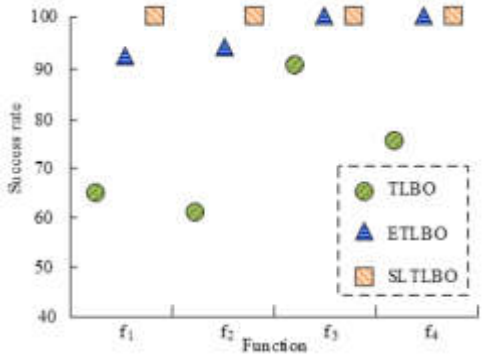
4.1. Analysis of teaching optimization algorithms based on self-learning mechanism. To verify the performance advantages of the SLTLBO, the Enhanced Teaching-Learning Based Optimization Algorithm (ETLBO) and TLBO are experimentally compared. Function evaluation is an important means of evaluating algorithm performance and optimizing algorithm design, which refers to quantifying and evaluating the performance of algorithms in solving optimization problems. By systematically evaluating functions, algorithms can be better understood and improved, thereby improving the efficiency and quality of problem solving. The test functions used include unimodal function f_1, multimodal function f_2, the rotation function f_3 of unimodal function f_1, and the rotation function f_4 of multimodal function f_2. The optimal value for all functions is 0.

Table 4.1: The specific case of each function

Function	Name	Value range	Acceptable solution
f1	Sum square	[-10,10]	1E-8
f2	Ackley	[-32.768,32.768]	1E-6
f3	Rotated sum square	[-10,10]	1E-8
f4	Rotated ackley	[-32.768,32.768]	2



(a) The average number of successful function evaluations for each algorithm



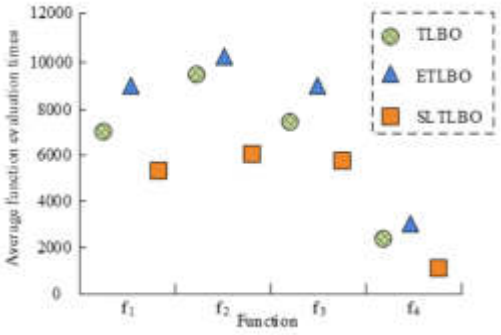
(b) The success rate of each algorithm's operation

Fig. 4.1: Running results of various algorithms in 30 dimensional situation

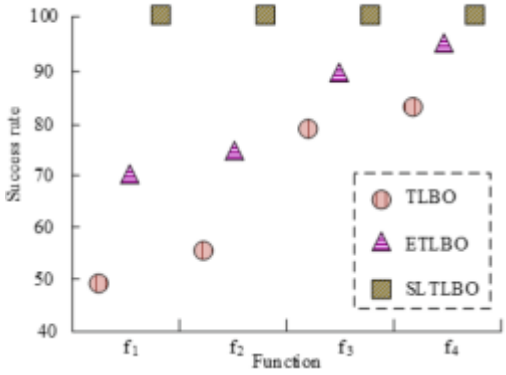
The specific situation of each function is displayed in Table 4.1.

The experimental environment is a Windows 7 system with a 3.2GHz CPU, 2GB RAM, and MATLAB 2016a. The population size is 50. The dimensions of the function include 30 and 50. The maximum function evaluations are 300000. To ensure the effectiveness of the experiment, each function is run independently 50 times. When the algorithm converges to an acceptable solution, it represents the successful operation of the algorithm. Success rate is an important indicator in function evaluation, used to measure the degree of success of algorithms in solving optimization problems. It represents the probability that the algorithm can find the optimal solution or approach the optimal solution. The success rate is usually expressed as a percentage, calculated by dividing the number of times the algorithm has successfully found or approached the optimal solution by the total number of experiments, and multiplying by 100. For a specific optimization problem, a higher success rate means that the algorithm performs better in solving the problem. A high success rate algorithm can find the optimal solution or approach the optimal solution more frequently, while a low success rate algorithm may often fall into local optima or find poorer solutions. When the dimension is 30, the average function evaluations and success rates of each algorithm are shown in Figure 4.1. From Figure 4.1, on the unimodal function f_1, the average function evaluations for the SLTLBO algorithm are only 3859. Compared to the ETLBO algorithm and TLBO algorithm, it has decreased by 2293 and 1634, respectively. On the multimodal function f_2, the average function evaluations for the SLTLBO algorithm are only 4735. Compared to the other two algorithms, it reduces 2057 and 1367 respectively. On the rotation function f_3, the average function evaluations for the SLTLBO algorithm are 4022. The ETLBO algorithm is as high as 6831. On the rotation function f_4, the average function evaluations for the SLTLBO algorithm are only 1204. At the same time, the success rates of the SLTLBO algorithm are all 100%. When the function dimension is 30 dimensions, the SLTLBO algorithm has a lower function evaluations and a higher success rate compared to the other two algorithms.

When the dimension is 50, the average function evaluations and success rates of each algorithm are shown



(a) The average number of successful function evaluations for each algorithm



(b) The success rate of each algorithm's operation

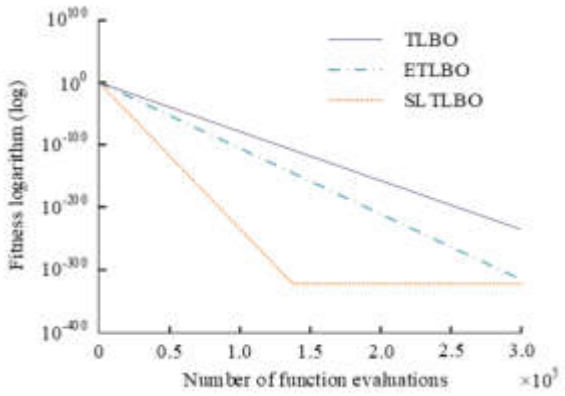
Fig. 4.2: Running results of various algorithms in 50 dimensional situation

in Figure 4.2. From Figure 4.2, the SLTLBO algorithm outperforms other algorithms in the average function evaluations on each function. Among them, on the unimodal function f_1, the average function evaluations for the SLTLBO algorithm are 5093. On the multimodal function f_2, the average function evaluations for the SLTLBO algorithm is only 5929. On the two rotation functions, the average function evaluations for the SLTLBO algorithm are 4813 and 1368, respectively. Meanwhile, the success rate of the algorithm on each function is 100%. When the dimension is 50, the SLTLBO algorithm still has lower function evaluation times and better operational stability.

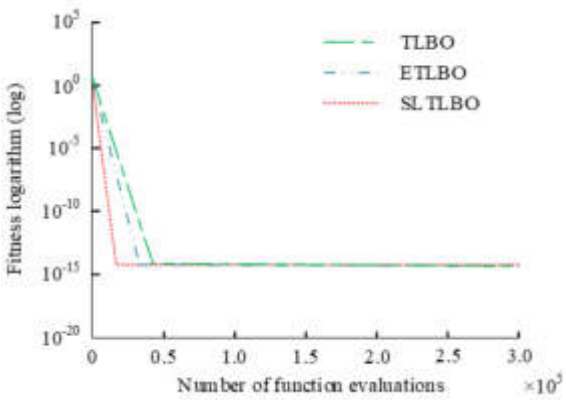
The convergence of each function under different algorithm optimizations is shown in Figure 4.3. In Figure 4.3, the SLTLBO algorithm outperforms other algorithms in convergence across various functions. Among them, the SLTLBO algorithm converges faster on the unimodal function f_1. On the multimodal function f_2, the SLTLBO tends to converge when the function evaluations are 0.15×10^5. The ETLBO tends to converge when the function evaluations are 0.31×10^5, while the TLBO tends to converge at 0.43×10^5. On the rotation function f_3, the SLTLBO algorithm tends to converge at 1.4×10^5. On the rotation function f_4, the SLTLBO tends to converge at 0.14×10^5, while the ETLBO tends to converge when the function evaluations are 0.32×10^5. The TLBO tends to converge when the function evaluations are 0.43×10^5. This indicates that the SLTLBO algorithm has more significant convergence performance.

From an overall perspective, the optimization performance of each algorithm is compared. At a significance level of 0.05, the double tailed t-test results of each algorithm compared to SLTLBO are analyzed. Figure 4.4 displays the results. In Figure 4.4, "+", "-", and "=" respectively represent that the SLTLBO is superior, inferior, or equal to the algorithm being compared. From Figure 4.4, the SLTLBO algorithm outperforms the other two algorithms in various functions with dimensions of 30 and 50, respectively. It is only inferior to the ETLBO algorithm on the rotation function f_4. The SLTLBO algorithm has significant performance advantages.

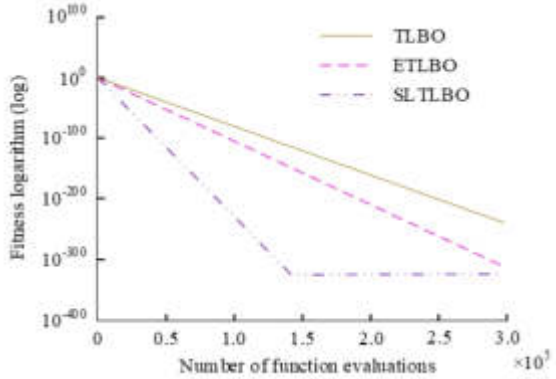
To verify the performance advantages of the MCITLBO, population diversity is used as a performance evaluation indicator. It is compared with the TLBO algorithm. The 2D Sphere function is used as the test function. TLBO and MCITLBO are used to optimize them, thereby obtaining the population distribution of each algorithm under different evolutionary algebras. Among them, the optimal value of the function is 0, the optimal solution is [0,0], and the search space is $[100,100]^2$. The population size is NP=100. The iteration is max Gen=100. The population distribution of each algorithm evolving to the 100th generation is shown in Figure 4.5. In Figure 4.5, MCITLBO has a faster optimization speed, reducing the search space to $[-2\times10^{-25},2\times10^{-25}]^2$. At the same time, compared to the TLBO algorithm, the population distribution of MCITLBO is more dispersed, indicating that the MCITLBO algorithm has better population diversity.



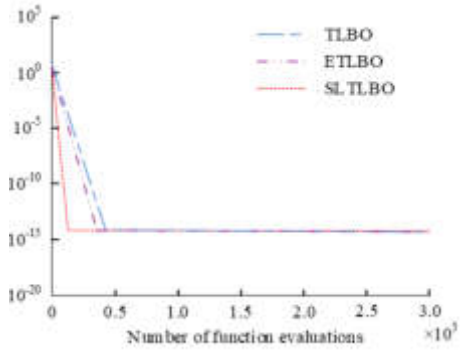
(a) The fitness convergence curve of function f1



(b) The fitness convergence curve of function f2

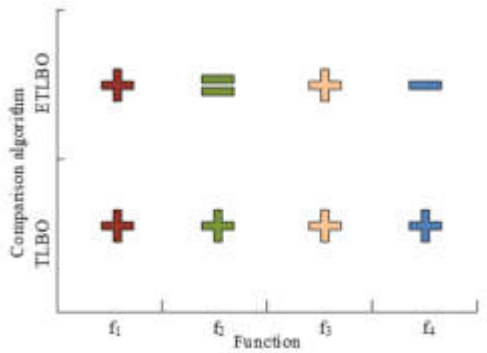


(c) The fitness convergence curve of function f3

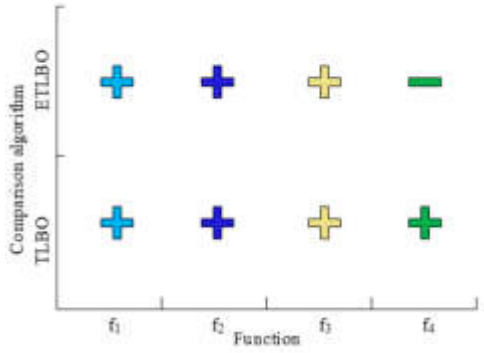


(d) The fitness convergence curve of function f4

Fig. 4.3: Convergence of various functions under optimization by different algorithms

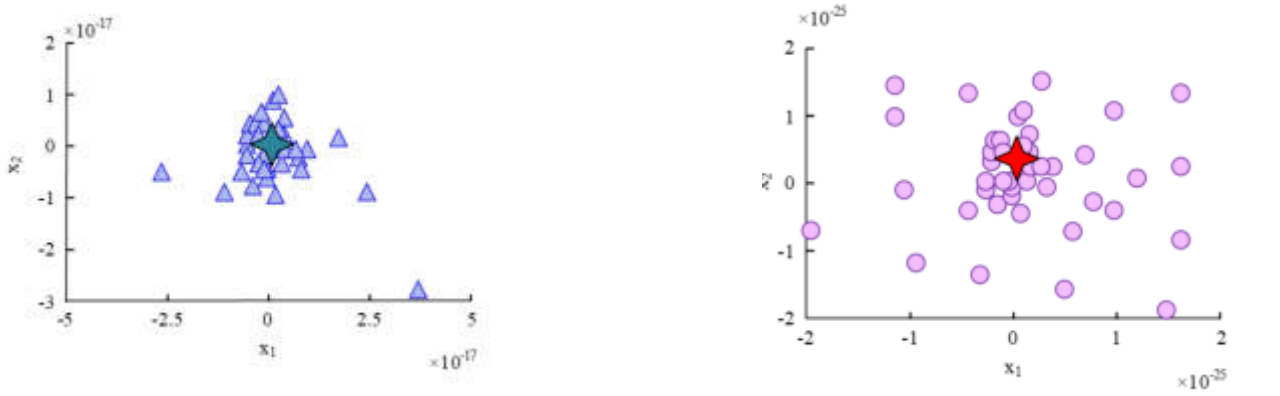


(a) Performance comparison results under 30 dimensional conditions



(b) Performance comparison results under 50 dimensional conditions

Fig. 4.4: Analysis of teaching optimization algorithms based on multi class interaction



(a) Population distribution results of TLBO algorithm

(b) Population distribution results of MCITLBO algorithm

Fig. 4.5: The population distribution of various algorithms evolving to the 100th generation

Table 4.2: The specific situation of two unconstrained functions

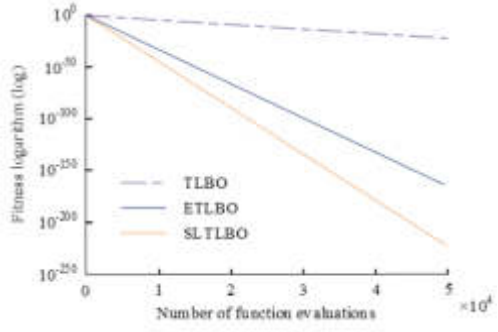
Function	Variable range
$f_5(x) = \sum_{i=1}^{D} x_i^2$	(-100,100)
$f_6(x) = \sum_{i=1}^{D-1}[100(x_i^2 - x_{i+1})^2 + (x_i - 1)^2]$	(-10,10)

The convergence performance of MCITLBO algorithm is verified. The TLBO and ETLBO are selected for performance comparison. The unconstrained test functions f_5 and f_6 are used for comparison. The specific situation of the two unconstrained functions is shown in Table 4.2.

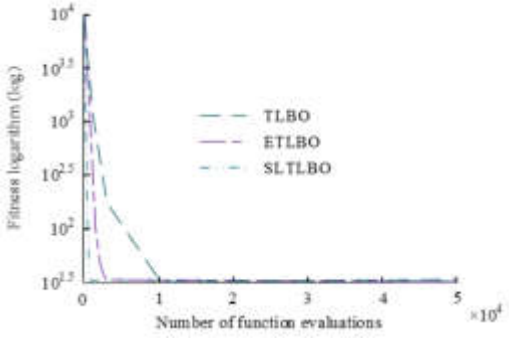
The function evaluations of the experiment are 50000 times, and the dimension is 30. Meanwhile, the subgroup in the MCITLBO algorithm is M1=5. The individual in each subgroup is M2=20. The population size of other algorithms is 50. The convergence curves of each algorithm on unconstrained functions are shown in Figure 4.6. From Figure 4.6, on function f_5, when the function evaluations are 5000, the fitness logarithm of MCITLBO algorithm is the lowest, indicating it has faster convergence speed. Meanwhile, on function f_6, the MCITLBO tends to converge when the function evaluations are 0.1×10^4. The TLBO only tends to converge at 1.0×10^4. The MCITLBO has a significantly faster decline rate in fitness values on f_5 and f_6 compared to other algorithms, with the fastest convergence speed and higher optimization accuracy.

The runtime of the algorithm on unconstrained test functions is further validated. The MCITLBO and TLBO algorithms independently run 50 times on function f_5. The average CPU consumption time is recorded. The runtime of different algorithms on various functions with dimensions of 30 and 100 is shown in Figure 4.7. In Figure 4.7, when the dimension is 30, the average running time of the MCITLBO algorithm on function f_5 is 1.03s. The ratio to the TLBO algorithm is 1.19. When the dimension is 100, the average running time of the MCITLBO algorithm on function f_5 is 2.86s. The ratio to the TLBO algorithm is 1.16. From this, as the dimension of the function increases, the complexity of each algorithm increases and the running time increases. However, the running time ratio of MCITLBO algorithm to TLBO has decreased. As the complexity of the fitness function increases, the proportion of operators in the entire running time decreases. In addition, MCITLBO can provide higher solution accuracy, and the runtime ratio to TLBO algorithm is relatively low. Therefore, the MCITLBO algorithm has stronger feasibility.

5. Conclusion. The TLBO algorithm is currently widely used for solving optimization problems in various fields. In response to the low solution accuracy and weak local search ability, SLTLBO algorithm and MCITLBO

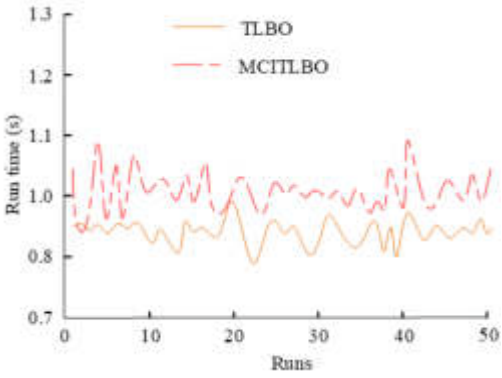


(a) The fitness convergence curve of function f5

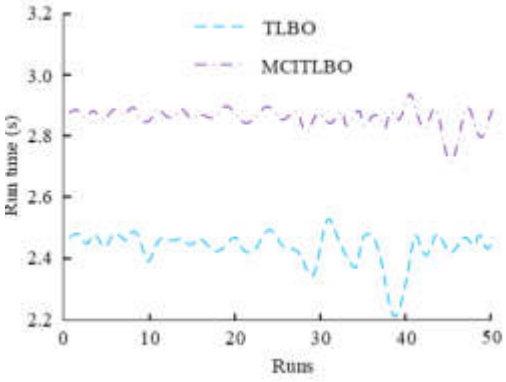


(b) The fitness convergence curve of function f6

Fig. 4.6: Convergence curves of various algorithms on unconstrained functions



(a) Running time of different algorithms in 30 dimensions



(b) Running time of different algorithms in 50 dimensions

Fig. 4.7: The running time of different algorithms in different dimensions

algorithm are introduced to improve the algorithm performance. In the experiment testing the SLTLBO algorithm, when the dimension is 50, the average function evaluations of the SLTLBO algorithm on the unimodal function f_1 are 5093. On the multimodal function f_2, the average function evaluations for the SLTLBO are 5929. On the two rotation functions, the average function evaluations for the SLTLBO are 4813 and 1368, respectively. Meanwhile, the success rate of the algorithm on each function is 100%. In the performance experiment to verify the MCITLBO, the optimization speed of the MCITLBO is faster. It reduces the search space to $[-2\times10^{-25},2\times10^{-25}]^2$ when it iterates to 100 times. At the same time, compared to the TLBO algorithm, the population distribution of MCITLBO is more dispersed, indicating that the MCITLBO algorithm has better population diversity. In addition, when the dimension is 30, the average running time of the MCITLBO algorithm on function f_5 is 1.03s. The ratio to the TLBO algorithm is 1.19. When the dimension is 100, the average running time of the MCITLBO algorithm on function f_5 is 2.86s. The ratio to the TLBO algorithm is 1.16. The two improved algorithms proposed have significant performance advantages and stronger feasibility in solving engineering problems. However, the research does not consider the balance between the global and local search capabilities. Therefore, further improvement is needed.

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VIRTUAL REALITY SCENARIO ANALYSIS OF ART DESIGN TAKING INTO ACCOUNT INTERACTIVE DIGITAL MEDIA PATTERN GENERATION TECHNOLOGY

YUN LIU *

Abstract. In art design, 3D printing technology is crucial, and more and more creators conceive scenes using 3D modeling software to get a three-dimensional and beautiful work. Due to the large amount of noise and redundant points in the raw data collected during the modeling process, the generation speed and rendering effect of 3D models are reduced. Given the above problems, the study designed an interactive 3D lightweight modeling system based on the combination of hand-drawn sketching and laser 3D scanning based on the streamlined algorithm. The experimental results showed that when the hand-drawn speed was 300, the number of triangular slices, model size, and time required to generate the model of the hand-drawn sketching model based on the streamlined algorithm were reduced by 67.39%, 65.48%, and 63.79%, respectively. In the real-time point cloud data streamlining process of the laser 3D scanning model, the point cloud data reduction ratio and the streamlining goodness index of the point cloud streamlining algorithm are 71.99% and 3.06%, respectively. The system performance is robust, and the data processing speed and rendering effect are good.

Key words: : hand sketching, laser scanning, Three-dimensional modeling, real-time resampling, latitude and longitude line refinement method

1. Introduction. Virtual and real is an important aesthetic principle in art creation, and its application to artworks can effectively highlight the uniqueness of the works [4]. With the popularization of 3D printing technology, the art design based on virtual reality is no longer satisfied with the traditional drawing on paper, but gradually developed into three-dimensional modeling works [19, 18]. 3D modeling works with complete details, and more comprehensive treatment of reality and darkness can better help the public to understand the three-dimensional artworks and facilitate the appreciation of the works from multiple perspectives [16]. Traditional 3D modeling has a high threshold, its data is less streamlined, and the resulting 3D model is less well rendered, which cannot meet the public's and designers' needs. Hand-drawn sketch (HS) 3D modeling based on digital boards is interactive and real-time, but there are more noise and redundant points in the collected data, affecting the model's rendering effect [15]. Laser Scanning (LS) is to obtain 3D point cloud data by measuring the physical surface; this modeling method has high measurement speed and accuracy, but too much data collection is not conducive to network data transmission [13, 17]. To address the problem of high data density, noise, and redundancy, the study proposes an interactive three-dimensional lightweight (ITL) modeling system that combines HS and LS based on traditional 3D modeling. The first point is that the research uses a real-time streamlining algorithm to streamline the noise and redundant points in the collected data, to ensure the rendering effect of the model; the second point is that the HS and LS modeling methods are integrated into the traditional 3D modeling, and the online ITL modeling system is obtained. The structure of the research is divided into four main parts, the first part is a review of related research results; the second part is based on the design of HS and LS models and the integration of HS and LS into traditional 3D modeling to obtain the ITL modeling system; the third part is the validation of the effectiveness of the modeling system proposed by the research; the last part is the summary of the research results. Table 1.1 lists technical terms involved in the study.

2. Related works. Traditionally, 3D modeling is mostly based on the function menu and icons of software pages, using a keyboard and mouse to create regular geometry models. However, this kind of human-computer interaction based on a keyboard and mouse is poor and cannot meet the popular demand. To improve the retrieval speed and human-computer interaction of 3D models, Shi X et al. designed an HS-based 3D retrieval

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Table 1.1: Technical Terminology Involved in the Research

Technical terminology	Meaning
HS	Hand-drawn sketch
LS	Laser Scanning
ITL	interactive three-dimensional light-weight
SWR	Sliding Window Reduction
CR	the streamlining ratio
E_{max}	The local maximum distance error
E_i	The overall length error
SCS	Single-stroke Closed Sketch
SUS	Single-stroke Unclosed Sketch
LALS	Latitude And Longitude Simplification
R_r	The reduction ratio
E_{dis}	The streamlining error
FOM_a	The streamlining goodness index
T_s	The point cloud streamlining processing time
R_F	The model size reduction ratio
E_{TBL}	The light-weighting error
FOM_b	The goodness of light-weighting index
T_R	The generated model time

algorithm, which simulates the ganglion perception mechanism in the retina and uses support vector machines to optimize the retrieval results. The experimental results show that the HS-based 3D retrieval algorithm can improve the retrieval accuracy [12]. Bai J et al. propose an end-to-end HS 3D model retrieval method based on joint embedding of spatiotemporal information to improve the retrieval effect, and the simulation results confirm the feasibility and effectiveness of the retrieval method [2]. Ito T et al. propose an end-to-end HS 3D model retrieval method based on joint embedding of spatio-temporal information to improve the retrieval effect. (CAD) The system's editing operation of drawing strokes can only target a single geometric object at a given time, and a general HS page-based 2D CAD system was proposed. It is shown that the HS-based CAD system is practical and convenient for beginners to operate and use [6]. Sarvadevabhatla R et al. proposed a deep neural model based on the incremental accumulation of HS stroke sequences as visual data, which can generate guesswords in response to HS and thus amplify the ability of intelligent machines to imitate humans. Experimental results demonstrate that the model can effectively respond to HS [11]. Donati L et al. designed a Pearson correlation-based line extraction algorithm and unbiased refinement algorithm for accurate and reliable vectorization of HS to construct 3D models, and simulation results confirm that the algorithm can efficiently and quickly complete HS vectorization [9].

Fancourt H et al. designed a fast 3D computerized shape analysis method to improve the classification efficiency of mixed skeletons and streamline the amount of 3D point cloud data for whole bone matching of 14 test samples [5]. Pistilli F et al. designed a deep learning algorithm using a graphical convolutional neural network to reduce noise and remove outlier points from point cloud data. The study was compared with other denoising methods. The algorithm can effectively deal with irregular regions and point cloud alignment invariance problems and construct complex domain graph feature hierarchies based on the similarity feature of points [10]. Zhang Z H designed a curvature and random filtering-based point cloud denoising algorithm to remove obvious noise points and random noise points in point cloud data and also used a bilateral filtering algorithm to perform point cloud smoothing after using this algorithm for denoising. The simulation results show that the error of the point cloud data processed by the denoising algorithm is smaller than that of the unprocessed point cloud data, confirming the algorithm's reliability [20]. Wu Q et al. proposed a linear LS-based method to measure the thickness of the thermal protection layer of solid rocket motors to determine the thickness of the thermal protection layer of solid rocket motors. They used the octree-based

streamlining algorithm to denoise and simplify the collected point cloud data. The results confirm that the linear LS and the octree-based streamlined algorithm are robust and can effectively measure the thickness of the thermal protection layer [14]. Chen H designed a point cloud denoising network combining recurrent network structure, convolutional neural network-based multi-scale feature aggregation module, circular propagation layer, and feature perception for denoising the 3D point clouds captured by depth cameras and 3D scanners. The experimental results demonstrate the superior performance of the denoising network and significantly improve the denoising efficiency of the point cloud data [3].

In summary, there are many research results on HS and LS modeling, but data processing based on HS modeling mainly focuses on segmentation and retrieval of HS and rarely involves real-time data streamlining; the data processing time of the point cloud denoising algorithm based on LS modeling is long, and the streamlining effect also needs to be improved. To address the problem of the modeling data streamlining effect being less than ideal, the study designs an ITL modeling system combining HS and LS based on traditional 3D modeling.

3. Methods. The acquisition of raw data is the prerequisite and foundation of 3D modeling, but in the acquisition process, there is more noise and a redundant amount of raw data memory. To improve the modeling real-time speed and rendering effect, the study introduces the streamlining algorithm to streamline the data in real time, and the chapter focuses on the design of the HS model and LS model based on the streamlining algorithm.

3.1. Establishment of HS model based on real-time data streamlining. As a common interactive model, the HS data essence is a series of discrete point series composed of auxiliary information such as serial number, time stamp, and speed. A large amount of noise and redundant points exist in the raw HS data, which can affect the data transmission within the system and thus degrade the quality of 3D modeling. To reduce the redundant data in HS, the study utilizes the chord length limit method to resample the data acquisition process in real-time [7]. The real-time resampling process of the chord length limit method is as follows, firstly, sketch and acquire the sketch trajectory start point P_1, then move the digital pen to acquire the trajectory point P_2 and calculate the chord length l_{12} of $\overline{P_1P_2}$, to determine whether the chord length l_{12} is larger than the threshold value l_ε. If the chord length is larger than the threshold, keep P_2 as the starting point and calculate the chord length l_{23}, if the chord length is smaller than the threshold, delete the point and calculate the chord length l_{13} until the chord length is larger than the threshold. The threshold value of l_ε is given in equation (1).

$$l\varepsilon = \chi \cdot \left(\frac{\sqrt{l_m^2 + w_m^2}}{d_m \cdot dpi} + n \right) \tag{3.1}$$

In equation 3.1, χ is the data streamlining factor, which takes the value of $[0.6, 1.2]$. l_m The horizontal resolution, vertical resolution, and diagonal length of the monitor are represented by $w_m 4$ and d_m, respectively. n is the parameter that controls the ratio of *ppi* and *dpi*, where *ppi* and *dpi* are the monitor pixel density and standard pixel density, respectively, and $dpi = 160px/inch$ [8]. After real-time resampling, non-critical vertices in the original data can still be streamlined. To address this problem, the study invokes the length error E_l to replace the discrete point local curvature and designs a Sliding Window Reduction (SWR) algorithm to streamline the resampled data in real-time. The length error E_l is shown in equation (2).

$$E_l = (L_{sum} - L) / L_{sum} \times 100\% \tag{3.2}$$

In equation (3.2),L and L_{sum} represent the length of the line segment at the first and last endpoints within the sliding window and the sum of the lengths of the line segments between two adjacent points, respectively. The expression of the SWR algorithm is shown in Figure 3.1.

Figure 3.1(a) and Figure 3.1(b) show the sliding window-based length error limit algorithm and the vertical distance limit algorithm, respectively. The length error limit algorithm initially removes the obvious redundant points, and the vertical distance limit algorithm precisely removes the remaining redundant points. The study first determines the coordinates of each vertex in the sliding window, when the window slides to $[P_3, P_4, P_5, P_6, P_7]$, the equation of the line P_3P_7 is $cx - y + d = 0$, where the expressions of c and d are shown

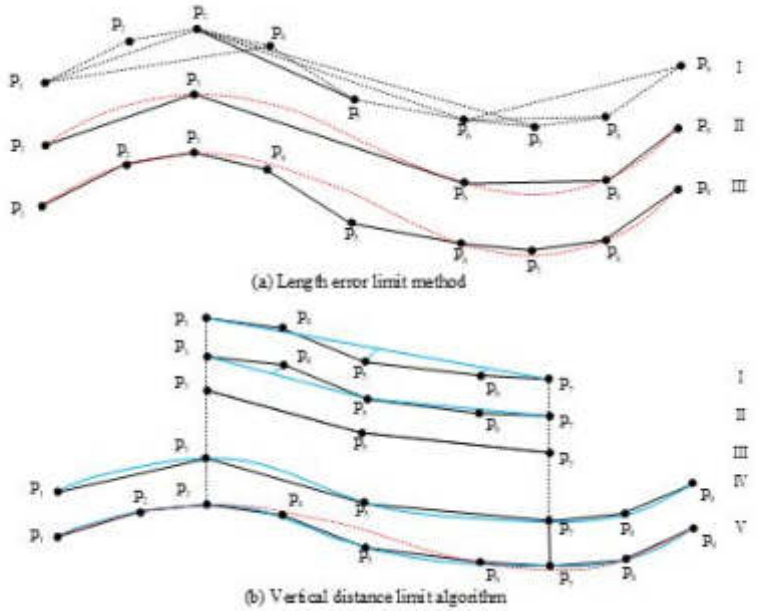

Fig. 3.1: Schematic diagram of length error limit algorithm and vertical distance limit algorithm based on sliding window

in equation (3.3).

$$\begin{cases} c = \frac{y_7 - y_3}{x_7 - x_3} \\ d = y_3 - \frac{y_7 - y_3}{x_7 - x_3} x \end{cases} \tag{3.3}$$

The study also needs to calculate the distances d_4,d_5 and d_6 from the points P_4,P_5 and P_6 in the window to the line P_3 P_7 , see equation (3.4).

$$\begin{cases} d_4 = \frac{|cx_4 - y_4 + d|}{\left|\sqrt{c^2 + (-1)^2}\right|} \\ d_5 = \frac{|cx_5 - y_5 + d|}{\left|\sqrt{c^2 + (-1)^2}\right|} \\ d_6 = \frac{|cx_6 - y_6 + d|}{\left|\sqrt{c^2 + (-1)^2}\right|} \end{cases} \tag{3.4}$$

The study compared d_4 ,d_5 and d_6 with the vertical distance threshold d_ε, respectively, to obtain $d_4 < d_\varepsilon, d_5 > d_\varepsilon, d_6 < d_\varepsilon$. Therefore,P_5 was chosen as the splitting point to split the sliding window into two parts, and a key vertex was added to the initial refinement to obtain significantly improved refinement results. The vertical threshold d_ε is determined in equation (3.5).

$$d_\varepsilon = \gamma \cdot \eta \cdot (L/L_{sum} + \omega) \cdot \frac{300}{v + 150} \tag{3.5}$$

In Eq. (3.5), γ and η denote the streamlining control factor and error sign change factor, respectively. γ takes the values of $[0.5, 1.5]$ and β takes the values of 0.5 or 1. ω is the factor to correct L/L_{sum} . The study uses the streamlining ratio CR , the local maximum distance error E_{max}, and the overall length error E_l to evaluate the streamlining effect of the SWR algorithm, see equation (3.6).

$$\begin{cases} CR = N/C \\ E_{\max} = \max_{1 \le i \le n} e_i \\ E_i = (L_n/L_c) * 100\% \end{cases} \tag{3.6}$$

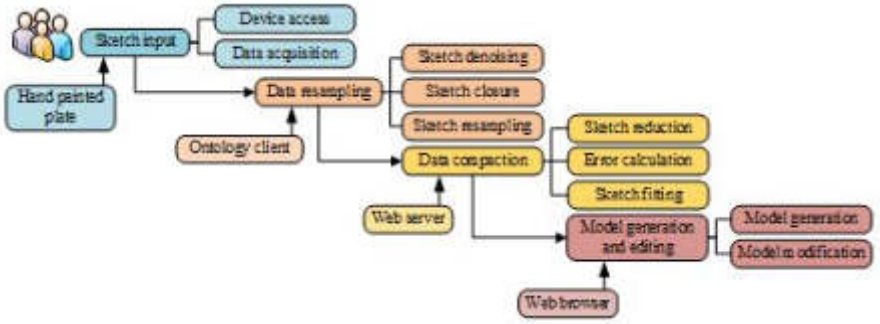

Fig. 3.2: HS 3D Lightweight Modeling Process

In Eq. (3.6),N and C denote the number of vertices before and after streamlining, respectively; e_i denotes the vertical Euclidean distance from a vertex of the original data to the streamlined curve; L_n denote the total length of the original HS trajectory and the total length of the streamlined data, respectively. After the streamlining of HS data, the study needs to stretch the processed data to generate 3D models.$z = 0$ Stretching sketch 3D modeling is mainly divided into Single-stroke Closed Sketch (SCS) and Single-stroke Unclosed Sketch (SUS) 3D modeling. The 2D contour points are $S_m = \{P_i : (x_i, y_i, z_i), i = 1, 2, 3, \cdots, m, z_i = 0\}$, which are stretched in the positive direction of Z-axis, see equation (3.7).

$$\begin{cases} x = x \\ y = y \\ z = z + h \times d, i \in N \end{cases} \tag{3.7}$$

In Eq. (3.7),d and h are the stretch length and the number of copy translation layers, respectively, and the expression of the stretched 3D point cloud model is shown in Eq. (3.8).

$$S_{gm} = \begin{Bmatrix} P_{01}(x_1, y_1, 0) & P_{02}(x_2, y_2, 0) & \cdots & P_{0m}(x_m, y_m, 0) \\ P_{11}(x_1, y_1, 0) & P_{12}(x_2, y_2, h) & \cdots & P_{1m}(x_1, y_1, h) \\ \cdots & \cdots & \cdots & \cdots \\ P_{g1}(x_1, y_1, g * d) & P_{g2}(x_2, y_2, g * d) & \cdots & P_{gm}(x_m, y_m, g * d) \end{Bmatrix} \tag{3.8}$$

$g = D/d$ in Eq. (3.8) is rounded. Since the beginning and end of SUS are not connected, it is not possible to obtain a closed 3D point cloud directly. The study transforms SUS into a closed figure by the offset point coordinate calculation method, and then follows the SCS stretching to generate a 3D point cloud method, so as to obtain the 3D modeling of SUS. The HS modeling process is mainly divided into four stages: sketch input, data pre-processing, data refinement, and model generation and editing, see Figure 3.2.

The modeling process in Figure 3.2 is as follows: first, the sketch data are collected by connecting the digital board, and the collected data are pre-processed by noise reduction, closure and real-time resampling using the ontology client, then the sampled data are streamlined by using the SWR algorithm, and finally they are input to the client browser to generate a lightweight 3D model.

3.2. Integration and Improvement of HS and LALS-LS ITL Model Construction. In addition to using HS for 3D modeling, the study uses LS equipment to obtain scan line point cloud data for 3D modeling[20]. There are more redundant points in the scan line point cloud data, so the data need to be streamlined by the Latitude And Longitude Simplification (LALS) method before actual use. The LALS method provides an efficient and accurate solution for point cloud data processing by combining meridian simplification based on chord height and latitude refinement based on adaptive layering. This method can effectively alleviate the problem of local hollowing in point clouds caused by chord height and angle deviation methods, while significantly reducing noise in point cloud data. Through adaptive layered slicing, the LALS method optimizes

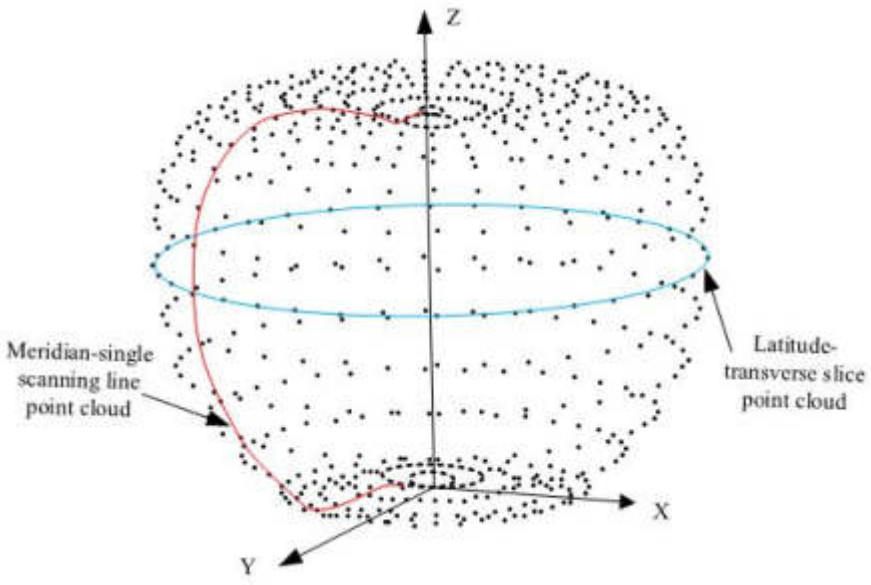

Fig. 3.3: Schematic diagram of point cloud LALS method

data reduction in the latitude direction, ensuring the integrity and accuracy of point cloud data and thereby improving the quality and efficiency of 3D modeling. In addition, the efficiency and accuracy demonstrated by this method in processing large-scale point cloud data greatly improve the reliability of subsequent 3D modeling and analysis. The point cloud LALS method is shown in Figure 3.3.

The LALS method in Figure 3.3 is mainly divided into the angle-chord height-based point cloud meridian refinement and the adaptive stratification-based latitude refinement method. The angle-chord height-based point cloud meridian streamlining method can improve the problem of local hollowness in the point cloud due to the deletion of too many points by the chord height method and the angle deviation method without significantly increasing the number of retained points and effectively remove the noise in the point cloud meridian direction. The adaptive layering-based weft line refinement method first requires adaptive layered slicing in the direction perpendicular to the scan line. Let the longitude line be parallel to z axis, and the latitude line be parallel to xoy plane, then the point cloud layering direction is z axis direction, and the layering position is determined in equation (3.9).

$$Z_i = \begin{cases} Z_{\max}, i = 0 \\ \sum_{j=1}^{i} o + Z_{\min}, Z_i \leq Z_{\max} \\ Z_{\max}, Z_i > Z_{\max} \end{cases} \tag{3.9}$$

In Eq. (9),o and Z_i are the layered thickness of the point cloud and the end position of the point cloud in the i layer, respectively. Z_{max} and Z_{min} denote the maximum and minimum values of the Z coordinates. After the adaptive layering process, the point cloud has a certain thickness and width. In order to reduce the computational effort, the projection method is used to extract the outer contour of the sliced point cloud data instead of the curve fitting method to improve the overall efficiency of the algorithm, and the projected planar sliced point cloud is stored in a data structure similar to the image raster grid column. For a sliced point cloud withn points $p(x_i, y_i)$, the point cloud is minimally enclosed by a rectangle of $L \times H$ and the rectangle is divided into an array of cells of $a \times b$, where the cell located in the i row and j column is noted as K_{ij} , and the expression of K_{ij} is given in equation (3.10).

$$K_{ij} = (i-1) \cdot L + j \quad (1 \leq i \leq a, 1 \leq j \leq b) \tag{3.10}$$

The formula for the cell number F_i and column number P_i where any point $p(x_i, y_i)$ is located is shown in equation (3.11).

$$\begin{cases} F_i = \text{int}\left[\left(x_i - x_{\text{minn}}\right)/(L/b)\right] \\ P_i = \text{int}\left[\left(y_i - y_{\min}\right)/(H/a)\right] \end{cases} \tag{3.11}$$

In the formula (3.11), $int[]$ indicates the rounding function,L/b and H/a indicate the length and width of the cell respectively, and the serial number of the cell $K(p_i)$ see formula (3.12).

$$K(p_i) = (F_i - 1) \cdot L + P_i \tag{3.12}$$

After the gridding of the sliced point cloud data, the study also needs to use image processing techniques for binarization. In the process of gridding and binarization of the sliced point cloud data, the size of the grid size $S_{cell} = L/a = H/b$ directly determines the final degree of streamlining, and the formula for calculating S_{cell} is given in equation (3.13).

$$S_{\text{cell}} = \xi\sqrt{\frac{\left(x_{\max} - x_{\min}\right)\left(y_{\max} - y_{\min}\right)}{n}} \tag{3.13}$$

In Eq. (3.13), n and ξ denote the number of sliced points cloud data points and the scale adjustment factor, respectively, where ξ is mainly used to adjust the grid edge size. To comprehensively evaluate the streamlining effect of the LALS algorithm, the reduction ratio R_V, the streamlining error E_{dis} and the streamlining goodness index FOM_a are introduced in Eq. (3.14). R_V is defined as the volume ratio between the original and simplified datasets, mainly quantifying the degree of volume reduction during the data simplification process. E_{dis} measures the difference between the simplified dataset and the original dataset, reflecting the impact of the simplification process on data integrity. FOM_a is a comprehensive performance indicator that evaluates the effectiveness of algorithm simplification by considering both reduction rate and simplification error, to balance the efficiency of data simplification and the accuracy of results.

$$\begin{cases} R_V = \frac{V_1 - V_2}{V_1} * 100\% \\ E_{dis} = \frac{1}{V_2}\sum_{p \in S_2} d(p, S_1) \\ FOM_a = \frac{R_V}{E_{dis} \cdot T_S} \end{cases} \tag{3.14}$$

In Eq. (3.14), V_1 and V_2 denote the number of streamlined point clouds before and after streamlining, respectively, $d(p, S_1)$ denotes the Euclidean distance from a point in the point cloud S_2 to the nearest point in S_1, and T_S is the point cloud streamlining processing time. Based on the final streamlined data, it is optimized by preliminary triangulation and minimum internal angle maximum criterion, and the final LS lightweight model is obtained. The LS lightweight modeling flow is shown in Figure 3.4.

The modeling process in Figure 3.4 consists of four steps: point cloud acquisition, point cloud preprocessing, point cloud refinement, and network reconstruction, firstly, the point cloud data is obtained by accessing the measurement equipment to scan the object, and then the point cloud data is preprocessed by the ontology client, and then the final refined point cloud data is obtained by adaptive layering and projection, and then the final LS lightweight model is obtained by fast triangulation and mesh optimization of these refined data. The evaluation of the lightweight effect of the ITL model can be expressed by the model size reduction ratio R_F, the lightweight error E_{Vol}, and the goodness of lightweight index FOM_b, as shown in equation (3.15). R_F is used to measure the ratio between the size of the lightweight model and the original model, which can reflect the reduced storage requirements during the lightweight process. E_{Vol} refers to the degree of difference in output results between the lightweight and original models used to evaluate the impact of lightweight on model performance. FOM_b is a comprehensive evaluation indicator that quantifies the overall effect of the lightweight process by balancing the model size reduction rate and lightweight error, to find the best balance between lightweight and performance loss.

$$\begin{cases} R_F = \frac{F_1 - F_2}{F_1} * 100\% \\ E_{Vol} = \frac{|Vol_1 - V_{ol}|}{Vol_1} * 100\% \\ FOM_b = \frac{R_F}{E_{Vol} \cdot T_R} * 100\% \end{cases} \tag{3.15}$$

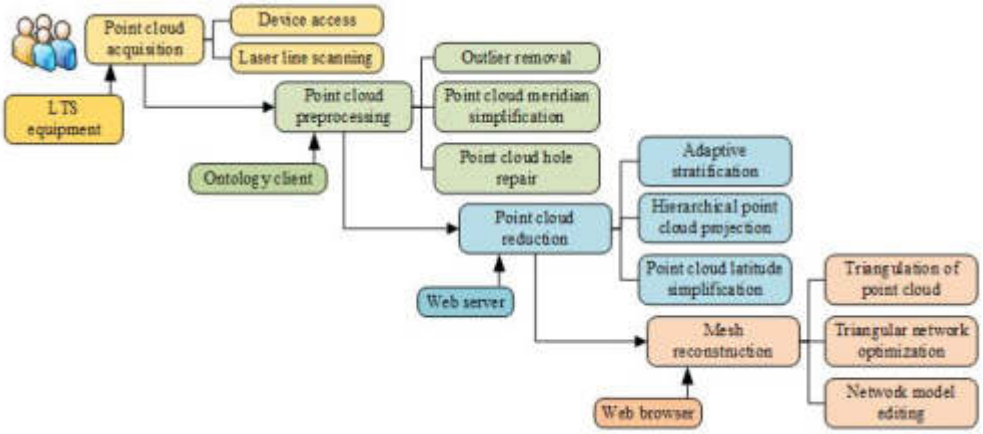

Fig. 3.4: LS lightweight modeling process

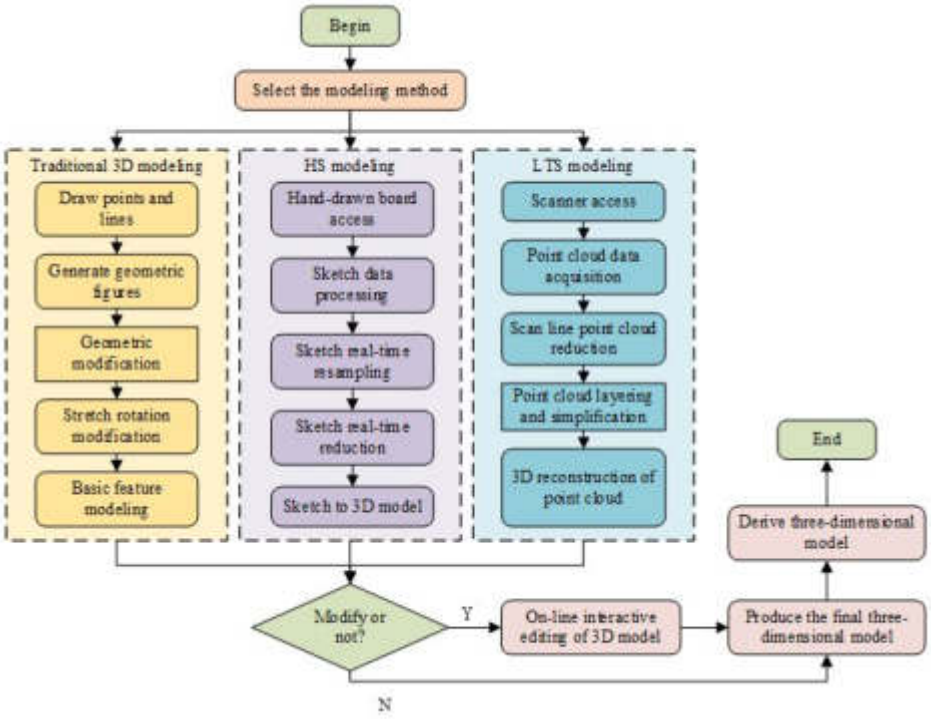

Fig. 3.5: 3D modeling process under different interaction modes

In Eq. (3.15), F_1 and F_2 denote the generated model file size before and after streamlining, respectively, Vol_1 and Vol_2 denote the generated model volume before and after point cloud streamlining, respectively, and T_R is the generated model time. For the needs of 3D modeling, the study constructs a combined HS and LS ITL modeling system based on traditional geometric modeling, see Figure 3.5 [1].

Figure 3.5 modeling process is as follows, first of all, Different modeling methods are selected according to the modeling objects, the regular geometric shape selected traditional 3D modeling, irregular shape selected HS

Table 4.1: Experimental parameter setting

Model	Parameter selection						
HS	I_ε		E_I		d_ε		
	χ	n	ε_1	ε_2	γ	η	ω
	1.0	0.5	1%	5%	1.0	0.5	0.5
LS	h	D	D	α	δ	η	
	0.1mm	123.8 mm	0.74mm	15°	0.45mm	0.4	

modeling, need to reverse the existing physical creation of data models selected LS modeling. After the study determines the modeling method and the initial model, it is necessary to use the 3D model online interactive editing to improve the model construction further, to get the final ITL modeling system. ITL modeling system can record the real three-dimensional information of the scene and input it into the system to create a data model in reverse, then scale, rotate, and translate the scene in the system to highlight the contrast between reality and reality of artworks.

4. Results. To validate the performance of the ITL modeling system, the study conducts experiments on HS and LS models separately. This section focuses on preparing the experimental data and analyzing the performance of both models based on the streamlining algorithm.

4.1. ITL modeling system experimental data preparation. In the experimental data preparation stage, to comprehensively evaluate the adaptability of the model processing algorithm to different geometric features, the selected experimental graphics of the HS model include the number 8-shaped, multi-arc, chromosome, and serrated leaves. The experimental object of the LS model is the Stitch model $70.2mm \times 84.7mm \times 123.8mm$, which was selected because its complexity is moderate and can effectively test and demonstrate the performance of the algorithm when dealing with practical models with a certain level of complexity. The parameters of the HS and LS models were set, as shown in Table 4.1.

In Table 4.1, h is the highest accuracy of the 3D scanner, D is the height of the Stitch model as the scanned object, d , α and δ denote the chord height threshold, angle threshold and maximum radial width threshold, respectively, and the number of vertices of the point cloud model is 42852 when ξ=0.4 is used. Sampling (RS) method, Uniform Grid (UG) method, Discrete Curvature (DC) method and Local Density (LD) method are used to compare with the LALS algorithm. The evaluation metrics based on HS model are resampling ratioSR ,CR ,E_{max} ,E_l, η_F, and η_S . The evaluation metrics based on the LS model are data simplification metrics R_V and R_F , accuracy metrics E_{dis} and E_{Vol} , runtime metrics T_S and T_R , and goodness indices FOM_a and FOM_b. The experimental parameter settings in Table 1 aim to provide consistent evaluation criteria for the HS model and LS model. The setting of HS model parameters reflects the adaptability and flexibility of the algorithm when processing point cloud data with different shapes. In order to ensure that sufficient model details are captured, and considering computational efficiency and practicality of model processing, the LS model parameters were selected with the values shown in Table 1.1. By setting these parameters and selecting diverse experimental subjects, the study aims to comprehensively evaluate the performance of various algorithms in data simplification, accuracy preservation, and computational efficiency.

4.2. Performance analysis of HS model based on resampling and SWR algorithm. To verify the performance of the real-time resampling algorithm of the HS model, the study plots the contour curves of four graphs at the speed of $150px/s$, $2004px/s$, $300px/s$, $400px/s$, and $500px/s$ respectively.

Figure 4.1 shows the real-time resampling results for the four shapes.SR decreases as the hand-drawing speed increases over a range. When the hand-drawing speed is 150 px/s, the value of SR is 3.09 for chromosome, 3.05 for figure-8, 3.04 for *saw* tooth leaf, and 2.93 for multi-circle arc. When the hand-drawing speed is $500px/s$, the value of SR is 1.01 for chromosome, 1.02 for figure-8, 1.01 for sawtooth leaf, and 1.00 for multi-circle arc. It is proved that the real-time resampling algorithm can effectively reduce the amount of redundancy in the original data.

To verify the effectiveness of the SWR algorithm, the data refinement results of the four figures at different

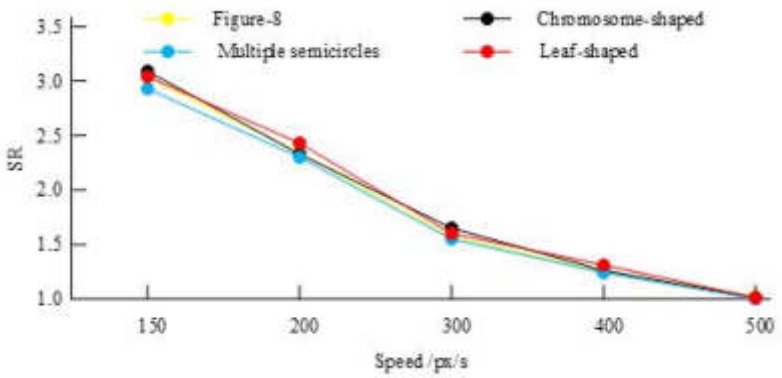

Fig. 4.1: Real-time resampling results of four graphs

Table 4.2: Generation time of HS 3D model

Time/ms		Figure 8	Chromosome-shape	Multiple semicircles	Leaf-shaped
Before streamlining	Total time	1285	2101	2361	3524
	Mean time	264	425	474	716
Streamlined	Total time	481	801	932	1253
	Mean time	97	164	174	251
Reduce percentage		65.53%	61.41%	63.29%	64.94%

hand-drawing speeds are shown in Fig. 4.2. Fig. 4.2(a) shows the variation curves of for the four figures. The mean values of CRCR for the figure- 4.3, chromosome, multicircular arc, and serrated leaf shapes are 3.67, 3.85, 3.61, and 3.82. Fig. 4.2(b) shows the variation curves of E_{max} for the four sketches. The mean values of for the figure- 4.3, chromosome, multicircular arc, and serrated The mean values of E_{max} are 0.75, 1.33, 1.43, and 1.05 for figure- 4.3, chromosome, multi-circular arc, and serrated leaf shapes, respectively. Figure 4.2(c) shows the variation curves of E_l for the four sketches, and the values of E_l are 0.98%, 2.80%, 3.71%, and 3.02% for figure- 4.3, chromosome, multi-circular arc, and serrated leaf shapes, respectively. It can be seen from the figure that the overall error and local error of the figure 8 shape are smaller than the other three sketches.

Figure 4.3 shows the 3D model lightening results of different shapes before and after data refinement at a hand-drawing speed of $300px/s$, where F_1, F_2, S_1 , and S_2 indicate the number of triangular surface pieces and model size before and after data refinement, respectively. Figure 4.3(a) shows the results of F_1, F_2 η_F for the four graphical generation models. The values of F_1 are 1541, 2580, 3016 and 3874 for figure- 4.3, chromosome, multi-circular arc and sawtooth leaf shapes, respectively; the values of F_2 are 490, 768, 965 and 1428, respectively; and the values of η_F are 68.20%, 70.23%, 68.00% and 63.14%, respectively. Figure 4.3(b) shows the $S1$, $S2$ and η_S results for the four graphical generation models. The values of $S1$, $S2$ and η_S are 77.7KB, 26.3KB and 66.11% for the figure- 4.3 shape respectively, the values of S_1, S_2 and η_S are 128.4KB, 41.2KB and 67.91% for the chromosome shape respectively, the values of S_1, S_2 and η_S are 150.4KB, 52.3KB and 65.23% for the multicircular arc shape respectively, and the values of S_1 , and for the serrated leaf shape respectively, $S_2$and η_S are 191.6KB, 71.5KB, and 62.68%, respectively. To verify the fluency of the HS model based on the SWR algorithm, the model generation time before and after the streamlining of 10 sets of HS data was selected for the study, and the average value was taken as the final result, which is shown in Table 4.2.

Table 4.2 shows the experimental results of the time required for the four graph generation models. The average time before and after streamlining for the figure-8 shape is 264 ms and 97 ms, respectively; the average time before and after streamlining for the chromosome shape is 425 ms and 164 ms, respectively; and the average time before and after streamlining for the multi-circle arc shape is 474 ms and 174 ms, respectively. The average time reduction percentages for each graph are 65.53%, 61.41%, 63.29%, and 64.94%, respectively.

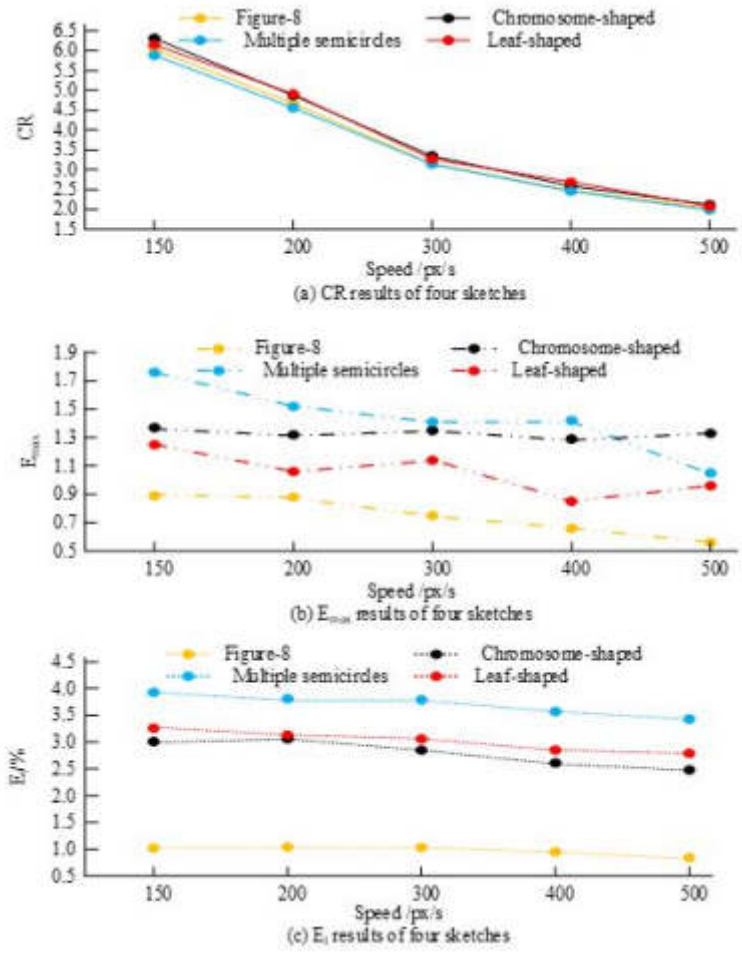

Fig. 4.2: Real-time reduction results of four graphics

Combining these results, it can be concluded that the SWR algorithm proposed in the study can effectively improve the model data processing speed.

Figure 4.4 shows the comparison of the effects of the 3D models generated before and after data reduction for the sketches of "Number 8", "Colored Body", "Multi Circular Arc", and "Sawtooth Leaf". Through simplification, the model significantly reduces the amount of data while retaining key geometric features and overall shape. This not only improves the processing and rendering speed of the model but also optimizes storage efficiency while ensuring high-quality visual representation. In addition, the simplified model still has rich details and accurate morphology.

4.3. Analysis of LS model application based on LALS algorithm. In order to comprehensively compare the performance advantages and disadvantages of LALS algorithm with other algorithms, the study was conducted by scanning the physical objects to obtain 152, 944 point clouds of raw data, and experiments were conducted using RS, UG, DC and LD, and the experimental results are shown in Figure 4.4 and Figure 4.5.

Figure 4.5 shows the performance comparison results of five algorithms in point cloud refinement processing, including the comparison of reduction rate $R_V 4$ and simplification error E_{dis} (Figure 4.5 (a)), as well as the comparison of processing time T_S and simplification goodness index FOM_a (Figure 10 (b)). In terms of R_V, LALS, RS, UG, DC, and LD algorithms exhibit similar performance, reaching 71.99%, 71.95%, 71.88%,

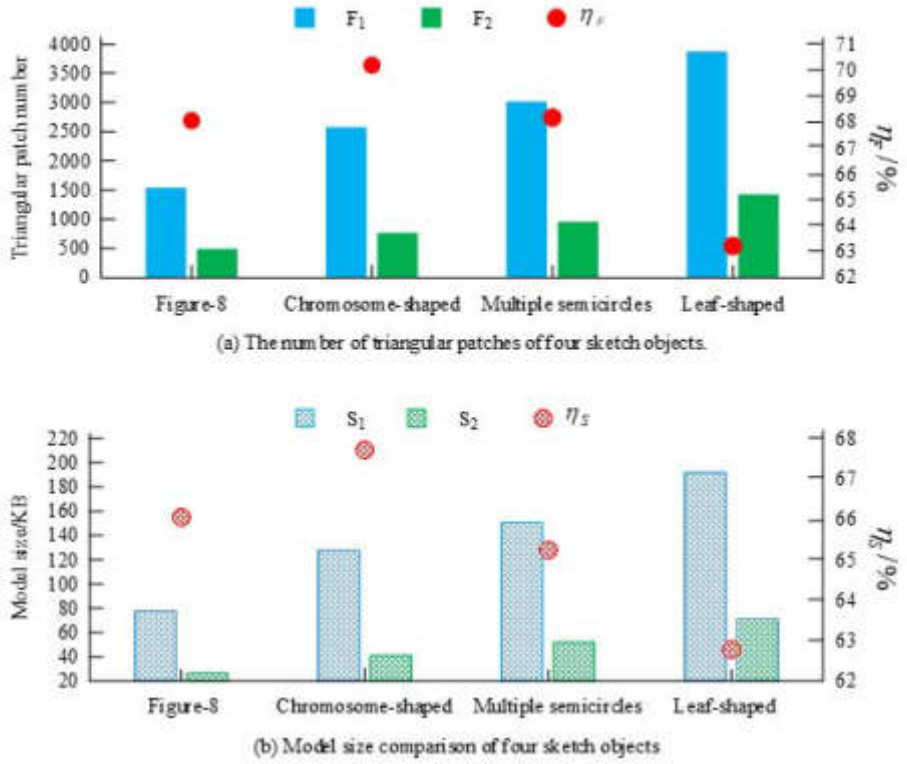

Fig. 4.3: Lightweight results of the model before and after data reduction

71.94%, and 71.97% respectively, indicating that these algorithms have similar efficiency in reducing data volume. However, on E_{dis}, the performance of the LALS algorithm is superior to other algorithms, with a value of 0.1724mm, which is lower than the error values of RS and UG (0.2688mm and 0.2609mm, respectively), but slightly higher than the DC and LD algorithms of 0.1167mm and 0.1104mm, indicating that the LALS algorithm has better performance in maintaining the accuracy of point cloud data. T_S and FOM_a further evaluated the comprehensive performance of the algorithm. The processing time of the LALS algorithm is 1.363 seconds, slightly higher than that of the RS and UG algorithms, but the highest FOM_a value is obtained, reaching 3.06, reflecting its good balance between efficiency and refinement effect. In contrast, although the processing time of DC and LD algorithms exceeds 2 seconds, their FOM_a values are 2.74 and 2.88, respectively, indicating that they have lower efficiency while maintaining high refinement effects. As a result, the LALS algorithm has shown relatively balanced performance in point cloud refinement tasks, especially in maintaining low simplification errors and achieving high simplification goodness indicators.

Figure 4.6 shows the performance of five different algorithms in model lightweight tasks. Figure 4.6 (a) evaluates the model from two dimensions: reduction factor R_F and additional volume ratio E_{Vol}. In terms of R_F, the performance of algorithms is similar, with the RS algorithm accounting for 70.14%, slightly better in reducing model volume. The lowest R_F of the LD algorithm is 69.65%. In terms of E_{Vol}, the DC and LD algorithms perform well, with values of 0.0252% and 0.0236%, respectively, indicating that these two algorithms minimize additional changes to the model shape while reducing the model volume, maintaining high fidelity of the original model. Figure 4.6 (b) further compares the results of processing time T_R and lightweight optimization index FOM_b, revealing the relationship between algorithm efficiency and lightweight quality. In terms of T_R, the $LALS$ algorithm significantly outperforms other algorithms with a processing time of 3.405 seconds, while the processing time of RS, UG, DC, and LD algorithms exceeds 4 seconds, indicating that the LALS algorithm has higher computational efficiency while maintaining lightweight performance. From the

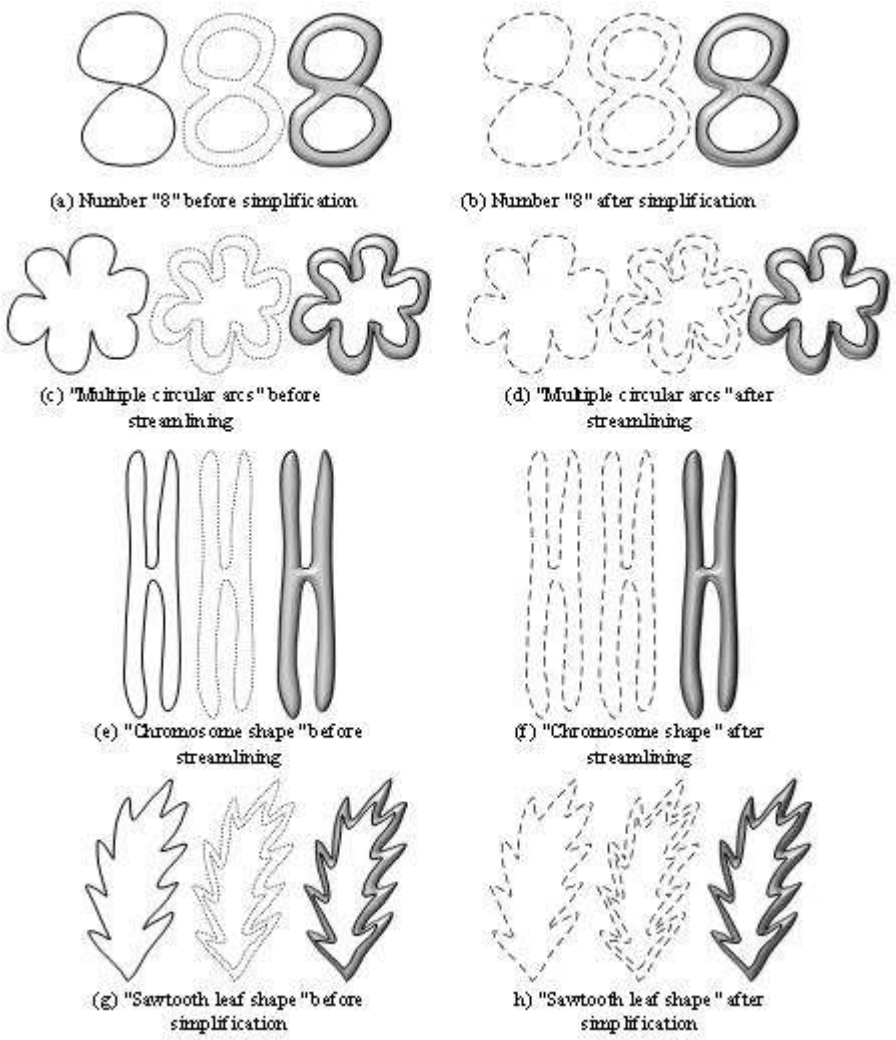

Fig. 4.4: Three-dimensional models generated from four types of images

FOM_b value, it can be seen that the LALS algorithm outperforms other algorithms with a score of 712.51, reflecting its optimal performance in overall efficiency and lightweight quality during the model lightweight process. As a result, the LALS algorithm has shown superior comprehensive performance in model lightweight, not only comparable to other algorithms in aspect R_F but also the outstanding performance in E_{Vol} and T_R metrics, while maintaining a relatively low FOM_b. The above results highlight the efficiency and superiority of the LALS algorithm in the lightweight process of LS models generated from simplified point cloud data.

5. Discussion and Conclusion. In the field of art design, the application of virtual and real scenes is essential. With the emergence of 3D printing technology, creators use 3D modeling software to complete the processing of virtual and real scenes of their works, thus making the works more three-dimensional and beautiful. Traditional 3D modeling software has weak human-computer interaction and cumbersome functions, and the collected raw data also has more noise and redundant points, which is not conducive to the rendering of the model. To address this problem, the study proposes a modeling system that combines the HS model based on the SWR algorithm and the LS model based on the LALS algorithm to obtain ITL modeling system on the

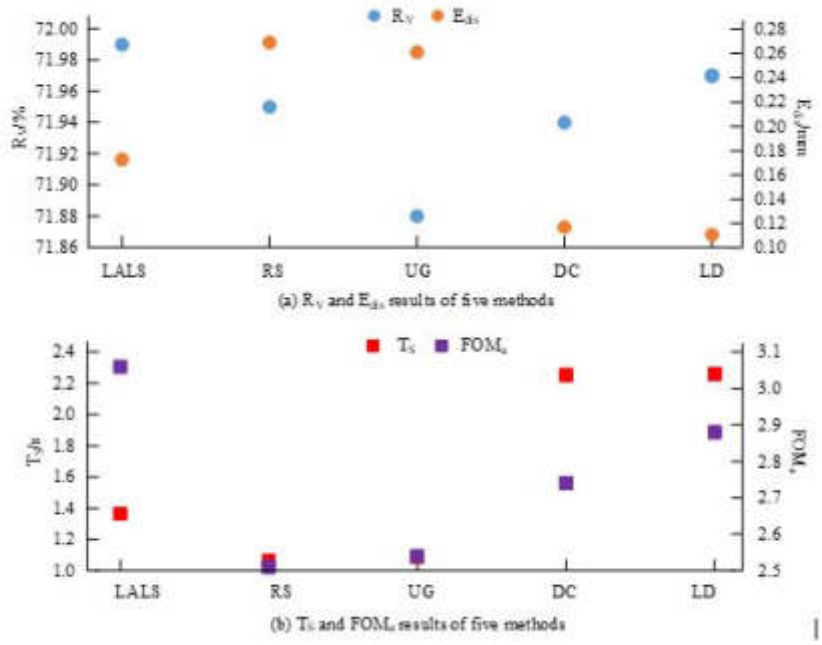

Fig. 4.5: Point Cloud Simplification Results of Five Algorithms

basis of traditional 3D modeling. The results show that the average values of E_l and E_{max} for figure 4.3 shapes by SWR algorithm are 0.98% and 0.75, respectively, which are lower than 3.71% and 1.43 for multi-circular arc shapes. When the hand-drawing speed is 300px/s, the values of η_F and 65.48% for the HS model based on SWR algorithm are 67.39% and η_S, and the time required to generate the model is reduced by 63.79% compared with that before the refinement. In the point cloud data refinement of the LS model, the values of R_V and FOM_a of the LALS algorithm are 71.99% and 3.06, respectively, which are 0.11% and 0.52 better than the UG algorithm. The value of R_F of LS model based on LALS algorithm is 69.92%, which is higher than 69.81% of UG algorithm, and the value of FOM_b is 712.51, which is higher than 329.17 of UG algorithm.

The proposed modeling system demonstrates significant advantages in virtual and real scene processing in the field of art and design by combining the HS model based on the SWR algorithm with the LS model based on the LALS algorithm. The introduction of the SWR algorithm and LALS algorithm not only optimizes the human-computer interaction interface of traditional 3D modeling software but also effectively reduces noise and redundant points in model data, thereby improving the efficiency and quality of model rendering. The application of SWR and LALS algorithms in the field of art and design has significantly improved the efficiency and quality of the transformation of artworks from virtual to physical. This method optimizes the human-computer interaction interface, allowing artists to create more intuitively and flexibly while ensuring the details and realism of the work. Through this technological advancement, the creative process of art and design works has become more efficient, and the expressive power of the works has been significantly enhanced, providing artists with broader creative space and possibilities.

In addition, there is still room for expansion in the potential applications and algorithm improvements of the proposed method in industrial prototype design, medical modeling, and other fields. In the field of industrial design and prototype manufacturing, high precision and model quality are required. The application of SWR and LALS algorithms can provide high-quality model data for rapid prototyping of complex parts. By further optimizing the algorithm to adapt to the printing characteristics of specific materials, printing efficiency, and prototype accuracy can be significantly improved. In addition, in the field of medical modeling, especially in personalized medical device design and biological tissue printing, the application of these algorithms is expected

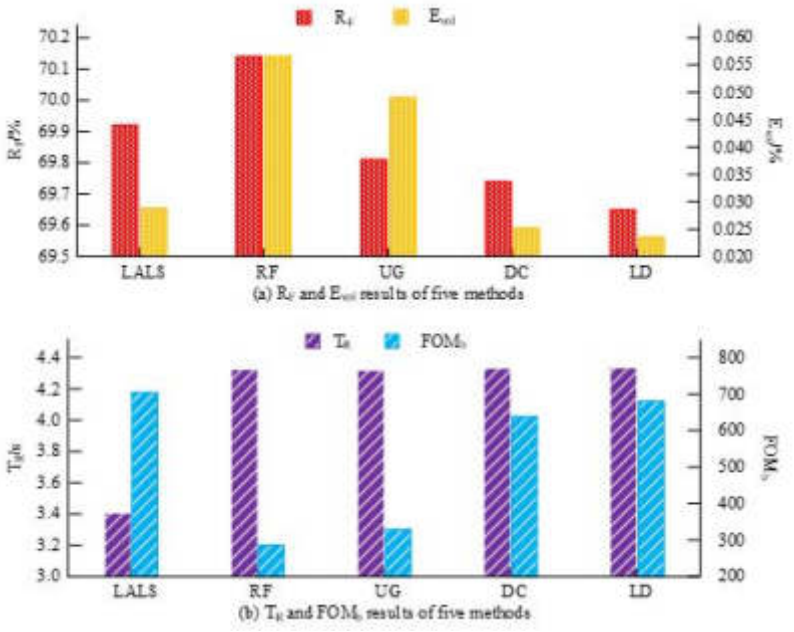

Fig. 4.6: Lightweight results of the model based on five algorithms

to improve the precision of tissue structure models and promote the development of medical model printing technology.

Although research has achieved certain results, there are certain limitations in experimental settings and algorithm design. The efficiency and accuracy of algorithms in handling extremely complex models still need to be improved. In response to this limitation, future research can consider introducing advanced technologies such as machine learning to automatically optimize parameter selection during model processing, further improving the adaptability and efficiency of the algorithm. Future research directions also include in-depth optimization and improvement of algorithms, such as introducing more advanced data compression techniques further to reduce the noise and redundancy of model data, or developing new algorithms to support real-time rendering of dynamic models better.

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SCAN ALGORITHM TO OPTIMIZE DYNAMIC INSTRUCTIONAL INFORMATION NETWORK FOR PREDICTING STUDENT BEHAVIOR

JUNTING TENG*

Abstract. With the integration of work, study and life on campus taking shape gradually in major universities across China, the concept of education from classroom to life is more widely accepted and the smart education model has become a trend in education informatization. However, most of the existing studies are not applicable to student behaviour data in the campus environment, and the temporal as well as cyclical characteristics in the data are not accessible in the student behaviour prediction problem. In this study, a hypergraph-based dynamic campus behaviour information network is designed to address the needs of the student behaviour prediction problem, and a student campus behaviour prediction algorithm is proposed in the dynamic campus behaviour information network-based student behaviour prediction problem. The effectiveness and rationality of the algorithm is verified through experiments with real campus data sets. The experimental results demonstrated that the periodic nature of the data acquired by the cycle gated cyclic unit module needs to be built on top of the snapshot gated cyclic unit module to help the algorithm achieve better results. The area under the curve of the algorithm proposed in the study achieves more advantageous results on both the 21-day and 35-day datasets. The cycle gated cyclic unit module of the student campus behaviour prediction algorithm proposed in this study can more effectively extract the cyclic features present in the dynamic campus behaviour information network and better accomplish the prediction of student campus behaviour.

Key words: Dynamic instructional information networks; Student behaviour prediction; Cycle gated cyclic units; Snapshot gated cyclic units

1. Introduction. With the release of the national standard "General Framework for Smart Campus", the construction of a smart campus that integrates campus work, learning and life has been gradually carried out and taken shape in major universities across China [1]. The concept of education from classroom to life has been accepted by the public, and traditional teaching concepts and methods can no longer meet the demand for personalized training of current innovative talents [2]. The smart education model, which takes advantage of information technology such as big data analysis and artificial intelligence, has become a trend for new types of education. By analyzing students' interests, hobbies, habits and other behaviours, it has a significant impact on their personal development and academic performance [3]. The key to predicting student behaviour is an understanding of behavioural patterns in students' habits. In today's smart campuses, students' daily behaviours are recorded through information technology [4]. These data records, which truly reflect the habits and behavioural patterns of students within the campus environment, contain information on the number of students, locations, times and events. Campus behavioural data is dense, multi-sourced, dynamic and cyclical in nature, and as such, a network structure is a widely used approach to data modelling today [5]. Based on the analysis of the characteristics of campus behavior data, this study constructed a multi-source campus behavior information network for student search behavior to more accurately predict student behavior. To solve the problem of predicting student behavior in dynamic campus behavior information networks, a SCAN algorithm based on dynamic behavior information prediction is proposed. Research and design a Similar Campus Lifestyle Student Miner (SCLSM) algorithm that integrates multi-source behavior information mining and student similarity analysis to address the problem of similar student search in multi-source campus behavior information networks. Processing high-dimensional data: Because in a smart campus environment, student behavior data usually contains multiple types and dimensions of information. These data are high dimensional and are characterized by high complexity, dynamics and periodicity. Therefore, SCAN algorithm is selected in this study because SCAN algorithm can effectively process high-dimensional and complex data. Secondly, it

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can capture this dynamic nature, and can effectively integrate these multi-source information, and carry out in-depth mining and analysis. Moreover, the cyclic neural network module in SCAN algorithm can effectively process time series data and capture the dynamic characteristics of students' behaviors over time. However, other machine learning algorithms are often only able to process data from a single source and cannot efficiently process time series data or capture these dynamic features. This study innovatively integrates multi-source behavioral data of students and conducts deep mining and analysis based on the SCAN algorithm to construct a graph of student behavior characteristics. This study provides more effective support for further improving the accuracy of student behavior prediction and school education management. The research is divided into three main parts, the first of which analyses the characteristics of campus behavioural data as they exist. A multi-source campus behaviour information network is designed for the student search problem, and a dynamic campus behaviour information network is designed for the student behaviour prediction problem. The second part is the implementation of the SCAN algorithm for student behaviour prediction in a dynamic campus behaviour information network. Each of the individual structures in the algorithm framework is explained, and two feasible SCAN algorithm framework designs are also designed. The third part is an experimental recording of student behaviour on campus to verify the feasibility of the SCAN algorithm and the effectiveness of the SCAN-S and SCAN-P framework structures on a real data set.

2. Related works. With the development of information technology such as big data analysis and artificial intelligence, the smart education model has become a trend in education informatics, which can better facilitate personal and social development by predicting student behaviour. Wang et al. equationted behavioural entries as a set of contextual items and proposed a multi-type item set embedding learning method. Finding complementary contexts for people to make their behaviour more likely to succeed. The proposed method was shown to be both efficient and applicable when compared to state-of-the-art behavioural prediction and contextual recommendation methods [6]. Yang X et al. proposed a method for recommending student learning resources based on a bidirectional long and short-term memory recurrent neural network. Based on the deep learning model, learning analysis techniques are used to construct students' specific learning patterns and provide appropriate learning resources. The experimental results show that the student adaptive learning system of the deep learning model has better stability and interpretability in terms of recommendation results [7]. Zhang M et al. proposed a learning pattern analysis method to predict academic performance by describing students' beliefs about learning and their motivation, and by analyzing individual students' learning patterns. The results of the study showed that the proposed method could effectively extract micro-level behavioural information and produced better prediction results [8]. Ji et al. proposed a Bayesian inference and learning scheme. The problem of target tracking under completely unknown maneuvers was investigated to cope with complex target manoeuvres. Tests showed that the proposed tracker can significantly reduce the peak tracking error, which is one of the most important performance indicators to prevent tracking failure [9]. Joshi A et al. proposed to integrate a model with robust machine learning and evaluated a prediction model. This model improves the accuracy of previous student performance predictions through identification. The results of the study showed that our integrated machine learning model Cat Boost outperformed standard machine learning models with an accuracy of 92.27%. This new model was able to prove itself reliable through the use of shocks and hyperparameter optimization, which proved to be a valuable method and approach [10]. Zhang Z et al. proposed an extensible semantic description structure. On this basis, a heterogeneous information embedding framework based on CMG is designed. In the fusion process, an attentional mechanism is used to automatically learn the weights of these potential vectors so that each final node representation focuses on the proximity of the most information-rich order. Experimental results show that the proposed method is superior to the most advanced isomorphic and heterogeneous network embedding methods in three network mining tasks: node classification, node clustering and node similarity search [11].

With the development of information technology, people's habits and behavioural patterns are recorded in the form of data, and it has become a trend to use network structures and intelligent algorithms to solve problems in large environments. Gardoni et al. tested the effect of different biological deacidifications on volatile and non-volatile components. Malolactic fermentation was carried out with brewer's yeast inoculated with Brettanomyces and Lactobacillus plantarum strains. Different fermentation treatments were carried out in 0.75 L vessels. The results showed that the concentration of higher alcohols, fatty acids and acetic acid was reduced

and that the simultaneous fermentation of alcohol and malolactic acid reduced malic acid by approximately 80% [12]. Huang Z et al. based on Convolutional Neural Networks (CNN) for a permeability inversion scheme. A single PET scan from a radiotracer pulse injection experiment was used as input. The results showed that the scheme provides an unprecedented method for effectively characterizing multi-scale permeability inhomogeneities in complex geological samples [13]. Prigioniero et al. explored the relationship between particulate matter, PAH leaf concentrations, uptake rates and foliar functional traits in four Mediterranean evergreen trees. uptake of PM10 was positively correlated with interspecies and upper cuticle thickness, and PM2.5 was positively correlated. The uptake of different components of PAHs was usually weakly correlated with different leaf functional traits. Experimental results indicated that both plant surface morphology and chemical leaf characteristics affect the retention of PM and PAHs [14]. Meng et al. proposed a new ironing technique to study a mechanism design problem with network agents and stochastic evolutionary private information. The network intervention problem is further discussed based on the optimal dynamic mechanism obtained to define some important nodes and edges in the network under different ranges of synergy parameters, i.e., subjects can intervene to change the ex-ante distribution of individual types [15]. Khan A. et al. proposed A least significant steganography method to hide secret information into the original image. A convolutional neural network was used to train the model to detect and extract patterns of hidden features in the image, and to classify the steganographic original image and cover image. The experimental results show that the proposed scheme can realize both information hiding and information revealing, with an accuracy of 95.1%, and the model is robust in terms of efficiency [16]. Qin X et al. developed a new structured Bayesian interactive analysis method to effectively integrate network information. Using Bayesian technique, an effective variable dB Bayesian expectation maximization algorithm is designed to explore the posterior distribution. Experimental studies show that the results are biologically sensitive, and the prediction accuracy and selection stability are satisfactory [17].

In summary, the prediction of people's behaviour within the wider environment in everyday life can contribute to the development of people as individuals as well as to the progress of society. However, existing research still suffers from semantic deficits and insufficient temporal and periodic features in the face of similar behaviour search problems, as well as behaviour prediction problems. Therefore, further research is still needed to face the student behaviour prediction problem to help the student behaviour prediction goal to be better accomplished.

3. Prediction of Student Behaviour Based on Dynamic Instructional Information Networks. For different groups of students, the network is flexibly used to represent their behavioural data, to design a multi-source campus behavioural information network suitable for student search, and a dynamic campus behavioural information network suitable for student behaviour prediction. This chapter will focus on analyzing the characteristics of students' behavioural data at school to provide a basis and scheme for this research, which will be validated by means of experiments.

3.1. Research on campus behavioral information network model. Campus behavior data is a record of students' behavior on campus, which is composed of people, time, place and events [18, 19]. However, students' behaviors on campus occupy a relatively large proportion of students' life, resulting in a large number of recorded behaviors, complex, and high intensity. Therefore, this study designed a campus behavior information network model. Among them, the single-source campus behavior information network is the campus behavior data built through a single source, and its information network is shown in Figure 3.1.

There are five types of binding for the single-source campus behavioural information network, such as student ( ), behaviour ( ), time ( ), place ( ) and event ( ). There are four types of articulation and weight types, relationships between students and instances, relationships between instances and time, relationships between behaviours and locations, and relationships between behaviours and events, and each relationship has a weight value of 1. However, student behavior changes with time, and the single source campus behavior information network cannot predict student behavior in time. Therefore, the definition of time node in the single-source campus behavior information network mode is changed, and the network model after the change is shown in Figure 3.2.

Use hypergraphs to represent relationships between students, places, and events. The date indicates an hour in a day. However, the data source of campus behavior data is highly variable, and the whole network

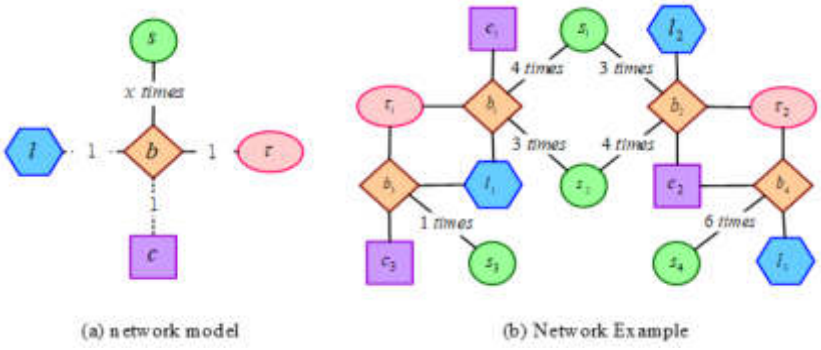


Fig. 3.1: A Single Source Campus Behavioral Information Network

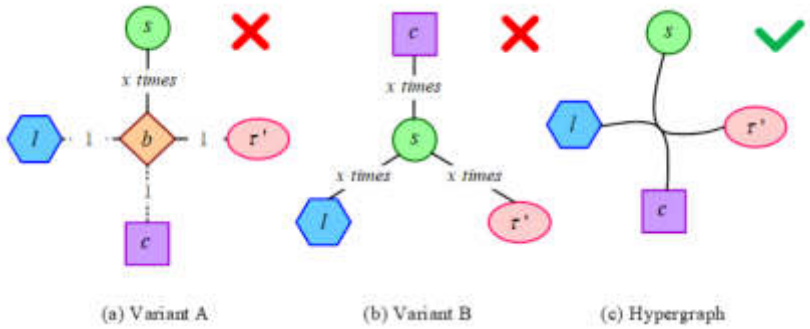


Fig. 3.2: Time node defines the single-source campus behavior information network model after the replacement

structure needs to be updated constantly, which is not conducive to the expansion of the algorithm. Therefore, it is necessary to combine the dynamic properties of student behavior prediction on the basis of single source campus information network structure. While retaining the benefits of a behavioral information network, you can also retain additional data when the data source changes.

3.2. Research on SCAN algorithm based on dynamic behavior information prediction. Aiming at the problem of Student Behavior Prediction in dynamic Campus network, the SCAN algorithm of Student Campus Behavior Prediction based on Hypergraph Information Propagation (HIP) is studied [20, 21]. The algorithm combines the connection prediction of hypergraphs with dynamic features and the extraction of periodic features. Among them, It includes HIP module, Gated Recurrent Unit-Snapshot (GRUs), Gated Recurrent Unit-Period (GRUp), and Hyperlink interactive scoring module Interaction Scoring,INT). The flow framework of SCAN algorithm is shown in Figure 3.3.

HIP first transforms the super-edge into a similar ordinary graph structure during the computation against the super-edge to facilitate subsequent computations [22]. The SCAN algorithm, on the other hand, uses the graph convolution module to process the clusters formed by the hyperedges and in this way obtains the vector representation corresponding to each node in the hyperedges. Since the direct use of the regimented representation of student behaviour leads to ambiguity, the representation of each node in is obtained for a given hyperedge using information propagation. The equation for this is shown in equation 3.1.

$$g_v^{\varepsilon} = W_{\text{clique}} \sum_{u \in \varepsilon - \{v\}} r_u + b_{\text{clique}} \tag{3.1}$$

In equation 3.1, u is denoted as the nodes in the hyperedge ϵ except v, r_u is denoted as the initial vector rep-

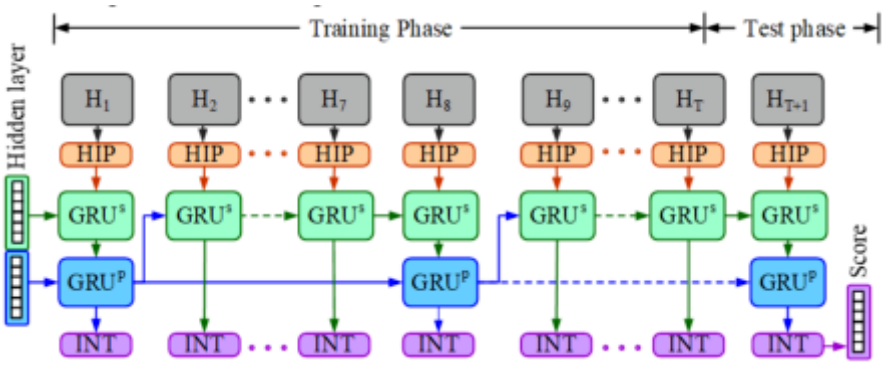


Fig. 3.3: SCAN algorithm process framework

resentation of node u, and BBB and b_{clique} are denoted as the parameters to be trained. Vector representations of nodes other than the current node are added as representations of nodes for information propagation. At the same time, the initial vector representation is also used for information propagation, so that more information can be retained during calculation. Therefore, a is added to the information dissemination part carried out by the initial characterization. Its calculation formula is shown in equation 3.2.

$$l_v = W_{\text{self}} r_v + b_{\text{self}} \tag{3.2}$$

In equation 3.2, r_u is represented as the initial vector representation of node AA, and W_{self}, b_{self} are represented as the parameters to be trained. The campus behavior information network has the characteristics of temporal relationship, so it is necessary to extract the structure of temporal characteristics to obtain the change of student behavior with time. In the SCAN algorithm framework, the cyclic units of recurrent neural network are used, including RNN units, LSTM units and GRU units. These units can help to better understand student behavior patterns. The mathematical expression of RNN unit structure is shown in equation 3.3.

$$h_t = \tanh\left(W \cdot [h_{t-1}, x_t] + b_n\right) \tag{3.3}$$

In equation 3.3, h_{t-1} is the hidden layer of the RNN at the previous moment, x_t is the input at the current moment, $tanh$ is the activation function, W and b_n are the parameters that the RNN needs to be trained. The Z_t mathematical expression of the unit structure in GRU is shown in equation 3.4.

$$Z_t = \sigma\left(W_z \cdot [h_{t-1}, x_t] + b_z\right) \tag{3.4}$$

In equation 3.4, h_{t-1} is the previous moment hidden layer, x_t is the current moment input, σ is the activation function, W_z and b_z are the parameters to be trained by GRU, and the structural equation of Z_t unit in GRU is shown in equation 3.5.

$$r_t = \sigma\left(W_r \cdot [h_{t-1}, x_t] + b_r\right) \tag{3.5}$$

In equation 3.5, h_{t-1} is the hidden layer at the previous moment, x_t is the input at the current moment, σ is the activation function, and W_r , b_r are the parameters to be trained by GRU. The SCAN algorithm uses a clustering method based on shared neighbors. For any pair of nodes u and v in graph G whose similarity is higher than a given threshold, the two nodes are considered similar. The similarity here is calculated by the intersection of the set of neighbor nodes of nodes u and v. In this process, Jaccard similarity is used as a metric,

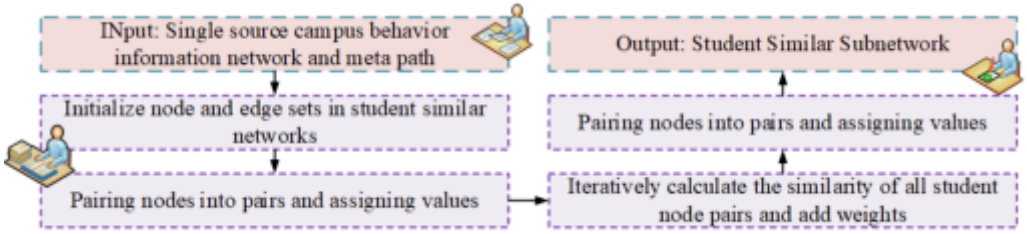


Fig. 3.4: The construction steps of a similar student network

and its mathematical expression is shown in equation 3.6.

$$\mathrm{Sim}(u,v) = \frac{|N(u) \cap N(v)|}{|N(u) \cup N(v)|} \tag{3.6}$$

In formula 3.6, $N_{(u)}$ and $N_{(v)}$ represent the set of neighbor nodes of nodes u and v , respectively. The SCAN algorithm divides the time into multiple time Windows, then calculates the similarity of nodes within each time window, and takes the average value of these similarities as the final similarity, the mathematical expression of which is shown in equation 3.7.

$$\mathrm{Sim}(u,v) = \frac{\sum_t w_t \cdot |N(u) \cap N(v)|}{\sum_t w_t \cdot |N(u) \cup N(v)|} \tag{3.7}$$

In formula 3.7, $N_t(u)$ and $N_t(v)$ represent the set of neighbor nodes of nodes u and v in time window t, and w_t is the weight of time window t. Compared with the traditional RNN structure, LSTM increases a lot of parameters, but it occupies too much computing resources and space resources, and GRU does not need to calculate and save the cell state.

3.3. Construction of multi-source behavioral information similar student search model optimized by SCAN algorithm. In order to solve the problem of searching Similar students in multi-source Campus behavior information network, a Similar Campus Lifestyle Student Miner (SCLSM) algorithm combining multi-source behavior information mining and student similarity analysis was designed [7]. By integrating multi-source behavioral data of students, this algorithm carries out in-depth mining and analysis based on SCAN algorithm to build the behavioral feature map of students. At the same time, an efficient similarity search algorithm is introduced to achieve accurate search and recommendation for similar students. The characteristics of selection mainly include students' learning behavior, living habits and other multi-source behavioral information, which can fully reflect the characteristics of students' behavior. By integrating the multi-source behavior data of students, the SCAN algorithm is used for in-depth mining and analysis [24, 25, 26] to build the behavioral feature map of students. In addition, an efficient similarity search algorithm is used to achieve accurate search and recommendation for similar students. Among them, the construction steps of similar student network are shown in Figure 3.4.

Calculating the similarity between students is a key step in constructing the student similarity network, in which the similarity calculation between every two students is independent. However, there is a certain correlation between these characteristics, for example, students' learning behaviors and living habits may influence each other. By calculating the similarity between the features and applying the constrained meta-path similarity calculation method, the correlation between these features is considered and mined. Therefore, by introducing multi-process or multi-thread method, the execution efficiency of the program can be improved during the construction of the similar sub-network connection of a single student. In addition, the process of constructing similar subnetworks of different students is also non-interference, in which the similar networks do not affect each other. Based on the multi-source behavioral information similar student search model optimized by SCAN algorithm, the network model is optimized and calculated to improve the search accuracy and

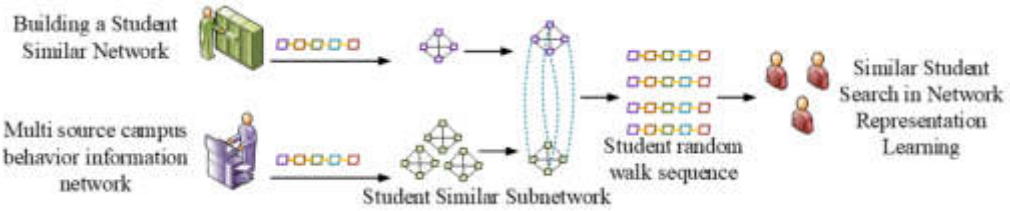


Fig. 3.5: A SCLSM algorithm framework that integrates student similar networks and network representations

meet the needs of campus education management. The SCLSM algorithm framework that integrates students' similar networks and network representations is shown in Figure 3.5.

Based on the correlation between features, a clustering method based on shared neighbors is used to calculate the similarity between students. Moreover, the biased random walk is used to generate the random walk sequence of students on the student similarity network to capture the contextual semantic information of students, and further improve the precision of the similar student search. The constrained meta-path similarity calculation method is adopted in the construction design of student similarity subnetwork. For each single campus behavior information network and each meta-path, the similarity between all students can be calculated. Students are the nodes and similarity is the weight. The biased random walk is performed on the student similar network to generate the student random walk sequence. In the similar student search process based on network representation learning, the random walk sequence of students is taken as the contextual semantics of students to obtain the vector representation of students. Then the similarity with other students is calculated by vector representation, and then sorted to get similar students. For the node vector features output by GRUs and GRUp, the possibility of constituting a super-edge needs to be evaluated using an evaluation function, which is shown in equation 3.8.

$$\text{Score}_{\varepsilon} = \sigma(W \cdot f(\varepsilon) + b) \tag{3.8}$$

In equation 3.8, $\text{Score}_{\varepsilon}$ is denoted as the score of the possibility of the existence of the super-edge, σ is the activation function, and W , b are denoted as the training parameters. $f(\varepsilon)$ is denoted as the function to obtain the ε vector representation through the representation of node $v \in \varepsilon$ in the super-edge. The SCLSM loss calculation equation for each network snapshot H_t is shown in equation 3.9.

$$L_t = \frac{1}{|\varepsilon_t^+|} \sum_{\varepsilon^+ \in \varepsilon_t^+} + \wedge \left(\frac{1}{|\varepsilon_t^-|} \sum_{\varepsilon^- \in \varepsilon_t^-} (\text{Score}_{\varepsilon^-} - \text{Score}_{\varepsilon^+}) \right) \tag{3.9}$$

In equation 3.9, ε_t^+ denotes the hyper-edge (ε_t), H_t denotes the hyper-edge that exists in the momentary network snapshot H_t in the dynamic campus behavioural information network, $\wedge(x)$ denotes a monotonically non-decreasing function, and L_t denotes the loss obtained in the model from the t momentary network snapshot H_t , so the total loss of the dynamic campus behavioural information network is calculated as shown in equation 3.10.

$$L = \sum_{t=1}^{T} L_t \tag{3.10}$$

In equation 3.10, L is denoted as the loss function of the SCLSM algorithm to obtain the smallest L after the final optimization objective. the objective function of the optimization is to have as many super-edge ε_t^+ with ratings higher than the average rating of the super-edge ε_t^- as possible, in order to achieve the objective

Table 4.1: Scale of dynamic campus behavior information network

Number					
Time span	Node	Student	Train Hyperlink	7-days Increases	Test Hyperlink
7-days	2238	2147	45348	45349	6770
14-days	2272	2175	90808	45456	6541
21-days	2491	2395	136468	45654	7483
28-days	2526	2417	186511	50041	7471
35-days	2529	2426	23278	46287	7316

Table 4.2: Comparison between SCAN model and different ML models in AUC scores and Recall@k scores

Data Set	7-days		14-days		21-days		28-days	
Algorithm	AUC	R@k	AUC	R@k	AUC	R@k	AUC	R@k
SVM	0.523	0.23	0.561	0.288	0.622	0.301	0.487	0.234
Logistic Regression	0.527	0.267	0.584	0.295	0.583	0.276	0.556	0.274
Random Forest	0.835	0.423	0.826	0.431	0.797	0.41	0.814	0.406
SCAN-MEAN	0.849	0.417	0.894	0.448	0.877	0.434	0.853	0.397
SCAN	0.875	0.434	0.939	0.475	0.91	0.45	0.878	0.446

of having the ratings of the presence of super-edge ε_t^+ higher than all non-super-edge ε_t^- ratings. In the multi-source behavior information similar student search model optimized by SCAN algorithm, the similarity calculation between each two students is independent. The method takes students as nodes and similarity as weights, and obtains the most similar students through the representation calculation of student vectors, so as to realize campus education management.

4. Validation Test of SCAN Algorithm to Optimize Dynamic Instructional Information Network. This section tests the effectiveness of dynamic campus behavioural information networks in real campus behavioural data, as well as validating the feasibility of the SCAN algorithm for student behavioural prediction. The advantages and disadvantages of two SCAN framework structures, SCAN-P and SCAN-S, are explored in terms of their effectiveness. Data from selected time periods were taken for experimental recording, with data from 7, 14, 21, 28 and 35 days taken as training datasets. The experimentally recorded data sets are shown in Table 4.1.

In table 4.1, students' campus behavior continues to be cyclical. In the first cycle, there was a significant increase in the number of students, and students were more involved in activities. In the third cycle, the number of students' campus behaviors was more stable. In the fourth cycle, the number of students' campus behavior tended to increase again, but in the fifth cycle, it showed a decline. For the reliability of student behavior prediction, the SCAN model was compared with other successful ML models, SVM, Logistic Regression and Random Forest model. There are two evaluation indicators used in the experiment, namely AUC and Recall@k, to verify the validity of the SCAN algorithm. The comparison between SCAN model and different ML models in AUC scores and Recall@k scores is shown in Table 4.2.

As can be seen from Table 4.2, since the SCAN algorithm takes into account the dynamic and periodic characteristics of campus behavior data, the effect of student behavior prediction is significantly better than other ML models. The AUC score of SCAN model is 0.08 higher than that of SVM, 0.12 higher than Logistic Regression, and 0.10 higher than that of Random Forest. On Recall@k, the SCAN model also performs well, which is 0.15 higher than SVM, 0.20 higher than Logistic Regression, and 0.18 higher than Random Forest. It can be seen that the SCAN model shows significant advantages in predicting students' behavior, surpassing other successful ML models in both AUC scores and Recall@k scores, indicating the superiority of the SCAN model in processing such dynamic and periodic data. However, the accuracy of this prediction needs to be improved, and more factors, such as students' personal background and course load, will be considered in subsequent studies to improve the accuracy of the prediction. To this end, in order to verify the soundness of

(a) AUC Score

(b) Recall@ k score

Fig. 4.1: AUC scores of SCANS and its variants and Recall@k fraction

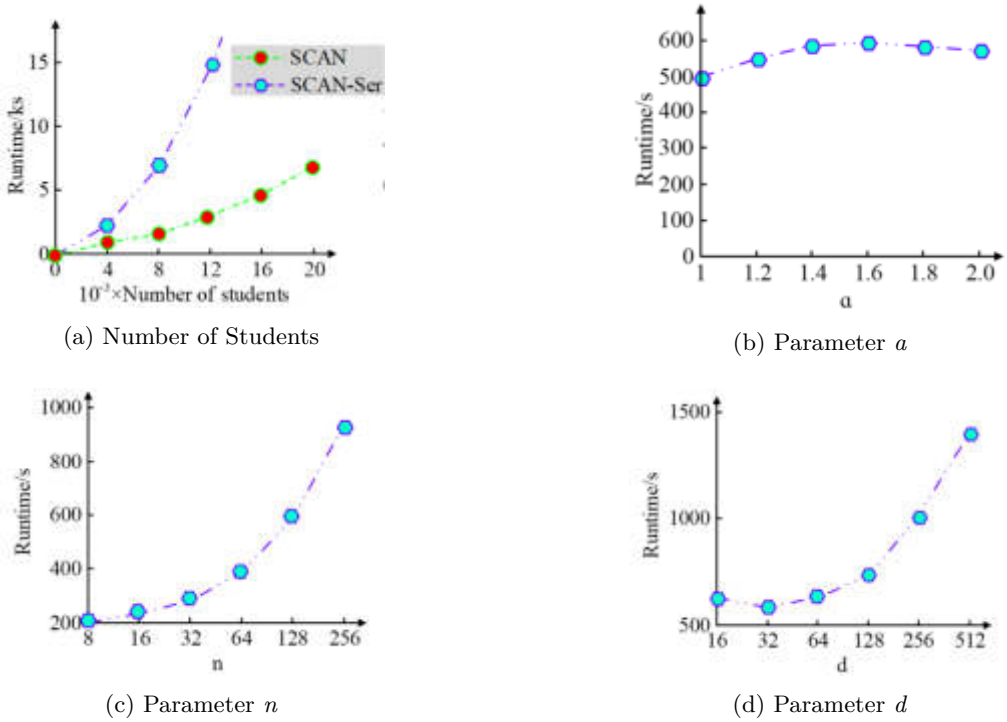
the framework structure of the SCAN algorithm, the results of the two variants, the SCAN-P algorithm and the SCAN-S algorithm, will be compared on the dataset as shown in Figure 4.1.

As can be seen from Figure 4.1, SCAN achieves better results on the main evaluation metric AUC scores, with data only slightly lower than SCAN-P at day 28. On the Recall@k evaluation metric, SCAN-P overtakes SCAN in its dataset at day 21, with a gradual trend towards higher SCAN-P. This shows that the characteristics of the data extracted by the GRUs module are particularly important here. SCAN-S has a more pronounced trend of decreasing model effectiveness when the vector representations of nodes are updated without the GRUp module. As the size of the dataset increases, the results are shown in Figure 4.2 in order to verify the effect of SCAN on efficiency improvement.

From Figure 4.2a, it can be concluded that the SCAN algorithm has good scalability and can still support the prediction of student behaviour on campus when the number of students is 20,000. From Figure 4.2b, it can be concluded that α has little effect on the efficiency of SCAN and only takes slightly less time at lower hours. From Figure 4.2c it can be concluded that when the parameter n increases in a multiplicative form, SCAN elapsed time also shows a non-linear increase, but the rate of increase does not increase in a multiplicative form. From Figure 4.2d it can be concluded that there is an overall trend of non-linear increase, with a decreasing trend in elapsed time and a significant decrease in efficiency as parameter d grows from 16 to 32. It can be seen that the periodic nature of the GRUp module for acquiring data needs to be built on top of the GRUs module in order to help the SCAN algorithm achieve better results. Its effectiveness results are shown in Figure 4.3.

From Figure 4.3, it can be concluded that the SCAN-GRUs algorithm outperformed the SCAN algorithm in both evaluation metrics in the overall 35-day dataset, instead the GRUp module made the overall model less effective. Therefore, the updated nodal vector representation using the GRUp module is not applicable to everyday student behaviour. Selective use of the GRUp module is performed in special scenarios. In SCAN, the hyperparameters that have an impact on task relevance and the period that affects the frequency with which the GRUp module updates the hidden layers of the GRUs module. Sensitivity analysis of the two parameters was performed on 7, 21-and 35-day data sets. A demonstration of the sensitivity validation results for the h and *period* parameters is shown in Figure 4.4.

From Figure 4.4, it can be concluded that SCAN achieves better results for the main evaluation metric AUC on both the 21- and 35-day datasets when *period* is 7. This shows that the GRUp module updates the frequency of the hidden layer with the periodic features present in the data, and achieves the best results when the fit is right. In addition, in the data set with longer time span, the experimental effect obtained at 7 is more advantageous. However, when the time span is short or even less than one cycle, it cannot achieve great advantages, and even the effect is completely inferior to the experimental effect obtained by updating the hidden layer and vector characterization with high frequency. In this regard, we will further optimize our algorithm model to make it better adapted to the prediction task.



(a) Number of Students (b) Parameter a

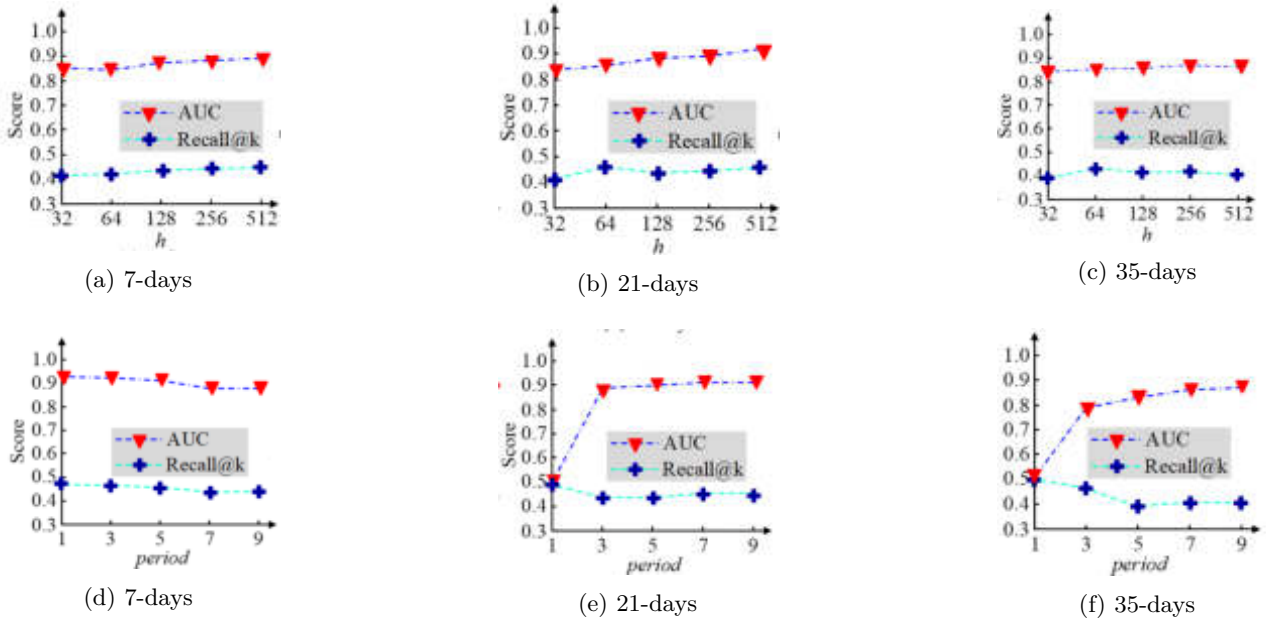
(c) Parameter n (d) Parameter d

Fig. 4.2: Impact of Extensive Testing and Parameters on SCAN Efficiency

(a) AUC Score (b) Recall@ k score

Fig. 4.3: Effectiveness of GRUp module in SCAN

5. Conclusion. Predicting student behaviour on campus has a positive effect on controlling footfall in campus areas, course check-in status, and resource allocation on campus. The problem of predicting student behaviour is transformed into a super-edge prediction problem in dynamic campus behavioural information networks by modelling campus behavioural data. This study proposes the SCAN algorithm to address the shortcomings of the temporal and periodic features in the acquired data. the SCAN algorithm has good scalability and can still support the prediction of campus student behaviour when the number of students is 20,000. In addition, the AUC scores and Recall@k scores of the SCAN algorithm were analyzed separately, and it was concluded that the SCAN algorithm obtained better results on the second cycle of the dataset. For the



(a) 7-days (b) 21-days (c) 35-days

(d) 7-days (e) 21-days (f) 35-days

Fig. 4.4: Sensitivity analysis of SCAN parameters

Table 5.1: Abbreviated table

HIP	Hypergraph Information Propagation
SCAN	Student Campus Behavior Prediction
GRUs	Gated Recurrent Unit-Snapshot
GRUp	Gated Recurrent Unit-Period
INT	Hyperlink Interaction Scoring
SCLSM	Similar Campus Lifestyle Student Miner

dynamic and periodic features present in the campus behaviour data, the GRUs module was used to obtain the temporal features of each network snapshot in the dynamic campus behaviour information network, as well as the GRUp module to update the vector representations of the hidden layers and nodes in cycles as time phases. The results indicated that the updated node vector representations using the GRUp module are not applicable to everyday student behaviour. Selective use of the GRUp module is carried out in special scenarios. the periodic character of the data acquired by the GRUp module needs to be built on top of the GRUs module in order to help the SCAN algorithm to obtain better results. And with an parameter of 7, SCAN achieved better results for both the 21-day and 35-day datasets for the main evaluation indicator AUC. It can be seen that the GRUp module updates the frequency of the hidden layer with the periodic features present in the data, and is able to achieve the best results when it fits. However, the existing research in the face of similar behaviour search problems, and behaviour prediction problems still cannot be used in everyday life, but only in special situations. Therefore, further research is still needed to face the student behaviour prediction problem.

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THE MD-BK-MEANS CONSTRUCTION METHOD FOR LIBRARY READER PORTRAITS

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Abstract. Due to the rapid development of internet technology, knowledge acquisition has become more convenient and efficient in network operations. University libraries serve as important resources for readers to acquire knowledge, and online resources and services in libraries have become the main direction for readers to acquire knowledge at present. Research the use of binary K-means clustering algorithm and library reader portrait technology to optimize the design of the reader portrait module and construct a multidimensional and multi perspective reader feature system. Reuse Spark programming language and support vector machine to perform computational processing on reader profile data to ensure accurate segmentation of the dataset. Finally, three datasets were used to test the accuracy and efficiency of the algorithm. The experimental comparison shows that the mining and precision segmentation of parallel SVM on the dataset are 93.20%, 85.16%, and 79.35% on the sample set, respectively, in order to optimize the mining performance of the data. The MD multi view binary K-means algorithm has a total Mahalanobis distance of 3.543, 5.268, and 22.385 on the sample dataset, respectively, to demonstrate its superiority in clustering performance. Therefore, the multi view binary K-means algorithm based on Mahalanobis distance has high advantages in reader portrait technology design, and provides technical support and theoretical reference for library reader portrait technology.

Key words: Portrait technology; Reader characteristic system; K-means clustering algorithm; Multi perspective clustering; Mahalanobis distance

1. Introduction. Library collection resources and book information have always been representative sources of high-quality books. With the development of internet technology, the demand for readers to enter libraries is gradually decreasing, and the resources and services of libraries are also difficult to meet the diverse needs of readers. Therefore, in order to improve personalized services in libraries, in-depth research is conducted on the needs and preferences of readers for book resources to construct a reader behavior database, and to provide readers with high requirements for personalized services. However, the customization of these personalized services did not conduct in-depth analysis of reader behavior and book preferences, thus failing to meet the resource needs and specific services of readers in a timely manner, leading to the waste of book resources. The issue of library education and learning education is highly valued both domestically and internationally, and the utilization of library electronic resources requires in-depth investigation of readers in order to attract them. However, most university libraries lack the utilization of professional book resources for specialized and customized services, and the system service functions of library management personnel also lack scientificity. There are also service problems such as the inability to achieve real-time transformation of the ever-changing needs of readers, insufficient timely updates of book resources, etc. These require in-depth analysis of reader needs and book resource management, and the establishment of a reader behavior database to meet the ever-changing requirements of readers, Furthermore, we provide professional and personalized reader customization services. Based on this, in-depth analysis of the reader profiling technology framework is conducted to obtain reader behavior information, thereby understanding the diverse reading needs of readers. Using optimized binary K-means clustering algorithm to design the portrait module of reader portrait technology, to construct multi perspective and multi-dimensional reader feature information, and finally construct the reader portrait technology system of Backbone Initial K-means clustering algorithm (BK-means) based on Mahalanobis distance, aiming to improve the accuracy of the algorithm and provide technical reference for reader information feature acquisition.

The study consists of four parts. The first part is an elaboration and summary of the current LRPT. The second part is an explanation of LRPT and the construction of a reader behavior feature system, and the modular design of the reader user system using multi perspective clustering. The third part combines the

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calculation of the sum of MD to construct a reader portrait technology system and tests and compares it with readers from multiple perspectives, to prove the superiority of its algorithm. The final part is a summary and narration of the entire study.

2. Related works. At present, the LRPT relies on the acquisition and analysis of reader behavior characteristics and algorithm citation, so it requires theoretical and technical support. In recent years, many scholars have conducted extensive research on LRPT and system construction.

Byrkovych et al. proposed to transform the modernization concept of the library industry by combining the current education situation and policies in response to the issue of library and information reform in Ukrainian universities, to assist in the development of the library industry [1].

Wangdi et al. [2] and Van Melik [3] analyzed the necessity of resources for the development of libraries in Bhutan and public libraries in the Netherlands.

Zhou proposes to use blockchain technology to collect user profile information in mobile libraries to promote real-time sharing of profile data [5].

Navarrete et al. proposed editing the main body of the article, recording views and frequencies, and determining museum content to increase online attraction for museums in the English version of Wikipedia [6].

Hamilton et al. proposed using 360 tools to create library service guidance methods and provide technical references for library services [7].

Zeng et al. used K-means to extract image features and construct a model to provide technical support for the protection of Dunhuang culture and heritage in the Smart Library. The object resources of the library are relatively rich, and relevant technologies need to be used to support the development of the library industry [8].

Chen et al. proposed the use of crawler technology and questionnaire surveys to explore the key and difficult points of the construction of smart libraries in universities, thereby providing a theoretical basis for the information construction of university libraries [9].

For the problem of college teaching intelligent service system, Qu uses Big data to analyze mobile learning intelligent services and add resources, teaching models and infrastructure to help personalized services [10].

Ahmad proposed to investigate the preservation of digital resources in university libraries and explore their significant differences, in order to provide protection for the preservation of digital resources [11].

Shiri et al. used digital media to preserve archives and obtain digital interface features to protect cultural heritage. The utilization of library resources by new technologies can also protect library collection resources [12].

Zhang et al. proposed combining time series segmentation and clustering techniques to provide research data for the profiling of attack behavior regarding the issue of path planning intelligent attacks [13].

Li utilizes IoT technology to collect and analyze data from students and faculty for smart campus management systems, in order to improve teaching plans and campus management [14].

Candela G et al. proposed using datasets to create machine operable sets for digital information resources in libraries [15].

As for personalized autonomous learning system, Wang et al. proposed Differential evolution to construct learning path and design system to provide learning resources [16].

Tong et al. designed campus scene logic using virtual logic technology combined with artificial intelligence algorithms to provide reference requirements for campus scene management [17].

Gao proposed a Big data analysis and construction model for short video recommendation strategies to provide theoretical reference for personalized recommendation services [18].

Long uses user-defined input simulations to construct an augmented reality framework to enhance students' interest in learning, thereby increasing learning attractiveness. It can be seen that in addition to user profiling, new technologies can also play a recommendation and personalized service role in other fields [19].

In summary, although many scholars have established many systematic methods for LRPT and its education, there is still a lack of in-depth research on the application of portrait technology and educational resources. Therefore, the use of MD's BK-means algorithm (MD-BK) in this study has innovative advantages in user profiling technology.

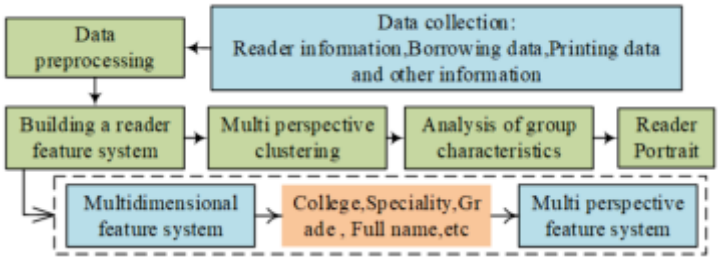


Fig. 3.1: Technology roadmap of Reader Portrait

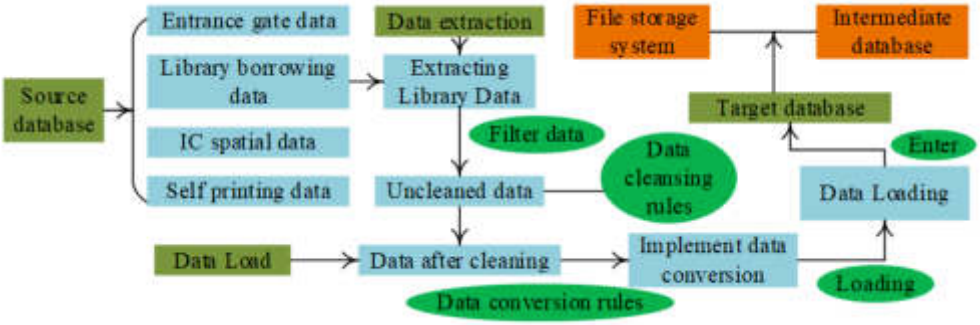


Fig. 3.2: ETL flowchart

3. Model Construction of BK-means Algorithm Based on MD. In order to improve the personalized service quality of library readers, libraries are no longer just the only way to obtain book resources. Due to its lack of precise control over reader needs, data mining techniques and reader profiling techniques can be used to analyze reader behavior. Furthermore, this chapter proposes a multi perspective binary K-means algorithm for MD (MD-MBK-means) to construct a reader feature system.

3.1. LRPT and its feature system construction. University library is an important Big data book resource sharing center, which is rich in resources and high in value, but the diversity of reader needs makes the library service inefficient. Therefore, data mining techniques can be used to collect and process reader behavior information, construct and train models, and then construct reader profiling technology processes to gain a deeper understanding of reader needs. As shown in Fig. 3.1.

In Fig. 3.1, the reader portrait technology roadmap first goes through data processing, builds a feature system through multi-dimensional reader feature information, and then carries out multi perspective clustering and group feature analysis to get the reader portrait. Then, based on the constructed database, the data is effectively extracted to enter the target database, and then extracted through the Extraction-Transformation-Loading (ETL) system. The process is Fig. 3.2.

In Fig. 3.2, the ETL process includes data extraction, cleaning, transformation, and loading. Data cleansing and transformation are carried out according to relevant rules. The transformed data corresponding fields are transformed into the target database to facilitate data preprocessing. The subsequent construction of a multi perspective reader feature system involves dividing readers through information labeling. The reader feature system is divided into linear features (dimensional features such as college, grade, major, and name) and implicit features. It includes the perspective characteristics of reader activity, reader borrowing rate, electronic resource utilization rate, public resource utilization rate, and text features of books borrowed by readers. Finally, the

implicit feature formula is calculated to obtain the Reader Activity (AR) formula (3.1).

$$\mathrm{AR} = \frac{T}{D} \tag{3.1}$$

In equation (3.1), T represents the number of times readers have entered the library during the statistical time, and D is the number of valid days for readers in the library. It intuitively reflects the degree of reader demand for the library. However, the number of valid days in the library varies among readers of different grades and majors in universities, so it is necessary to determine individual valid days based on grade and identity. The formula for reader borrowing rate (BR) is Eq. (3.2).

$$\mathrm{BR} = \frac{B}{T} \tag{3.2}$$

In equation (3.2), B is the number of times the reader has borrowed. The borrowing behavior of readers also reflects their demand for library book resources. The Utilization rate of Electronic Resources (ER) formula is Eq. (3.3).

$$ER = \frac{\sum_{x \in E} (d_x + l_x)}{T} \tag{3.3}$$

In equation (3.3), E represents the collection of electronic resource databases, x represents a certain database within the collection, d_x represents the download volume in database x, and l_x represents the browse volume. The effective utilization of electronic resources by readers reflects the attractiveness of book resources within the library and reflects the preferences of readers' needs. The formula for the Use of Public Resources (PR) is Eq. (3.4).

$$PR = (pt + zt + kt)/T \tag{3.4}$$

In equation (3.4), pt is the number of times self-service printing is used, zt is the number of times seat reservation is used, and kt is the number of times reading space is used. The number of uses of public resources indicates their attractiveness to readers in order to encourage libraries to increase public resources. The formula for the text features of books borrowed by readers is Eq. (3.5).

$$Z(a_i, y) = \frac{af(a_i, y) \times \log\left(\frac{N}{n_i} + 0.01\right)}{\sqrt{\sum_{a_i \in y}\left[af(a_i, y) \times \log\left(\frac{N}{n_i} + 0.01\right)\right]^2}} \tag{3.5}$$

In equation (3.5), $Z(a_i, y)$ is the weight of feature a_i in all information texts. y is the collection of all textual information. $af(a_i, y)$ is the word frequency of a_i in all texts. N is the total number of information texts. n_i is the number of texts with a_i appearing in the text set, and the denominator is the normalization factor. Vectorization processing is performed on book information, with feature items and their weights forming each dimension of the vector to express readers' needs for the book.

3.2. Design of Library User Profile Module Based on Multi perspective Clustering. The utilization of library book resources not only depends on the book needs of readers, but also on the service quality of librarians in organizing and collecting information, which requires in-depth investigation and analysis of the needs of librarians and readers. The needs of librarians lie in the management of individual portraits of readers and group portraits. The needs of readers include input and modification of personal portrait information, annual report data, personalized recommendation of books, library service recommendation, and interest preference social recommendation.

Using the MD-MBK-means algorithm for clustering a certain dimension of the reader population, and then analyzing the characteristics of several groups to obtain the reader population characteristics. Based on the basic information of readers, a library portrait module for librarians and readers is designed, as displayed in Fig. 3.3.

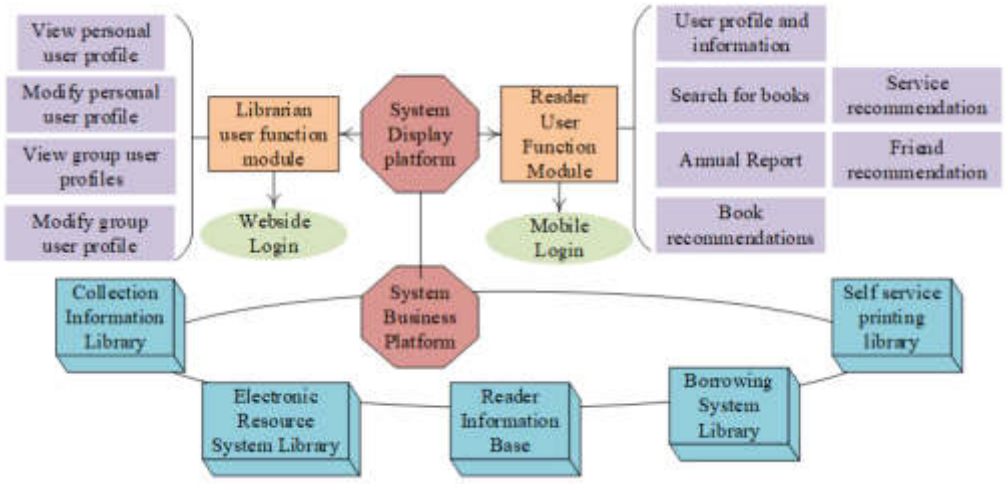


Fig. 3.3: Design of Library User Profile Module

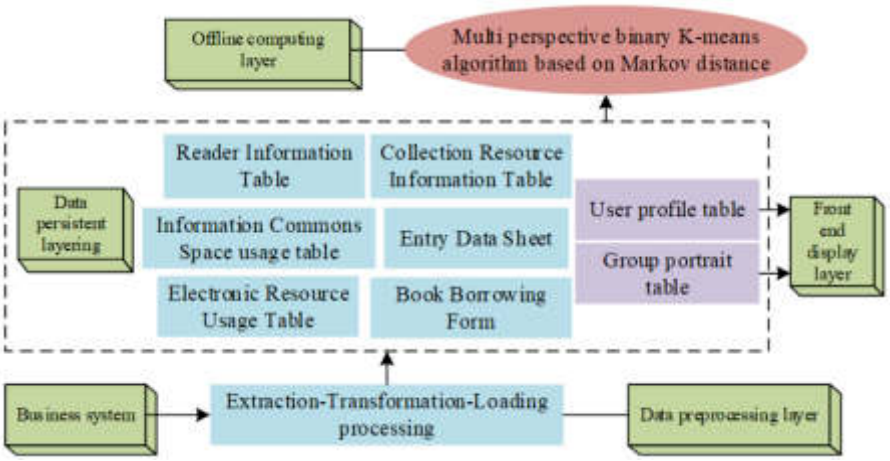


Fig. 3.4: Framework diagram of data computing and backend services

From Fig. 3.3, the business platform in the entire system is most frequently used between librarians and readers, mainly including library collections, electronic resources, reader information databases, borrowing system databases, self-service classical Chinese libraries, and other content. In the front-end platform display, librarians can use web login to view and modify reader user profiles and group user profiles; Readers can use mobile login to modify user profiles, search for book resources, view annual reports, and have functional sections for book services and friend recommendations. The functional modules designed by the system based on the needs of librarians and readers effectively consider their needs and personalized services. Fig. 3.4 shows the framework of the system's data calculation and backend services.

From Fig. 3.4, the data computing layer adopts MD-MBK-means. The business system used by librarians and readers is preprocessed and inputted into various databases for offline storage of information data. User profiles and group profiles are displayed on the front-end platform system. The clustering analysis used in the system framework is derived from the field of data mining and the improvement of classical K-means. Cluster analysis is the process of aggregating data of the same type, where the differences between the same type of

data are relatively small, while the differences between different types of data are significant. In the process of classifying similar data objects, cluster analysis establishes a similarity matrix based on the similarity of the objects and represents it as a data matrix, as Eq. (3.6).

$$\begin{bmatrix} x_{11} & x_{12} & ... & x_{1j} \\ ... & ... & ... & ... \\ x_{i1} & x_{i2} & ... & x_{ij} \end{bmatrix} \tag{3.6}$$

In equation (3.6), $i$represents the number of readers, j represents the attributes of each reader, and x represents the data object. The similarity between different data objects is represented by distance, and the smaller the distance between two objects, the more similar they are. Conversely, the greater the difference. Furthermore, Euclidean distance is used to represent the similarity between two objects, as Eq. (3.7).

$$O(u,v) = \sqrt{\sum_{i=1}^{n} (u_i - v_i)^2} \tag{3.7}$$

In equation (3.7), O represents the distance between data objects u and v, while u_i and v_i represent the coordinates of u and v, respectively.

3.3. MD-MBK-means algorithm. According to the system framework, clustering algorithms are used to introduce the processes of classic K-means, binary K-means, and MD-MBK-means. Among them, classical K-means is a simple Unsupervised learning method, which can find clusters and cluster centers and is widely used, but it is easy to fall into local optima. Due to the large amount of data on reader behavior characteristics in the study, it is easy to be influenced by the dimension of perspective attributes and optimize the classic K-means. The basic idea of binary K-means is to first receive all datasets into a cluster to form a cluster, recycle one of the clusters, and perform K-means clustering with a cluster number of 2 on it; Then select the two clusters with the smallest total distance from the center of the cluster and place them back in the original cluster set. The cycle will not end until the total number of clusters in the cluster set reaches K. The calculation formula for the cluster center is Eq.(3.8).

$$c = \frac{\sum_{x \in D} x}{m} \tag{3.8}$$

In equation (3.8), c represents the cluster center vector, D represents the dataset, x represents the data objects in the dataset, and m represents the total number of data in the D set. Furthermore, the Sum of Squared Errors (SSE) clustering index is introduced to measure the clustering effect, which calculates the sum of squared Euclidean distances from each data point to the cluster center to obtain the SSE value. The formula is (3.9).

$$SSE_D = \sum_{x \in D} O(x,c)^2 \tag{3.9}$$

In equation (3.9), c represents the center of the dataset D, and $O(x,c)^2$ is the square of the Euclidean distance from x to c. Since Euclidean distance is limited by the dimension of view attribute, which affects the clustering effect and the determination of the optimal cluster number, the calculation formula of MD's Statistical distance is used for multi-attribute analysis. Use the sample matrix X to calculate the formula as Eq.(3.10).

$$M = E\{X\} \tag{3.10}$$

In Formula (3.10), M is the mean value of X, E is the Identity matrix, and the mean value is represented by Identity matrix. The formula for obtaining the mean is (3.11).

$$E\{X\} = X^T \left(\frac{1}{s}\right)_{s \times 1} \tag{3.11}$$

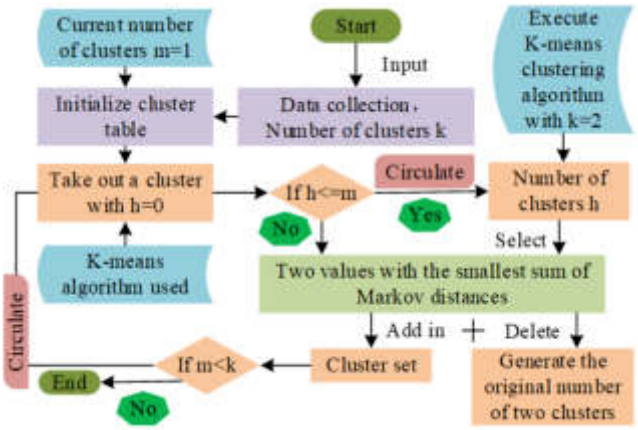


Fig. 3.5: Flow chart of MBK-means algorithm based on MD

In equation (3.11), $\left(\frac{1}{s}\right)_{s\times 1}$ represents a s-dimensional column vector where all elements are $\frac{1}{s}$. The autocorrelation matrix formula of F is (3.12).

$$C = \frac{X^T \times X}{s} \tag{3.12}$$

In equation (3.12), C represents the autocorrelation matrix. The formula of Covariance matrix L is (3.13).

$$L = E\left\{(X - M)^T\right\} = \frac{1}{s}X^T X - M \times M^T \tag{3.13}$$

Based on the evaluation results of the sample matrix above, MD will be calculated, as formula (3.14).

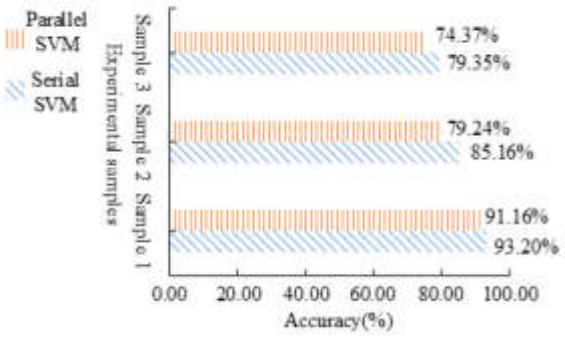
$$J^2\left(X_i - X\right) = \left(x_i - M\right)^T \times \sum_{I}^{-1}\left(x_i - M\right) \tag{3.14}$$

In equation (3.14), X_i and X represent the sample population and sample, respectively, while $J^2\left(X_i - X\right)$ represents the Markov distance from the sample to the sample population. MD calculation is based on the overall sample to enhance the clustering effect, and the number of sample data needs to be greater than the sample dimension to ensure the operation of the Covariance matrix. However, the stability of MD clustering algorithm mainly depends on the Covariance matrix and strengthening its stability. Finally, an improved algorithm that replaces Euclidean distance with MD is introduced, and the specific process of combining MBK-means is Fig. 3.5.

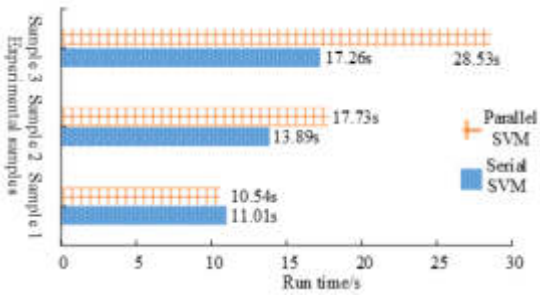
From Fig. 3.5, first introducing binary thinking to optimize K-means, and then introducing MD to improve the multi perspective clustering algorithm. Furthermore, the binary K-means is used to classify the number of clusters based on the judgment of the minimum sum of MD. Subsequently, to verify the effectiveness and accuracy of the algorithm, a comparative analysis was conducted on the accuracy of MD-MBK-means, binary K-means, and classical K-means, as Eq. (3.15).

$$A = \sum_{i=1}^{k}\frac{p_i}{n} \tag{3.15}$$

In equation (3.15), A represents the accuracy of the clustering algorithm, k is the number of clusters, p_i is the number of samples in the i-th individual classification accuracy of the result, and n represents the total number of samples in the sample set.

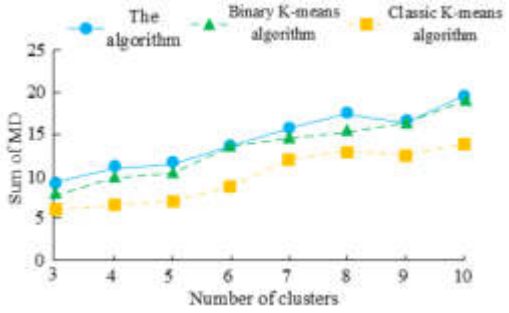


(a) Accuracy

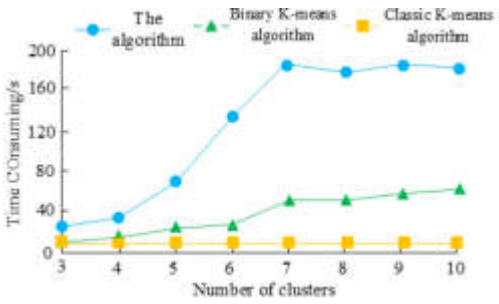


(b) Run time/s

Fig. 4.1: Comparison of accuracy and duration between two algorithms



(a) The total variation of MD for different algorithms under different cluster numbers



(b) Changes in time consumption of different algorithms under different cluster numbers

Fig. 4.2: Changes in MD and time consumption of three algorithms under different cluster numbers

4. Comparative Experimental Analysis of MD-MB-K-means Algorithm. One operational method for processing datasets is to parallelize the Spark programming language with Support Vector Machine (SVM) to ensure the efficiency of data mining. The image information of school students is used as experimental subjects and three sets of samples are randomly selected. Then, 70% of each set of samples are set as training samples and 30% as test samples. Subsequently, a Spark based parallel and serial accuracy and duration comparison experiment was conducted to obtain Fig. 4.1.

From Fig. 4.1, the accuracy of parallel SVM in dataset segmentation is 93.20%, 85.16%, and 79.35%, respectively, which are higher than those of serial SVM. The results of parallel SVM in terms of runtime are 11.01 seconds, 13.89 seconds, and 17.26 seconds, respectively, which are generally lower than serial SVM, thus proving the superior performance of parallel SVM in data mining. Then, based on the constructed multidimensional perspective reader feature system, reader data is obtained, and the MD sum and runtime of the clustering results are calculated using MD-MBK-means, binary K-means, and classical K-means, respectively. Fig. 4.2 shows the comparative experimental results.

From Fig. 4.2, the total MD of the MD-MBK-means algorithm is smaller than the binary K-means and classical K-means. Due to the fact that the higher the sum of MD, the better the clustering effect, the MD-MBK-means has the best clustering effect and can avoid falling into local optima. In the time variation experiment, the same algorithm was performed 10 times under each cluster number to obtain the MD-MBK-means with the

Table 4.1: Number, proportion and range of indicators for each group

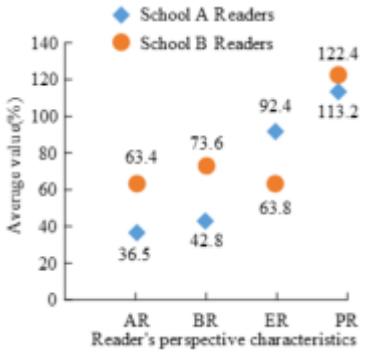
Group	Number	Proportion	AR range	BR range	ER range	PR range
Group 1	9847	51.14%	[0,0.236]	[0,0.461]	[0,0.738]	[1.253,2.064]
Group 2	3169	16.46%	[0.454,1.125]	[0.496,1.022]	[0.675,1.285]	[0,0.497]
Group 3	160	0.83%	[1.582,3.580]	[0.623,0.723]	[1.758,2.527]	[0.365,0.582]
Group 4	4536	23.56%	[0.237,0.545]	[0.782,0.935]	[1.264,1.862]	[1.165,1.348]
Group 5	1544	8.06%	[0.850,1.768]	[0.378,0.823]	[2.235,5.492]	[0.462,1.254]

shortest time, highest efficiency, and stable time consumption. Therefore, MD-MBK-means outperforms the other two algorithms in clustering performance, time consumption, and stability. Then, based on the algorithm indicators of the reader feature system, the reader perspectives in the system are classified. A K-5 clustering analysis is conducted on 19,256 readers from a certain university to obtain 5 user groups, and the number of readers and the proportion of each indicator are calculated. As listed in Table 4.1.

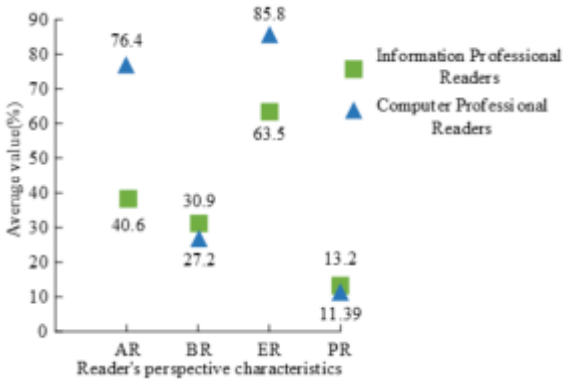
Table 4.1 shows the proportion of people in each reader group and the range of perspectives, and grading different ranges to distinguish between high and low is necessary to obtain user group characteristics for the system settings. Customized reader activity, reader borrowing rate The highest and lowest levels of electronic resource utilization and public resource utilization from the four reader perspectives are ≥ 1.5 and [0,0.5], ≥ 0.8 and [0,0.3], ≥ 1.6 and [0,0.7], and ≥ 1.0 and [0,0.4]. The results can customize personalized services for readers and users to achieve precise services and personalized recommendations. Then, multi-dimensional portrait comparisons of readers and users are conducted, and different dimensions are used to classify readers and analyze the characteristics of books borrowed by readers to achieve targeted and personalized services. The experiment uses four dimensions: school, major, gender, and grade to compare and summarize the characteristics of readers' perspectives, as Fig. 4.3.

In Fig 4.3, the reader activity, borrowing rate, and electronic resource utilization rate of the 19256 reader groups in School A are low, while the high utilization rate of public resources indicates that the service plan for the school is to recommend public and electronic resources. The reader activity and electronic resource utilization rate of 21485 readers in School B are low, while the borrowing rate and public resource utilization rate are high, indicating that their service recommendations are based on the collection resources and public resources. In the comparison chart of the professional dimension, it is found that information and computer readers have lower results in terms of reader activity, borrowing rate, and electronic resource utilization, while the utilization rate of public resources is also higher. However, the recommended services vary depending on the profession and the characteristics of the books used. The former is mainly recommended for public resources and electronic resources, while the latter is mainly recommended for library activities and electronic resources. Then, by comparing gender, it can be concluded that service recommendations for male readers are mainly electronic and public resources, while service recommendations for female readers are library activities and collections of books. Finally, comparing the grade dimensions, it was found that the service recommendations of 2981 readers in the 2016 grade mainly focused on electronic resources and public resources; In 2015, 4004 readers recommended electronic and public resources. Afterwards, the constructed multi-dimensional reader feature system will be used for MD-MBK-means and clustering experimental analysis. To verify the feasibility of this algorithm, it was compared and analyzed with binary K-means and classical K-means in terms of algorithm accuracy, MD sum, and algorithm time. Fig. 4.4 shows the comparison of three algorithms under the algorithm accuracy formula.

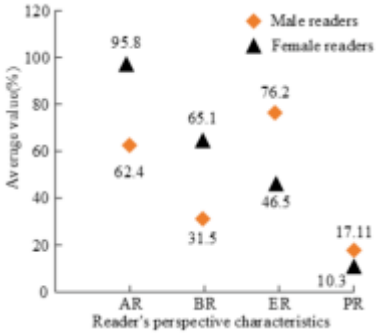
The datasets used for comparison in Fig. 4.4 are Iris Data Set (Iris), Liver injuries Data Set (Liver), and Ionosphere Data Set (Ionophere). The result shows that the accuracy of MD-MBK-means is the highest in all three sample sets, with values of 92.56%, 78.62%, and 72.57%, respectively, and they are all higher than classical K-means and binary K-means. All three datasets belong to machine learning, among which the Iris dataset, as a relatively old dataset, is often used to introduce linear discriminant analysis and contains 150 samples. The sample features are the sepal length and width of iris flowers and the petal length and width. The Liver dataset mainly includes liver injury and its multivariate, standard test datasets, while the Ionophere dataset includes



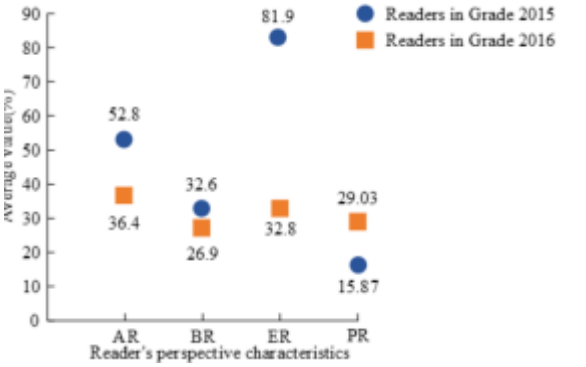
(a) Comparison Table of School Dimensional Perspective Characteristics



(b) Comparison of Professional Perspective Characteristics



(c) Comparison of Gender Dimension Perspective Characteristics



(d) Comparison of Perspective Characteristics of Grade Dimensions

Fig. 4.3: Comparison of Different Dimensions on the Characteristics of Reader's Perspectives

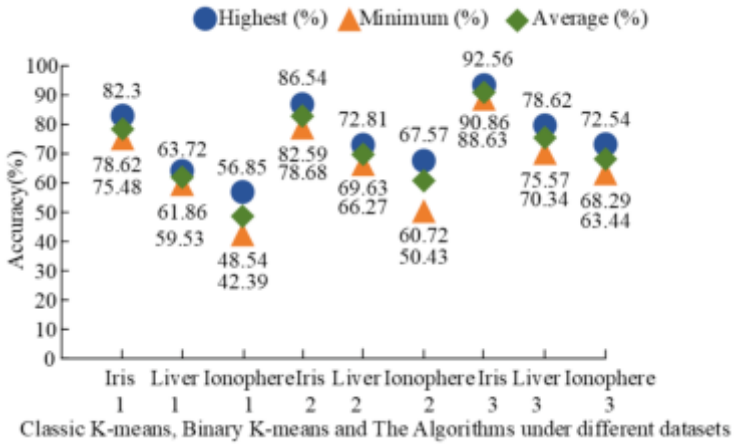


Fig. 4.4: Comparison of Accuracy of Three Algorithms

Table 4.2: Comparison of Clustering Effects of three algorithms on different sample sets

Algorithm	Sample set	Highest (Sum of MD)	Minimum (Sum of MD)	Average (Sum of MD)
Classic K-means algorithm	Iris	5.526	3.649	4.400
	Liver	7.687	6.398	7.159
	Ionophere	38.486	30.726	33.682
Binary K-means algorithm	Iris	4.173	4.136	4.158
	Liver	6.872	6.136	6.652
	Ionophere	35.549	28.527	30.296
The algorithm	Iris	3.854	3.543	3.685
	Liver	6.357	5.268	5.872
	Ionophere	24.861	22.385	23.026

Table 4.3: Comparison of Time Consumption of three algorithms for each sample set

Algorithm	Sample set	Highest (Second)	Minimum (Second)	Average (Second)
Classic K-means algorithm	Iris	0.036	0.024	0.031
	Liver	0.034	0.094	0.065
	Ionophere	0.051	0.113	0.075
Binary K-means algorithm	Iris	0.033	0.027	0.030
	Liver	0.035	0.080	0.059
	Ionophere	0.038	0.099	0.074
The algorithm	Iris	0.030	0.021	0.027
	Liver	0.029	0.056	0.048
	Ionophere	0.031	0.085	0.062

ionosphere and its classification, multivariate, and standard test datasets. Compare the MD sum of the three algorithms again to solve the defect of local optimum in classical K-means and obtain Table 4.2.

From Table 4.2, the smaller the sum of MD values, the better the clustering effect. The sum of MD of MD-MBK-means in the three sample sets is smaller than that of classical K-means and binary K-means, with values of 3.543, 5.268, and 22.385, which proves the advantage of its algorithm clustering performance. Finally, the running time of the three algorithms was compared to consider computational efficiency, as Table 4.3.

In Table 4.3, the shorter the algorithm running time, the higher the computational efficiency. The results show that the running time of MD-MBK-means in the three sample sets is 0.021s, 0.056s, and 0.085s, and is significantly better than classical K-means and binary K-means.

5. Conclusion. Regarding the design of LRPT and its system, this study proposes to partition reader information and analyze its perspective characteristics based on the multidimensional perspective feature system of readers. Firstly, based on the design framework of the portrait system, MBK-means is introduced to optimize the classic K-means. Secondly, the calculation results of MD sum are compared between MD-MBK-means, binary K-means, and classic K-means. The experiment shows that the MD sum of MD-MBK-means is the smallest and the clustering effect is the best. This study also compared the multi-dimensional aspects of reader perspective characteristics and recommended services to various dimensions of reader groups based on the personalized service function of the system. In the final experiment, three sample sets were used to compare the accuracy, MD sum, and running time of the three algorithms. Among the three sample sets, the MD multi MBK means algorithm had the highest accuracy, with values of 92.56%, 78.62%, and 72.57%; The sum of MD results is the smallest, with values of 3.543, 5.268, and 22.385, respectively; The running time is the shortest, with a duration of 0.021s, 0.056s, and 0.085s for the three sample sets. The multi perspective clustering algorithm provides rich and accurate algorithms for the customization needs of library reader profiles. The reader profile system also deepens the correlation between readers and book resources, and enhances readers' reading interest. This proves the superiority of the MD multi perspective binary K-means algorithm.However,

its algorithm still lacks experimental data on the dimensional features of reader portrait perspectives, as well as the representativeness of extensive sample set experimental data. Therefore, further research and improvement are needed in future research.

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ANALYSIS OF LIFT-APRIORI-DP JOINT ALGORITHM-BASED DATA EXTRACTION IN BUSINESS ENGLISH ACHIEVEMENT IN COLLEGES AND UNIVERSITIES

HONGYING XIAO*

Abstract. This paper investigates the application of data mining based on a correlation-rule algorithm in business English performance in colleges and universities. The extracted correlation degree rules are screened by adopting three indexes of support degree confidence degree and lifting degree to measure the correlativity. Experimental validation is carried out on different sets of data sets, and the experimental results show the effectiveness of the Lift-Apriori-DP algorithm. Based on the improved Lift-Apriori-DP algorithm, it is applied to the analysis of students' performance. Taking the chapter test scores of students in business English courses in colleges and universities as an example, the student's achievements are extracted and analyzed, and the final appropriate parameter values are selected according to the evaluation of the extraction results under different privacy pre-estimation. The experimental results verify the effectiveness of the Lift-Apriori-DP algorithm in the analysis of student grades and evaluate the accuracy of the algorithm application. The results of this paper show that data mining based on the correlation degree rule algorithm has a wide range of applications in business English grades in colleges and universities, which can provide useful references for teaching and at the same time protect students' private information from being leaked. In addition, this paper also explores the evaluation class method of the mining results under different privacy pre-estimation, which provides a useful reference for the application of privacy-protecting relevance degree rule mining type algorithms.

Key words: lift-Apriori-DP; achievement big data; data mining; privacy preservation; law of association

1. Introduction. With the continuous progress of science and technology, massive data resources have been gathered in today's era [1-2], and the scale of data resources is still continuously expanding. How to explore the potential information behind the data, data mining technology [3-4] has emerged. The hidden information behind educational data can be more intuitively extracted through the use of data mining techniques to improve the quality of teaching and learning [5-6]. Among various data mining algorithms, the relevance rule mining algorithm [7-8] is one of the important branches, that has been widely used in various industries. Relevance rule mining algorithms aim at mining interesting relevance relationships in transaction databases to help people better utilize the knowledge behind the data, which is an indispensable guide for teaching and education, business decision analysis, evaluation and analysis of the healthcare industry, and the enhancement of higher education. A classic example is "80% of the customers who buy bread also buy milk". The most commonly used algorithm in the relevance rule extraction algorithm is the Apriori algorithm [9]. In practical applications, the L-Apriori-ll algorithm is relatively concise and clear, and can better discover the implicit rules between the data, for example, in higher education and other industries to analyze the student performance data for relevance degree rule mining, and early warning of student performance [10]. At the same time, with the development and practical application of data mining technology, the problem of privacy data leakage becomes more and more serious when mining the hidden information behind the data [11-12], Dalenius [13] firstly put forward the protection of data privacy for data security problem, and its main point is that during the period of querying the data, for any data user, whether it is legal or illegal user, can not get the information of the data. Dwork first proposed the concept of differential privacy [14]. Differential privacy has two outstanding advantages, on the one hand, it does not need to take into account the knowledge of the background possessed by the attacker; on the other hand, the model is based on rigorous mathematical calculations with quantitative evaluation class methods, and thus it is gradually being widely used [15].

In 2015, Li11 [16] and Gan [17] improved the efficiency of the algorithm by mapping the data to a relatively low dimensional space and reducing the dimensionality by truncating the transactions, respectively, and Cheng

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[18] proposed a frequentness class-term group mining-type algorithm based on the preservation of differential degree privacy by transaction splitting. In 2017, Zeyu Shen et al [19] introduced a parallelized environment, which mainly performs parallel computation under the Hadoop framework, and the computational effectiveness of the algorithm is significantly improved when mining large-scale data. In 2018, Yihui Cui and Wei Song et al [20] investigated a multi-source data relevance rule mining algorithm under the protection of differential privacy, which performs noise perturbation through the Lap-Las mechanism that publishes data in the form of a tree of frequency class itemsets with high security. In 2019, Han et al [21] investigated an association degree rule mining-type algorithm for distributed databases with differential degree privacy protection by adding Laplacian noise to the counts of frequent 1-itemsets for each candidate itemset set. In 2019, Tingting Chen et al [22] proposed a heuristic algorithm for frequentness class itemset mining with differential degree privacy, which performs heuristic truncation of transactions to reduce the degree of global sensitivity, and the improved algorithm has a high degree of usability. In 2019, Chen Jiang et al [23] proposed the Trun-Super algorithm to address the low efficiency of long transaction mining in the frequentness class item mining-type algorithms oriented towards privacy, and privacy protection, which mainly reduces the efficiency of the data through the transaction data group set intelligence truncation for dimensionality reduction.

In the field of educational data extraction, the research on the correlation degree rule has achieved certain results. The research mainly lies in the analysis of teaching data through the L-Apriori-ll algorithm based on the L-Apriori-ll algorithm and the improvement of the L-Apriori-ll algorithm according to the problems in the practical application. Analyzing the extracted relevance degree rules provides guidance suggestions for future teaching. The following are the applications of association degree rule algorithms in the field of educational data mining. In 2005, Markellou et al [24] proposed a personalized learning framework for the problem of personalized online learning by using the L-Apriori-ll algorithm to find the group of frequency class items that can better recommend learning materials for users. In 2009, Huo Shuhun et al [25] extracted and analyzed the teaching degree evaluation data accumulated in higher education institutions, and analyzed the implied correlation relationship between the quality of teaching and the teachers' related information according to the correlation rule extraction algorithm, to motivate the teachers to better improve the quality of teaching [26]. 2010, Buldu et al [27] used the L-Aprori-ll algorithm to find the frequency class items of the group of students in a high school business class in Istanbul and proposed a personalized learning framework. Istanbul Higher Business High School students' achievements were mined and analyzed to help students make independent career choices by revealing data relationships between students' social activities, areas of interest, and unsuccessful courses. In 2011, Milicevic et al [28] proposed a personalized e-learning system capable of automatically adapting to the learner's interests, habits, and level of knowledge using the Apriori-All algorithm, by mining and analyzing data from the Istanbul Higher Business High School students' achievements and helped students to make independent career choices. -All algorithms to recommend learning programs adapted to learners by mining the frequency sequence in each learning habit to improve the quality of teaching and learning. In 2012, Xiao [29-32] analyzed the data using the Apriori algorithm for the stored teaching-degree evaluation data in distance education to derive the key evaluation data in the mining results that have an impact on the quality of teaching and learning, which in turn improves the teaching-degree evaluation quality. In 2018, SungSik et al [33], used L-Apriori-ll to extract and analyze students' math performance and problem-solving patterns and analyzed the results of the extraction to select the information that is valuable for improving students' performance. Cheng-Yong Wang [34] targeted the L-Apriori-ll algorithm running with low efficiency due to multiple scans of the D database, etc., and proposed an altered procedure for control.

In practice, the Apriori algorithm based on differential privacy preservation often mines a large number of invalid rules [35-36], mainly because of some problems in filtering segments based on support and confidence. To solve this problem, this paper introduces the lifting degree to improve the Apriori-DP algorithm. Boosting degree can measure whether a rule is better than a random guess, thus helping us to better filter out valid rules. In addition, to better protect students' private information, this paper adopts the Apriori algorithm based on different degrees of privacy protection for data mining. This algorithm can ensure that students' private information is not leaked, and at the same time, it can get relatively accurate results. To summarize, in the field of educational data mining, the research on relevant rule-based mining algorithms based on the protection of differential degree privacy has practical application value. Therefore, in this paper, a data mining

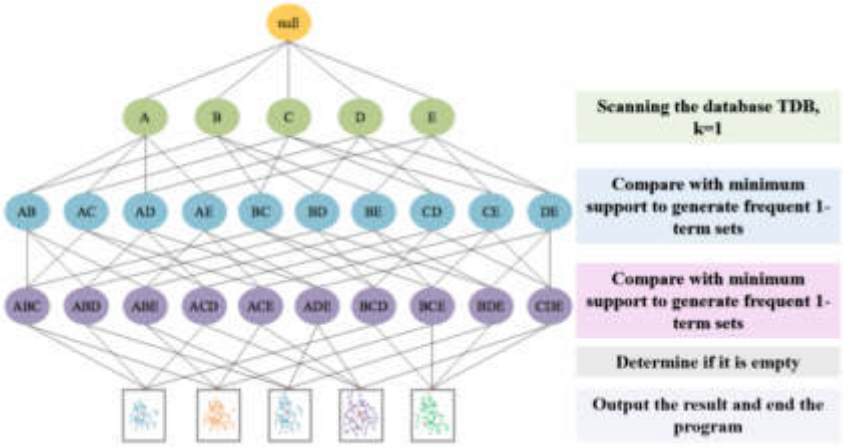

Fig. 2.1: A priori-based algorithmic flow

model based on the algorithm of relevance rules is developed for the achievement of business English, which can quickly realize the intelligent analysis of the achievement while guaranteeing privacy.

2. Lift-Apriori-DP algorithm.. This chapter first describes the problem that in the Apriori algorithm based on the protection of differential degree privacy, many invalid correlation degree rules are extracted when clips are screened according to the support degree and confidence degree. Secondly, the lifting degree is introduced to improve the Apriori-DP algorithm. Then the design of the Lift-Apriori-DP algorithm with the introduction of the lifting degree is introduced. The experimental analysis is carried out according to the improved algorithm, and the experimental results show the effectiveness of the improved Lift-Apriori-DP algorithm. Finally, the Lift-Apriori-DP algorithm is applied to the analysis of students' performance to analyze the effectiveness of the Lift-Apriori-DP algorithm in the analysis of student's performance and to assess the accuracy of the algorithm application.

2.1. Lift-Apriori-DP New Algorithm Flow and Logic.. The basic idea of the new joint Lift-Apriori-DP algorithm is divided into two main steps: one is to find the frequency class itemsets, and the other is to generate the strong-associative degree rules. First, the algorithm scans the discrete database and generates a frequency 1-item set L. Then, it uses L to generate candidate item sets A/B/C/D/E items, etc., accumulates the frequency of item sets of C2 and compares it with the minimum support, removes non-frequent item sets, and generates items such as AB, i.e., frequency 2-item sets. This process is looped until no more frequency k-item groups can be found. The entire database needs to be scanned once for each frequency class item group found. The specific process is shown in Figure 2.1.

The core of the Lift-Apriori-DP new joint algorithm is to connect and clip the frequency class item group lookup, mainly layer-by-layer search iteration, the algorithm is simpler and clearer, more suitable for transaction database mining analysis, and thus is widely used in various fields of relevance of the degree of the rule of mining analysis, pseudo-code algorithm description as shown in Table 2.1.

2.2. Differential Processes for Privacy Protection.. Differential degree privacy model for privacy protection provides a higher level of semantic security and, a greater possibility to protect data security from successful attacks, and thus is widely used in various aspects. The relevant definition of the differential degree privacy model in the model of this paper is as follows:

There are two data sets D and D', when the data records in D and D' satisfy equation 2.1, i.e., D and D' differ by one data set, then they are called neighboring data sets.

$$|(D - D') \cup (D' - D)| = 1 \tag{2.1}$$

Table 2.1: Process control code for the joint Lift-Apriori-DP algorithm

Lift-Apriori-DP New Joint Algorithm Code
Input: data set TDB, support level min_sup Output: frequency class item set
1.// Scanning TDB to get C
2.C, = find_candidate_1_itemsets (TDB); for Vt eTDB{
// Scanning the TDB for counts
3. C, = subset(C„ t); // generate C
4. for VcEC,;
5. c.count++;
6.7.8. l, = {ceC, Ic.count/t_num 2 min_sup)//C, clip generates L, for (k=2; L+O; k++){
9.C= apriori_gen(L): // Generate C from L self-connection
10. for Vt eTDB{
11.C, = subset(Ck, t); // get the subset containing the subset over C
12. for VceC.
13.c.count ++;
14.}
15.L={ceC, lc.count/t_num 2 min_sup)//from C, generate L
16.17. return L =ULk

The parameter ε is a positive real number and is a privacy-preserving pre-estimate. There is a randomized algorithm M, and PM is the set consisting of any outputs of the randomized algorithm M. For any two neighboring dataset sets D and D', as well as the set of outputs P, and any subset Sy of it, a randomized algorithm M is said to protect e-differential degree privacy if the effect of the randomized algorithm M on the neighboring dataset sets satisfies Equation 2.2.

$$|(D - D') \cup (D' - D)| = 1P_r \left[M(D) \in S_M\right] \leq \exp(\varepsilon) \times \left[M\left(D'\right) \in S_M\right] \tag{2.2}$$

Figure 2.2 shows the output probabilities of the randomized algorithm M acting on D and D'. The choice of the size of the pre-estimated value for the degree of privacy is very important. The higher the degree of privacy protection required by the algorithm, the smaller the value of e is, the better, but the degree of usability of the algorithm's extraction results is relatively lower; relatively speaking, when c is larger, the degree of usability of the data extraction results is better, and the effect of privacy protection is relatively lower. In the practical application of the algorithm, the privacy pre-estimation limit boundary value should be selected reasonably according to the demand.

Let x-Laplace (μ, b), where the position parameter is μ and the scale parameter is b, and its probability density function is Equation 2.3:

$$f(x) = \frac{1}{2b} \exp\left(-\frac{(|x - \mu|)}{b}\right) \tag{2.3}$$

The distribution of the Laplace probability density function for different parameters (under input and output values) can be observed in Figure 2.3 below. By presenting the probability density distributions under different parameter points P, respectively, it can be found that the relationship between the input and the output is plotted as shown on the left side, and the simultaneous transformation leads to the Laplace-Las probability model shown on the bottom right. It can be seen that: in the position parameter, the same case, the scale parameter is the smaller b, the smaller ε, that is, the larger the noise introduced.

2.3. Lift-Apriori-DP new joint algorithm control model. In the Apriori-DP algorithm, the confidence level of the rules is calculated based on the frequency class item set, and the rules that satisfy the confidence level limit boundary value are screened as strong correlation degree rules, but the resulting correlation degree rules are not all correlated, and some of them are invalid correlation degree rules, and the existence

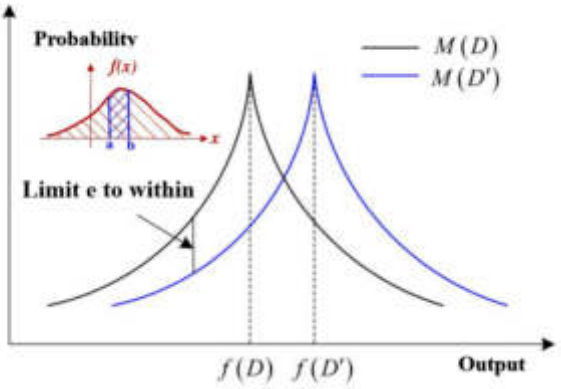

Fig. 2.2: The probability of output based on the randomized algorithm in a set of adjacent data sets

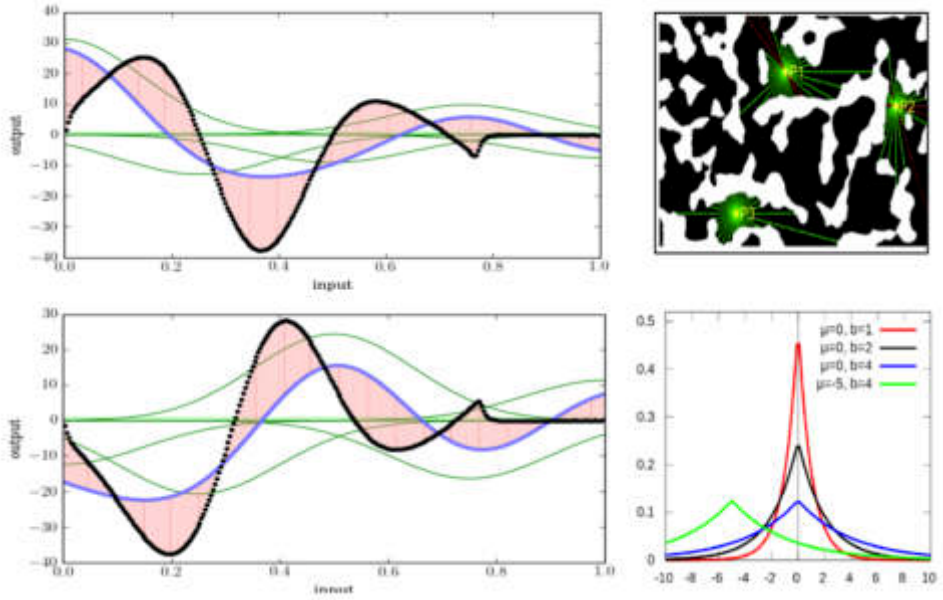

Fig. 2.3: Laplace probability density derived distribution function

of a large number of invalid rules affects the usability of the algorithm when the privacy pre-estimation is reduced. The flow control of the algorithm is shown in Table 2.2.

Figure 2.4 shows the mining results for a data set of 100 data sets extracted for an English score under different privacy pre-estimates, mainly the change of the number of invalid relevance rules in the mining results. As shown in Figure 4, as the privacy pre-estimation decreases, the ratio of invalid relevance rules to the total number of rules in the extraction results gradually increases. In addition, as the privacy pre-estimation decreases, the number of correlation rules obtained from mining grows, and the number of invalid correlation rules in them also increases. For the associativity rule mining algorithm based on the protection of differential-degree privacy, the number of invalid associativity rules increases as the noise perturbation increases, and the large number of invalid associativity rules reduces the utility value of the algorithm.

Table 2.2: Apriori Algorithm Code

Algorithmic Control Flow
Inputs: set of data sets, level of support, level of confidence, privacy pre-estimation
Output: Frequency class item sets and strong correlation degree rules
1. scan the entire set of achievement data sets, k=1, to produce a candidate 1-item set.
2, add noise to the support level of candidate 1-item groups, and filter to produce frequent 1-item groups that satisfy the support level limit boundary value.
3, Self-connection, such that k=k+1, produces candidate k-item groups from frequent (k-1)-item groups.
4, clip, add noise to the support level of candidate k-item groups, and filter to produce frequent k-item groups that satisfy the support limit boundary values.
5, the frequency k-item group is not empty, go to 3.
6, the set of strong association degree rules that satisfy the confidence level is generated from the set of frequency class items.

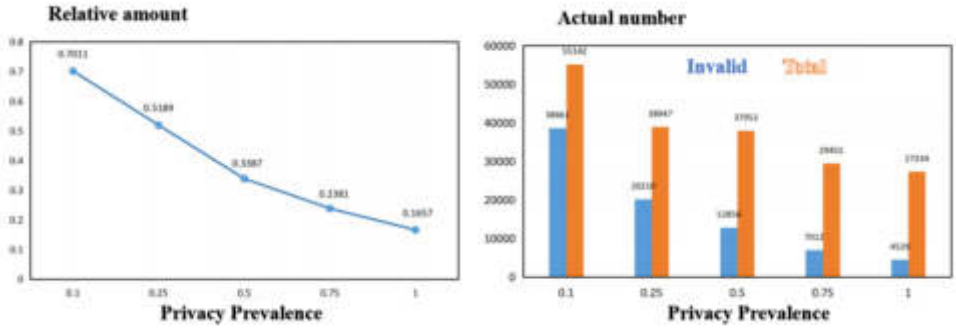

Fig. 2.4: Privacy pre-estimation of correlation metrics in extraction results

In summary, based on the Apriori-DP algorithm under the framework of the degree of support a degree of confidence, the number of invalid correlation degree rules in the extraction results increases when the privacy degree pre-estimation decreases, and the large number of invalid correlation degree rules reduces the utility value of the algorithm. As a result, boosting degree is introduced to screen and remove the invalid rules that do not meet the relevance. In this chapter, the existing Apriori-DP algorithm is improved by introducing the enhancement degree, and the correlation rules of mining are filtered by the limit boundary value of the support degree, the limit boundary value of the confidence degree, and the limit boundary value of the enhancement degree, and the correlation rules that do not satisfy the relevance are deleted, so that the correlation rules obtained from mining are all effective, and thus the algorithm's efficiency can be improved.

3. An experimental analysis of business English performance under Lift-Apriori-DP.. The experimental data set used in this chapter is the big data of business English in one or two colleges and universities in Chengdu City, Sichuan Province, which is obtained through surveys and studies, to establish a big database under the factors of various variables of business English. The Lift-Apriori-DP algorithm is experimented with the big database as an example, and the experimental results are analyzed. The experimental environment in which the Lift-Apriori-DP algorithm is realized is shown in Table 3.1.

The Lift-Apriori-DP algorithm is validated on different sets of data sets (randomly divided into three groups) to verify the computational effectiveness and accuracy values of the improved algorithm by analyzing the number of correlation degree rules extracted and the running time. In the experiments, since the differential degree privacy implementation mechanism involves randomized noise generation when adding noise, the experiments are repeated five times for each set of data and the average value is taken as the experimental result for analysis. The results of the algorithm are analyzed by analyzing the running time of the Apriori-DP algorithm using the

Table 3.1: Business English Lift-Apriori-DP Experimental Environment

Type of environment	causality	
host processor	Intel i7	
C-PU	8-core	
random access memory (RAM)	4-GB	
operating system	Windows-10 Flagship	
agglomeration environment	PyCharm-3.1+python-3.7	
Algorithm implementation language	Python	

Table 3.2: Business English Lift-Apriori-DP Experimental Environment

Data set	Frequency k-term group	Level of support	Confidence level (math.)	Privacy pre-estimation	Evaluation indicators	Running time (s)	Number of association degree rules
1	3	0.04	0.7	0.5	sup-conf	0.0249	29
					sup-conf-lift	0.0232	16
2	3	0.04	0.7	0.5	sup-conf	0.6301	301.4
					sup-conf-lift	0.5599	191.4
3	4	0.02	0.7	0.5	sup-conf	273.03	14052.3
					sup-conf-lift	236.85	8832.1

degree of support and confidence and the Lift-Apriori-DP algorithm after the introduction of the lifting degree, as well as the number of correlation degree rules generated. The experiments are conducted mainly to compare the extraction results under the same privacy pre-estimation. The privacy degree pre-estimation is set to 0.5 and the minimum lifting degree is 1. The experimental results are shown in Table 3.2.

In Table 3.2, sup-conf denotes the Apriori-DP algorithm with support degree and confidence degree limit boundary values. Sup-conf-lift denotes the Lift-Apriori-DP algorithm with support degree confidence degree and lift limit boundary values, and the experimental results are analyzed as follows. First, the comparison of the number of association degree rules in the extraction results: under the same data set, the Apriori-DP algorithm after the introduction of the lifting degree filters out the invalid association degree rules than the Apriori-DP algorithm consisting of the degree of support and the degree of confidence, so that the output results of the Lift-Apriori-DP algorithm are positively correlated association degree rules, which are valid association degree rules, thus improving the usability of the algorithm. Secondly, for the comparison of the running time of the algorithm: although the Lift-Apriori-DP algorithm increases the computation of lift after the introduction of lift, the overall running time of the Lift-Apriori-DP algorithm is shorter than that of the Apriori-DP algorithm composed of the support degree and the confidence degree. The main reason is that by reducing the number of invalid rules, the length of the output relevance rule list is reduced and the running time is shortened when the set of data increases, the gap between the Apriori-DP algorithm and the Lift-Apriori-DP algorithm in terms of running time and invalid rules filtered out gradually increases.

The data classes in data set 3 are richer and further experimental analysis is performed on data set T10I4TDB00K. Figure 3.1 shows the comparison of the number of association degree rules extracted under the same privacy degree pre-estimation timing and different boosting degree limit boundary values. Setting the privacy degree pre-estimation to 0.5, the orange dashed line shows the number of all association degree rules mined by the Apriori-DP algorithm, and the blue dashed line shows the change in the number of association degree rules mined by the Lift-Apriori-DP algorithm. When the lift limit boundary value increases, the higher the relevance of the association degree rules mined by the Lift-Apriori-DP algorithm, the more valid association degree rules obtained gradually decrease. Figure 3.1 shows the variation in the number of invalid correlation degree rules screened out by the Lift-Apriori-DP algorithm with different privacy pre-estimates at a lift of 1. The orange dashed line shows the change in the number of all association degree rules mined by the Apriori-DP

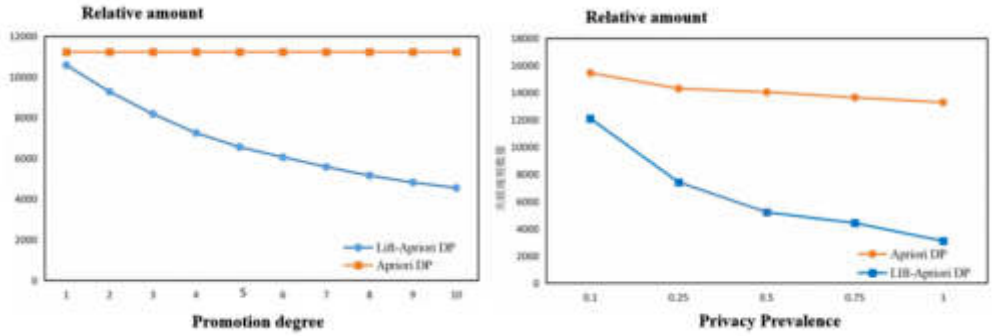

Fig. 3.1: Privacy pre-estimation of correlation metrics in extraction results

chapter1_score	chapter2_score	chapter3_score	chapter4_score	chapter5_score	chapter6_score	chapter7_score	chapter8_score
80	60	40	65	55	50	0	0
0	85	70	65	80	0	0	0
0	90	90	90	90	80	0	0
0	55	80	65	65	80	0	0
60	70	50	90	90	70	0	0
100	90	70	80	80	90	85	83
80	80	90	90	85	70	0	0
100	75	80	80	75	0	64	0
80	75	90	70	70	50	70	0
100	50	70	70	70	60	70	79
80	80	70	90	90	70	73	80
100	55	90	85	90	80	88	92
100	80	70	75	80	80	82	97
0	70	60	85	75	80	88	97
100	70	80	90	70	90	82	78
100	70	100	95	75	80	70	91
80	85	40	55	55	30	73	0
20	40	20	65	55	10	37	2
100	85	80	65	75	80	72	86

Fig. 3.2: Schematic Representation of Business English Raw Performance Data

algorithm, and the blue dashed line shows the change in the number of invalid association degree rules screened out by the Lift-Apriori-DP algorithm. The number of association degree rules mined by the Apriori-DP algorithm gradually increases when the privacy pre-estimation is decreasing, and the number of invalid association degree rules screened out by the Lift-Apriori-DP algorithm gradually increases after screening by lifting degree.

In addition, to make the data more adequate and convincing in practical use. The actual follow-up test needs to be conducted for the actual situation of business English grades. The follow-up test was conducted and the same instructor taught the Business English course in both academic years, so the student chapter grade data from both academic years were combined. The original set of data sets included a total of 588 students' grade information. The data information mainly includes students' names, genders, student numbers, chapter test scores, etc. Some of the data are displayed as shown in Figure 3.2.

In addition one to eight sections of the performance information is represented by the serial numbers 1 to 8. After the data cleaning, conversion of the preprocessing, with the processing and output process shown in Figure 3.3 data cleaning is the process of processing the original data set set of default values, duplicate values, and anomalous data. In the collected student scores, some students have student information but did

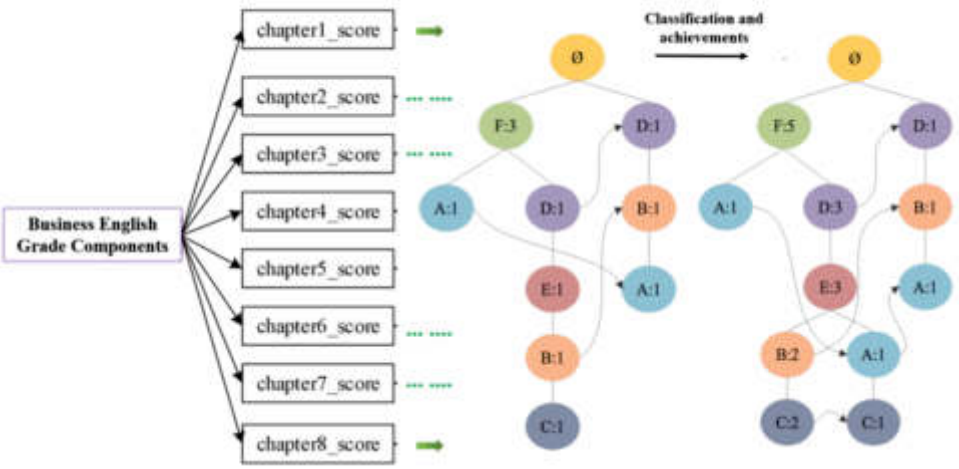

Fig. 3.3: Intelligent Algorithm to Convert Business English Scores Flow

chapter1_score	chapter2_score	chapter3_score	chapter4_score	chapter5_score	chapter6_score	chapter7_score	chapter8_score
A1	D2	E3	E4	E5	E6	E7	E8
A1	A2	A3	A4	A5	A6	C7	A8
A1	B2	B3	A4	B5	A6	C7	B8
A1	A2	B3	A4	E5	A6	C7	A8
A1	B2	A3	C4	B5	C6	C7	A8
B1	E2	E3	E4	E5	E6	E7	E8
A1	A2	C3	B4	B5	A6	B7	B8
A1	E2	C3	C4	C5	D6	C7	C8
B1	B2	C3	A4	A5	C6	C7	B8
A1	E2	A3	B4	A5	B6	B7	A8
A1	B2	C3	C4	B5	B6	B7	A8
A1	C2	B3	A4	C5	A6	B7	C8
A1	C2	A3	A4	C5	B6	C7	A8
E1	E2	E3	D4	E5	E6	E7	E8
A1	B2	B3	D4	C5	B6	C7	B8
A1	B2	D3	C4	B5	A6	C7	B8
A1	B2	E3	A4	B5	D6	C7	B8
A1	C2	A3	B4	B5	D6	C7	B8
A1	C2	C3	B4	C5	D6	B7	A8
A1	C2	B3	D4	D5	C6	D7	D8

Fig. 3.4: Schematic representation of the transformed form of business English performance data

not take part in the chapter test, and the chapter test scores are populated with zeros. As a result, there will be certain students with missing course chapter grades in the collected raw data, and to improve the accuracy of the experimental results, the student information with missing certain chapter grades will be deleted. Only the student information with all eight section chapter grades will be retained. After cleaning these invalid data, the remaining 326 students' performance information. After a series of pre-processing of student grades, the data set is described as shown in Figure 3.3.

In the actual test results, the data values of each evaluation index according to the correlation degree rule extraction results are plotted as a trend graph, as shown in Figure 3.5. The graph shows that when the privacy preestimation increases, the overall trend of the data accuracy, precision pattern, and recall gradually increases, and the overall value of the comprehensive evaluation index also increases. That is to say, the degree of usability

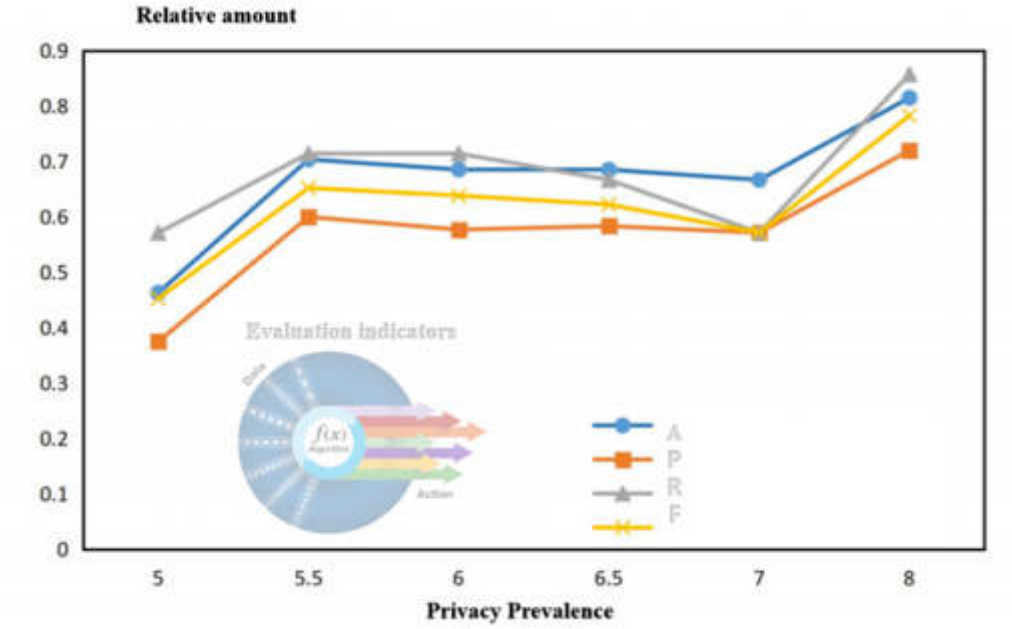

Fig. 3.5: Relative Measures of Correlation Indicators in Actual Measurements

of the data is increasing as the privacy pre-estimation increases. According to the value of the accuracy of the extraction results, when the privacy pre-estimation is chosen to be less than or equal to 5, although the data privacy protection effect is strong, the accuracy of the results will be less than 0.5, and the degree of data usability will decrease. When the privacy pre-estimation is greater than or equal to 7, the accuracy of the data is high, but the protection of the privacy of the data is poor. As a compromise, when the privacy pre-estimation is 5.5, the experimental results are more accurate and usable, i.e., the strong-correlation degree rule extracted has a high degree of accuracy while protecting the privacy of individual students.

4. Conclusions and discussions. This paper investigates the application of data mining based on the correlation degree rule algorithm in business English grades in colleges and universities, aiming at discovering the correlation relationship between students' grades, providing a reference for teaching improvement, and at the same time, protecting students' private information from being leaked. Aiming at the problem that in the Apriori algorithm based on the protection of differential degree privacy, a lot of invalid rules will be mined when the clips are screened according to the degree of support and the degree of confidence, the lifting degree is introduced to improve the Apriori-DP algorithm. The specific conclusions are as follows:

1. Experimental validation is carried out on different sets of data sets, and the experimental results show the effectiveness of the Lift-Apriori-DP algorithm.
2. When the privacy pre-estimation decreases, the correlation degree rules mined by the Apriori-DP algorithm gradually increase, and the number of invalid correlation degree rules screened out by the Lift-Apriori-DP algorithm.
3. In the choice of privacy pre-estimation, too small a privacy pre-estimation may lead to over-protection of data privacy, making the extraction results less accurate. On the contrary, too large a privacy pre-estimation may lead to a weakening of the privacy protection of the data and a decrease in the usability of the data.

Although the research in this paper has achieved certain results, there are still some limitations and deficiencies such as data sources and data quality, suitable relevance indicators, and so on. In the future, we can further explore and study how to improve the quality and accuracy of data, optimize the algorithm

parameter settings, select more appropriate relevance indicators, and enhance privacy protection and data security.

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INTELLIGENT EDUCATION MANAGEMNT SYSTEM DESIGN FOR UNIVERSITIES BASED ON MTCNN FACE RECOGNITION ALGORITHM

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Abstract. Face recognition technique has made significant advancements in security and attendance, but its application in teaching management is minimal. To address the issues of insufficient teacher resources and declining educational quality, the paper designs an intelligent education management system for colleges and universities based on improved Multi-task Cascaded Convolutional Neural Networks (MTCNN) face recognition. The purpose is to achieve accurate recognition of faces through improved facial recognition technology, thereby analyzing the attendance status of students, and improving the efficiency and quality of educational resource utilization. Firstly, an improved MTCNN facial recognition technology is adopted to achieve real-time monitoring of student status and attendance in the classroom through a B/S network structure. Secondly, through cluster deployment and load balancing, system stability and response speed can be improved. The results indicated that the improved MTCNN had better facial recognition accuracy and GPU utilization than traditional systems under different occlusion conditions. When there was no occlusion, recognition accuracy was 99.4%. However, when occlusion was presented at 10%, 20%, and 30%, the accuracy dropped to 92.3%, 84.25%, and 73.4%, respectively. Additionally, when the number of concurrent users was 1000, the maximum GPU utilization rate was 75%, which was 11% lower than traditional MTCNN systems. The use of an improved MTCNN facial recognition-based intelligent education management system in universities can effectively enhance the quality of classroom teaching and monitor the status of students. Further optimization of algorithm performance is needed in subsequent research to support larger-scale concurrent user usage while reducing hardware resource consumption.

Key words: Face recognition, MTCNN, Education management system, Classroom, Intelligence

1. Introduction. With the continuous development of the economy and the expansion of educational resources, many universities are facing a rapid increase in student numbers that far exceeds the supply capacity of high-quality teacher resources, leading to an imbalance in educational quality [9]. The modern education system requires teachers not only to impart knowledge but also to pay attention to the personalized development and ability cultivation of students, which puts higher demands on the teaching staff. Although live education platforms have emerged in recent years, the quality of teaching on education platforms varies, and online classes cannot monitor students' classroom status, resulting in poor overall student performance [19]. Some parents have to attend off-campus tutorials for the sake of their children's studies, and the quality of off-campus tutorials also varies, which cannot solve the current contradiction between the number of teachers and students. In this context, the rapid development of artificial intelligence technology has brought new solutions to the education field. For instance, intelligent homework evaluation systems and educational robots have shown significant improvements in learning efficiency [5]. The current intelligent education mainly includes intelligent homework assessment and intelligent educational robots. The homework assessment software utilizes algorithms to evaluate assignments and generate learning plans based on the results. Additionally, education robots interact with students to enhance their learning abilities [20]. The main development direction of artificial intelligence is face recognition, which is currently used in security, time and attendance, robotics smartphone unlocking, etc. [8]. Among them, face recognition-based face check-in technology is available because of its advantages of convenience and no manual check-in. This paper proposes an intelligent education management system that integrates Multi-task Cascaded Convolutional Neural Networks (MTCNN) facial recognition technology with traditional education to address the issue of declining education quality and the application of facial recognition technology. It aims to assist teachers in managing the classroom status of students, improve the

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quality of classroom education, and provide effective technical support and solutions for the education field.

2. Related Works. The world is entering a new era of intelligence, which has prompted the development of artificial intelligence. One important direction of this development is face recognition, making it a hot topic for domestic and international research. Basjaruddin N C and his team have designed an attendance system that integrates MTCNN face recognition, mask detection, and body temperature reading systems. This system addressed the limitations of feature extraction and recognition of faces wearing masks during the COVID-19 epidemic. Facial recognition technology was combined with mask detection technology to recognize the face, and a temperature reading system was used to detect body temperature, allowing for contactless attendance. The experimental results showed that the accuracy of facial recognition on the original dataset was between 92% and 100% [2]. Liu J proposed a face recognition model based on the MTCNN algorithm to address the issue of poor stability in dynamic videos with multiple angles and facial expressions. This model used Proposal Network (P-Net), Refine Network (R-Net), and Output Network (O-Net) network models to extract and process facial image features, and finally output the processed facial image. Through training experiments on the Wide Face database training set, the MTCNN algorithm outperformed SVM algorithm and traditional algorithms, achieving the requirements of facial image recognition [6]. Khan and Bhat proposed a face recognition attendance system based on neural networks to achieve intelligent student attendance. However, the system has limited applicability in large-scale concurrent users and diverse classroom environments. The system extracted image features through MTCNN and used SVM for image classification to achieve computer recognition of faces. Through simulation experiments, it has been proven that the system can accurately record attendance of attendees [10].

Dang T V et al. investigated the adaptability issues of user processing capabilities and different classroom scenarios. They applied the ArcFace model architecture of MobileNet V2 to deep Convolutional Neural Networks (CNN) and utilized highly discriminative feature technology to improve facial recognition, forming an effective deep learning model for facial recognition. The recognition accuracy of this model reached 97% and the processing speed is 25FPS [4]. Ramaraj P et al. proposed a face recognition technique based on self channel attention combined with self spatial attention to address the issue of adaptability under different lighting and pose changes. The original image was translated using a Gaussian filter and facial contours were recognized using edge detection algorithms. Self-channel attention was utilized to fuse feature maps in both channel and space. The experimental results showed that this face detection technology was superior to other face recognition models [13].

Sun et al. proposed an English pedagogy model to enhance students' learning efficiency. They utilized a decision tree algorithm to extract necessary data from a large amount of information. Then, they summarized and analyzed the data and patterns through neural networks to improve English performance and assist teachers in enhancing their education [14]. Wu C et al. addressed the problem that face detection cannot achieve fast detection and the problem of ensuring accuracy. They proposed a FaceNet face detection technique based on MTCNN. The MTCNN was used for fast alignment and detection of faces, and the face was verified and recognized by an optimized loss function FaceNet model. By comparison, the model outperformed other models with 99.85% recognition accuracy [18].

Ozdemir and Ugur addressed the challenge of identifying whether a student is present in distance education and proposed a remote attendance model based on a face recognition algorithm. They used filters for image processing to detect faces and trained the model in combination with an SQL server database. This model ensured that students could actively participate in learning and improve learning efficiency. Simulation experiments proved that the accuracy exceeded 80% [11].

Tata Sutabri et al. proposed a face recognition attendance system based on deep metric learning combined with neural network of nearest neighbor algorithm to address the problems of long time and missed signatures in traditional attendance. Deep metric learning was utilized to achieve face embedding. The nearest neighbor algorithm was then used to classify student faces, enabling computer recognition of faces and automatic attendance. Attendance records were then saved [15].

Pabba et al. propose a real-time monitoring system based on CNN for problems such as the difficulty of offline education teachers to control student participation and interactivity. The student states collected by CNN were analyzed using frame-by-frame group participation estimation to automatically detect and analyze

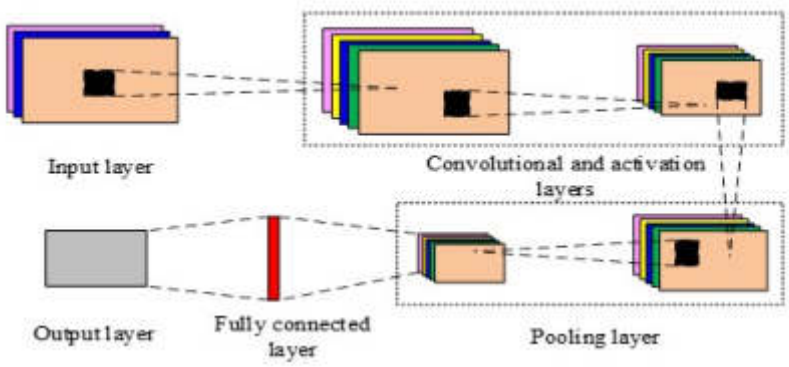

Fig. 3.1: CNN Structure

student participation and behavior. The accuracy of the model training reached 78.7% and the surveillance system was feasible [12].

In summary, many scholars have researched the use of facial recognition technique in the education industry, but there is still a need for improvement in the intelligent education management systems. Therefore, the study uses improved MTCNN face recognition combined with a new education management system to achieve an intelligent education management system, expecting to provide some help to the education business.

3. Design of an intelligent management system for education based on enhanced MTCNN facial recognition.

3.1. Improvement of MTCNN face detection algorithm. Currently, the network architecture has become more perfect, and in face recognition, researchers are commonly implementing by changing the loss function to enhance the precision of recognition [3]. CNN detection is the basis of face recognition algorithm. Input, convolutional, pooling, activation function, and fully connected layers typically make up a CNN. Fig. 3.1 indicates its structure diagram.

In Fig. 3.1, the input layer first normalizes and removes the mean of the original image, and then uses convolutional layers to capture features from the image and process them to output the dimension of the feature map. The obtained output image features are input into the pooling layer to sample the element map, and the activation function layer is used to solve nonlinear calculations. Through fully connected layers, different abstract image features are combined, and finally, the same image as the original image is output. The convolution layer serves as the foundation for the image's feature extraction. Its operation equation is shown in 3.1.

$$y_j' = f\left(\sum_{i \in M_j} y_j^{l-1} * k_{yj}^J + b_j^l\right) \tag{3.1}$$

In equation 3.1, $y_{\prime}'$ represents the activation value of the output feature map j at the first layer after passing the activation function, M_j represents the input original map or the output feature map at the previous layer. $*$ represents the two-dimensional convolution operator. $b_{\prime}'$ represents the bias value. $k_{ij}^{\dagger}$ represents the convolution kernel. The expression of the dimension of the convolutional output feature map is shown in 3.2.

$$\begin{cases} W_{at} = \frac{W_{in}-K+2P}{S} + 1 \\ H_{at} = \frac{H_{in}-K+2P}{s} + 1 \\ C_{ost} = C_{wn} \end{cases} \tag{3.2}$$

In equation 3.2, W_{at} denotes the output feature map width.H_{at} denotes the output feature map height.C_{ost} denotes the number of outputs.W_{in} denotes the input feature map width.H_{in} denotes the input feature map

height. C_{wn} denotes the number of inputs. k denotes the convolutional kernel size. p denotes the number of boundary padding. s denotes the convolutional step size. The pooling layer can reduce the complexity and computation of the network, as shown in equation 3.3.

$$y_j^l = D\left(y_j^{l-1}\right) \tag{3.3}$$

In equation 3.3, the function $D()$ represents downsampling. The nonlinear problem is solved by the activation function, and the activation function equation is shown in equation 3.4.

$$\mathrm{Re}\, LU(x) = \begin{cases} x & if x > 0 \\ 0 & if x \leq 0 \end{cases} \tag{3.4}$$

In equation 3.4, x denotes the input value. By batch normalization process, the inputs of each layer are normalized to obtain the output normalized to a normal distribution of (0,1), and the computational equation is shown in equation 3.5.

$$\hat{x}_i = \frac{x_i - \mu}{\sqrt{\sigma^2 + \xi}} \tag{3.5}$$

In equation 3.5, x_i denotes the input small batch of data.μ denotes the mean of the input values. σ^2 denotes the variance of the input values. ξ denotes the deviation. The data distribution learned in the previous layer is restored using equation 3.6.

$$y_i = \gamma \hat{x}_i + \beta \tag{3.6}$$

In equation 3.6, γ represents the stretching parameter and β represents the offset parameter. The output result is obtained by combining all the above output image features through the fully connected layer, and equation 3.7 displays the equation for the fully connected layer.

$$y = wx_i + b_j^i \tag{3.7}$$

In equation 3.7, is the weight, and the final image classification is achieved. The commonly used face detection algorithm in multi-person face recognition technology is MTCNN, which is chosen due to its multi-level network structure, including P-Net, R-Net, and O-Net. This network can recognize and correct facial information at different levels, and can also handle diverse lighting conditions in the classroom, various expressions and postures of students, and potential facial occlusion issues [1]. Firstly, after preliminary detection, the recognition results are gradually refined, and the recognition accuracy under partial occlusion is improved through key point localization. Secondly, O-Net can adapt to different sitting positions and head angles of students in the classroom based on actual situations, while maintaining high detection accuracy even when lighting conditions change. Fig. 3.2 displays the MTCNN face detection flowchart. The original image is processed by P-Net to generate a bounding box. The generated bounding box is input to R-Net, corrected by R-Net to generate a new bounding box. Then, the newly generated bounding box is corrected by O-Net to generate an exportable bounding box and key features of the face.

According to Fig. 3.2, MTCNN face detection must consider the varying distance of the face from the camera in the picture, which can result in different face sizes. Therefore, the picture needs to undergo resizing processing, as shown in equation 3.8.

$$\text{nextsize} \;=\; \text{originsize} * \left(\frac{12}{\min\ \text{size}}\right) * \ \text{factor}\ ^n, n = \{1, 2, 3,\ \text{L}, n\} \tag{3.8}$$

In equation 3.8, *originsize* denotes the initial size of the original image. $factor$ denotes the scaling ratio. *nextsize* denotes the minimum value of the detected face. *nextsize* denotes the scaled image. After the cropped image is obtained, the image is classified using the loss function of cross-entropy, which is calculated as shown in equation 3.9.

$$L_i^{\text{det}} \;= -\left(y_i^{\text{det}}\ \log\left(p_i\right) + \left(1 - y_i^{\text{det}}\ \right)\left(1 - \log\left(p_i\right)\right)\right) \tag{3.9}$$

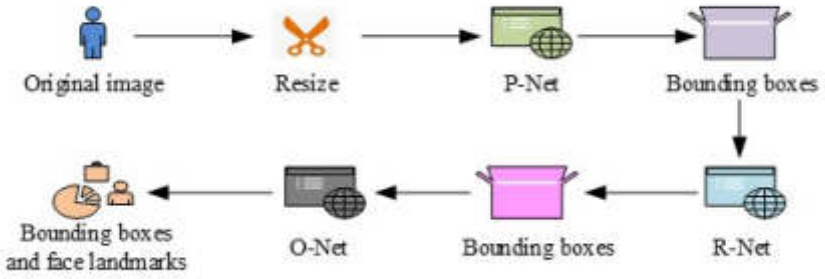

Fig. 3.2: MTCNN algorithm flowchart

In equation (9), p_i denotes the predicted value. $y_1^{det} \in \{0,1\}$ denotes the true value. To generate the bounding box of the face, by figuring out the difference between the current bounding box and the labeled bounding box, the difference is calculated as shown in equation 3.10.

$$L_i^{box} = \left\| \hat{y}_i^{box} - y_i^{box} \right\|_2^2 \tag{3.10}$$

In equation (10), $\hat{y}_i^{box}$ denotes the candidate frame of the model output. $y_i^{box} \in \mathbb{R}^4$ denotes the labeled bounding box. The face regions are corrected by the regression of the bounding boxes and merged using Non-Maximum Suppression (NMS), and the NMS formula is shown in equation 3.11.

$$G_i = \begin{cases} G_i, & \text{iou}\,(M, q_i) < N_t \\ 0, & \text{iou}\,(M, q_i) \geq N_t \end{cases} \tag{3.11}$$

In equation (11), G_i indicates the score of the bounding box. M indicates the box with the highest score at present. q_i indicates one of the remaining boxes. indicates the set queue. To avoid large fluctuations in the detection results, the problem is solved by the score reset function, which is shown in equation 3.12.

$$G_i = G_i e^{-\frac{iou(M,q_i)^2}{\sigma}}, \forall q_i \notin D \tag{3.12}$$

In equation (12), D denotes all bounding boxes. In the classroom environment, errors or omissions in MTCNN face detection may occur due to factors such as posture, angle, and facial occlusion by students or teachers. Facial marker localization is a key factor in generating faces. By comparing the differences between the annotation results and the model results, parameter fine-tuning is introduced in the O-Net stage, abandoning the facial alignment module. The calculation formula is shown in equation 3.13.

$$L_i^{\text{lamamar } k} = \left\| \hat{y}_i^{\text{lamdmark}} - y_i^{\text{landmark}} \right\|_2^2 \tag{3.13}$$

In equation 3.13, denotes the coordinates of feature points of the model output. denotes the coordinates of the labeled real position. Equations 3.9, 3.10, and 3.13 can be fused by an objective function, which is shown in equation 3.14.

$$\min \sum_{i=1}^{N} = \sum_{j \in \{\text{det}, box, \text{ landmark }\}} \alpha_j \beta_i^j L_i^j \tag{3.14}$$

In equation (14), α_j and β_i^j denote super-parameters. After introducing the parameter fine-tuning module, the accuracy of face detection can be improved, but false detection still exists. As a result, the discriminant formula

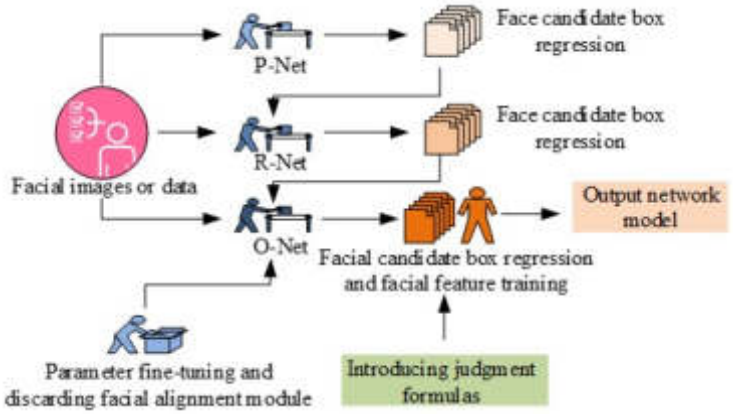

Fig. 3.3: Structure diagram of improved MTCNN algorithm

module is added out of the face feature point training frame, thus further improving the MTCNN structure. Equation 3.15 shows the discriminant formula.

$$f(p) = \begin{cases} 1 & p \geq 0.97 \\ 0 & p < 0.97 \end{cases} \tag{3.15}$$

In equation 3.15, p denotes the probability of face detection. When $f(p) = 1$, the result of detection is a face, and vice versa, When $f(p) = 0$ is not a face. Fig. 3.3 illustrates the MTCNN algorithm's enhanced structural diagram. This algorithm is based on the traditional MTCNN algorithm and adds parameter fine-tuning models at the O-Net structure. By selecting hyper-parameters, it ensures that the MTCNN model can adapt to the needs of different scenarios. Discriminant formulas are introduced in the facial feature point training box to determine whether the detected image is a human face. The selection of hyper-parameters is primarily accomplished through the following methods. First, a preliminary screening is conducted based on previous research and experimental experience. Next, a grid search method is used to systematically explore various combinations of hyper-parameters [17]. Then, the random search is used to explore valuable parameter combinations within a wider parameter space. Finally, Bayesian optimization methods are used to predict the performance of each set of parameters. After determining the hyper-parameters, the generalization ability and stability of these parameters on different subsets are verified through cross-validation.

3.2. Intelligent education management system design. The study adopts an improved MTCNN face detection algorithm to construct a face recognition model, and uses accuracy, recall, and F1 score evaluation indicators to evaluate the recognition performance of the model in occlusion or missed detection situations. The experiment was conducted on a machine containing an Intel i7 processor and 32GB of memory, operating system Windows 10. The main software used included TensorFlow 2.x and OpenCV 4.x. The study used the Megaface public dataset, which has a diverse range of facial images, including different poses, expressions, and lighting conditions [16]. In data preprocessing, the image is first converted to grayscale and resized to reduce the computational complexity of model training. Secondly, data augmentation techniques such as random rotation and cropping are used to increase the diversity of the dataset. Based on this face recognition algorithm, the intelligent education management system of colleges and universities is designed to realize the intelligence of education management. Fig. 4 illustrates the functional structure of the intelligent education management system.

Fig. 3.4 shows that the management system includes four main functions, such as classroom attendance, status monitoring, report analysis and background management. The classroom attendance module mainly includes attendance information inquiry, attendance information export and attendance status warning. The classroom analysis module is to analyze and save different kinds of classroom reports for each class, which

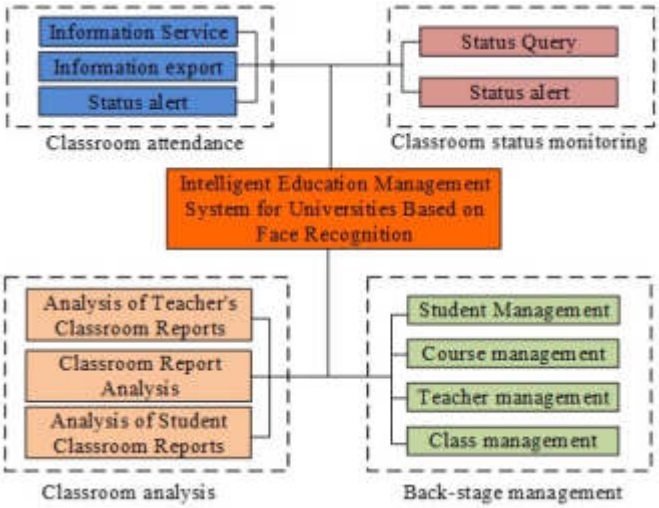

Fig. 3.4: Structure of intelligent education system in universities

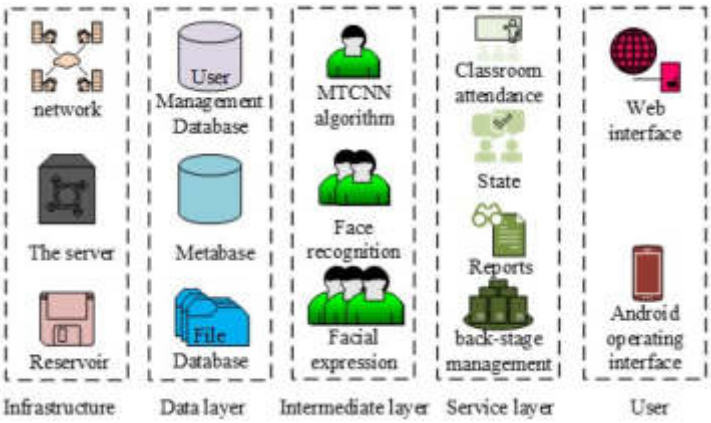

Fig. 3.5: Intelligent education management system architecture

mainly includes classroom, teacher and student report information. Users can send these reports to the objects they want to know. The background management module is divided into student, teacher, course and class management. The module consists of administrators and common users, wherein common users can only view, retrieve and other operations, only administrator users can modify or add content. In the design of intelligent education management systems, research is conducted on the use of B/S network structure models, as well as P-Net, R-Net, and O-Net network structures, to construct an education system that is easy to expand, manage, and maintain. The system's servers are cluster deployed while balancing the load on each server. The architecture of the intelligent education management system is shown in Fig. 3.5.

In Fig. 3.5, the intelligent education management system architecture design contains user layer, service layer, middle layer, data layer and infrastructure. The user layer is designed with two ports, Web side and Android side. Customers may sign in and use the education management system on different operating systems. The service layer is a service designed based on the division of the modules of the intelligent education management system, and this layer is mainly used for the Web server and APP side to handle the logic of each transaction. The middle layer comprises the enhanced MTCNN face detection algorithm, face recognition

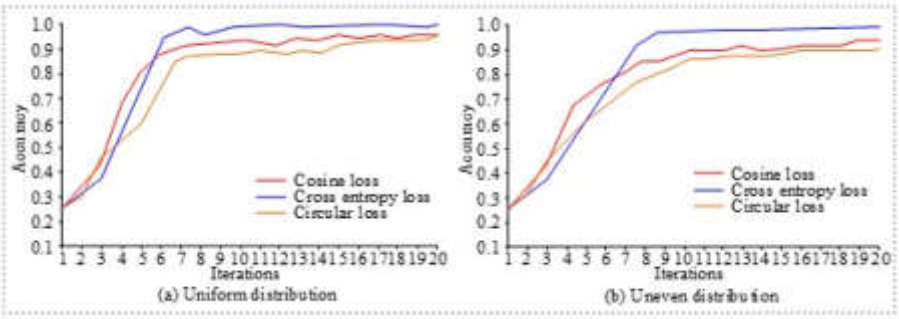

Fig. 4.1: Comparison of accuracy under different data distributions

algorithm, and expression recognition algorithm. This layer enables the system to obtain facial data of both students and teachers, which is the core technology for the system to achieve intelligent face recognition. The data layer includes three parts: user management database, meta database and file database. This layer has storage function and mainly stores data files required for test data, students' and teachers' data, all algorithm model training, etc. Finally, the infrastructure includes three parts: network, server and disk. The system transmits data through the network and uses disk to store the server and data for system operation, which is the hardware support. MySQL is used to store the system's user, student and attendance information. A distributed file system is used to handle the files needed to store the system. Video streams are processed through Redis and sent to the algorithm model and data is cached. TensorFlow and OpenCV are used as the system's computational framework. SpringBoot is used to handle the low coupling between the module layers. To meet persistence operations, the database interacts with data through MyBatis. Application program interfaces communicate with each other through HTTP/HTTPS. Finally, Vue.js and Layui are used on the Web and App ends, which have the characteristic of easy scalability. Finally, nginx negative balance is used to achieve balanced optimization of the system and decrease the pressure of the intelligent education management system [7].

4. Intelligent education management system performance analysis.

4.1. Face recognition effect analysis. The study utilized publicly available WIDER FACE datasets and self-collected university classroom datasets. These datasets contained facial images captured in various lighting conditions and classroom scenes with occlusions. The experiment divided the dataset into 70% training set, 15% validation set, and 15% testing set. The performance of the model is evaluated using accuracy, recall, and F1 score to comprehensively assess the effectiveness of face detection and recognition. One of the key points of the improved MTCNN is alterations to the loss function. In the case of the same face recognition model, different loss functions are introduced to compare and analyze its accuracy. The accuracy comparison under different data distribution is shown in Fig. 4.1.

In Fig. 4.1 (a), the precision of the cross-entropy loss function reaches about 95.6% after 7 iterations of the data distribution and stabilizes between that value. Among them, the accuracy of the circular loss function tends to stabilize after 15 iterations with a value of 90.1%, and its accuracy is the lowest. In Fig. 4.1(b), the precision of the cross-entropy loss function is also the best when the data are not evenly distributed, with the accuracy reaching 93.4% and stabilizing after 9 iterations. The accuracy of the circular loss function is 84.7% and stabilizing after 17 iterations, which is the worst. It is proved that the face recognition accuracy of the quoted cross-entropy loss function is the best and has stronger generalization ability. In the same dataset, the accuracy recall of the traditional MTCNN and the improved MTCNN are compared under simple, medium and complex difficulty, respectively, as shown in Fig. 4.2.

In Fig. 4.2, the improved MTCNN outperforms the traditional MTCNN algorithm in terms of its recall rate under inter-single, medium, and complex dataset difficulties, and the accuracy is inversely related to the

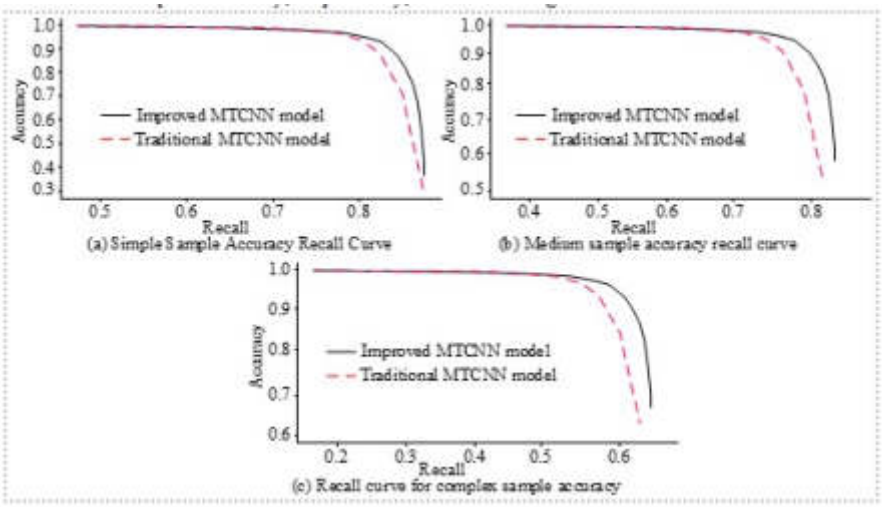

Fig. 4.2: Accuracy recall rate under different samples

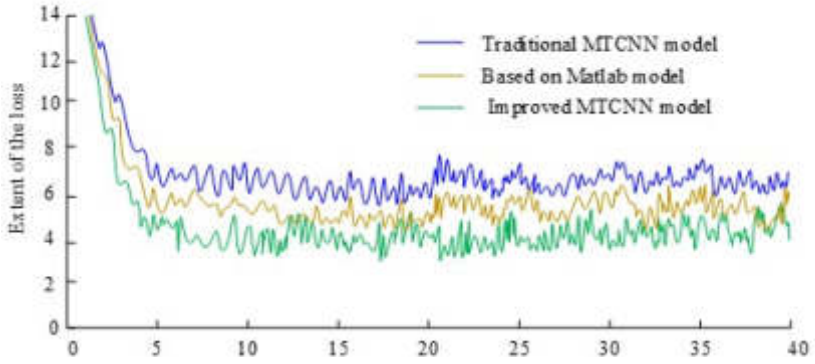

Fig. 4.3: Comparison of loss results between different models

recall rate. In Fig. 4.2 (a), the precision of the improved MTCNN algorithm face recognition model decreases exponentially when the recall is 0.85 under the condition of simple dataset, and increases 0.08 compared to the recall of the traditional MTCNN. In Figure 4.2(b) and 4.2 (c), the accuracy of the improved MTCNN algorithm for face recognition decreases as the dataset difficulty increases, with a recall of 0.74 and 0.56, respectively. However, both still outperform the traditional MTCNN algorithm, indicating an improvement in accuracy. Further network training is performed on the algorithms, both based on the cross-entropy loss function. The comparison of the loss function results of different models is obtained as shown in Fig. 4.3.

From Fig. 4.3, the improved MTCNN face recognition system has the fastest loss function reduction. After 5 iterations, its loss function decreases to about 4 and stays up and down in the range of 4 to 6. The loss function curve of the Matlab face recognition system is similar to that of the improved MTCNN face recognition system, and the loss function remains stable between 5 and 7 after 7 iterations. The loss function of the traditional MTCNN face recognition system decreases the slowest, and the loss function tends to stabilize after 10 iterations and stays between 6 to 8. It indicates that the improved MTCNN face recognition system has the least curve fluctuation and its accuracy and stability are better than the other two models. The cross entropy loss function has a high penalty for misclassification, and can quickly guide the model to learn and distinguish different categories in early iterations. Therefore, the cross entropy loss function performs well on the Megaface dataset.

Table 4.1: Comparison of recognition accuracy under different degrees of facial occlusion conditions

Algorithm type	Number of testers	Alignment rate/%	Unobstructed Recognition accuracy/%	Facial occlusion 10% recognition accuracy/%	Facial occlusion 20% recognition accuracy/%	Facial occlusion 30% recognition accuracy/%
Traditional MTCNN	1500	99.80%	97.33%	71.21%	62.30%	43.20%
Matlab	1500	99.87%	97.13%	68.60%	52.10%	31.20%
Dlib	1500	99.73%	98.67%	74.22%	60.81%	39.80%
Adaboost	1500	99.93%	96.40%	80.10%	69.20%	49.21%
Improving MTCNN	1500	100.00%	99.40%	92.30%	84.25%	73.40%
CNN-Based Approach	1500	99.85%	98.00%	98.32%	97.22%	72.32%
Ensemble Method	1500	99.90%	98.50%	98.50%	98.50%	82.22%
MobileNetV2	1500	99.78%	99.65%	97.80%	97.65%	75.89%
FaceNet	1500	99.82%	99.78%	98.20%	82.05%	78.27%

The circle loss function, on the other hand, needs to undergo more precise adjustments and optimizations to adapt to complex facial recognition tasks.

The study compares the performance of the descent rate and stability of the loss function with the accuracy indicators of other systems. Under the same conditions, the improved MTCNN model achieves a recognition accuracy of 98.5% on the Megaface dataset, while the Matlab face recognition system achieves 97.8% and the traditional MTCNN system achieves 96.2%. This comparative result indicates that although the Matlab system is similar to the improved MTCNN in terms of stability of the loss function curve, there is still a gap in accuracy.

Table 4.1 indicates the contrasting of the recognition precision of each face recognition system in a classroom environment with different degrees of face occlusion.

Table 4.1 shows that the MobileNetV2 facial recognition system has the highest recognition accuracy of 99.65% when there is no occlusion. FaceNet follows with an accuracy of 99.78%, and the improved MTCNN has an accuracy of 99.4% under all test conditions. This is because the algorithm adopts feature learning and error correction methods when dealing with partially occluded facial features. However, Adaboost's facial recognition accuracy is 96.4%, with the worst performance. This is because the feature extraction and classification processes are highly sensitive to facial integrity and lack sufficient mechanisms to adapt or correct feature distortions caused by occlusion. The MTCNN face recognition accuracy is highest at 10%, 20%, and 30% face occlusion, with values of 92.3%, 84.25%, and 73.4%, respectively. In contrast, the Matlab-based face recognition system has the lowest recognition accuracy, with values of 68.6%, 52.1%, and 31.2%, respectively. Adaboost facial recognition has an accuracy of 96.40% in unobstructed conditions. However, its recognition rate drops to 49.21% when facial occlusion is 30%, indicating a significant decrease in performance when dealing with occlusion. Therefore, the improved MTCNN facial recognition system has better facial recognition accuracy than other systems in the presence and absence of occlusion. Even if students wear masks, the system can still effectively identify areas such as the eyes and forehead that are not covered by masks. This is because the system compensates for missing information in occluded areas by weighting key facial regions and utilizing contextual information.

4.2. Performance analysis of intelligent education system based on face recognition. This paper assesses the performance of an intelligent education administration system that utilizes enhanced MTCNN face recognition technology. Table 4.2 displays the system's environmental configuration.

In Table 4.2, the MTCNN face recognition college intelligent education management system is compared to the traditional MTCNN face recognition model and Matab face recognition model in terms of system response speed under different concurrent user conditions. The comparison of the response time of the three education management systems is shown in Fig. 4.4.

In Fig. 4.4, each education management system's response time is longer as the users increases. The response time of the intelligent education management system with MTCNN face recognition is the slowest,

Table 4.2: System environment configuration

Name	System Configuration
GPU version	NVIDIA GTX 1080 Ti
Tensorflow version	1.12.0
Opencv	3.4.2
Python	3.6
Java	1.7
System memory, hard disk size	16GDDR, 1Thard disk
Database	MySQL
GPU operating system	Ubuntu 14.0

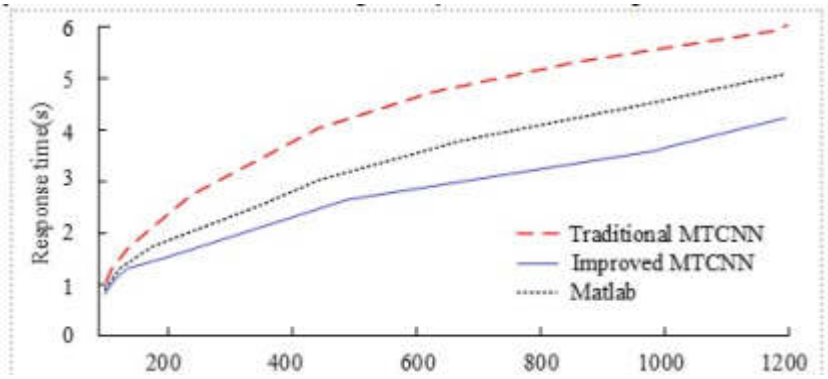

Fig. 4.4: Comparison of response times of three education management systems

taking about 1.48 seconds when there are 200 users. In comparison, the Matlab-based face recognition education management system takes 1.85 seconds and the traditional MTCNN face recognition education management system takes 2.3 seconds with 200 users. MTCNN's response speed is the fastest, and the traditional MTCNN's response speed is the slowest. Additionally, enhancing the MTCNN facial recognition education management system will encourage students to initiate videos and keep track of those who have not yet done so. If a student fails to open the video within the specified time, the system will automatically send a reminder to both the student and the teacher. Secondly, teachers can manually mark the attendance status of students through the system backend and judge their classroom participation based on their voice participation. Therefore, the improved system demonstrates performance stability, system architecture optimization, and efficient resource management in high concurrency environments. Fig. 4.5 illustrates a comparison of the GPU utilization rate between the traditional MTCNN face recognition education management system and the improved MTCNN face recognition education management system with varying numbers of concurrent users.

From Fig. 4.5 (a), the GPU utilization rate of both systems is almost the same when the users are 200. From Fig. 4.5 (b), when the users are 500, the GPU utilization rate of the educational management system for traditional MTCNN face recognition is greatly increased, reaching a maximum of about 62%, while for the improved MTCNN system, the maximum GPU utilization rate is 54%. In Fig. 4.5 (c), when the users increase to 1000, the GPU utilization rate of the improved MTCNN system is 75% at maximum, while the GPU utilization rate of the traditional MTCNN system reaches 86%. The improved MTCNN system saves GPU memory during runtime and can withstand more users using it simultaneously. It improves the scalability and reliability of the system while reducing the cost of optimizing resource utilization.

5. Conclusions. In university management, the conventional education management platform can only facilitate regular teaching management. It cannot monitor students' learning status and quality, and relies solely on teachers' in-class management. To enhance the quality of classroom instruction for kids, the study

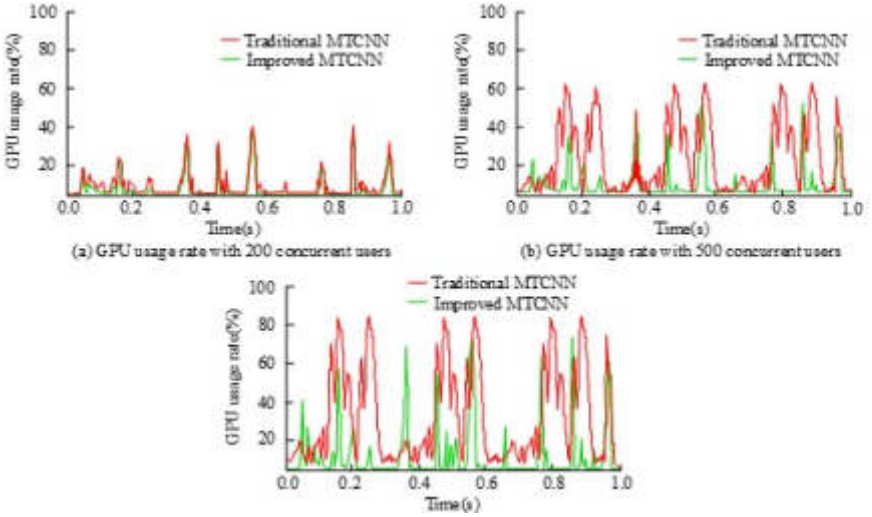

Fig. 4.5: Comparison of GPU usage between traditional MTCNN and improved MTCNN with different concurrent users

introduced parameter fine-tuning model and discriminant formula for optimization on the basis of traditional MTCNN face recognition. Moreover, the improved MTCNN face recognition was introduced into the education management system for design to realize the intelligence of education management system. The results indicated that the loss function of the improved MTCNN face recognition system decreased the fastest to 4 and kept fluctuating between 4 and 6, which was better than the other two systems. The recognition accuracy of the improved MTCNN face recognition system was 99.4%, 92.3%, 84.25% and 73.4% when there was no occlusion, 10% occlusion, 20% occlusion and 30% occlusion. The system could effectively monitor student attendance and participation in the classroom, providing accurate data support for teachers. This allows for timely adjustments to teaching strategies and classroom activities, enhancing student learning motivation and classroom interaction, ultimately improving the quality of education. The improved MTCNN facial recognition university intelligent education management system had a maximum GPU utilization rate of 75% when the number of concurrent users was 1000, which was 11% lower than the traditional MTCNN system. This fully demonstrates the significant advantages of the system in saving computing resources and supporting large-scale user management. It is evident that the system can enhance both the efficiency and quality of classroom management while also aiding teachers in promptly adjusting their teaching strategies based on students' real-time classroom performance. However, the performance of the system in facial recognition of different races, ages, and expressions has not been explored, and it is still difficult to completely avoid the problem of dataset bias, which can easily lead to recognition errors. Secondly, as the number of students using the system increases, the utilization rate of GPU resources increases, which is a key constraint on the performance of its computing resource system, making it difficult to maintain high system performance. Future research will add more datasets, including facial images of different races, age groups, and expressions, to enhance the universality of the system in different environments. By combining image processing technology to assist facial recognition, the robustness of the system in extreme occlusion situations can be improved. In addition, student learning assessment data is included in the system to build a comprehensive educational analysis system, providing teachers with more comprehensive teaching feedback and helping them understand students' learning progress and situation.

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TEACHING RESOURCE RECOMMENDATION OF ONLINE SPORTS COLLABORATIVE LEARNING PLATFORM BASED ON OPTIMIZED K-MEANS ALGORITHM

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Abstract. The online collaborative learning platform for physical education is an interactive and open physical education teaching mode. To improve students' learning interest and efficiency, the online sports collaborative learning platform is designed. From the perspective of person-post matching, the role in the group is designed and the improved clustering algorithm is used to realize the grouping. The combination of the k-mean algorithm and the firefly algorithm is used to enhance the real-time and accuracy of learning resource recommendation. The outcomes demonstrated that the Firefly algorithm had obvious advantages in convergence speed and other aspects. Relative to the classical K-means algorithm and the Firefly algorithm, the average clustering accuracy of the presented algorithm was improved by 7.23 % as well as 2.18 %, and the average processing time was improved by 4.35 % and 2.26 %, respectively. In the dataset Iris, the average clustering accuracy and processing time were 91.29 and 8.65, respectively. The optimal, worst, and average values of the online collaborative learning platform on the ground of the firefly-optimized K-means algorithm were 0.3006, 3.2176, and 1.5234, respectively. The fusion algorithm proposed in this study can optimize the recommendation of teaching resources on sports online collaborative learning platforms, improve learners' learning passion, learning efficiency, and satisfaction, and relieve teachers' teaching pressure.

Key words: K-means algorithm; Firefly algorithm; Sports; Online collaborative learning platform; Cluster analysis

1. Introduction. Sports online collaborative learning is a new type of physical education teaching mode that uses the Internet as the carrier, computer network technology as the support, and integrates information technology with physical education courses. It is an open, personalized, and interactive online learning environment [1-2]. It can provide richer learning resources and more interactive methods, allowing learners to have more opportunities to communicate with other learners, share learning resources, learn experiences, and independently explore sports knowledge, skills, etc. With the continuous development of online collaborative learning platforms, a large amount of user data has been accumulated [3]. These data contain a lot of useful information, and how to discover potential knowledge and patterns from these data, to provide better and more effective online learning services for learners, is the focus of current research. With the continuous development of the internet, the application of online collaborative learning platforms in teaching is becoming increasingly widespread. Through these platforms, students can be provided with an open learning environment, enabling them to learn independently, collaborate, communicate, and learn. By mining and analyzing user data from online collaborative learning platforms, personalized learning guidance can be provided to learners, helping them better engage in sports online collaborative learning [4-5]. To increase students' interest in sports, a sports online collaborative learning platform model is designed and optimized by introducing the Firefly Algorithm (FA) to address the shortcomings of the K-means algorithm (KMA). The aim is to overcome the sensitivity of the KMA to initial centroid selection and ensure its clustering quality and accuracy.

2. Related works. In clustering analysis, the KMA is a fundamental partitioning method that can be applied to multiple data types, making it widely used in many fields. However, there are still problems such as being prone to falling into local optima. To accurately classify gas risks and improve the safety of coal mining operations, Huang et al. established a multi-factor coupling relationship analysis and warning model on the ground of the KMA and Apriori algorithms. The model optimized the KMA through the initial clustering

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center, optimized the Apriori algorithm by filtering outliers in the collected dataset, and finally set the risk warning level using association rules for mining and analyzing outliers, the effectiveness of the model was verified [6]. To enhance the company's capability to match segmented customers in the market, the Li team used KMA and an adaptive particle swarm optimization algorithm to segment the customer group. Firstly, the inertia weight, learning factor, and position update method were redesigned to improve the particle swarm algorithm (PSA) to improve clustering accuracy. Then, the improved PSA was utilized for optimizing the K-means clustering center. After comparison, this method has certain effectiveness and practicality [7]. Gao and other scholars developed a multi-dimensional spatial feature vector expansion K-means model to address the problem of poor DoS detection methods and defense mechanisms. They optimized the weight of the K-means multi-dimensional feature vector through a genetic algorithm to improve the detection rate of DoS attacks. Simulation results showed that the model improved the accuracy to 96.88 % [8]. The Li team proposed a clustering model on the ground of the KMA and genetic algorithm to partition the electricity, heat, cooling, and gas loads of each building. Firstly, the KMA was utilized to uniformly analyze various indicators in the resource database, and then the genetic algorithm was used to optimize the configuration of each partition. Finally, the linear weighting method was used to sort and obtain the optimal partition configuration [9]. Wang Y and other researchers improved the KMA to address issues like long algorithm time in the clustering research of passenger hotspots. They first established a dynamically adjustable region, then used a Gaussian mixture model for data distribution statistics, and finally used the KMA for completing the clustering of various local regions. The results showcased that the algorithm could offer higher accuracy at the same time [10].

With the boost of the big data era, although there were some improvements in the personalized recommendation technology of academic resources, such as "cold start" and "data sparsity", there are still many urgent problems to be solved. Therefore, many scholars have conducted research on this. To enhance the learning performance and reduce resource consumption of online collaborative learning platforms, Han et al. developed a new effective edge learning framework for heterogeneous edges with resource constraints. By modeling the dynamic determination of collaboration strategies as an online optimization problem, they achieved a balance between performance and resource consumption. They also introduced synchronous and asynchronous learning modes to improve learning efficiency [11]. Tang J and other scholars proposed a system for optimizing English learning platforms on the ground of a collaborative filtering algorithm through in-depth analysis of recommendation algorithms for cognitive ability and difficulty, in response to the problem of poor recommendation performance on online English learning platforms. This method built a Spring Cloud platform, imported actual business data, and connected the recommendation system with the formal production system. After verification, the system design was reasonable [12]. To retain learning platform users and strengthen the competitiveness, researchers such as Xu H constructed a structural equation model of online learning platform user switching behavior on the ground of Push-Pull Mooring theory. After testing, information overload and dissatisfaction were the main influencing factors, while functional value and network externalities were secondary factors that influence user switching behavior [13].

Sun Z et al. developed an online English teaching assistance system on the ground of artificial intelligence education. This system combined deep learning with knowledge recommendation algorithms, and applied decision tree algorithms and neural networks to construct an implementation mode of applying decision tree technology in English teaching evaluation. Practice showed that this system can help students improve their learning efficiency [14].

To build an efficient sports network multimedia teaching platform, the Li W team used the black box test method to test the university sports management module and analyzed students' learning results from multiple perspectives. Finally, using the scoring method, a set of non-contradictory and non-repetitive indicators were selected. After verification, the system greatly improved the effectiveness of university sports teaching [15].

To sum up, although the existing resource recommendation technology has solved the phenomenon of academic information overload on the platform to a certain extent, it is not closely connected with the learning link, which makes it difficult for learners to actively learn with limited learning enthusiasm. To improve the cooperation efficiency of learners, meet their personalized needs in learning resources, and realize an online collaborative platform that can provide visual management and intelligent evaluation support for teachers and learners, an online collaborative learning platform for sports is constructed. The recommendation of teaching

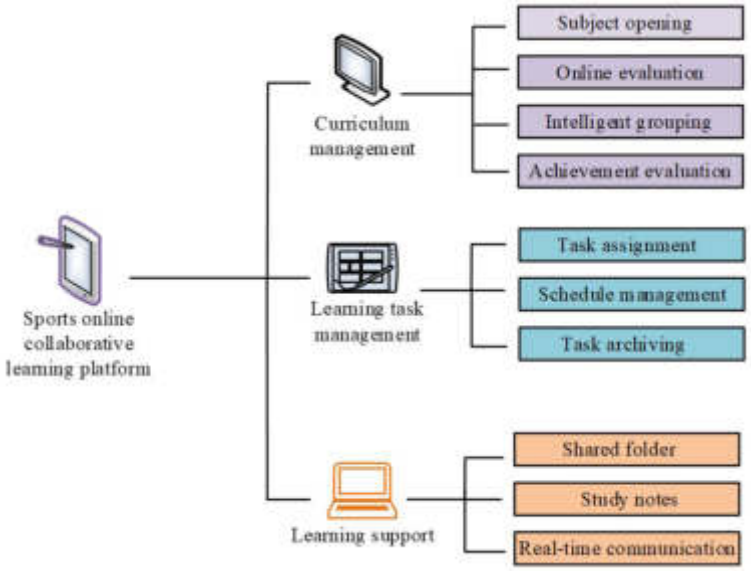


Fig. 3.1: Basic framework of sports online collaborative learning platform

resources is optimized by introducing the FA optimization k-mean algorithm to enhance learners' learning passion, learning efficiency, and satisfaction, and relieve teachers' teaching pressure.

3. Online collaborative learning platform construction based on FA optimized K-means algorithm. Through research and analysis of user needs, system business, and performance requirements, the overall function design of an online collaborative learning platform is completed. The main functions include learning project and task management, learning note recommendation, online assessment, and resource management, among others. Then, in response to the problem of traditional KMAs easily falling into local optima during the clustering process, the FA-optimized KMA is introduced. The optimized algorithm is used to select the initial clustering center, making the clustering results more accurate and optimizing the user experience of sports online collaborative learning platforms.

3.1. Online collaborative learning platform design for sports. The online collaborative learning platform for sports mainly utilizes methods such as course training, exam competitions, exam exercises, surveys, and training exchanges that students participate in online to track and manage their learning status and physical fitness throughout the entire process, thereby providing a comprehensive understanding of students' learning and training needs. It can also import the training, exams, and other content that students have participated in offline into the platform, forming a complete student learning and training file and providing strong data support for teachers to conduct fair evaluations and accurate analysis of student quality [16].

The research and design of a sports online collaborative learning platform mainly consists of three modules, including classroom management, learning task management, and learning support. The main functions of each module are shown in Figure 3.1. In the classroom management module, teachers can set topics, establish learning plans, provide physical education teaching guidance on the grounds of each student's learning process, and complete the writing and release of exams through the online evaluation module. After the physical education course is completed, students will also be graded. In this module, students can also see the arrangement of questions and projects and complete online exams, and at the end of the course, they can conduct self-evaluation and self-evaluation. They can also see the comprehensive scores of themselves and their team members.

The teacher arranges teaching tasks for each learning stage through the learning task management module. After the start of the physical education course, the team leader will assign learning tasks on the grounds of the learning abilities of the team members and set completion deadlines. Individual students can make appropriate

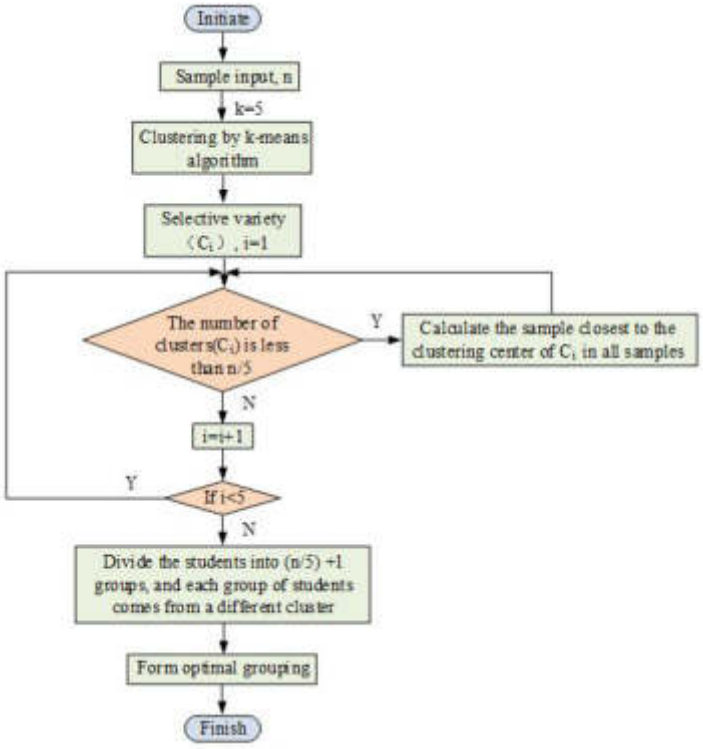


Fig. 3.2: Group working flow chart

adjustments accordingly. At the same time, teachers and students can see the learning progress of each group to enhance their positive competitive awareness and adjust their learning task arrangements promptly.

The recommendation of grouping strategies and learning resources has always been the most important issue in online collaborative learning platforms. Its main function is to help students find suitable learning companions and help them find their positioning in the learning group. On this basis, through reasonable division of labor and resource recommendations, individual learning motivation is stimulated, thereby improving overall learning efficiency and reducing the workload of teachers.

Figure 3.2 is the grouping workflow diagram of the research design. Students are classified using an improved K-means method; Then, on the grounds of the analysis of clustering results, the location of each type of student can be located. After the role type of each cluster is determined, to prevent uneven role distribution caused by large differences in the number of samples between clusters, it is necessary to recalculate the distance between all samples and the final cluster center, to adjust the samples' quantity within the cluster. Finally, according to the principle of "homogeneity between groups, heterogeneity within groups", students are randomly divided into groups, so that each student has a suitable positioning [17].

A 7-dimensional student feature model is constructed to group students, and the mathematical expression is shown in equation (3.1).

$$x = (A, B, C, D, E, F, G), x \in X_m \tag{3.1}$$

In equation (3.1), A represents behavioral style, B represents knowledge acquisition ability, C represents knowledge application ability, D represents management ability, E represents interaction ability, F represents integration ability, and G represents learning level. A can be obtained through style testing, B, C, D, E, and F can be obtained by weighting and summing the dynamic data of students after logging in using the Analytic Hierarchy Process. Firstly, five judgment matrices are established, and then feature vectors are calculated and

normalized to obtain the weights of various indicators. The calculation method is showcased in equation (3.2).

$$x^* = \frac{x - \min}{\max - \min} \tag{3.2}$$

In equation (3.2), x^* represents the weight of each indicator. Then a consistency check is performed on the 5 judgment matrices. The relevant calculation is showcased in equation (3.3).

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \tag{3.3}$$

In equation (3.3), $C.I.$ represents the consistency index, $\lambda_{\max}$ represents the maximum eigenvector, and n represents the order of the matrix. Finally, the consistency ratio is calculated on the ground of the consistency index, as shown in equation (3.4).

$$C.R. = \frac{C.I.}{R.I.} \tag{3.4}$$

In equation (3.4), $C.R.$ serves as the consistency ratio and $R.I.$ represents the random consistency indicator. If $C.R.$ is below 0.1, the weight setting of the indicator is reasonable. G is obtained by weighting the static data obtained during registration with the dynamic data obtained after login, and the specific calculation method is shown in equation (3.5).

$$L = a \times \arg\_score + b \times s\_eval + c \times o\_eval + d \times score \tag{3.5}$$

In equation (3.5), $\arg\_score$ represents the average credit score, s_eval represents self-evaluation results, o_eval represents other evaluation results, $score$ represents the online setting results, a, b, c, and d are all weight coefficients.

3.2. K-means grouping and recommendation algorithm based on FA optimization. During the learning process, students' learning status reflects their characteristics. Grouping students with similar learning characteristics can better recommend suitable learning content for them. Research is on the grounds of improved clustering algorithms to group students in the classroom. By improving the accuracy of feature analysis, more optimized grouping results can be obtained. This method models students' ability attributes, locates their roles on the grounds of their characteristics, and finally groups them on the grounds of student evaluations to obtain classification results. The traditional K-means method clusters on the ground of the distance between samples, but due to its limitations in selecting the clustering center, the clustering results are often unsatisfactory, which in turn affects the grouping quality [18]. The Firefly Algorithm (FA) can greatly support the selection of cluster centers, so the research is on the ground of K-means and integrates FA.

The KMA is an unsupervised clustering algorithm that is easy to carry and possesses excellent clustering outcomes, making it extensively utilized [19]. The K-means clustering process is shown in Figure 3.3. Given the sample points T, U, V, W, X, Y, and Z, randomly set V and Z as the initial cluster centers. The clustering results after the first classification on the ground of Euclidean distance are: TVX, UXYZ. Then the above process is repeated until the cluster centers of each sample point do not change.

The KMA utilizes Euclidean distance for determining the similarity between samples [20]. Euclidean distance is the straight-line distance between two points in Euclidean space, and its calculation is shown in equation (3.6).

$$d(x_i, x_j) = \sqrt{\sum_{k=1}^{m} (x_i - x_j)^2} \tag{3.6}$$

In equation (3.6), $d(x_i, x_j)$ serves as the Euclidean distance between the sample x_i and the cluster center x_j of the cluster, m represents the spatial dimension, and k represents the cluster centers' quantity. For student datasets $X = \{x_1, x_2, x_3 \ldots, x_m\}$, research randomly selects samples $u_1, u_2, \ldots, u_k$ as initial k clustering

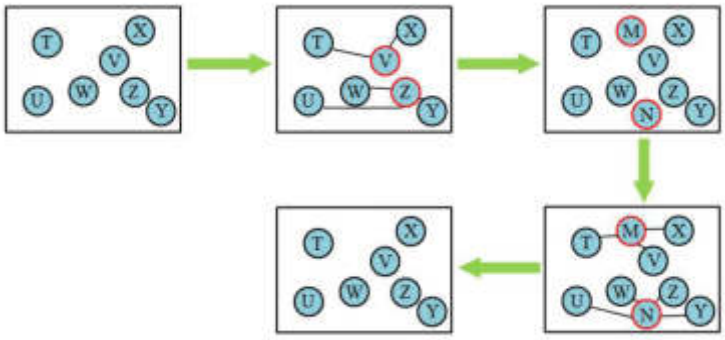


Fig. 3.3: K-means clustering process

centers, divides sample points on the ground of the minimum Euclidean distance, and obtains the mathematical expression of the clustering center c^i closest to the data x_i, as shown in equation (3.7).

$$c^i = \arg\min_j \|x_i - u_j\|^2 \tag{3.7}$$

After dividing the sample points, the mean of the sample points in the k subcategory is recalculated according to equation (3.8), it is used as the new clustering center, and the above operation is repeated continuously until the clustering center no longer changes.

$$u_j = \frac{\sum_{i=1}^{n} \{c^i = j\} x^i}{\sum_{i=1}^{n} \{c^i = j\}} \tag{3.8}$$

The sample set $X = \{x_1, x_2, x_3 \ldots, x_m\}$ is divided into k clusters $\{C_1, C_2, \ldots C_k\}$ with a clustering center of $\{\mu_1, \mu_2, \ldots, \mu_k\}$, and its minimum objective function can be expressed as equation (3.9).

$$\begin{cases} J(x, \mu) = \sum_{i=1}^{5} \sum_{x_j \in C_i} d(x_j, \mu_i) \\ d(x_j, \mu_i) = \sqrt{\sum_{l=1}^{7} |x_{jl} - \mu_{il}|^2} \end{cases} \tag{3.9}$$

In the FA algorithm, there is a negative correlation between the brightness of fireflies and the value of the objective function. To decrease computational complexity and enhance the algorithm's time efficiency, this algorithm uses the reciprocal of the objective function $J(x, \mu)$ for representing the brightness of fireflies. The specific expression formula is shown in equation (3.10).

$$I(x_j) = \left(\sum_{i=1}^{5} \sum_{x_j \in C_i} \sqrt{\sum_{l=1}^{7} |x_{jl} - \mu_{il}|^2} \right)^{-1} \tag{3.10}$$

In equation (3.10), $I(x_j)$ represents the brightness of fireflies. To optimize the clustering effect, the formula for evaluating the brightness of a single firefly can be expressed as equation (3.11).

$$I(x_j) = \sum_{p \in x} dist(p, x_j)^2, j = 1, 2, \ldots, k \tag{3.11}$$

In equation (3.11), $dist(p, x_j)^2$ represents the sum of the squared distances of all data to x_j within the cluster with fireflies x_j as the cluster centroid. By studying the principle of equivalent infinitesimal substitution,

the mutual attraction formula of FA has been improved to reduce computational complexity and improve computational speed. The improved mutual attraction formula can be expressed as equation (3.12).

$$\beta(d) = \frac{\beta_0}{1 + \gamma d_{ij}^2} \tag{3.12}$$

In equation (3.12), β_0 serves as the maximum attraction, γ is a constant, representing the light intensity absorption factor, and d_{ij} represents the Cartesian distance from the firefly i to the firefly j. When updating the position of fireflies, inertia weights are added to the calculation formula of position updates to expand the search range of the firefly population and enhance the global optimization ability of the algorithm. The mathematical expression for updating the position of fireflies is shown in equation (3.13).

$$x_j(t+1) = \omega(t)\, x_j(t) + \beta_{ij}(x_i(t) - x_j(t)) + \alpha(rand - 0.5) \tag{3.13}$$

In equation (3.13), $x_j(t+1)$ represents the updated position of the firefly, t serves as the number of iterations, $rand()$ serves as the random value between [0,1], ω represents the inertia weight, α is a constant, and can generally be taken as any number within [0,1]. The calculation formula for the attraction β_{ij} of firefly i to j is equation (3.14).

$$\beta_{ij} = \beta_0 \exp\left(\gamma d_{ij}^2\right) \tag{3.14}$$

According to the characteristic of fast and then slow descent speed of the Firefly algorithm, when selecting inertia weights, a logarithmic descent strategy is used, and the current mathematical expression for weights ω_t is Equation (3.15).

$$\omega_t = \omega_{ls} - (\omega_{ls} - \omega_{le}) \log_{T_{\max}} t \tag{3.15}$$

In equation (3.15), ω_{ls} serves as the maximum value of inertia weight, ω_{le} serves as the minimum value of inertia weight, and ω_{le} serves as the maximum number of iterations.

The entire algorithm process is shown in Figure 3.4. Firstly, various parameters and the position of individual fireflies are initialized, and then the brightness of each firefly individual is counted on the ground of clustering partitioning criteria until every individual within the firefly population is selected. The brightness of each individual firefly is compared in the population. If the firefly $I(x_i)$ is larger than the firefly $I(x_j)$, the position of the firefly population is updated according to equation (3.13). Conversely, the firefly moves randomly. According to the classification principle of the nearest neighbor rule, the clustering result of the firefly is calculated, and then the new clustering center is recalculated on the ground of the current clustering result, and the position of the firefly is updated in the current population. Finally, the fitness values of fireflies are sorted, the optimal solution is found, and the optimal solution is output. Steps 3 to 6 are repeated for the firefly population that has completed a complete evolution until the stop condition is met or the maximum evolution algebra is reached.

4. Online collaborative learning platform performance verification . The study selected four different types of experimental datasets, comparing and analyzing the advantages and disadvantages of the improved KMA with other clustering algorithms. Then, through simulation analysis, the performance of the online collaborative learning platform was verified, and the grouping and recommendation effects of the platform were compared.

4.1. Simulation results of K-means algorithm based on FA optimization. This simulation was conducted on a PC with a Windows 64-bit operating system, with 4GB of physical memory and a CPU rate of 3.10GHz. The program was run using Matlab 2014b software. The maximum attraction $I(x_j)$ was set to 100, the absorption coefficient γ was set to 1, the step factor α was set to 0.06, the maximum number of iterations ω_{le} was set to 50, and the maximum fluorescence brightness I was set to 100. The four UCI datasets selected for the simulation experiment were standard experimental datasets commonly used in clustering algorithms, which were derived from the machine learning database established by Ervine at the University of California. The various information from these four datasets is demonstrated in Table 4.1.

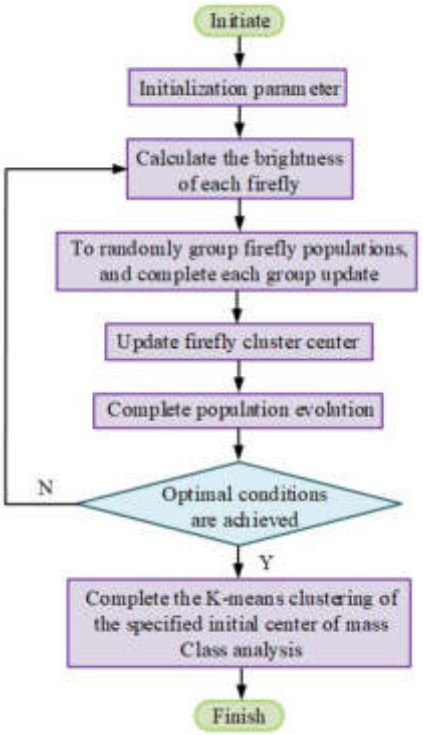


Fig. 3.4: Flowchart of K-means clustering algorithm on the ground of firefly algorithm

Table 4.1: Data set information

Data set	Number of data objects	Data dimension	Number of clusters
Iris	150	4	3
Wine	178	13	3
Hayes-Roth	162	5	3
Glass	214	9	6

Fig. 4.1: Sample contents of the four data set

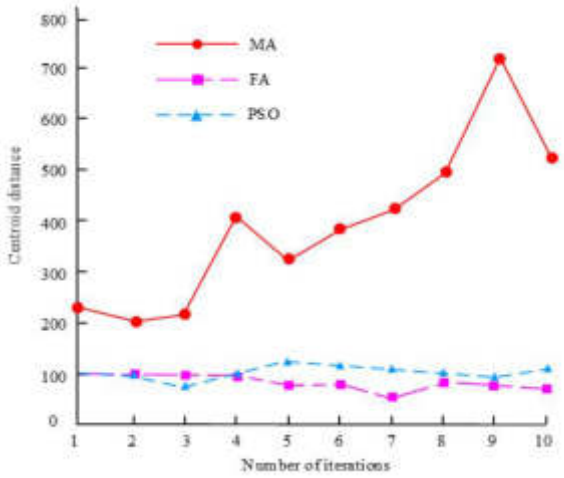


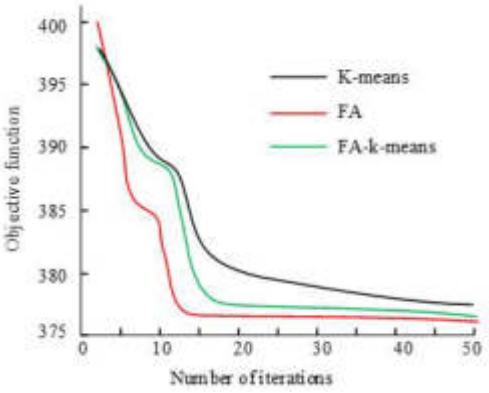
Fig. 4.2: Algorithm to actual clustering centroid distance

For verifying the possibility of the EFA algorithm breaking through local optima, the Monkey Algorithm (MA), FA algorithm, and Particle Swarm Optimization (PSO) algorithm were used in the experiment for calculating the distance between the actual clustering centroids of the Iris dataset. The outcomes are demonstrated in Figure 6. As shown in the figure, the MA algorithm had good optimization ability in the early stages of iteration. As the number of iterations increased, the distance between its centroids fluctuated significantly, indicating that the algorithm was prone to deviations during the solution process as the population evolved, leading to instability in the solution. Compared with FA, PSO had obvious advantages in convergence speed and had a gradually decreasing trend, indicating that FA can find global extremum from local extremum. The centroid distance fluctuation of PSO was greater than that of the FA algorithm, and although the overall curve was relatively stable, there was no obvious downward trend. Although PSO had a strong global search ability, it was still difficult to escape the dilemma of entering the local optimal solution.

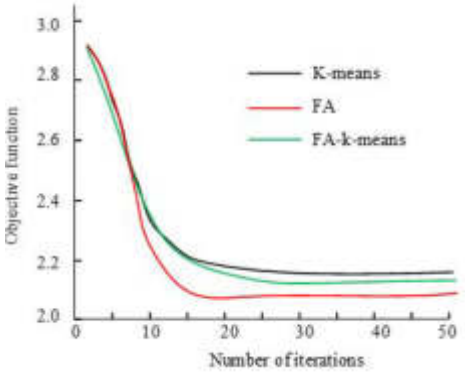
Figure 4.3 shows a comparison of the convergence curves in four datasets. The graph analysis demonstrates that when using the KMA, FA, and FA K-means selected centroids as the initial clustering centroids for analysis, the research found that although they both had certain convergence, they cannot accurately break through the local optimal dilemma. However, on the ground of the centroid selected by the FA-KMA, this clustering method not only had good stability but also had higher clustering accuracy and better convergence performance when performing clustering analysis on the specified initial centroid.

The study compared the clustering accuracy and processing time of FA KMA with KMA, and the specific outcomes are demonstrated in Table 2. The table analysis illustrates that the FA-KMA optimized the cluster center value k by using the maximum and minimum distance algorithms. Compared to the classical KMA and FA algorithms, the average clustering accuracy was improved by 7.23 % and 2.18 %, respectively, and the average processing time was improved by 4.35 % and 2.26 %, respectively. In the dataset Iris, the average clustering accuracy and processing time of the three algorithms were 91.29 and 8.65, which were better than other datasets due to their smaller dimensions. Overall, the average processing time and clustering accuracy of the FA KMA were superior to the FA algorithm and weighted KMA in all four datasets, demonstrating the effectiveness of the algorithm.

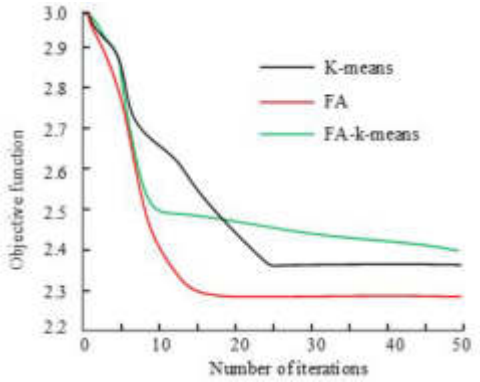
4.2. Platform performance verification and accuracy analysis of clustering results.. The study utilized Griewank, Alpine, and Salomon test functions to independently conduct 30 experiments using MA, FA, and FA K-means, respectively. Three test functions were selected with dimensions of 30 and 60, respectively. Figure 8 shows the optimization results of solving each test function once at 30 and 60 dimensions. From the graph, in the cases of 30 and 60 dimensions, FA-K-means performed better than MA and PSO for the three test



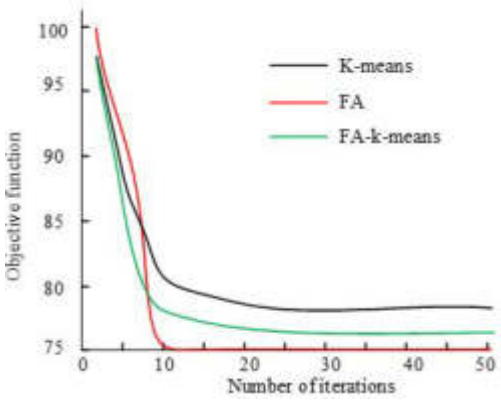
(a) Convergence Curve of the Glass data set



(b) Convergence Curve of the Hayes-Rothdata set



(c) Convergence Curve of the Wine data set



(d) Convergence Curve of the Iris data set

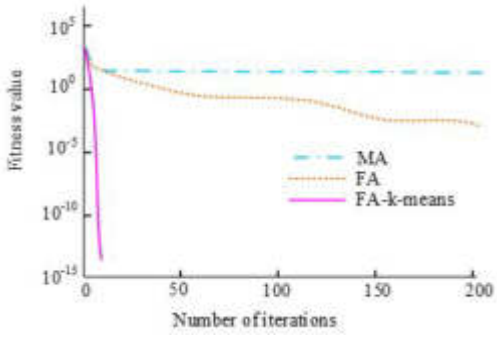
Fig. 4.3: Convergence curves of the three algorithms on six data sets

Table 4.2: Comparison of simulation results of different algorithms

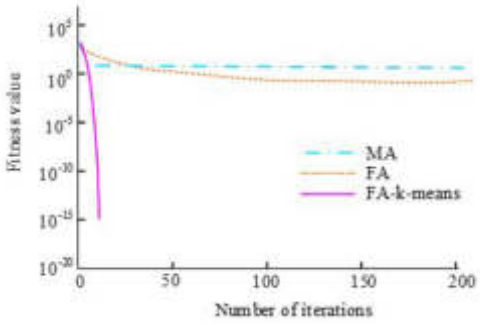
Data set		Glass	Hayes-Roth	Wind	Iris
K-means algorithms	Clustering accuracy (%)	60.72	81.47	70.44	91.50
	Processing time (s)	18.36	11.26	14.42	8.36
FA	Clustering accuracy (%)	62.47	81.27	70.70	91.20
	Processing time (s)	17.52	10.74	13.83	9.25
FA-K-means algorithms	Clustering accuracy (%)	63.14	82.36	72.15	92.15
	Processing time (s)	17.43	10.44	13.16	8.33

functions, and its convergence accuracy was significantly improved compared to other methods. Overall, the FA KMA can find the optimal solution with lower iterations and exhibit better stability for high-dimensional functions.

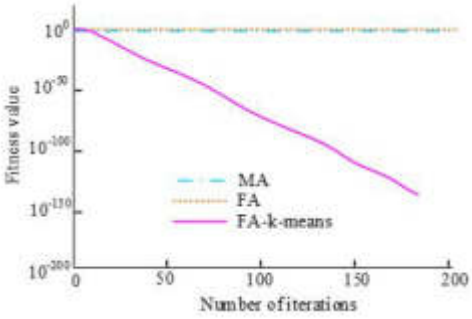
Table 4.3compares the optimization performance of the test function at 60 dimensions, using the optimal, worst, and average values of the global minimum to reflect the quality of the solution, and the standard deviation to reflect the stability of the optimal solution. The table showcases that the FA KMA had zero performance indicators in the Griewank test function, making it the best among several algorithms, while the MA algorithm



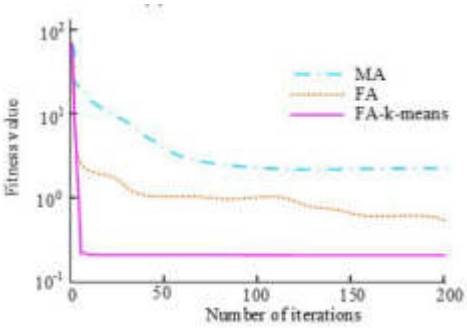
(a) 30 dimensional of Griewank function



(b) 60 dimensional of Griewank function



(c) 30 dimensional of salomon fuction



(d) 60 dimensional of salomon fuction

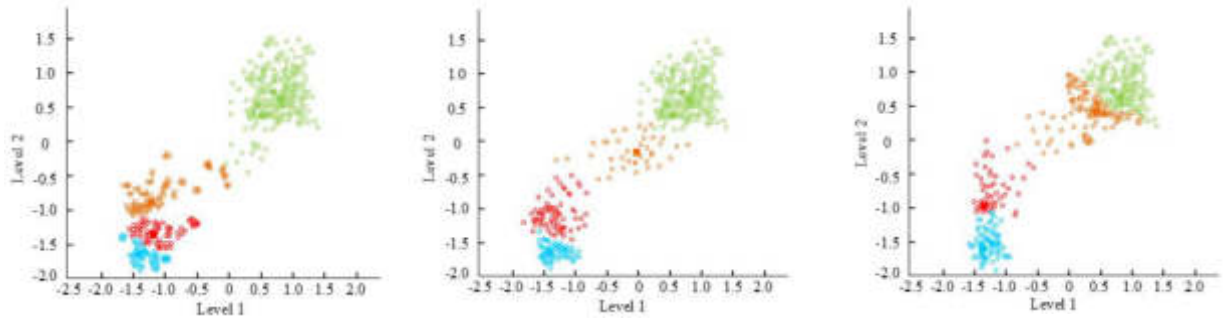
Fig. 4.4: Convergence diagram of two test functions

Table 4.3: The optimization performance comparison of the test function in 60 dimensions

Function	Algorithm	Optimal value	Worst value	Average value	Standard deviation
Griewank	MA	24.1036	51.4285	37.4169	6.7895
	FA	0.0834	0.2215	0.1459	0.0346
	FA-K-means	0	0	0	0
Salomon	MA	0.4963	0.9045	0.7136	0.1026
	FA	2.3996	4.2015	3.2104	0.4789
	FA-K-means	0.0084	0.1995	0.1678	0.0645
Alpine	MA	13.1342	25.7154	19.8475	3.4982
	FA	72.1523	149.2457	103.9364	21.1978
	FA-K-means	0.3006	3.2176	1.5234	0.8692

had an average value of 37.4196. In the Salomon test function, the optimal, worst, and average values of the FA KMA were closest to the optimal values compared to the other three. In the Alpine test function, the optimal, worst, and average values of the FA-KMA were 0.3006, 3.2176, and 1.5234, respectively, which were the lowest relative to the two algorithms.

The study randomly selected 200 sample data and tested them using online collaborative learning platforms on the grounds of three different clustering algorithms. The outcomes are demonstrated in Figure 9, where the diamond denotes the cluster center, and the hollow point represents the sample points. In the figure, most of the cluster centers in the online collaborative learning platform on the ground of the KMA were relatively concentrated, but most of the sample points had a long Euclidean distance from the cluster center, indicating



(a) The clustering result Of K-means algorithm (b) The clustering result Of FA algorithm (c) The clustering result Of FA K-means algorithm

Fig. 4.5: Comparison of clustering results of the three algorithms

Table 4.4: Grouping and recommendation effect of online collaborative learning platform

Data set		Glass	Hayes-Roth	Wind	Iris
C-OCLP	Optimal value	729.65	101.33	162.63	80.67
	Worst value	1095.63	145.63	210.63	152.34
	Average value	912.64	123.48	186.63	116.51
	Standard deviation	81.52	21.58	23.45	17.64
P-OCLP	Optimal value	689.21	123.36	172.45	80.62
	Worst value	1140.36	168.77	250.36	153.23
	Average value	914.79	146.07	211.41	116.93
	Standard deviation	115.63	26.36	33.25	22.36
F-OCLP	Optimal value	600.68	136.55	196.24	80.06
	Worst value	854.23	186.41	263.47	152.12
	Average value	727.46	161.48	229.86	116.09
	Standard deviation	72.63	24.69	28.14	22.35

that the platform's recommendation accuracy for learning content needed to be improved. Compared with learning platforms on the ground of KMA, the recommendation accuracy of the FA method was improved, but the quality still needed further improvement; The learning platform on the ground of the FA-KMA had the minimum Euclidean distance between each sample point and its cluster center, which greatly improved the clustering results of the learning platform, thereby improving the efficiency of group clustering and the recommendation accuracy of learning content.

For testing the grouping and recommendation performance of the online collaborative learning platform proposed by the research institute, simulation analysis was conducted to compare the optimal, worst, average, and standard deviation of the learning platform on the ground of the FA KMA (F-OCLP), the learning platform on the ground of the Cuckoo KMA (C-OCLP), and the learning platform on the ground of the PSO-KMA (P-OCLP). The specific results are shown in Table 4.4. The data results in the table illustrate that the F-OCLP data results had better clustering quality compared to the other two learning platforms. In the Iris dataset, the optimal values for F-OCLP, C-OCLP, and P-OCLP were similar, with 80.67, 80.62, and 80.06, respectively, but F-OCLP was more stable. On the Wind dataset, the optimal value of F-OCLP was 263.47, and the optimization effect was significantly improved compared to the other three methods. In the Glass dataset, the optimal, worst, and average values of F-OCLP were significantly improved compared to the other three. In the Hayes-Roth dataset, the optimal, worst, and average values of F-OCLP were 136.55, 186.41, and 161.48, respectively, which was the highest compared to the other two learning platforms.

Table 4.5: Performance summary of FA-k-means algorithm

	Data set	Glass	Hayes-Roth	Wind	Iris
Algorithm performance	Clustering accuracy(%)	63.14	82.36	72.15	92.15
	Processing time(s)	17.43	10.44	13.16	8.33
Platform performance	Optimal value	600.68	136.55	196.24	80.06
	Worst value	854.23	186.41	263.47	152.12
	Average value	727.46	161.48	229.86	116.09
	Standard deviation	72.63	24.69	28.14	22.35

Table 4.5 summarizes the performance of the teaching resource recommendation algorithm of the sports online collaborative learning platform based on optimized k-mean. In the table, the research improved the traditional clustering algorithm by integrating the firefly algorithm and inertia weight and improved the clustering accuracy. Based on the analysis of clustering results, learners were automatically grouped and assigned roles. Fully combined with the real-time needs of learners and the characteristics of learning notes in the learning process of the sports online collaborative learning platform, learners' self-assessment and mutual assessment were added to the evaluation function, and learners' learning behavior data were obtained to automatically calculate the normal score, reduce the proportion of teachers' scoring, and make the results more objective and accurate by reducing the subjectivity of evaluation.

5. Conclusion. In response to the phenomenon of some students not acting and learning resource overload in the current online collaborative learning platform for sports, this study proposes a K-means grouping and recommendation algorithm on the ground of FA optimization, which uses random weight factors to influence the iteration of firefly positions and improves the random disturbance term to improve the diversity of the population. Last, simulation experiments verify the effectiveness. The results showed that FA had obvious advantages in convergence speed and a gradually decreasing trend, indicating that FA can find global extremum from local extremum. Compared with classical KMA and FA algorithms, the average clustering accuracy of FA-KMA was increased by 7.23 % and 2.18 %, respectively, and the average processing time was increased by 4.35 % and 2.26 %, respectively. In the dataset Iris, the average clustering accuracy and processing time were 91.29 and 8.65, while the FA-KMA had zero performance in several indicators of the Griewank test function. The average value of the MA algorithm was 37.4196. In the Alpine test function, the optimal, worst, and average values of the FA-KMA were 0.3006, 3.2176, and 1.5234, respectively. The FA K-means method minimized the Euclidean distance between each sample point and its cluster center. In the Iris dataset, the optimal values for F-OCLP, C-OCLP, and P-OCLP were 80.67, 80.62, and 80.06, respectively. On the Wind dataset, the optimal value for F-OCLP was 263.47, and on the Glass dataset, the optimal value for F-OCLP was 854.23. The optimal, worst, and average values of F-OCLP in the Hayes-Roth dataset were 136.55, 186.41, and 161.48, respectively. The application efficiency of the fusion algorithm proposed in this paper is low, and an adaptive mechanism will be introduced into the combination algorithm in the next step. In future work, research should be done on the implementation of diversified applications of the algorithm. To avoid the situation that the accuracy of the score results is affected by malicious bad reviews, the suspicious degree will be integrated into the next step, the evaluation with too large a score difference will be filtered out, and the accuracy of learning effect evaluation will be further improved.

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RESEARCH ON THE APPLICATION OF VR TECHNOLOGY BASED ON HUMAN POSTURE RECOGNITION IN ONLINE PHYSICAL EDUCATION

FUYANG HE*

Abstract. Offline and current online physical education classes are characterized by low learning efficiency and poor teaching quality. To solve this problem, the study combines a dynamic time regularization algorithm and local image feature action recognition with virtual technology, which is applied to online teaching to improve teaching quality. Experimental results indicate that the overall model accuracy reaches more than 94%, and in the public dataset MSR, the model accuracy reaches 91.4%. In the UTK dataset, the accuracy reaches 85.8%. When the accuracy of pose recognition is compared, the research model is superior to the two traditional models. The validation results against KNN and SVM are 62% and 71% as well as 79% and 84%, respectively, and the experimental results of the research model have improved by 9% and 5%. The research technique achieves an overall fit of more than 90% for different parts in the analysis of motion capture, which is superior to the traditional online instruction. The overall teaching satisfaction reaches more than 93.5% in the comparison of online physical education courses with offline courses. In summary, the optimized and improved posture recognition system is better for human motion capture, and the applied virtual technology can effectively improve the learning effect and teaching quality of online physical education courses.

Key words: VR technology; Online teaching; Gesture recognition; Motion capture

1. Introduction. With the progress of science and the change of educational needs, the combination of Virtual Reality (VR) technology and online education has become an important direction in teaching in recent years. Especially in physical education, VR is changing the way of learning, providing new possibilities for improving the interaction and learning effect of distance teaching. However, research usually focuses on the technology of teaching platforms or the learning theoretical models. But they pay less attention to the application and optimization of human posture recognition based on VR in physical education, especially in solving the low learning efficiency and low teaching quality in online teaching [1-3]. In the traditional offline physical education, there are many challenges that affect teaching efficiency and quality. For example, due to the large number of students, teachers are often unable to provide personalized guidance and feedback to each student. Especially when learning complex motor skills, such as basketball dribbling or soccer kicking, students often need immediate and specific motion corrections to avoid inveterate learning of wrong skills. In addition, students may be reluctant to actively participate because of shyness, strong self-awareness, or physical limitations in physical education classes. These conditions not only reduce the quality of teaching, but also affect the acquisition of students' motor skills and the cultivation of healthy habits. At present, human posture recognition technology is a crucial part of VR physical education. Although many studies have focused on this, the existing pose recognition methods still face challenges such as incomplete motion capture and insufficient accuracy. These technical limitations reduce the effectiveness of VR physical education and hinder its widespread application in education. To this end, this research focuses on the limitations of existing human posture recognition technology in online physical education and tries to develop effective solutions to improve its performance [4-6].

The current literature shows that while VR in education has evolved, there is still limited research on its technical details and enhancement of learning outcomes. Some early studies have provided valuable insights and foundations. But due to the rapid evolution of technology, it is necessary to introduce the advanced methods to ensure research relevance and innovation [7-8].

In this study, the specific needs of the combined application of VR technology and online physical education are first identified. Then, through in-depth analysis of the limitations of the existing pose recognition

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technologies, the research aims at proposing an improved human body pose recognition system to effectively improve the quality of online physical education and learners engagement. Subsequently, the experimental validation of the proposed method is presented, and the model performance is compared and analyzed to prove its effectiveness in different scenarios. Finally, the practical significance of this study and its potential contribution to the development of online physical education in the future are discussed.

2. Related Works. With the development of information technology, posture recognition technology has also received much concern, and many researchers at home and abroad have studied this technology in-depth and applied it to different fields. Hong Zhen et al. proposed a collaborative solution based on artificial intelligence and Internet of Things (IoT) to solve the high rate of misjudgment in motion capture in healthcare. And they proposed a multi-pose recognition offline algorithm implemented on wearable hardware for recognizing poses based on multidimensional data. The results showed excellent performance in terms of accuracy and reliability [9].

Zhang et al. explored gesture recognition and behavior tracking in swimming motion images under computer machine vision. They incorporated the Gaussian mixture model and filtering algorithm into the recognition tracking system. The experimental results indicated that this model could obtain the motion trajectory of the object relatively completely, and the filtering tracking algorithm could obtain the motion speed of the object better [10].

Xiaoyun Tong et al. proposed a second-order pooled convolutional neural network for facial expression recognition to explore the correlation information between facial features after deep network learning. The results indicated that the correct rate was above 88%, which was superior to other algorithms [11].

MGR Alam et al. proposed an improved loMT for an emotion recognition system to study the recognition of human emotion states, and the experimental results showed that the performance of the proposed method was analyzed using benchmark datasets with high classification accuracy to determine human emotion states [12].

Research related to online teaching has grown more rapidly since 2020. Dolighan et al. studied the relationship between specific variables, teaching experience, professional development, teaching support, and the self-efficacy of teachers who transitioned to online teaching during the pandemic. Results indicated that higher online teaching efficacy scores were associated with taking online additional driving qualification and professional development courses. The highest online teaching efficacy scores were associated with prior use of board-provided learning management systems and the virtual technology [13].

Daumiller et al. analyzed the attitudes and fatigue of students and teachers who switched from offline to online teaching in learning. The study showed that teachers' learning goals were positively associated with viewing the transition to online teaching as a positive challenge and useful for their own competency development. It was also noted that teachers' goals and attitudes were correlated with successful online teaching [14].

Siegel et al. taught the knowledge of skin cancer to nurses through online teaching and divided them into two groups for a controlled experiment. The results showed that participants in the intervention group scored significantly higher on the "behavior" and "role" indicators, suggesting that the intervention was successful in influencing these dimensions [15].

Truzoli et al. explored faculty experience with online teaching, risk factors (e.g., stress) and protective factors (e.g., sources of control), and their impact on satisfaction during social distance. The results showed that satisfaction with online teaching was affected by changes in the environment and teaching style and that increasing satisfaction required better maintenance of a teaching mindset and adaptation to teaching style changes [16].

Kwong et al. set up a control experiment to compare the effects of offline and virtual labs. The results of the control experiment showed that students became more sensitive in applying parameter adjustment and backtracking strategies. Questionnaires indicated that students found such virtual labs satisfactory [17].

A Lester et al. set up a controlled experiment with Australian students to maximize students' motivation in physical education classes, enhance youth understanding of physical education, and increase their interest in physical education. The results showed that AMPED achieved modest improvements in MVPA compared to previous face-to-face-only interventions better. Online teacher training can help facilitate the widespread dissemination of professional learning interventions [18].

To improve online teaching, Z Fen proposed a bioimmune algorithm framework using the GBDT algorithm encoding to improve the efficiency of teaching English online. And a bagging learning-based stream feature selection algorithm was proposed to solve the problem that redundant information between features could reduce the accuracy of the framework. The results showed that the model constructed by the study had high reliability [19].

The research on online education and human pose recognition by domestic and foreign scholars show that there are numerous studies on both, but there is still much room for optimization of how to accurately identify and apply online education. Therefore, this study incorporates the dynamic time regularization algorithm and Harris corner point detection algorithm into pose recognition to explore the optimization and development of online education.

3. Construction of a human posture recognition model based on skeleton features and local image recognition.

3.1. Construction of pose recognition system based on skeleton features. The human body's pose feature is rich in semantic information, which is an important part of biometric features. Human pose recognition can be solved as a time-series problem by transforming an action into a pose sequence in space and modeling the action in space. A pose sequence is then viewed as a combination of skeletal frame data for action. There are many methods to identify actions by skeleton features extracted from human joint point data. In online physical education, the study uses joint body data features for human gesture recognition. The Dynamic Time Warping (DTW) algorithm mainly addresses the similarity of two temporally unequal sequences, which is first applied in fields such as speech recognition. Although the movement speed of two people is not the same in action recognition, the movement trajectory and the relative movement amplitude are similar. DTW can be used to solve the action judgment of the same action sequence with the different time that exists between teachers and students. The training sample$X$ is set as the horizontal axis and the test sample Y is set as the vertical axis. Then a time series matrix is constructed, in which an element value in the matrix represents the distance between two points and the similarity of these two joints, and the calculation formula is shown in Equation (3.1).

$$d(X_m, Y_n) = \sqrt{\sum_{k=1}^{K} d(X_{mk}, Y_{nk})} \tag{3.1}$$

In Equation (3.1),X_{mk} denotes the feature value corresponding to the m frame in the training sample, Y_{nk} denotes the feature value corresponding to the n frame in the test sample, and K denotes the feature vector dimension of one frame. Therefore, the nodal similarity problem can be transformed into a shortest distance problem between these two points, as shown in Equation (3.2).

$$f(X_m, Y_n) = d(X_m, Y_n) + \min\{f(X_m, Y_{n-1}), f(X_{m-1}, Y_n), f(X_{m-1}, Y_{n-1})\} \tag{3.2}$$

In Equation (3.2), $f(X_m, Y_n)$ refers to the cumulative distance $d(X_m, Y_n)$ is the Euclidean distance of the current point location. Therefore, the action recognition of the skeleton features is to match the joint point positions of the test data with the joint point positions of the training data to achieve action recognition. The flow of DTW-based pose recognition is shown in Figure 3.1.

The body somatosensory is transmitted into the test data, the joint point data are pre-processed for feature value extraction, and the training data are matched with the DTW template to derive the required recognition results. The depth image is evaluated using the skeletal tracking technology in the Kinect sensor to obtain joint point information of different parts of the human body. When teachers and students enter the Kinect detection position, the instrument automatically detects and obtains the coordinates of human joint point positions, as shown in Figure 3.2.

In Figure 3.2, the instrument detects the human body information entering the range, the orientation of the sensor is Z-axis, the upward direction of the sensor is Y-axis, and the vertical Z-axis extends in the left direction is X-axis. The collected data are stored in Xef format. The position of the human body joints in the image and the coordinates of the actual three-dimensional position can be obtained by saving the data

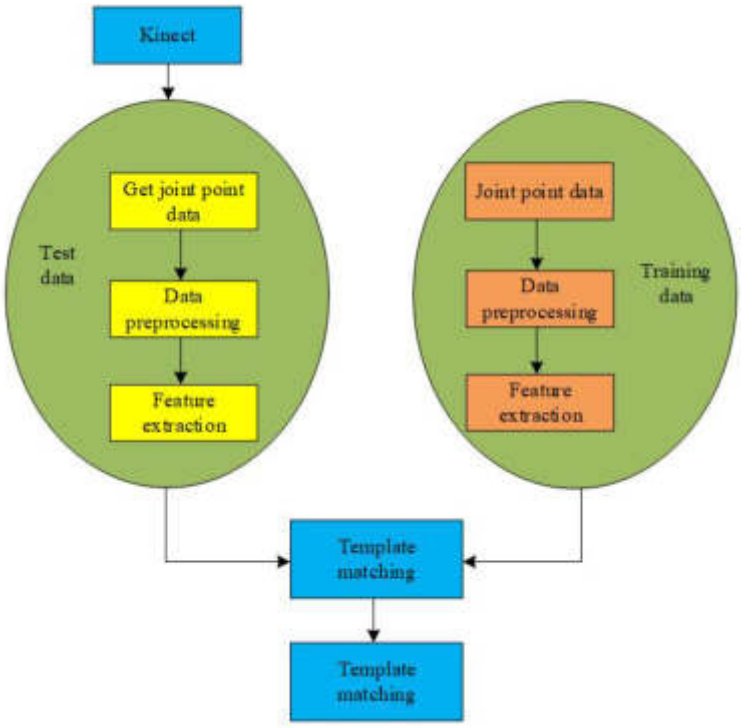


Fig. 3.1: Flow chart of attitude recognition based on DTW

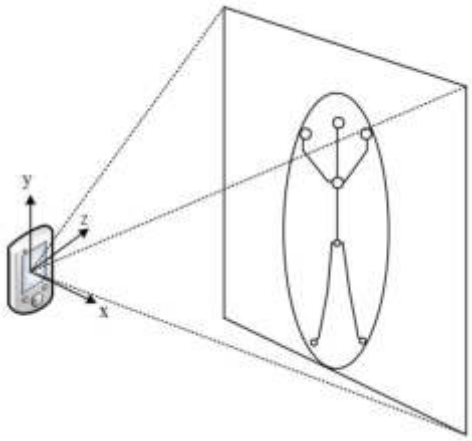


Fig. 3.2: Human joint detection

by frame through the file stream. After that, the data required for degree pre-processing are extracted by data segmentation and filtering with noise reduction. In the Kinect sensor range, a sequence of static and continuously changing images is used to represent the actions performed by a person. The motion recognition of the human body is performed by obtaining the coordinate data of the joint points to determine the activities of different parts. The raw skeleton data after pre-processing show incomplete inherent features of the action.

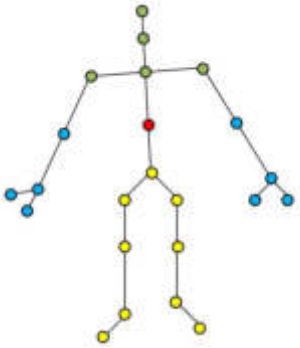


Fig. 3.3: Human skeleton model

To make the human pose model consistent with the actual action, the skeleton features are extracted from the sequence according to the displacement vector and relative position in the physical features. The definition formula of the displacement vector is shown in Equation (3.3).

$$v_i^s = \frac{p_i^{s+1} - p_i^{s-1}}{\Delta T} \qquad 1 < s < n \tag{3.3}$$

In Equation (3.3), s refers to the skeleton sequence, the maximum of the sequence is n, p_i^s is the coordinate representation of the position of the joint in the sequence, ΔT indicates the interval between different times, and T refers to the number of skeleton frames in a sequence. The relative position describes the information of the human body and consists of the relative positions of different joints. The formula for calculating the relative positions of two joints in a sequence is shown in Equation (3.4).

$$j_{i,k}^s = p_i^s - p_k^s \qquad i \neq k \tag{3.4}$$

In Equation (3.4), p_i^s and p_k^s represent the position coordinates of different joints in the same frame. The human skeleton consists of a fixed number of joints, and two skeletal models with 20 and 25 joints are used in this study.

In Figure 3.3, 25 skeleton models are counted into the neck as well as the fingers of the hand compared to 20 skeleton models, which can focus on different regions of the action metrics according to different needs. To get more representative skeleton features, the feature extraction method of global and local feature fusion is used to constitute the feature vector. Equation (3.4) can be transformed into Equation (3.5) required for the study.

$$f_{joint} = p_i(x_i, y_i, z_i) - p_1(x_1, y_1, z_1) \tag{3.5}$$

In Equation (3.5), $p_1(x_1, y_1, z_1)$ represents the location of the torso in model b of Figure (3.3), $p_i(x_i, y_i, z_i)$ is the 3D coordinates of the remaining skeleton points in model b of Figure (3.3), and f_{joint} is the new skeleton feature.

3.2. 3.2 Construction of recognition system based on local image features. In the pose recognition of skeleton features, the human body needs to be facing the sensor or completely back to the sensor to capture correct and complete joint point data. When the sensor is captured sideways or with different occlusion, incomplete joint acquisition and skeleton misalignment often occur, which do not accurately represent the human action features and reduce the feature differentiation. Therefore, local image features are added to the overall pose recognition to help describe the action features when the skeleton is occluded and to improve the action information under different scene interactions. In local feature extraction, it is most important to detect

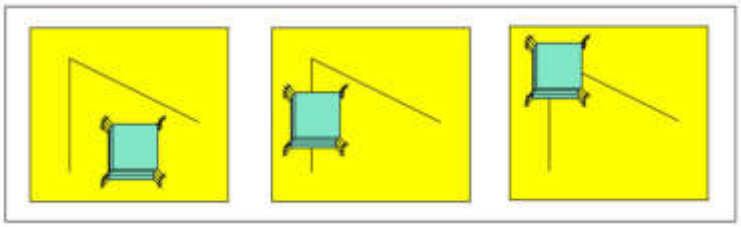


Fig. 3.4: HCD detection simulation diagram

the interest points in the temporal and spatial regions that can provide motion information and differentiation when the human motion mutates. So the study uses Harris Corner Point Detection Algorithm (HCD) for image interest point detection. The detection schematic diagram of HCD algorithm is shown in Figure 3.4.

The HCD algorithm uses a fixed local window moving in any direction to observe different grayscale situations. Detecting a significant sliding grayscale value change at any point in any direction is considered as the presence of a corner point. In the spatial domain, when the window is shifted, the gray value changes as shown in Equation (3.6).

$$E(u,v) = \sum_{u,v} w_{u,v} \left[f(x+u, y+v) - f(x,y) \right]^2 \tag{3.6}$$

In Equation (3.6), (u,v) represents the window offset, $f(x,y)$ and $f(x+u,y+v)$ represent the grayscale values of the pixel points before and after the shift, and $w_{u,v}$ represents the Gaussian window function. The gray value formula can be changed to Equation (3.7) by expanding the pixel point gray value Taylor.

$$E(u,v) \cong [u,v]\, M \begin{bmatrix} u \\ v \end{bmatrix} \tag{3.7}$$

In the human skeleton model, when the interest point data are sparse, iteration can be used for adaptive scale selection and cannot be accelerated, which can detect the required number of interest points in some scenes also to avoid excessive noise interference. When the simple background is too coefficient of interest points, it will lead to the lack of action features, which will have an impact on the recognition results. Therefore, Histogram of Orientation Gradient (HOG) and Histogram of Optical Flow Field Orientation (HOF) are chosen to describe the local information of interest points in detail. In the HOG, the RGB image is converted to grayscale map and then the X-axis and Y-axis gradient components are obtained by convolution operation using the set matrix template, and the calculation formula is shown in Equation (3.8).

$$\begin{cases} G_x = f(x-1,y) - f(x+1,y) \\ G_y = f(x,y-1) - f(x,y+1) \end{cases} \tag{3.8}$$

In Equation (3.8), $f(x,y)$ represents the grayscale value of the pixel at the corresponding position. G_x and G_y represent the horizontal and vertical gradients at the corresponding position. HOF is the amplitude weighted statistics of the optical flow and the horizontal axis angle and encodes the feature vector of the image, which reflects the change of the gray value of the pixel point as time passes. HOF is calculated as shown in Equation (3.9).

$$f(x+u\Delta t, y+v\Delta t, t+\Delta t) \tag{3.9}$$

In Equation (3.9), u is the component of optical flow motion in the horizontal direction at the corresponding moment of frame space position (x,y). v is the component of optical flow motion from the vertical direction at the corresponding moment of frame space position. t is the corresponding moment. When the interest points

are characterized, the bag-of-words model is used for template matching. And the K-means clustering method is chosen as the bag-of-words model, and the cost function of K-means is Equation (3.10).

$$J = \sum_{i=1}^{c} J_i = \sum_{i=1}^{c} \left(\sum_{k, x_k \in G_i} \|x_k - c_i\|^2 \right) \tag{3.10}$$

In Equation (3.10),$J_i = \sum \|x_k - c_i\|^2$ denotes the intra-class objective function.

When using DTW for pose recognition and local image features for action recognition, it is necessary to temporally synchronize the two types of data to ensure that the pose recognition results are fused in the same time. Therefore, the decision fusion of Bayesian algorithm is investigated to fuse the recognition results of both classifiers to improve the speed and accuracy of the classification system. When two sets of skeleton data are obtained, the decision fusion using Bayesian algorithm is expressed by Equation (3.11) when the recognizers are independent of each other.

$$p(s\,|\omega_k\,) = p(s_1, s_2, \cdots, s_L\,|\omega_k) \prod_{i}^{L} p(s_j\,|\omega_k) \tag{3.11}$$

In Equation (3.11), $p(s_j)$ is the probability that the classifier will classify the sample x in the class s_j.

In general, as a classical time series analysis method, DTW is used to measure the similarity between two time series. It allows the sequence to stretch or compress elastomeric across the timeline to achieve the best match. The key steps of DTW are as follows.

The construction of a Cumulative distance matrix, namely cost matrix. A matrix of $N \times M$ is constructed for two time series, where N and $M$are the lengths of the two time series, respectively. Each element (i, j) of the matrix represents the distance between point i of sequence A and point j of sequence B. Next is to find the optimal path. Starting from the upper-left corner of the cumulative distance matrix and ending in the lower-right corner, it needs to find a path that minimizes the cumulative distance on that path. This path shows how the two time series are aligned. Then the final distance is calculated. The overall similarity between two time series is obtained by summing the distance values on the optimal path. Harris corner detection algorithm is a classical algorithm used for corner detection in image processing. It is based on the change of gray level generated by local window movement to determine the corner points. The key steps of the algorithm are as follows.

First it is the calculation of the gradient values of each point of the image. This step is usually achieved using the Sobel operator or other image derivative filters. Next it is the calculation of the second moment matrix of the gradient. For each pixel, the second moment of the gradient is calculated, which reflects how much the image changes within the window of that point. Then the Harris response function applied. The Harris response value is calculated for each pixel, with high response values usually corresponding to corner points.

4. Performance verification and empirical analysis of motion capture system based on DWT algorithm and local image feature action recognition.

4.1. DWT algorithm and local image feature action recognition algorithm performance verification. In the gesture recognition experiment, two public datasets, MSR and UTK, and a self-collection dataset SCD were used. The MSR dataset collected 8 common actions in teaching scenes as a complete Kinect collection process. UTK dataset was a complete Kinect acquisition process performing 5 common teaching gestures by the same person. The SCD dataset was a complete Kinect acquisition process with the same person performing five common actions such as measurement and recording. The MSR dataset was collected from multiple online teaching scenarios, covering eight common teaching actions. The dataset consisted of 100 participants from different backgrounds, each performing each action five times, for a total of 4,000 action samples. Each sample contained the time series data of the keyframe and the corresponding skeleton model coordinates. In the data preprocessing stage, the standardization process was carried out to eliminate the influence of attitude scale, and the noise filtering algorithm was applied to reduce the random error in the acquisition process. The UTK

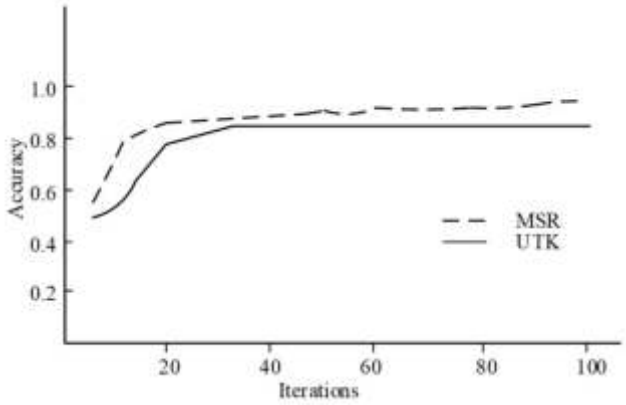


Fig. 4.1: Recognition accuracy of network model in MSR and UTK datasets

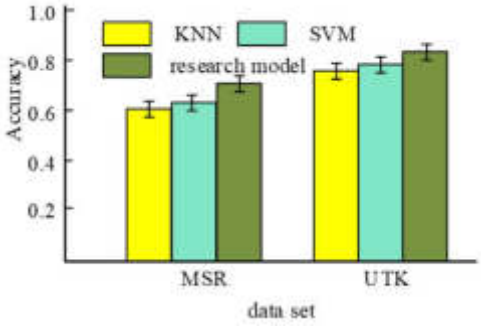


Fig. 4.2: Accuracy comparison of different attitude recognition methods

dataset consisted of five instructional gestures performed by a single participant, designed to capture gesture accuracy. The dataset contained 1500 samples, each recording the three-dimensional motion coordinates of gestures and the corresponding time stamp. The interference of irrelevant background action was eliminated by filtering algorithm, and the motion trajectory was smoothed to improve the accuracy of subsequent analysis. Self-collection dataset SCD was designed specifically for the needs of this study, recording 5 kinds of actions such as measurement and recording. 20 students participated in the collection, and each performed each action 10 times, which contained 1000 action samples in total. In addition to the use of standardization and filtering processing, data enhancement techniques such as rotation and scaling were introduced to improve the generalization ability of the model.

In Figure 4.1, during the iterations of the MSR dataset, the accuracy of the model increased substantially to more than 80% when the iteration started at 10. After about 60 iterations, the accuracy became stable gradually. After 100 iterations, the accuracy of the model reached 91.4%. Compared with the MSR dataset, the overall accuracy of the UTK dataset was slightly lower, with a significant increase in accuracy in the first 20 iterations and a gradual decrease in accuracy change after about 50 iterations, but still by an increase. Finally, it reached an accuracy of 85.8% after 100 iterations. Compared with the traditional recognition rate, the research model had effective convergence on the recognition process of different human postures, and the recognition accuracy was significantly improved. To verify the effectiveness of the improved model in pose recognition, a comparison experiment based on skeletal feature vectors for behavior recognition was designed on two public datasets with K-nearest Zero Classifier (KNN) and Support Vector Machine (SVM). The experimental results are shown in Figure 4.2.

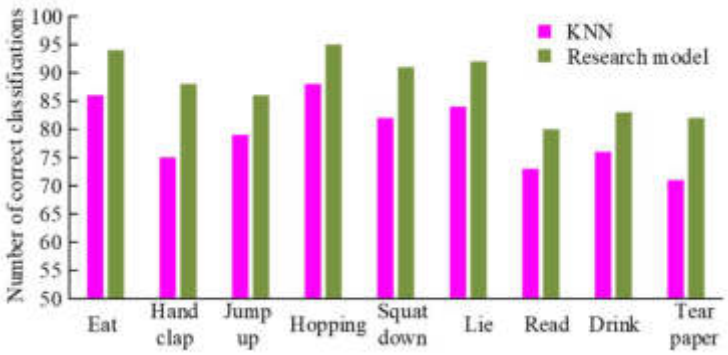


Fig. 4.3: Comparison of the number of different actions identified by the model in the MSR dataset

From the experimental results in Figure (3.6), the accuracy of the research model was superior compared to the two traditional models for pose recognition. The validation results compared with KNN and SVM were 62% and 71% as well as 79% and 84%, respectively. The experimental results of the research model were improved by 9% and 5%. The reason is that the research model can capture and recognize behavioral features at different time lengths using interest point detection, and the improvement is more obvious for more complex human gesture behaviors. The better ability to characterize action features with mask occlusion allows the model to learn with better robustness characteristics. Therefore, the research model has better performance and higher recognition accuracy compared to KNN over SVM. And to verify whether the research model can have good gesture recognition effect in different scenes, representative behaviors with different time complexity in life are selected as tests and compared with KNN model for analysis and verification, and the experimental results are shown in Figure 4.3.

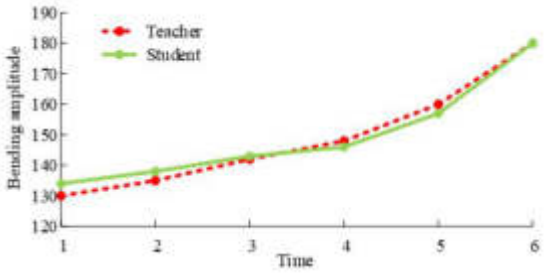
Figure 4.3 shows the comparison of the number of different categories recognized by KNN and the research model on the MSR dataset. The overall trend showed that the recognition of different actions by the research model was generally higher than that of the traditional human posture recognition. In the recognition of hand clapping, the traditional model was 13 lowers than that of the research model. In the Hopping recognition, both models could recognize the action effectively, and the KNN model had a recognition rate of 88, and the research model had an advantage in the recognition of the fully frontal action, reaching a recognition rate of 95. In the recognition of objects with occlusion, such as the three actions of reading, drinking and tearing paper, the research model with HOG and HOF was more sensitive to grayscale changes. And its dense interest point detector was also more sensitive to complex motion backgrounds, which could reduce the amount of computation and data redundancy. So the recognition system can effectively improve the action recognition rate and better real-time performance. It can better capture semantic information in different poses, has stronger descriptive ability for human pose, and has more advantages with other human recognition systems in certain complex action recognition.

To evaluate model performance more comprehensively, accuracy, precision, recall, and F1 scores were calculated to reflect the model's recognition performance on different datasets. Precision refers to the proportion of samples correctly identified as positive examples to all samples identified as positive examples. Recall refers to the proportion of samples correctly identified as positive examples to all samples that are actually positive examples. The F1 score is a harmonic average of precision and recall, which provides a single metric to evaluate the balance of these two aspects. Table 1 lists the performance specifications.

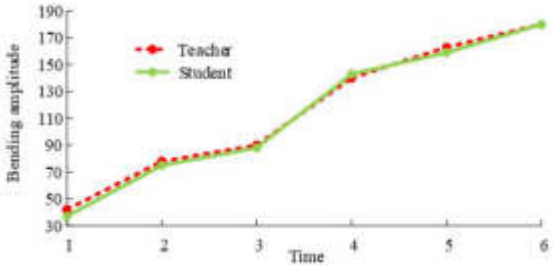
In Table 4.1, three different datasets were used to evaluate the performance of the model, including the four key metrics of accuracy, precision, recall, and F1 score. The accuracy of the model on the MSR dataset was 91.4%, with a slightly higher precision of 92.5%, meaning that 92.5% of all samples identified as positive cases were actually positive cases. The recall was 89.9%, indicating that the model could capture most of the actual positive cases. The F1 score, namely the harmonic average of accuracy and recall, was 91.2%, showing

Table 4.1: Performance evaluation

Datasets	Accuracy	Precision	Recall	F1 Score
MSR	0.914	0.925	0.899	0.912
UTK	0.858	0.87	0.835	0.852
Self-collection dataset	0.94	0.953	0.918	0.935



(a) Leg Range Comparison when shooting



(b) Arm Amplitude Comparison when shooting

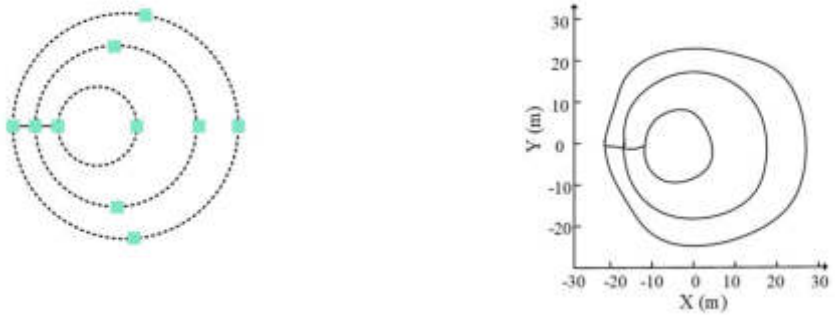
Fig. 4.4: Analysis of the action capture of the shooting action by teachers and students

that the model maintained a good balance between them. Compared to the MSR dataset, the performance on the UTK dataset was slightly lower, with 85.8% accuracy, 87.0% precision, 83.5% recall, and 85.2% F1 score. Finally, on the self-collection dataset, the model showed the highest performance with 94.0% accuracy, 95.3% precision, 91.8% recall and 93.5% F1 score. These results show that the model has high recognition accuracy on different datasets, especially on self-collection datasets.

In general, through comprehensive analysis of different models, although KNN is simple and easy to implement, it is limited by computational efficiency when dealing with large datasets, and its recognition performance is very sensitive to the size of selected neighbors. The SVM model performs well in high-dimensional spaces, especially for datasets with significant gaps, but when the datasets contain more overlap, the SVM's performance may decline, and its parameter adjustment process may be complicated.

4.2. Empirical analysis of the research model motion capture system. In online physical education, the human posture recognition system allows that student to understand the teacher's power points of certain movements from the data, three-dimensional, and other levels, instead of the traditional offline. This can be achieved through observation and thinking about the normality of the action by themselves. So the disassembly teaching process of shooting action in basketball training is chosen as the empirical evidence of motion capture. The experimental results are shown in Figure 4.4.

In Figure 4.4, the teacher's disassembly process of the shooting action and the time of student imitation are shown, disassembling the shooting posture for students to experience the change of body amplitude during shooting. By the two pose folds, the study utilized the limb tracking accuracy, namely the joint angle, as the algorithm performance index. In (a), for the change of leg bending amplitude between the teacher and the student during the shooting, the teacher's joint angle in the shooting demonstration was easier for the students to imitate and understand. And the students bent more than the teacher in the initial action, changed their subsequent posture in the middle of the shooting, and finally reached the same action with the teacher in the end, with an overall fit of more than 90%. In (b), for the change in arm bending amplitude during the shooting, the overall curve fit reached more than 96% because the arm bending was more easily perceived by themselves. Therefore, the above results show that the research improved pose recognition can separate the magnitude of the action, improve the anti-interference ability of the sensor, and accurately capture the correct motion pose.



(a) Travel estimation route map

(b) Body plane motion track

Fig. 4.5: Route walking experiment results

It not only has a higher accuracy rate but also has a lower error angle than the traditional pose recognition method, thus achieving accurate motion capture.

Figure 4.5 shows the verification of whether the studied human posture recognition system can correctly locate the human position and correctly capture the position according to the joint nodes. The study conducts experiments on the lasso route for the improved model, and from the experimental results. In Figure 4.5 (a), the proposed walking trajectory is shown, with the repeated action of walking a large circle from the starting point and then walking a small circle inward. Figure 4.5 (b) shows the simulation of the torso motion trajectory of the human posture recognition system for the human model. The range of movements captured by the research improved model was similar to the actual walking trajectory of the set of circles, showing that the research model could correctly identify the human body movements while effectively capturing the general path, and its accuracy of capture was high. The positional changes depicted were able to meet the teaching needs for teaching real-world simulations. In the comparative analysis, three key performance indicators, including learning satisfaction, learning effect, and teaching efficiency, were adopted to comprehensively evaluate the application effect of human posture recognition system in physical education teaching. Quantitative questionnaires were used to evaluate the results on a scale of 1 to 100, with higher scores indicating better results. Learning satisfaction reflects students' satisfaction with course content and teaching methods. Learning effect refers to the degree to which students absorb and master knowledge. Teaching efficiency focuses on the speed and effect from teachers on students' understanding and application of knowledge. Through this evaluation system, a single subject scored each indicator independently, and the scoring results were comprehensively compared according to the average values of the two groups of samples. This scoring mechanism is used in three different teaching scenarios: online physical education based on DTW and local image feature action recognition, traditional offline physical education, and online physical education supported by traditional pose recognition technology. The results of the analysis visually reveal the potential impact of various teaching methods on improving learning experience and outcomes. The comparison results are shown in Table 2.

From the scores of the three teaching methods through the two groups of experimental subjects in Table 4.1, the DWT algorithm and local image feature action recognition-based system scored higher in learning effect, learning satisfaction, and teaching effect than traditional offline education and traditional online teaching. The effect of absorbing knowledge in physical education class was better than the other two teaching methods. In the DWT algorithm and local image feature action recognition, the average learning satisfaction score of the two experimental groups was 95, the average learning effect score was 92, and the average teaching effect score was 93.5. The results show that the improved human posture recognition system is more effective for online physical education teaching, more popular among students than traditional offline physical education classes, and has better teaching effects and quality for teachers.

Table 4.2: Comparison of different teaching satisfaction

/	/	Research model	Offline teaching	Traditional online teaching
First group	Learning satisfaction	94	70	86
	Learning effect	91	78	84
	Teaching effectiveness	96	69	88
Second group	Learning satisfaction	90	72	87
	Learning effect	93	75	86
	Teaching effectiveness	91	71	89

Table 4.3: Algorithm comparison

Peculiarity	RM	KNN	SVM	DT	Instructions
Accuracy	0.914	0.88	0.9	0.85	The accuracy of this method on MSR dataset exceeds that of other systems, showing better recognition ability.
Real-time	Intermediate	High	Low	Intermediate	Although KNN has better real-time performance, this research method provides a balance of accuracy and response time.
Computational efficiency	High	Intermediate	High	Low	The method in this study uses efficient algorithm optimization, which makes the model run fast even on complex datasets.
Generalization	Strong	Intermediate	Strong	Weak	Through testing on multiple datasets, this method shows strong generalization ability.
Ability to handle complex movements	Outstanding	Good	Normal	Poor	This research improves the recognition ability of complex actions by introducing local features and deep learning techniques.
User adaptability	Strong	Weak	Intermediate	Intermediate	This research method performs well in user adaptability, adapting to learners with different body types and behavioral characteristics.
Ability to cope with occlusion situations	Strong	Weak	Strong	Normal	By combining various sensor inputs and advanced image processing technology, this method can better deal with the sight occlusion problem.
Complexity of experimental setup	Low	High	Strong	Low	Compared with KNN and SVM, this research method does not require complex experimental Settings and reduces the threshold of users in real application scenarios.
Expandability	High	Intermediate	Intermediate	Low	Due to the flexibility of the model architecture, this research method can be easily extended to different application scenarios and tasks.
Cost-effectiveness	High	Low	Intermediate	Intermediate	Considering the implementation cost and computing resources required, this research method provides a considerable cost-benefit ratio.

In the comparative analysis in Table 4.3, the pose recognition method achieved 91.4% accuracy on MSR dataset, which was better than 88.0% of SVM, 90.0% of KNN and 85.0% of DT. Although slightly inferior to SVM in terms of real-time performance, this method provided a balance of accuracy and response speed, reflecting a moderate compromise of real-time performance and accuracy in the recognition. The method also demonstrated strong generalization performance and robustness to motion occlusion, and surpassed DT in both user adaptability and ability to handle complex actions, proving its effectiveness in challenging environments. In addition, thanks to its low complexity experimental setup and high scalability, the cost effectiveness of the method in practical applications also showed competitiveness.

In summary, the pose recognition system in this study significantly improves student engagement by providing an immersive learning environment. Through virtual reality technology, the system allows students to

observe and imitate actions from a first-person perspective, creating a more interactive and interesting learning experience. In this way, students can more intuitively understand the correct posture and essentials of sports actions and get immediate simulation feedback, which greatly enhances the efficiency of content delivery. Students' satisfaction is improved not only because they are able to participate more actively in their learning, but also because they perceive a significant improvement in their personal skills.

5. Conclusion. VR technology has continuously come into the public's view. In education, teaching is a new way to effectively improve students' learning effects. To improve the effectiveness of online physical education teaching, the study proposed to integrate DWT and local image feature recognition into the human pose recognition system and applied the improved recognition system to online physical education courses. The experimental results show that the accuracy of the model can reach 91.4% in the public dataset MSR. In the UTK dataset, the model achieves 85.8% accuracy after 100 iterations. Compared with traditional recognition rates, the research model has effective convergence in the recognition of different human postures, and the recognition accuracy is significantly improved. Compared to the other two traditional pose recognition models, the research model has higher accuracy. The validation results compared with KNN and SVM are 62% and 71% as well as 79% and 84%, respectively, and the experimental results of the research model have improved by 9% and 5%. In the analysis of the disassembly of the shooting action, the degree of leg bending fit is more than 90%, the arm bending fit is more than 96%. The research with improved pose recognition can correctly separate the magnitude of the action and accurately capture the correct motion pose. If the improved system is applied to online physical education classes, all aspects of learning are better than traditional offline physical education classes, effectively improving teaching quality.

Despite the positive results of the study, there are certain limitations. For example, the real-time performance of current models may be limited when dealing with a large range of complex scenarios, especially in multi-user environments where performance has not been fully validated. In addition, the generality of the model across student groups of different ages and physical conditions still needs further study. In view of these limitations, in future work, the study plans to introduce more efficient algorithm optimization techniques, tests the model in a broader application field, and studies cross-population adaptation strategies. These measures are expected to provide strong support for improving the usability and popularization of the model.

Future research can be explored in the following directions. First, deep learning techniques have the potential to continue to improve the accuracy and real-time performance of gesture recognition. Especially, the latest neural network architectures are utilized to handle the recognition and prediction of complex movements. Second, the study of larger and more diverse data will help verify the generality and scalability of the model. In addition, empirical research on the psychological and cognitive impact of VR technology in education is also a necessary follow-up work, which will provide a deeper understanding and optimization direction for online physical education.

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EVALUATION METHOD OF COMPREHENSIVE ABILITY OF STUDENTS MAJORING IN PRESCHOOL EDUCATION BASED ON COMPUTER TECHNOLOGY

YUNFANG WEN*

Abstract. In order to improve the comprehensive ability evaluation effect of students majoring in preschool education, this paper combines computer technology to evaluate the comprehensive ability of students majoring in preschool education. Through linearization, this paper deduces the state space model of data load of students' comprehensive ability and the transfer function model of student's comprehensive ability data load. Moreover, this paper establishes an analytical expression between the model coefficients of the transfer function of student's comprehensive ability data load and the transfer parameters of student's comprehensive ability data load. In addition, this paper analyzes and selects the identification method of the parameters of students' comprehensive ability data load model. Since the parameters of the student comprehensive ability data load model have physical meanings, the parameter identification of the student comprehensive ability data load model is a gray box identification, and constraints are required when identifying the parameters of the student comprehensive ability data load model. The experimental study has verified that the comprehensive ability evaluation model of students majoring in preschool education based on computer technology can play an important role in the comprehensive ability evaluation of students majoring in preschool education. This article adopts the comprehensive load model in the Comprehensive Stability Calculation Program (PSASP) to eliminate the shortcomings of factor analysis in traditional teaching comprehensive evaluation, and has a certain reference value for the promotion of intelligent teaching in the future

Key words: computer technology; preschool education; students; comprehensive ability

Childhood is a very important period for human growth. Many potentials of human beings are stimulated in childhood. If this period is missed, the possibility of such potential stimulation will no longer exist. Therefore, it is no exaggeration to say that what a person masters in childhood can affect his life destiny [1]. Therefore, it is necessary to pay more and more attention to early childhood education, and to advocate scientific quality education for children to hope that children can improve their physical and mental quality in a healthy environment and scientifically cultivated, and then achieve the improvement of the quality of the entire nation. As we all know, art education is an indispensable part of quality education. Moreover, the great role of art education in cultivating people's moral sentiment, improving people's emotional character, and improving people's physical and mental quality is irreplaceable by other forms of education [2].

In the early childhood education system, which is increasingly valued by the people, scientific and efficient early childhood art education is very important for the healthy growth of the next generation and the overall improvement of physical and mental quality. Obviously, the success or failure of a kindergarten art education depends to a large extent on the comprehensive artistic quality of the kindergarten teachers themselves in each kindergarten. A child with high artistic ability, even if the child has a super high level of artistic talent, the future art prodigy may be strangled in the cradle by kindergarten teachers who do not understand art [3]. However, where does the comprehensive artistic quality of kindergarten teachers come from? Of course, it is the production and reserve base of preschool teachers—preschool education departments in colleges and universities and many preschool normal schools in various places. With the liberalization of the maternity policy, the demand for preschool teachers in various places is increasing, and the enrollment of preschool education majors in various schools is also increasing day by day [4].

Educational practice ability refers to the ability of educational subjects to apply theory to educational practice in a purposeful, planned and organized manner under the guidance of pedagogy, psychology and other theories, and to solve practical problems in education. Educational practice ability is a kind of ability that educators must have [5]. For preschool teachers, educational practice ability is the basic ability of preschool

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teachers to carry out preschool education activities, an important standard to measure the professional quality of preschool teachers, and an important basis for preschool teachers' post-service professional development. Therefore, preschool teachers must strengthen the cultivation of educational practice ability [6]. Many college-level colleges and universities have set up preschool education majors in order to cultivate skilled talents with early childhood education practical ability in response to the society's demand for preschool teachers. The preschool education major at the junior college level combines knowledge transfer and ability training to train students to be physically and mentally healthy, have good professional ethics, be proficient in the knowledge and skills required for the actual work of kindergartens, and have certain skills. Innovative ability, skilled application talents who can adapt to the needs of front-line work in kindergartens. Therefore, the preschool education major at the junior college level should give priority to cultivating students' educational practice ability [7].

Students majoring in preschool education must have good communication and coordination skills, including the ability to communicate with young children, the ability to communicate with parents of young children, and the ability to communicate with colleagues [8]. The ability to communicate with children means that students can have a good understanding of children's behavior and learning habits through scientific observation in educational practice, and can receive timely information such as expressions, language and physical behavior transmitted by children, so as to provide children with timely information. , accurate guidance or support; secondly, students are required to have good love, innocence and patience, care for and respect for children, which is a prerequisite for effective communication with children [9]: Third, students majoring in preschool education are required to have Communication skills for young children. In addition, due to the limitations of the language system, children may not be able to express themselves in language accurately and in an orderly manner. Students must also have good listening skills during educational practice, be good at listening, and use physical behaviors such as smiling and nodding to encourage children to express themselves and strengthen children. language ability. The ability to communicate with parents of young children refers to the ability of students to communicate with parents of young children in the process of preschool education practice activities: the ability to cooperate, requires students to have good oral expression skills, listening skills, and good communication skills or methods. And can use the Internet, home contact manuals or home visits to communicate with parents of young children. They are required to respect each other, understand each other, and help each other. At the same time, students are required to learn humbly in the process of practice and be good at listening to other children. Teachers' suggestions and opinions [10]. In addition, they should also actively participate in various academic seminars and teaching and research projects. Through communication and cooperation with other teachers in the project, they can not only improve their professional skills, but also enhance their relationship with colleagues, which will help Ding-professional development [11].

The organization and childcare ability of one-day activities refers to the ability of preschool education students to organize and arrange children's one-day activities in an orderly manner in the process of educational practice, so that various activities can be carried out smoothly, and at the same time, they can also smoothly carry out childcare work. Students majoring in preschool education must have good organizational skills in the process of educational practice. Organizational skills are the foundation of early childhood education. With good organizational skills, they can organize children's one-day activities well and ensure that one-day activities are carried out in an orderly manner. Improve the teaching effect [12]. Students majoring in preschool education must also have good safety and childcare ability in the process of educational practice, and have the ability to strengthen children's safety awareness and strengthen safety education through one-day activities, it is possible to predictably avoid some risk factors in activities [13].

The categories involved in the ability to create and utilize the environment mainly refer to the class environment in which kindergarten teachers work, and the ability requirements are also raised from the two aspects of creating a good spiritual environment and material environment, mainly including four basic contents: First, the ability to establish a good environment A good teacher-child relationship can help children establish a good peer relationship and make them feel warm and happy: second, it can establish class order and rules, create a good class atmosphere, and make children feel safe and comfortable; third, it can create a helpful environment It is an educational environment that promotes children's growth, learning, and games: Fourth, it can rationally use resources to provide and make suitable teaching aids and learning materials for children

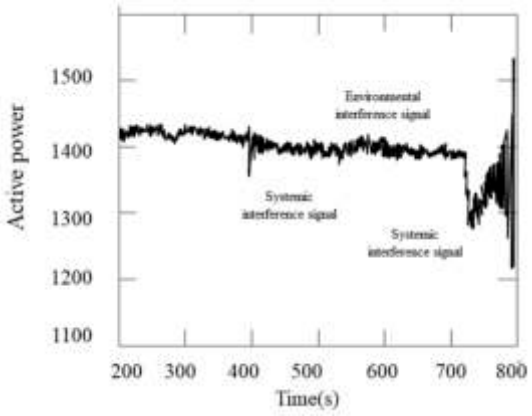


Fig. 1.1: Schematic diagram of system response signal and environmental interference signal

to trigger and support children's active activities [14].

Literature [15] believes that the educational practice ability of preschool education students at the junior college level includes interpersonal communication skills, organizational management skills. Literature [16] analysis skills according to the training objectives of preschool education majors at the junior college level. In the process of analysis, a talent training target framework was constructed. In this target framework, it is believed that the training targets are divided into five major items, of which the three items of knowledge, ability, practice and experience involve the educational practice ability of preschool education students at the junior college level. Competencies include environment creation and utilization, daily life organization and care, play activity support and care, educational activity planning and implementation, motivation and evaluation, and communication and cooperation, reflection and development; practice and experience include observing educational practice, participating in educational practice and researching educational practice.

The main contributions of this article are as follows: This article adopts the comprehensive load model in the Comprehensive Stability Calculation Program (PSASP) to eliminate the shortcomings of factor analysis in traditional teaching comprehensive evaluation, and has a certain reference value for the promotion of intelligent teaching in the future

This paper combines computer technology to carry out the comprehensive ability evaluation of students majoring in preschool education, and constructs an intelligent comprehensive ability evaluation model for students majoring in preschool education.

1. Preschool education data comprehensive processing algorithm.

1.1. PMU data characteristics and parameter identification method analysis. The online stability analysis based on the measured data is an effective method to solve the problem of the difficulty of stable calculation caused by the time-varying data of students' ability. However, the online stability analysis of student ability data faces the problem of inaccurate time-varying student ability data component models. Taking the load model as an example, it is a natural choice to collect the operational data of student ability data in real time to identify the load model online, which can meet the time-varying requirements of the load model. At the same time, more and more educational systems are equipped with PMU (Phasor Measurement Unit) devices, which help to obtain high-precision student ability data operation data (Figure 1.1). The operation data of student ability data collected by PMU is mainly stimulated by the following three signals: system response signal, environmental interference signal and artificial excitation signal.

1.2. PMU principal analysis. The functional block diagram of the PMU is shown in Figure 1.2. GPS receivers rely on the Global Positioning System to provide high-accuracy pulse-per-second (PPS) signals to data acquisition devices. The error between PPS and Coordinated Universal Time (UTC) is no more than $1/\mu s$, so the phasor angle error measured under the 50Hz power frequency is within 0.0180, and the synchro phasor

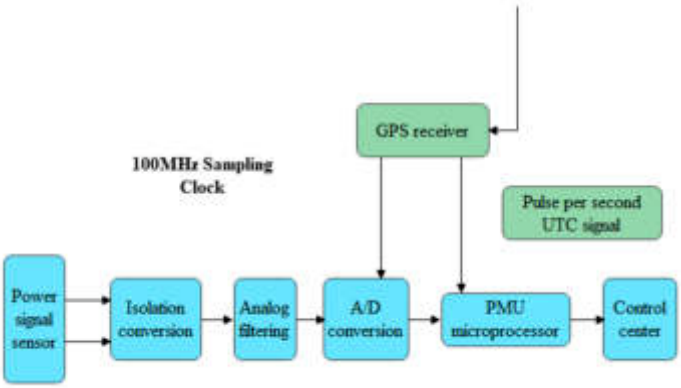


Fig. 1.2: PMU functional block diagram

measurement is realized. Next, the GPS receiver transmits the International Standard Time information to the data acquisition device. The signal used to sample the bus voltage is subjected to A/D conversion after isolation conversion and analog filtering, and the A/D converter controls data acquisition with a synchronous signal. The PMU microprocessor then continuously calculates new fundamental voltage and current phasors. Finally, the data is uploaded to the dispatch center through the high-speed communication channel.

The PMU device can provide accurate and detailed information for the real-time dynamic monitoring of the running status of the student ability data. The daily operation data of the student ability data collected by the PMU has the following three characteristics:

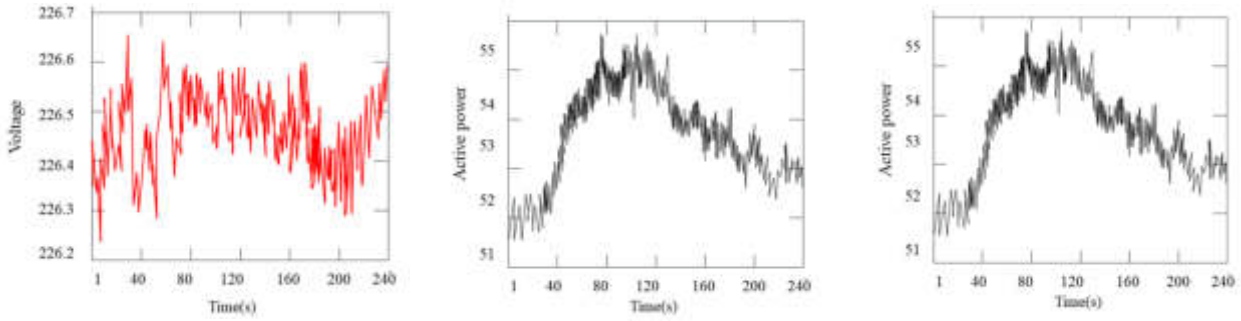
1. High accuracy. The PMU device uses the unified time of GPS timing to collect data, and the synchronization accuracy between each PMU device is high, which facilitates the comparison and analysis of the wide-area education system. In addition, the sampling frequency of the PMU is 25 frames, that is, a sampling value every 40ms. The high sampling frequency enables the PMU to record the dynamic information of the educational system in detail.
2. Large amount of data. When the PMU is installed in the educational system, the data collected by the PMU includes important parameters such as date, time (accurate to milliseconds), and synchrophasors of the educational system. Therefore, the amount of data collected and stored by the PMU is very large, and these data need to be preprocessed and selected during load modeling.
3. Small data fluctuations. Figure 1.3 is a schematic diagram of the voltage amplitude, active power and reactive power collected by the PMU installed in the educational system. It can be seen from Figure 1.3 that the maximum fluctuation of the voltage amplitude during the daily operation of the student ability data is 0.2%, and the fluctuation of the voltage amplitude is very small and changes all the time. The active power and reactive power response fluctuate around 6%, and have the same trend of change. Therefore, the signal-to-noise ratio of the small disturbance data measured by the PMU is low, which will affect the load modeling accuracy.

1.3. Hardware system. This paper adopts the comprehensive load model in the Comprehensive Stability Calculation Program (PSASP program), which consists of an equivalent static ZIP load and an equivalent motor in parallel. The equivalent circuit is shown in Figure 1.4:

The differential equations are shown in equations (1.1) to (1.3).

$$\frac{ds}{dt} = \frac{T_M - T_E}{T_J} \tag{1.1}$$

$$\frac{dE_d^{'}}{dt} = \frac{\left(X - X^{'}\right) I_q + T_{d0}^{'} E_q^{'} s - E_d^{'}}{T_{d0}^{'}} \tag{1.2}$$



(a) The voltage amplitude collected by the PMU

(b) Active power amplitude collected by PMU

(c) Amplitude of reactive power collected by PMU

Fig. 1.3: Schematic diagram of the data collected by the PMU

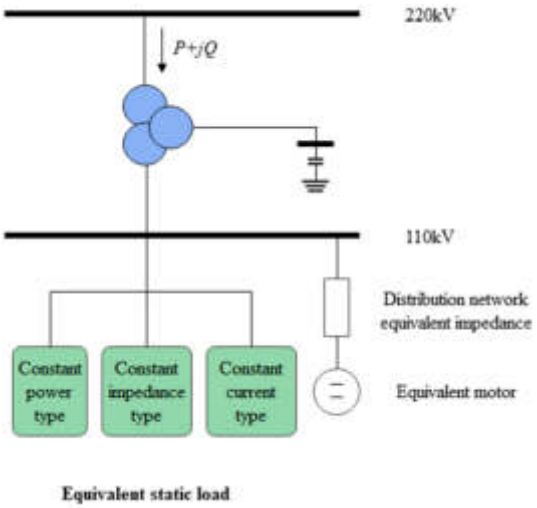


Fig. 1.4: The comprehensive load model used in this paperm

$$\frac{dE_q^{'}}{dt} = \frac{\left(X - X^{'}\right) I_d + T_{d0}^{'} E_d^{'} s - E_q^{'}}{T_{d0}^{'}} \tag{1.3}$$

In the equation, the mechanical load torque and electromagnetic torque equations are shown in equation (1.4) and equation (1.5), respectively.

$$T_M = K_L \left[\alpha + (1-\alpha)(1-s)^p\right] \tag{1.4}$$

$$T_E = -R_e(\dot{E}, \hat{I}) K_p = -\left(E_d^{'} I_d + E_q^{'} I_q\right) K_p \tag{1.5}$$

In the above equations,

$$X^{'} = X_s + \frac{X_r X_m}{X_s + X_m} \tag{1.6}$$

$$X = X_s + X_m \tag{1.7}$$

$$X_m = T_{d0}^{'} R_r - X_r \tag{1.8}$$

K_L is the load rate coefficient of the asynchronous motor, and Kz is the coefficient that converts the impedance of the base value of the unit itself into the impedance of the base value of the coefficient in the equivalent circuit. K_p is the coefficient for converting the standard value of the system base value into the standard value of the base value of the motor itself. The active power and reactive power of the motor can be expressed as follows,

$$P_m = T_E = -\left(E_x{}' I_x + E_y{}' I_y\right) \tag{1.9}$$

$$Q_m = V_y I_x - V_x I_y \tag{1.10}$$

Its form is shown in equations (1.11) and (1.12).

$$P_s = P_Z^* \left(V/V_0\right)^2 + P_I^* \left(V/V_0\right) + P_P^* \tag{1.11}$$

$$Q_s = Q_Z^* \left(V/V_0\right)^2 + Q_I^* \left(V/V_0\right) + Q_P^* \tag{1.12}$$

In the equation, V_0 represents the load node voltage at the equilibrium point.

In the case of small disturbance, the fluctuation of mechanical torque T_M is small, so the torque T_M is assumed to be a constant value in this paper. After linearizing equations (1.1) and (1.12), the state space model of the load can be obtained:

$$\begin{gathered} \dot{x}(t) = Ax(t) + Bu(t) + Le(t) \\ y(t) = Cx(t) + Du(t) \end{gathered} \tag{1.13}$$

In the formula, $u(t) = [\Delta V \Delta\theta], y(t) = [\Delta P \Delta Q]$, the state variable is $x(t) = \left[?E_x' ?E_y' ?s\right]$, and $?e(t)$ is the noise vector. The matrices A, B, C, D are shown below:

$$\begin{aligned} \boldsymbol{A} &= \begin{bmatrix} \frac{-X}{XT_{d0}'} s_0 E_{y0}' \\ -s_0 \frac{-X}{XT_{d0}'} - E_{x0}' \\ -V_0 \sin(\theta_0) \frac{V_0 \cos(\theta_0)}{X^2 T_j} 0 \end{bmatrix}, \\ \boldsymbol{C} &= \begin{bmatrix} \frac{V_0 \sin(\theta_0)}{X'} \frac{-V_0 \cos(?_0)}{X'} 0 \\ \frac{-V_0 \cos(\theta_0)}{X'} - \frac{V_0 \sin(\theta_0)}{X'} 0 \end{bmatrix} \end{aligned} \tag{1.14}$$

$$\boldsymbol{B} = \begin{bmatrix} \frac{X-X'}{XT_{d0}'} \cos(\theta_0) & -\frac{X-X'}{XT_{d0}'} \sin(\theta_0) V_0 \\ \frac{X-X'}{XT_{d0}'} \sin(\theta_0) & \frac{X-X'}{XT_{d0}'} \cos(\theta_0) V_0 \\ -\frac{E_{x0}'}{XT_j} \sin(\theta_0) + \frac{E_{y0}'}{XT_j} \cos(\theta_0) - \frac{E_{x0}' V_0}{XT_j} \cos(\theta_0) - \frac{E_{y0}' V_0}{XT_j} \sin(\theta_0) \end{bmatrix} \tag{1.15}$$

$$\boldsymbol{D} = \begin{bmatrix} \frac{E_{x0}'}{X'} \sin(\theta_0) - \frac{E_{y0}'}{X'} \cos(\theta_0) + \frac{2P_z^*}{V_0} & \frac{E_{x0}' V_0}{X'} \cos(\theta_0) + \frac{E_{y0}' V_0}{X'} \sin(\theta_0) \\ \frac{2V_0 - E_{x0}' \cos(\theta_0) - E_{y0}' \sin(\theta_0)}{X'} + \frac{2Q_z{}^\circ}{V_0} & \frac{E_{x0}' V_0 \sin(\theta_0) - E_{y0}' V_0 \cos(\theta_0)}{X'} \end{bmatrix} \tag{1.16}$$

There are five parameters related to the equilibrium point in the formula, which are respectively s_0, E'_{x0}, E'_{y0}, θ_0, V_0. Among them, θ_0 and V_0 are determined by the mean of $\theta(k)$ and $V(k)$. Since the linearization of the load is related to the equilibrium point, there are 9 load transient parameters to be identified, which are P_z^*,$Q_z^*, X, X', T'_{d0}, T_j, s_0, E'_{x0}, E'_{y0}$.

Since the measured data of the PMU mainly include voltage amplitude, active power and reactive power, this paper simplifies the above load model into a single-input dual-output model of $u = [\Delta V, y = [\Delta P \Delta Q]$, and sets $\theta_0 = 0$. Therefore, the load state space model matrix $ABCD$ can be simplified as:

$$\boldsymbol{A} = \begin{bmatrix} \frac{-X}{X'T'_{d0}} & s_0 & E'_{y0} \\ -s_0 & \frac{-X}{XT'_{d0}} & -E'_{x0} \\ 0 & \frac{V_0}{XT_j} & 0 \end{bmatrix}, \boldsymbol{C} = \begin{bmatrix} 0 & \frac{-V_0}{X'} & 0 \\ \frac{-V_0}{X'} & 0 & 0 \end{bmatrix} \tag{1.17}$$

$$\boldsymbol{B} = \begin{bmatrix} \frac{X-X'}{XT'_{d0}} \\ 0 \\ \frac{E'_{y0}}{XT_j} \end{bmatrix}, \boldsymbol{D} = \begin{bmatrix} -\frac{E'_{y0}}{X'} + \frac{2P_z^*}{V_0} \\ \frac{2V_0 - E'_{x0}}{X'} + \frac{2Q_z}{V_0} \end{bmatrix} \tag{1.18}$$

The load state space model is converted into a load transfer function model, and the expression of the load transfer function model is shown in equation (1.19).

$$\begin{aligned} \Delta P &= \frac{b_{0p}s^3 + b_{1p}s^2 + b_{2p}s + b_{3p}}{s^3 + a_1 s^2 + a_2 s + a_3}\Delta V + H_1 \Delta e \\ \Delta Q &= \frac{b_{0q}s^3 + b_{1q}s^2 + b_{2q}s + b_{3q}}{s^3 + a_1 s^2 + a_2 s + a_3}\Delta V + H_2 \Delta e \end{aligned} \tag{1.19}$$

In the formula, Δe is the noise, and H_1 and H_2 are the noise transfer functions of active power and reactive power, respectively. The coefficients of the terms are shown in equations (1.18) and (1.19).

$$a_1 = \frac{2X}{XT_{d0}{}'}, a_2 = s_0^2 + \frac{X^2}{X^2 T'^2_{d0}} + \frac{V_0 E_{x0}{}'}{XT_j}, a_3 = \frac{V_0 E_{x0}{}' X}{X^2 T_{d0}{}' T_j} + \frac{V_0 E_{y0}{}' s_0}{XT_j} \tag{1.20}$$

$$\begin{aligned} b_{0p} &= \frac{2P_z^{\cdot}}{V_0} - \frac{E_{y0}{}'}{X'}, b_{1p} = \frac{4XP_z^*}{XT_{d0}{}'V_0} - \frac{2XE_{y0}{}'}{X'^2 T_{d0}{}'}, b_{3p} = \frac{2E_{x0}{}'P_z^0 X}{X'T_{d0}{}'T_j} + \frac{2E_{y0}{}'s_0 P_z^{\cdot}}{XT_j} \\ b_{2p} &= -\frac{X^2 E_{y0}{}'}{X'^3 T_{d0}^2} + \frac{2X^2 P_z^{\cdot}}{X'^2 T'^2_{d0} V_0} + \frac{V_0 s_0 X}{X'^2 T_{d0}{}'} + \frac{2E_{x0}{}'P_z^{\cdot}}{XT_j} - \frac{V_0 s_0}{XT_{d0}{}'} - \frac{s_0^2 E_{y0}{}'}{X'} + \frac{2s_0^2 P_z^*}{V_0} \end{aligned} \tag{1.21}$$

$$\begin{aligned} b_{0q} &= \frac{2V_0 - E_{x0}{}'}{X'} + \frac{2Q_Z^*}{V_0}, b_{1q} = \frac{\left(3V_0 - 2E_{x0}{}'\right)X}{X'^2 T_{d0}{}'} + \frac{4Q_Z^* X - 1}{XT_{d0}{}'V_0} \\ b_{2q} &= \frac{\left(V_0 - E_{x0}{}'\right)X^2}{X'^3 T'^2_{d0}} + \frac{2Q_Z{}'X^2}{X'^2 T'^2_{d0} V_0} + \frac{V_0 X}{X'^2 T'^2_{d0}} - \frac{\left(E'^2_{x0} + E'^2_{y0}\right)V_0}{X'^2 T_j} \\ &\quad + \frac{2\left(V_0^2 + Q_Z{}'\right)E_{x0}{}'}{X_j T_j} + \frac{\left(2V_0 X' - E_{x0}{}'\right)s_0^2}{X'} + \frac{2Q_2^* s_0^2}{V_0} \\ b_{3q} &= \frac{E_{x0}{}'V_0^2 X}{X'^3 T_{d0}{}'T_j} - \frac{\left(E'^2_{x0} + E'^2_{y0}\right)V_0 X}{X'^3 T_{d0}{}'T_j} + \frac{E_{x0}{}'V_0^2}{X'^2 T_{d0}{}'T_j} + \frac{2Q_Z{}'E_{x0}{}'X}{XT_{d0}{}'T_j} + \frac{2\left(V_0^2 + Q_Z^*\right)E_{y0}{}'s_0}{XT_j} \end{aligned} \tag{1.22}$$

Among them, $b_{1p} = b_{0p} \times a_0, b_{3p} = (2a_3 \times P^*)/V_0$, so (1.18) $\sim$ (1.19) can be simplified into 9 equations, the load transient parameters can be used to solve the 9 load transient parameters to be identified: $P^{*2}, Q_z^*, X, X', T_{d_0}{}', T_j, s_0, E_{x0}{}', E_{y0}{}'$.

1.4. Analysis of parameter identification method. In the overall measurement and identification method, the commonly used load model parameter identification methods are based on the system identification theory, and there are many methods. Only by selecting a system identification method suitable for the characteristics.

System identification is to establish a mathematical model describing the dynamic behavior of the system based on the input and output time functions of the system. Figure 1.5 shows the principle of system identification.

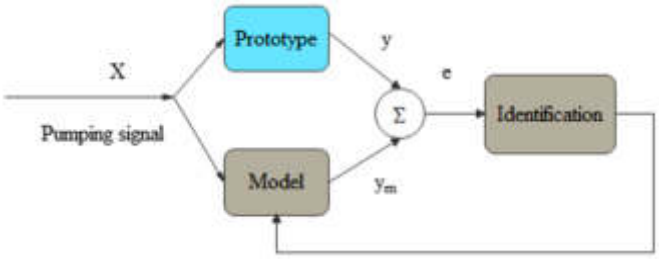


Fig. 1.5: Schematic diagram of system identification

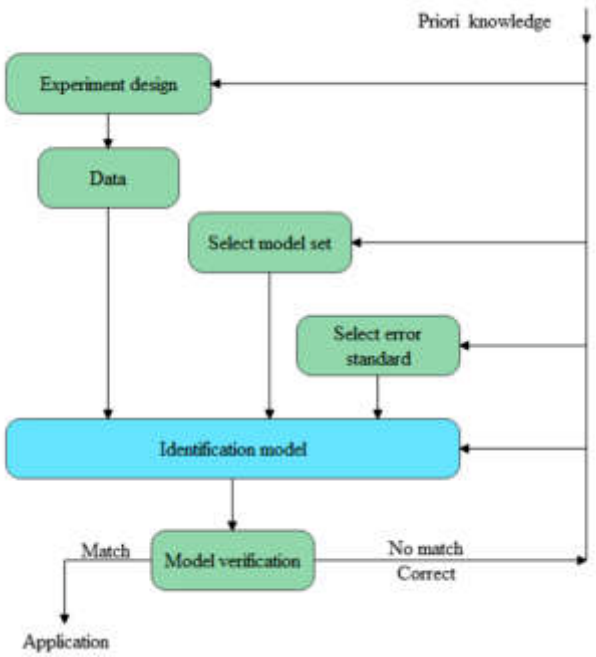


Fig. 1.6: System identification flow chart

Under the action of the same excitation signal x, the real model and the identified model generate the output response Y of the actual system and the output response ym of the identified model, respectively. The error e is obtained by comparing Y and ym, and then the model parameters are corrected through the optimization algorithm until the error e meets the accuracy requirements. Specifically, firstly, according to the prior knowledge, the identification experiment is designed, the identification data set is selected, the model structure is determined, and the error accuracy standard is selected. Then, the unknown parameters in the model are identified through the input and output data, and finally the applicability of the model is checked. The detailed system identification process is shown in Figure 1.6.

From the process of system identification, it is concluded that three kinds of information need to be set in advance to identify a model, namely data set, model set and model parameter identification method.

$$y(t) + a_1 y(t-1) + \cdots + a_n y(t-n) = b_1 u(t-1) + \cdots + b_m u(t-m) \tag{1.23}$$

We use a discrete-time model, mainly because the measured data is usually collected by sampling, so the connection between the sampled measured data and the discrete-time model is more direct. Equation (1.20) is

converted into the form of equation (1.21), and the next output value is determined by the measured input and output values. Equation (1.21) is also more practical.

$$y(t) = -a_1 y(t-1) - \cdots - a_n y(t-n) + b_1 u(t-1) + \cdots b_m u(t-m) \tag{1.24}$$

Equation (1.21) is written in the form of a vector:

$$y(t) = \phi^T(t)\theta \tag{1.25}$$

In the formula,

$$\phi(t) = [-y(t-1), \cdots, -y(t-n), u(t-1), \cdots, u(t-m)]^T \tag{1.26}$$

$$\theta = [a_1, \cdots, a_n, b_1, \cdots, b_m]^T \tag{1.27}$$

We assume a given system in which the value of the parameter θ is unknown, but there are input and output measurements $Z^N = \{u(1.1), y(1.1), \cdots, u(N), y(N)\}$ of the system at time $1 \le t \le N$. By optimizing the parameter θ, the calculated model output $\hat{y}(t,\theta)$ fits the measured output value $y(t,\theta)$ as much as possible, which is the core idea of the least squares method. The mathematical expression is shown in formula (1.25).

$$V_N\left(\theta, Z^N\right) = \frac{1}{N}\sum_{t=1}^{N}[y(\mathrm{t}) - \hat{\mathrm{y}}(\mathrm{t},\theta)]^2 = \frac{1}{N}\sum_{t=1}^{N}\left[y(\mathrm{t}) - \phi^T(\mathrm{t})\theta\right]^2 \tag{1.28}$$

In the formula, $V_M\left(\theta, Z_N\right)$ is the loss function. It should be noted that the loss function of the least squares method has no physical meaning, this choice is because the loss function is easy to calculate and easy to understand. The parameter obtained by minimizing the loss function $V_N\left(\theta, Z_N\right)$ is denoted as $\hat{\theta}_N$.

$$\hat{\theta}_N = \arg\min V_N\left(\theta, Z^N\right) \tag{1.29}$$

Since $V_N\left(\theta, Z_N\right)$ consists of the squared term of the parameter θ, the parameter can be solved by setting the derivative of $V_N\left(\theta, Z_N\right)$ to zero, that is:

$$0 = \frac{d}{d\theta}V_N\left(\theta, Z^N\right) = \frac{2}{N}\sum_{t=1}^{N}\phi^T(t)\left[y(t) - \phi^T(t)\theta\right] \tag{1.30}$$

The estimated value of the obtained parameter θ is shown in formula (1.31):

$$\hat{\theta}_N = \left[\sum_{t=1}^{N}\phi(t)\phi^T(t)\right]^{-1}\sum_{t=1}^{N}\phi^T(t)y(t) \tag{1.31}$$

According to the principle of linear algebra, equation (1.31) has a unique solution if and only if the matrix $\sum_{t=1}^{N}\phi(t)\phi^T(t)$ is non-singular, which is also the identifiable condition of the least squares method.

The least squares method is greatly affected by the perturbation level when applied. Otherwise, as the perturbation level increases, even if the order of the model is correct, the estimated value of the least squares method is biased. Therefore, to solve this problem, one way is to use a higher-order model, but the higher-order model may not match the real model and may appear numerically unstable. Therefore, the improved least squares method can be used to improve the accuracy of model identification. The improved least squares method includes pre-technical error method, output error method, auxiliary variable method and so on. Among these methods, the most widely used is the forecast error method.

The model expressed by equation (1.20) is improved, and the model is extended to the ARMAX model with noise model, and the unit forward operator q and the unit delay operator q^{-1} are introduced, which are

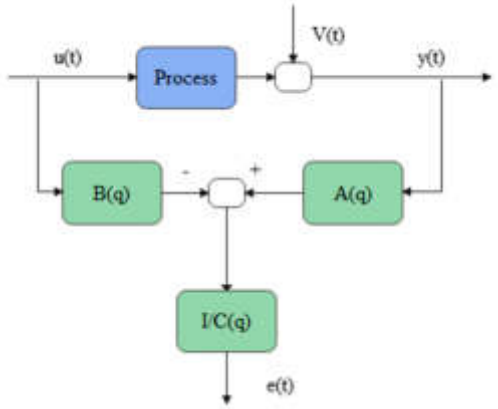


Fig. 1.7: The generation process of the forecast error method error

$qu(t) = u(t+1), q^{-1}u(t) = u(t-1)$ respectively. We set $A(q) = 1 + \sum_{k=1}^{n} a_k q^{-k}, B(q) = \sum_{k=1}^{m} b_k q^{-k}, C(q) = 1 + \sum_{k=1}^{m} c_k q^{-k}$, and the difference equation model is shown in equation (1.32).

$$y(t) = [1 - A(q)]y(t) + B(q)u(t) + C(q)e(t) \tag{1.32}$$

That is,

$$y(t) = \frac{B(q)}{A(q)}u(t) + \frac{C(q)}{A(q)}e(t) = G(q)u(t) + H(q)e(t) \tag{1.33}$$

Among them, e(t) is white noise. $v(t) = H(q)e(t), v(t)$ is the colored noise after the white noise is filtered by the filter H(q). According to the principle of conditional probability, the single-step prediction value of the above model is shown in equation (1.34).

$$\begin{aligned} \hat{y}(t|t-1) &= G(q)u(t) + \hat{v}(t|t-1) \\ &= H^{-1}(q)G(q)u(t) + \left[1 - H^{-1}(q)\right] y(t) \end{aligned} \tag{1.34}$$

Then the prediction error is equation (1.35).

$$y(t) - \hat{y}(t|t-1) = -H^{-1}(q)G(q)u(t) + H^{-1}(q)y(t) = e(t) \tag{1.35}$$

e(t) represents the part of the output y(t) that cannot be predicted from the data before time t-1. Figure 1.7 is the generation process of forecast error.

Therefore, the model parameters can be obtained by minimizing the loss function of equation (1.36).

$$V_{PEM} = \frac{1}{N}\sum_{t=1}^{N}\left[H^{-1}(q)y(t) - G(q)H^{-1}(q)u(t)\right]^2 \tag{1.36}$$

It is worth noting that the consistency of the forecast error method is premised on the loss function reaching the global minimum value. However, this requirement is generally difficult to meet in actual situations. In more cases, the loss function reaches a local minimum value, so the obtained model parameters are the local optimal solution.

2. System design. First, this paper constructs a comprehensive ability assessment system for students majoring in preschool education. The database of this system is divided into the central database and the front database. The central database is responsible for storing courseware information, test information, homework

information, and test question information related to teachers, class information, teacher information, and student information related to school administrators, and test question information, knowledge point information, and video information related to system administrators, workbook question information, system administrator information, school information and school administrator information related to teachers. The front-end database is responsible for storing the data generated in the school classroom (information related to students' quizzes and information related to student attendance).

The system environment mainly involves the development environment and application environment. According to the system plan, the server is divided into a central database server and various pre database servers named after the school name. Each front-end database server implements load balancing. When the network between the central database server and the front-end database server cannot be connected, it will not affect the use of the school, avoiding a single point of failure of the database server

The system consists of three types of users: teachers, school administrators, and system administrators. Three types of users log in to the teacher system, school management system, and system management system, respectively.

In the system, information query business is equally important. In order to facilitate user use, different query methods such as combination query, fuzzy query, and precise query are provided according to the actual business

Data statistics are presented to users in the form of data visualization, allowing them to view the corresponding data intuitively, quickly, and efficiently. Data statistics are generated by collecting and calculating corresponding data.

Software architecture and database design have been determined. According to the three different types of users: teachers, school administrators, and system administrators, the system is divided into three subsystems: teacher system, school administrator system, and system administrator system, so that the functions of the subsystems are relatively centralized and there is relative independence between the subsystems. Database design includes conceptual model design and logical model design, and the construction of the database is completed through the principles of process iteration and gradual refinement.

The system adopts a three-layer framework based on SpringMVC, achieving low code coupling and componentization design. The separation and interdependence between the presentation layer and the business logic layer make web applications easier to modify and maintain. Separating the business layer from the data access layer can improve code reusability. Layering the code facilitates system code refactoring while laying the foundation for future distributed deployment of the system.

The task of conceptual structure design is to abstract it into a data model that does not depend on any machine according to a specific method on the basis of the requirements specification jointly confirmed by users and system personnel. The purpose of conceptual model design is to synthesize the user's data requirements into a unified model based on the results of the analysis of the requirements of a specific system. The entity relationship diagram (E-R diagram) is shown in Figure 2.1.

Teaching evaluation section code:

```
Document. querySelectorAll ("[djdm='01 ']"). forEach() (item)=>item. click());
SetTimeout (document. querySelector (". but20"). click());
Code for textbook evaluation section:
Var list9=Array. from (document. querySelectorAll ("[value='9.2 ']"));
Var list4=Array. from (document. querySelectorAll ("[value='4.6 ']"));
Var list=list9. concat (list4);
List. forEach (item=>{
Item. click();
});
SetTimeout (document. querySelect ("[type='submit ']"). click(), 1000);
```

Figure 2.2 describes the process steps for teacher users to view students' historical test scores, select the semester to be searched in the drop-down box of the semester, and then select the subject to be searched in the drop-down box of the subject. Then, the teacher selects the class to be searched in the drop-down box of the

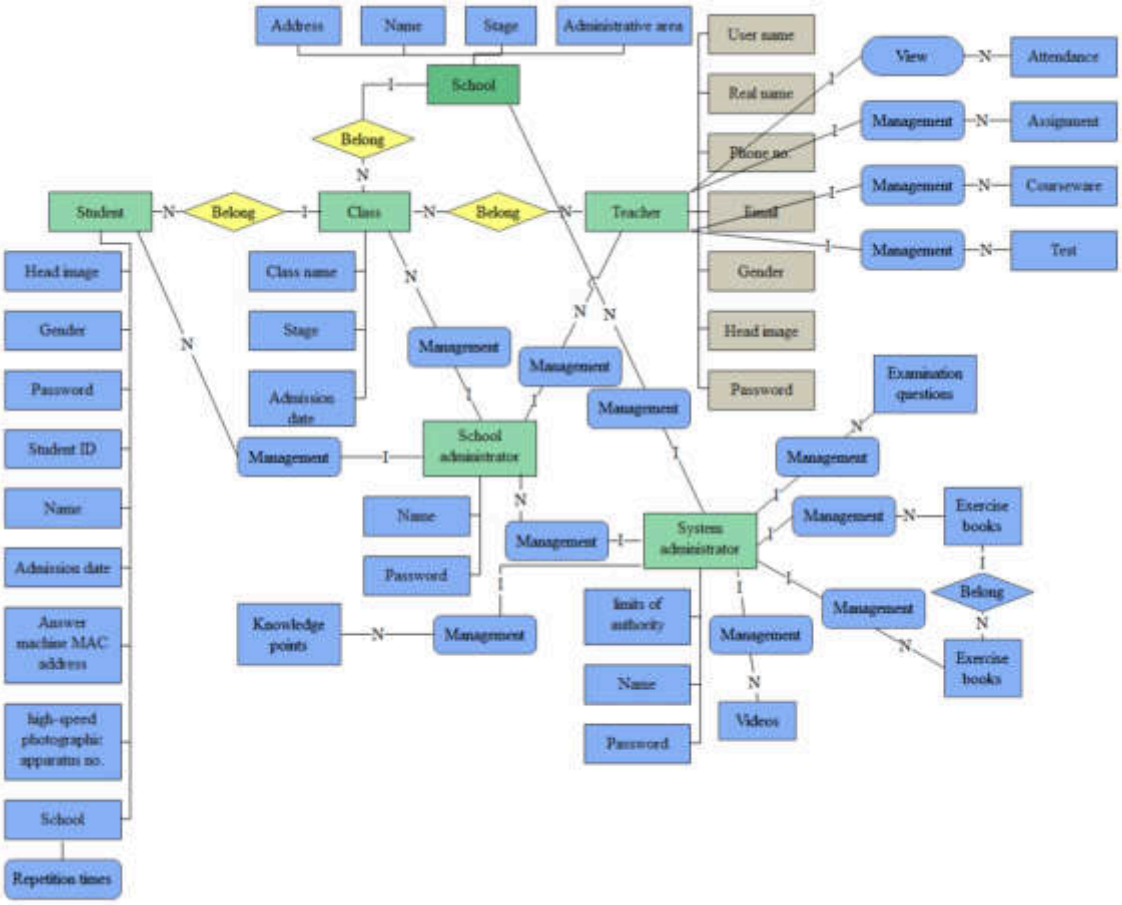


Fig. 2.1: Database conceptual model

class, selects the student number to be searched in the drop-down box of the student, and finally clicks search, and the page displays the line graph of the student's historical test scores.

The effect evaluation of the comprehensive ability evaluation model of students majoring in preschool education based on computer technology is carried out.The main source of data for this article is to validate the model through investigation and analysis. Using actual teaching data from multiple preschool education schools as input data, a total of 150 sets of data were obtained. After removing 6 sets of invalid data, 72 sets were used as training data, and the other 72 sets were used as experimental data. The results of the model obtained in this article were compared with the experimental data, and the evaluation results were quantitatively scored, and the final statistical test results are shown in Figure10 and Table 2.1.

From the above evaluation data, it can be seen that the average love results of the model in this article are quantitatively distributed between [79,90], and the evaluation results are relatively high, which is in line with the expected construction of the model in this article.Through the above research, it is verified that the comprehensive ability evaluation model of students majoring in preschool education based on computer technology can play an important role in the comprehensive ability evaluation of students majoring in preschool education.

3. Conclusion. At present, the overall artistic quality of kindergarten teachers is generally not high, and there is a big gap with the demand for art practice in kindergartens. This has a lot to do with the relative lag in the reform of preschool education majors in colleges and universities that train preschool teachers, and

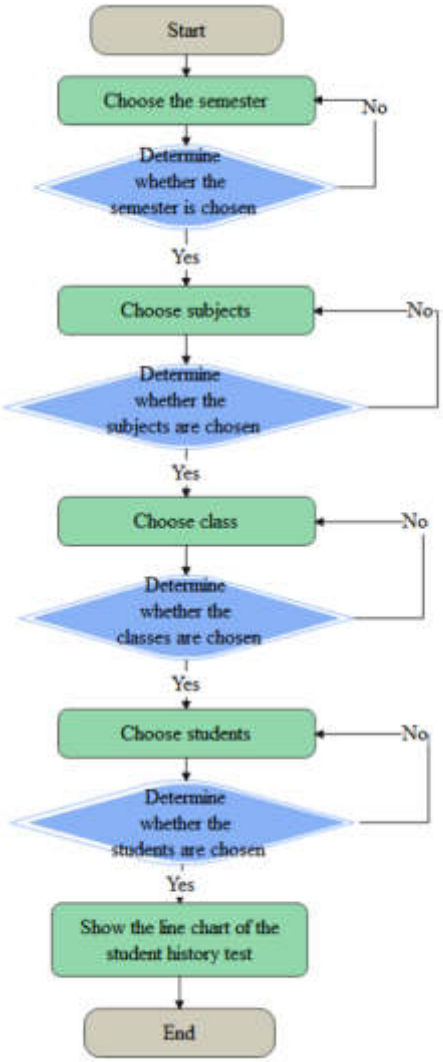


Fig. 2.2: The flow chart of viewing the student's comprehensive test scores and the line graph of each test scorem

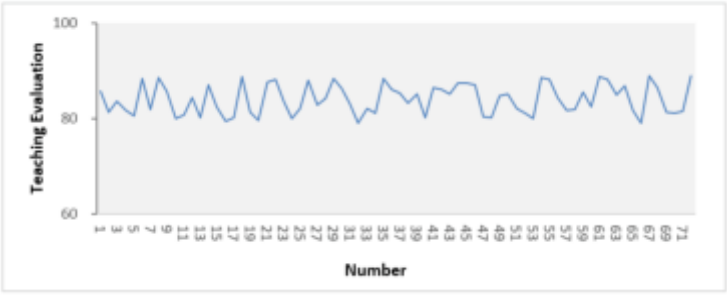


Fig. 2.3: Statistical chart of model evaluation results

Table 2.1: The effect evaluation of the comprehensive ability evaluation model for students majoring in preschool education based on computer technology

Number	Teaching Evaluation	Number	Teaching Evaluation	Number	Teaching Evaluation
1	85.813	25	82.184	49	84.875
2	81.312	26	88.002	50	85.216
3	83.661	27	82.920	51	82.083
4	81.787	28	84.257	52	81.116
5	80.623	29	88.350	53	79.968
6	88.386	30	86.353	54	88.633
7	81.986	31	83.044	55	88.124
8	88.593	32	79.085	56	84.384
9	85.787	33	82.084	57	81.708
10	80.126	34	81.166	58	81.869
11	80.747	35	88.407	59	85.535
12	84.322	36	86.201	60	82.460
13	80.192	37	85.289	61	88.711
14	87.061	38	83.183	62	88.234
15	82.474	39	85.141	63	84.983
16	79.393	40	80.231	64	86.818
17	80.161	41	86.518	65	81.673
18	88.867	42	86.067	66	79.179
19	81.400	43	85.173	67	88.887
20	79.739	44	87.444	68	86.555
21	87.578	45	87.393	69	81.341
22	88.142	46	87.019	70	81.275
23	83.728	47	80.343	71	81.489
24	80.125	48	80.192	72	88.996

the lack of emphasis on educational goals and practical effects. The pedagogy, psychology and professional theory courses offered by preschool education departments in colleges and universities have problems such as being too old in content and not closely related to the practice of kindergarten art teaching. Secondly, the professional and technical courses offered by the preschool education major are too specialized, and cannot be smoothly integrated with the comprehensive artistic characteristics and the technical needs of children's artistic characteristics in the practice of kindergarten art teaching. All of these are the biggest obstacles to the smooth improvement of the comprehensive quality and teaching practice ability of students majoring in preschool education. This paper combines computer technology to carry out the comprehensive ability evaluation of students majoring in preschool education, and builds a comprehensive ability evaluation model for intelligent preschool professional education students. The experimental research results verify that the comprehensive ability evaluation model of students majoring in preschool education based on computer technology can play an important role in the comprehensive ability evaluation of students majoring in preschool education.

As the amount of data in the system continues to increase, more data mining techniques are used to improve and optimize algorithms for analyzing student abilities, making them more accurate. Dig out potential and valuable information from massive amounts of data. For example, combining data mining techniques to analyze the teaching achievements of teachers to optimize their teaching plans, improve their teaching abilities, and further optimize the overall team of teachers; By analyzing the amount of big data for students, personalized assignments are developed and learning suggestions are provided.

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SVM-BASED SUPPORT VECTOR TYPE RECOGNITION MACHINE FOR SMART THINGS IN SOCCER TRAINING MOTION RECOGNITION

SHOUWEI WANG*

Abstract. With the development of IoT technology, machine learning, and other artificial intelligence technologies, there have been many related technologies applied to the sports industry. Soccer, as the world's number one sport, has a wide range of popularity, a high degree of attention, and a high degree of commercialization. In the traditional soccer training action recognition methods, there is insufficient collection and in-depth profiling of real data, and what is not available is soccer movement action capture and recognition based on kinematic knowledge To address the above shortcomings, this study designs a Support Vector Machine SVM-based intelligent IoT-type soccer training movement recognition and evaluation framework, and constructs a machine learning algorithmic model to recognize, evaluate and analyze soccer training movements. Common feature extraction methods are suitable for recognizing most monotonous movements, but soccer movements are highly variable and athletes' ankle movements are flexible and changeable. The actual acquired soccer data streams are noisy and the data patterns are not obvious, and the performance of the model to recognize the data will be degraded. To extract the effective feature values in the complex data stream and improve the correct degree of pattern recognition, the classification pattern of attitude angle type solving + SVM classification algorithm is constructed. The experimental results show that the designed algorithmic pattern based on the posture angular pattern solving + SVM classification algorithm pattern for soccer training movement recognition can reach 90% accuracy in recognizing different movements, which is extremely suitable for the recognition of soccer training movements.

Key words: smart internet of things; soccer ball movement recognition; stance angular pattern; SVM

1. Introduction. The new era of communication and information technology is becoming more and more developed, and the application of intelligent Internet of Things-type technology is becoming more and more widespread [1] . Its application field involves industry, agriculture, transportation, and other infrastructure fields, effectively promoting the intelligent development of various industries [2]. In contrast, the application of IOT technology in sports is still in the primary exploration stage. Combining intelligent IOT technology and machine learning algorithms to realize human-machine and human-network system-human interaction using inertial sensor-based motion capture has become an international cutting-edge research hotspot involving a high degree of multidisciplinary crossover and knowledge integration [3, 4] .The researchers have been working hard to realize the human-machine interaction using inertial sensor-based motion capture.

As the No. 1 sport in the world, soccer is widely popular, highly regarded, and commercialized. With the acceleration of urbanization in China, people's living standards and quality are improving, and the number of people who participate in soccer in their daily lives is also increasing [2]. In this context, there exists a great application demand and development potential for combining intelligent IoT-type technology and machine learning algorithms to be applied to the teaching, training, and even competition of soccer. Soccer training movement recognition and analysis mainly focuses on motion capture and evaluation of the athlete's lower legs and ankles, etc., and utilizes machine learning algorithms to recognize the movement movements and estimate the intensity of the movement. Overall, soccer players have very low sensitivity to motion recognition, and soccer players' footwork is difficult to recognize, there are very large differences in soccer players' behavioral logic, which are used by current soccer action methods for motion recognition. There is insufficient collection and in-depth profiling of real data, and what is not available is soccer movement action capture and recognition based on kinematic knowledge. The current model does not analyze the complex and high-noise action data stream deeply enough [1, 5].

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The automation of flight training quality assessment using soccer training movement data must do the following two things:

? the data source is sufficient and accurate, which can correctly reflect all kinds of movements in soccer training;

? automatically recognize the movements made by the players.

With the development of hardware conditions, the first requirement has been able to satisfy relatively well, while the second condition, i.e., the research in the field of deep analysis of players' movement parameters, has been a blank so far. Soccer training action recognition can be reduced to a pattern recognition problem, however, traditional statistical pattern recognition methods such as linear classifiers (Fisher discriminant, MSE algorithm) are too simple, the Bayes method is difficult to implement, and the generalization of artificial neural networks is weak, etc. have one or another problem. The traditional extraction method for soccer action recognition is to decompose the action-based footwork into features. However, this kind of behavior suffers from problems such as a low degree of correct extraction in high-level soccer sports competitions [6, 7].

Common machine learning methods are suitable for recognizing most monotonous movements, but soccer movements are highly variable and players' ankle movements are flexible. The actual acquired soccer data streams are noisy and the data patterns are not obvious, and the performance of pattern recognition on the data will be degraded. To extract the effective feature values in the complex data stream and improve the correct degree of pattern recognition, we construct a classification pattern of attitude angle solving + Support Vector Machine (SVM) classification algorithm for small-sample data with less influence of noise and adapted to the recognition of soccer movements in this study.[8] The SVM algorithm model is suitable for small-sample data with less influence of noise and suitable for recognizing soccer moves in this study.

Based on the above research background and significance, this paper researches the method of soccer training action data analysis based on intelligent IOT type, according to the shortcomings of the existing related research and the needs of the practical application scenarios, it designs the framework of soccer movement recognition and evaluation, collects the soccer movement data, and constructs the algorithmic mode of machine learning to recognize, evaluate and analyze the soccer movement, and it becomes possible to apply intelligent IOT type technology and SVM algorithm applied to the recognition and analysis of soccer training movements becomes possible, providing a new way to add the efficiency of training. And Ethical considerations should be emphasized when applying IoT and machine learning in sports training. Protect the privacy of athletes to ensure legal and compliant use of data; respect the right to informed consent by clearly communicating the use of data and obtaining consent; reduce data bias and improve model accuracy; avoid over-reliance on technology and respect the rights and interests of athletes. Follow ethical principles to ensure reasonable and compliant use of technology.

2. SVM Model and Algorithm. Support Vector Type Recognition Machine [9, 10] One of the most influential results in the last few years, This algorithm is a solution for re-identifying the type of analysis in a layer type of data related to the volume of the data., and the more solid theoretical foundation makes it well generalizable. With other tried-and-true amplifications such as LR-type methods, SVMs are often used for higher-order types or linearly inseparable solution answers, which are free to choose the parameter model and use the set of supported type vectors as the basis for the classification of the hyperplane, the problem in this study belongs to a small-sample linearly indivisible problem, and therefore the SVM algorithm pattern is chosen to solve it [11].

1. **Support vector type recognizer**
   The mathematical description of the two types of support vector type discriminators is as follows [12, 13]: Given the training sample data can be separated by the hyperplane. A hyperplane is an optimal hyperplane if the data type between the closest sample to the hyperplane and the hyperplane is maximal. The optimal hyperplane possesses the type that is the best solution to get the minimization ||w||2/2 with the constraint y_i (w^T -x) + $b \geq 1$. Using the pairwise rule, the linearly divisible optimization problem can be simplified to maximize

$$\left.\begin{array}{l} Max\, W(\alpha) = \sum_{i=1}^{n} \alpha_i - \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i y_i \alpha_j y_j (x_i \cdot x_j) \\ restrict \sum_{i=1}^{n} \alpha_i y_i = 0, \quad \alpha_i \geq 0, \quad i = 1, \cdots, n \end{array}\right\} \tag{2.1}$$

where $a = 0$ (a_1, ..., a_n) is the Lagrange multiplier, and the samples corresponding to $a_i \neq 0$ become support vectors; a" denotes the Lagrange multiplier corresponding to the support vector; and W(a) is a function of the Lagrange multiplier a. The value of b can be obtained from the KKT condition, the linear case

$$b = \frac{1}{2}\sum_{k=1}^{n} y_k \alpha_k^* \left(x_1 \cdot x_k + x_2 \cdot x_k\right) \tag{2.2}$$

where x_1 and x_2 are the support vectors for either of the two types of samples, respectively. Decision functions for support vector type recognizers, linear case

$$D(x) = \sum^{n} \alpha_i^* y_i \left(x_i \cdot x\right) + b \tag{2.3}$$

Sample x belongs to the following category

$$x \in \left\{ \begin{array}{l} \text{type } 1 D(x) > 0 \\ \text{type } 2 \text{else} \end{array} \right\} \tag{2.4}$$

If you apply a kernel function that satisfies the Mercer condition

$$kx, y == \ \Phi(x) \cdot \Phi(y) \tag{2.5}$$

Then there is no need to obtain the type form of the solution, which is a distinctive feature of support vector-type discriminators [4], and the kernel-type solution function implements the nonlinearization of the algorithm. The kernel-type solution function is

$$kx, y = xTy \quad \text{dot product kernel} \tag{2.6}$$

$$k(x, y) = (xTy + c)d \quad \text{polynomial kernel} \tag{2.7}$$

$$k(x, y) = ex - 12 \quad \text{radial nucleus} \tag{2.8}$$

where d is the number of polynomial kernel functions. With the kernel function, the nonlinear form of Eqs. (2.1), (2.2) and (2.3) can be expressed as

$$\left. \begin{array}{l} \max W(\alpha) = \sum_{i=1}^{n} \alpha_i - \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i y_i (x_i \cdot x_j) \\ \sum_{i=1}^{n} \alpha_i = 0, \quad 0 \leq \alpha_i \leq C, \quad i = 1, \cdots, n \end{array} \right\} \tag{2.9}$$

$$b = -\frac{1}{2}\sum_{k=1}^{n} y_k \alpha_k^* \left[K\left(x_1 \cdot x_k\right) + K\left(x_2 \cdot x_k\right)\right] \tag{2.10}$$

where x, x_1, and x_2 are the support vectors of either of the two sample classes, respectively. Sample x belongs to the following category

$$x \in \left\{ \begin{array}{l} \text{type } 1 D(x) = 1 \\ \text{type } 2 D(x) = -1 \end{array} \right\} \tag{2.11}$$

2. **Multi-class support vector type recognizer**
Traditional N-class support vector type discriminators solving multi-class classification are usually transformed into N two-class problems, i.e., one-to-many classifiers[14, 15]. N two-bounded classifiers are constructed for the N-level problem, and the ith SVMs use the data in the ith level as positive

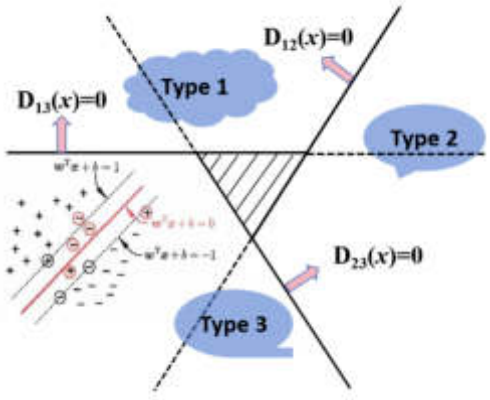

Fig. 2.1: Unclassifiable regions for one-to-one classification

training samples and the others as incorrect hypothesis samples [16]. This algorithm is called 1-a-r (1-aginst-rest). Let the ith decision function in level i be

$$D,(x) = wx + b \tag{2.12}$$

level when D, (x)=0 is the optimal type solution; D, (x)=1 is a low-level SVM, and the others satisfy D, (x)=-1. For traditional SVMs to recognize type-level machines, if the collected type data x is satisfied only for an I, i.e.

$$D, x > 0 \tag{2.13}$$

then x belongs to class i.
If Eq. (2.13) is right for more than one i or not at all; Eq. (2.13) is satisfied so that an indivisible region is produced. To solve this problem, dual classifiers are proposed[14], which constructs all possible two-class classifiers in N classes of training samples, and each class is trained on just 2 of the N classes of training samples, resulting in the construction of a total of N(N-1)/2 classifiers, and the algorithm is called 1-a-1(1-aginst-1)[17]. Let the decision function between class I and Class; be

$$D_{ij}(x) = w_{ij}^{\mathrm{T}} x + b_{ij} \tag{2.14}$$

where D, (x) = -D, (x). For the vector x, we have

$$D_i(x) = \sum_{j=1, j\neq i}^{n} sign\left(D_{ij}(x)\right) \tag{2.15}$$

and x is solved at type level arg max D, (x).
To test the effectiveness of the algorithm, a fuzzy support vector type recognizer is applied to the recognition of flight patterns [18].

3. Methods of recognizing soccer training movements.

3.1. Acquisition of soccer training movement data. This study was conducted in a standard soccer field for data collection experiments. A total of 30 soccer players were recruited, including 5 female and 25 male soccer players. They were asked to perform passing and shooting using various positions on a turf-type soccer field.

Figure 3.1 shows the soccer players when they performed passing and goal shooting. Acquiring soccer player action images is a prerequisite for extracting training action features. Since the action images acquired

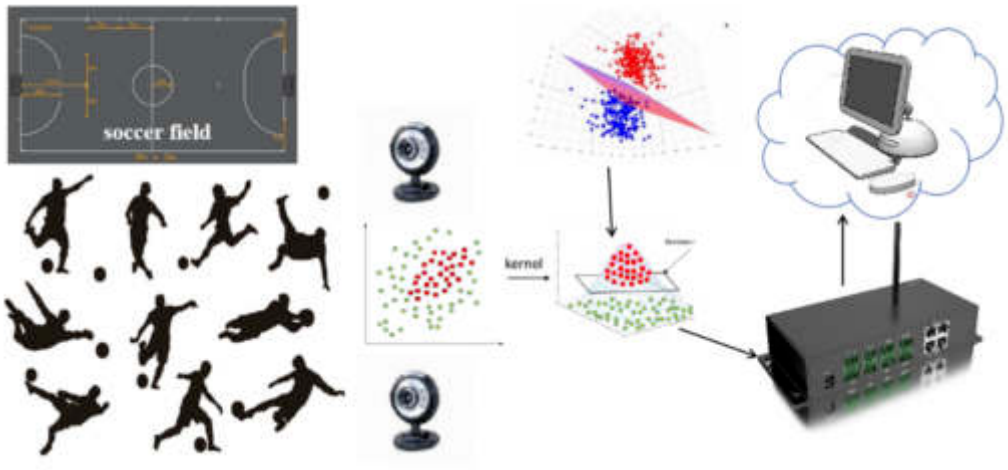

Fig. 3.1: Experimental setup for action data acquisition in a smart IoT-type system

Table 3.1: Number of pixel elements per segment in signal columns and signal rows of motion images

HSYNC Signal Column	Number of elements	VSYNC Signal Column	Number of elements
Paragraph (a)	256	Paragraph (o)	5
Paragraph (b)	347	Paragraph (p)	49
Paragraph (c)	1589	Paragraph (q)	1568
Paragraph (d)	32	Paragraph (r)	2
Paragraph (e)	1786	Paragraph (s)	1422

by traditional methods have large visual errors, which directly affect the degree of correct extraction of foul action features, for this reason, this paper utilizes an intelligent IoT-type system to acquire soccer player action images.

In the smart IoT-type system, the use of cameras to obtain images of soccer players in action can be achieved by selecting the OV7670 model camera OV7670 model camera is a COMOS camera element, with the ability to obtain color images, and the sensitivity array can reach up to 640 * 680, the transmission rate of up to 30 frames / s. The OV7670 model camera is a COMOS camera element, with the ability to obtain color images, a sensitivity array up to 640 * 680, and a transmission rate of up to 30 frames / s.

The camera has only one set of parallel data ports, noted as Y [7], through the data port to read the pixel value of the action image to obtain the soccer player training action in parallel. The OV7670 camera to obtain images of the components of the PL and PS, based on the line interrupt and field interrupt to determine the completeness of the data to use the VGA interface to display the soccer player training action images.[19] The VGA timing is shown in Figure 3.2. Wherein Data denotes a column of motion picture information; HSYNC and VSYNC denote a signal column and a signal row; (a), (b), (c), (d), and (e) denote the HSYNC signal column synchronization segment, the rear gallery segment, the activation segment, the front gallery segment, and the number of column elements, respectively; (o), (p), (q), (r), and (s) denote the VSYNC signal row synchronization segment, the rear gallery segment (o), (p), (q), (r) and (s) represent the number of VSYNC signal row synchronization segments, rear corridor segments, activation segments, front corridor segments and row elements, respectively.

The number of pixel elements per segment in the signal columns and signal rows of the motion picture is shown in Table 3.1.

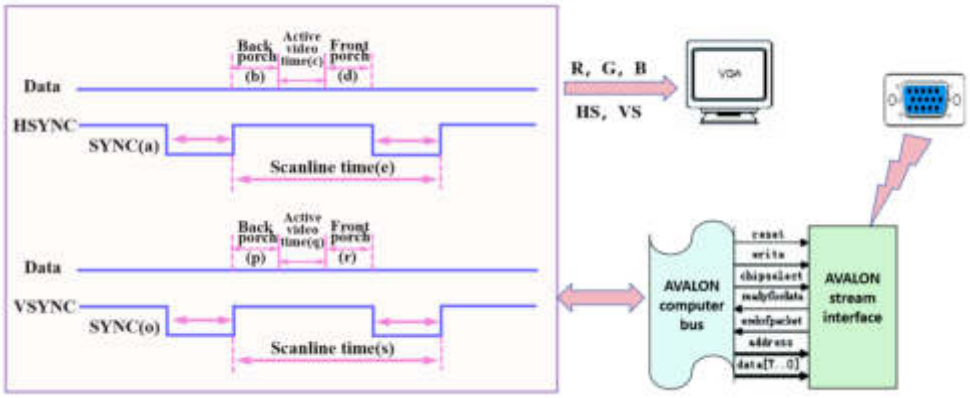

Fig. 3.2: VGA Timing Schematic

3.2. Pre-processing of soccer training movement data. Each frame of the experimenter's action image extracted from the video is processed in grayscale to establish a grayscale image database and divide the training and test sets; each frame of the experimenter's action image extracted from the video is processed using background subtraction and median filtering to generate a binary image library containing only the contours of the human body's action[20].

The dimension of the action pictures is too large to cause the slow computing speed, to address this problem, PCAis used to downsize the training samples, extract the principal components, and downsize the feature vectors of each person's action in the training set samples, so that the classification problem is simplified to the problem of dividing in the downsized space, to be the result of becoming for saving the time type and energy of arithmetic [21].

When an athlete is doing soccer training, the state of the action is continuously changing, however, due to the limitation of the sampling frequency of the parameters and the existence of random errors, the change of the parameters reflecting the state of the training action is not continuously and uniformly changing. To make the state changes of soccer training movements continuously and uniformly, it is necessary to take a period and average the parameters or the changes of parameters in this period [22, 23]. In the actual application of soccer training action data, it is necessary to expand the action data of 1 frame to 8 frames, and 3 frames will be expanded to 24 frames, so let p be the soccer training action data, m be the starting frame, and the converted soccer training action data p' is

$$p' = \frac{1}{24}\left(\sum_{i=0}^{23} p_{m+i}\right) \tag{3.1}$$

The extension of the data can be achieved by linear interpolation, where the values of the average distribution are then interpolated between the two neighboring parameters noted.

Because of the definition of the steering angle (0° and 360° are in the same position), there may be an abrupt 360° change in the direction of the athlete's rotation between two adjacent frames, e.g., the direction of motion is left from 10° to 350°. The athlete has turned only 20°, but when interpolating linearly, there will be some directional values between 10° and 350°, and the same for the roll angle.

For the direction angle 360° mutation, in the linear interpolation, set the change of heading angle as, if$\Delta\phi$ >180°, then =$\Delta\phi\Delta\phi$ -360; if$\Delta\phi$ <-180°, then =$\Delta\phi\Delta\phi$ +360°; the processing method of the roll angle is the same as that, and will not be described in detail here.

For an abrupt 360° change in heading angle, the following can be done in linear interpolation: let the change in heading angle be$\Delta\phi$:

If$\Delta\phi$ > 180 then =$\Delta\phi\Delta\phi$ -360;

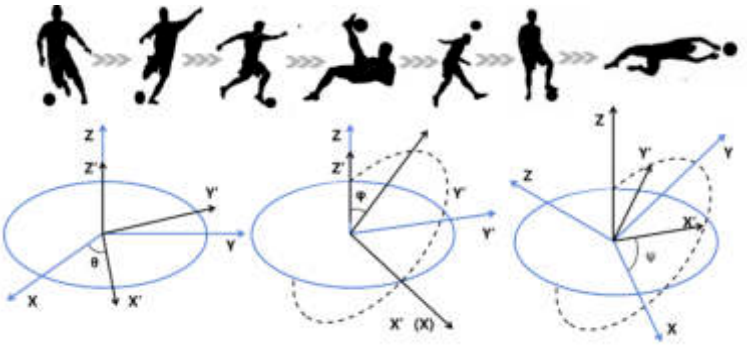

Fig. 3.3: Sectional of the attitude angular shape

If$\Delta\phi$ <-180 then =$\Delta\phi\Delta\phi$ + 360;

For an abrupt 360° change in roll angle, the following can be done in linear interpolation: let the change in roll angle be$\Delta\Upsilon$:

If$\Delta\Upsilon$ > 180 then$\Delta\Upsilon$ =$\Delta\Upsilon$ -360; if$\Delta\Upsilon$ <-180 then$\Delta\Upsilon$ =$\Delta\Upsilon$ + 360;

3.3. Soccer Motion Recognition and Assessment Models. Soccer is more complex than other sports (e.g., badminton, tennis, and volleyball): the completion of the action mainly relies on the lower limbs the movement patterns are variable, and there are more ineffective lower limb actions and higher similarity between actions during the movement. Therefore, posture angular features based on the ankle area play a key role in improving the accuracy of movement classification, and more implicit movement feature information can be obtained through posture angular pattern solving to reflect the differences between movements, which helps pattern learning [24]. The model uses PCA to balance complexity and accuracy. The patterns are balanced in terms of complexity and accuracy using PCA; Then SVM-based classification algorithm is used to discriminate this type of soccer movement. Then the data are subjected to some advanced preparation type of operation, firstly the algorithm is to be used to smooth the type of drop of the collected data; then the peak of feature type is calculated by some small angle type of algorithm to automatically segment the data content of the sport recognition [25].

For the recognition of foot-based sports movements, in addition to the two important features of angular velocity and acceleration, the rotation of the ankle is also important in the recognition and evaluation of soccer movements, and mining the information of the stance angularity pattern can obtain the features containing more information in the movements. In this paper, we add a posture angularity pattern to extract more useful features [26]. The model is used in this paper to extract more useful features.

The attitude angular type consists of three types of variations of yaw angle, pitch angle, and roll angle of small angular types. Figure 3.3 demonstrates the angular type variation.

Typically, three-dimensional rotation problems are solved by rotation matrices [4, 27]. Quaternions are directional solution problems in the angle trace of the correct answer. The quaternion's representation model category is p-pa + pix + pyj + pzk with one actual category pe and three imaginary category parameters px, py, and pz. the attitude angular pattern is computed from equation (3.2):

$$\begin{cases} \theta = \arcsin(\alpha_{x0}) \\ \varphi = \arctan\frac{magy_0}{magx_0} \\ \psi = \arctan(-\frac{a_{y0}}{a_{z0}}) \end{cases} \tag{3.2}$$

where a_{y0} anda_{z0} represent the rate of increase, θ andψ represent the yaw, roll, and pitch of the initial category.

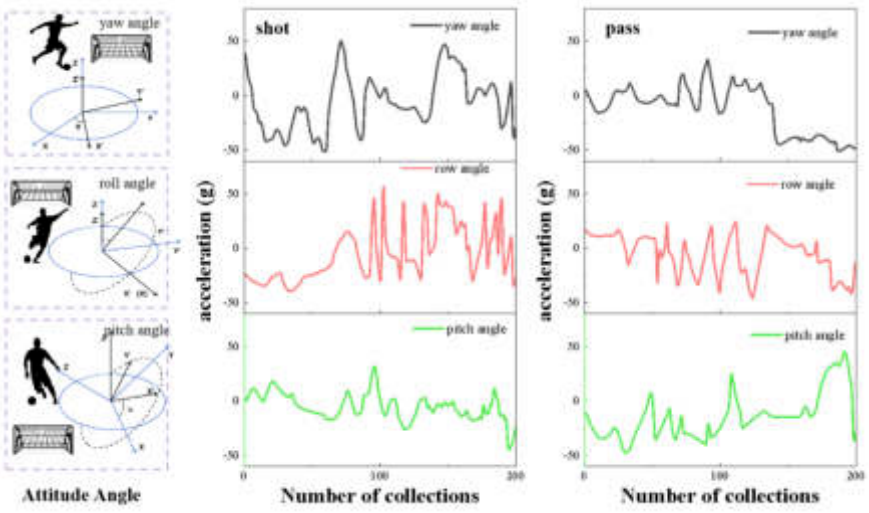

Fig. 3.4: Acceleration variation for different attitude angle patterns

The attitude angular pattern using quaternions is equation (3.3) [4, 28] :

$$\begin{cases} roll = \arctan \frac{2(p_0p_3+p_1p_2)}{1-2(p_0^2+p_1^2)} \\ pitch = \arctan \frac{2(p_1p_3-p_0p_2)}{4(p_0p_3+p_1p_2)^2+(1-2(p_0^2+p_1^2))^2} \\ yaw = \arctan \frac{2(p_0p_1+p_2p_3)}{1-2(p_2^2+p_3^2)} \end{cases} \tag{3.3}$$

The frequency was 100 Hz and then tit was substituted to solve the stance angular pattern A_{n-i}. Figure 3.4 shows the comparison of the acceleration change for different stance angular patterns of shooting and passing in soccer training movements.

By dividing the An-i type and S_{n-i} type into one level of Rn-i, and then extracting the morphological type and level of the R_{n-i} segment, as shown in Table 2 [4, 29].

F(n) = (fi, fmn) is combined into a large 6xm matrix F. The procedure is shown in Fig. 3.5.

PCA is performed on the data that has been extracted to characterize the variables. Higher accuracy can be achieved by using the mode of PCA compared to other nonlinear dimensionality reduction methods. Suppose that the matrix type prime F has dimension type n × m, i.e., there are a total of n data in dimension size of type m.

F is categorized into UΣVT, U with the same dimensions as F. The orthogonal type of matrix dimension V is mXm, and Σ is a diagonal type of dimension matrix of the same type V. There is YUΣr = F(ΣVT) (-1) Σr.

The extracted features from a vector feature of the summed type 42 dimensions, where F = [F1, F2, F34]. After going through the types of the process PCA, the new features obtained can be expressed as Y.= [Yr1, Yr2, Yrm], and m represents the computational dimension. There is equation (3.5):

$$Y_{rm} = F_i a_{ij} + F_2 ai_j + +F_m a_{ij} \tag{3.4}$$

$$Y_{rm} = F_i a_{ij} + F_2 ai_j + +F_m a_{ij} \tag{3.5}$$

where aj is a special type of covariance type size. Equation (2.10) may be conveniently viewed as Eq. (3.6):

$$Y_{rm} = F_i a_1 + F_2 a_2 + +F_m a_m \tag{3.6}$$

Table 3.2: Feature selection

eigenvalue (math.)	define	eigenvalue (math.)	define
Ray.	incrementally weighted root value of y up or down	IQRax	x Increasing interquartile range up or down
Rex	x Upward rotated weighted square root	IQRay	y Increasing interquartile range up or down
Rwy	y Upward rotated weighted square root	IQRaz	z Increasing interquartile range up or down
Rwz	z Rotated upward weighted square root	IQRwx	x Upward or downward rotating quartiles
Dax	Rotation sums of squares in the x-direction	IQRwz	z Upward or downward rotating quartiles
Day	Rotation sums of squares in the y-direction	Stdax	x Upward or downward incremental difference value
Dwy	y the squared difference in the direction of the upward translation	Stdwy	y upward or downward rotational phase difference value
M X x	The preferred solution for the downward direction of rotation of x	Mp	pitch average
Maxay	The preferred solution for the y-down direction of rotation	Mr	roll Mean
Minay	y upward or downward increasing inferior programs	My	yaw Mean
Minwz	z Inferior programs with upward or downward rotation	Rp	pitch weighted root value
Sax	x Increasing bias coefficients upwards or downwards	Rr	Roll weighted root value
Say	y Increasing bias coefficients upwards or downwards	Ry	yaw weighted root value
Swx	x Upward or downward rotational bias coefficients	Step	pitch Difference
Swy	y Upward or downward rotational bias coefficients	Std	roll Difference
Swz	z Upward or downward rotational bias coefficients	Stdy	yaw Difference

Table 4.1: SVM algorithm mode parameter settings

Optional parameter C		kernel function (math.)
1	10^{-5}	Linear
500	5×10^{-5}	Polynomial
10^3	10^{-4}	RBF
510^3	510^{-4}	Sigmoid
10^4	10^{-3}	
510^4	510^{-3}	

After data acquisition and data preprocessing, the process of pattern arithmetic in the soccer action recognition and evaluation system can be divided into three types: data division, pattern arithmetic, and classification, as shown in Figure 3.6.

4. Experimental results and analysis. In the action categorization experiment, two labels are set up: passing and shooting, which are represented by 0 and 1, respectively. 264 sets of passes and 250 sets of shots were obtained from the data collection experiments. In the action categorization experiment, two labels are set: pass type recognition and shot type recognition, and 0 and 1 are used to indicate the two categories. 264 sets of passes and 250 sets of shots were obtained from the data collection experiments. These datasets are divided into a training set in the recognition type and a test set in the recognition type according to the principle of randomness, of which 80% is used for the training type of recognition base. The results of the different parameter types set are shown in Table 3. Where the optional parameters C is from 1 to 50000, Y is from 0.00001 to 0.05, and the recognition types of the kernel function include Linear type, RBF type, Sigmoid type, and Polynomial category. To solve the overfitting problem, a 3-fold crossover was used. From the results, it is seen that the kernel function with C=1, Y of 0.0001, and Unitary type is used for the best pattern.

Then SVM-based classifiers are used to recognize shots and passes. Decision tree and KNN were chosen as the comparison algorithms for the experimental algorithms. Table 4 summarizes the accuracy of soccer action recognition. Among them, four methods, SVM+ Attitude Angle Pattern, SVM, KNNdecision tree and LDA have different accuracies with different parameters with maximum of 0.9,0.88,0.86 and 0.79 respectively.

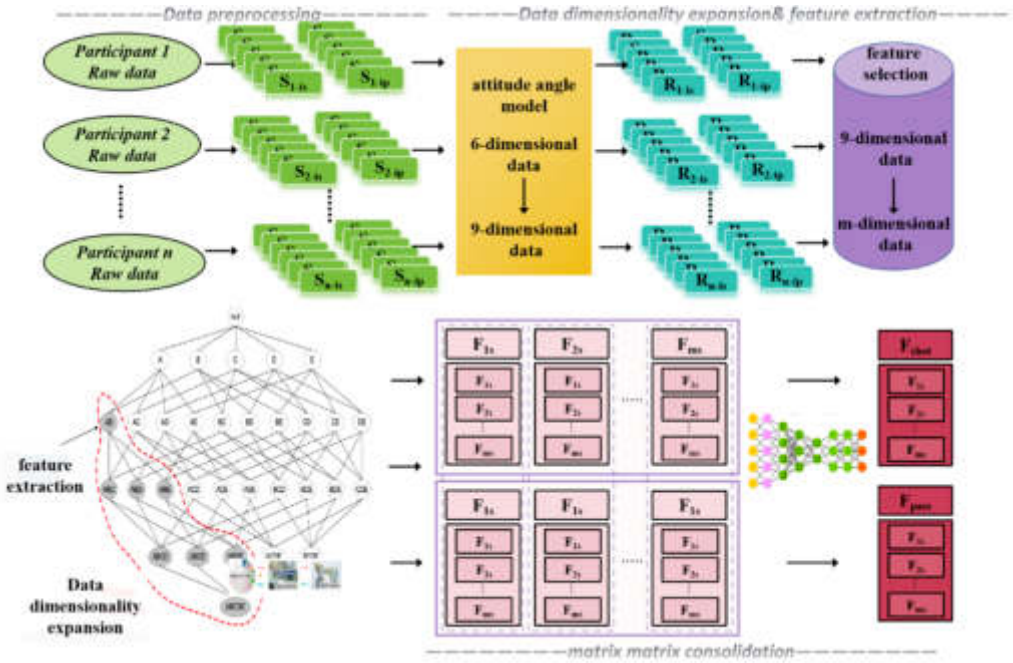

Fig. 3.5: Data processing process

Fig. 3.6: Flow of soccer action recognition and evaluation system

It can be seen that the SVM-based algorithm chosen in this study has a better performance than the other comparative algorithms in all aspects combined. In addition, one of the algorithms with attitude angle pattern has better performance than the other algorithms as shown in Figure 4.1.

Figure 4.2 shows the experimental results of different algorithmic patterns for soccer training movement recognition and movement quality assessment. The SVM algorithm pattern based on the posture angular pattern recognizes passes and shots correctly to the extent of 85.7% and 88.5%, which indicates that there is a distinction between the passing and shooting action features. but the results of the SVM algorithmic pattern based on the posture angle pattern show that the degree of correctness, recall, and F1-score are better than the other algorithmic patterns, which indicates that the intelligent IoT type based on the SVM support vector-type recognition machine established in this paper has a significant improvement in the recognition rate in soccer training action recognition compared with the traditional algorithmic patterns. To improve the robustness of the framework to noise, measures such as data preprocessing, feature selection, algorithm optimization, and training strategies can be taken. These measures help to reduce the impact of noise on the recognition accuracy and thus improve the performance of the framework in practical applications.

Table 4.2: Comparison of results of different algorithmic modes for action recognition

algorithmic model	parameters	rightness
SVM+ Attitude Angle Pattern	C=1 $\gamma = 10^{-5}$	0.9
SVM	$\gamma = 10^{-4}$ C=1	0.88
KNNdecision tree	N_Neighbors=4 Min_Samples_Split=3 Max_Depth=6	0.85 0.86
LDA	C=1 $\gamma = 10^{-5}$	0.79

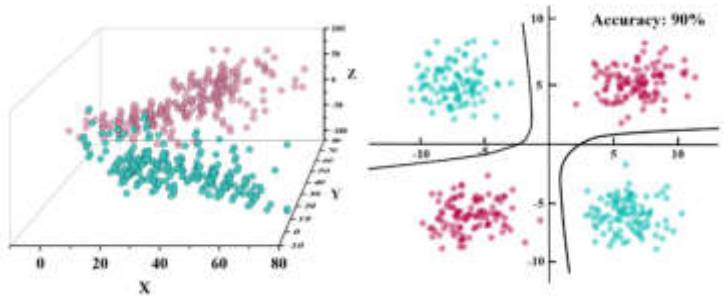

Fig. 4.1: Recognition results of soccer training movements based on SVM algorithm with posture angular pattern

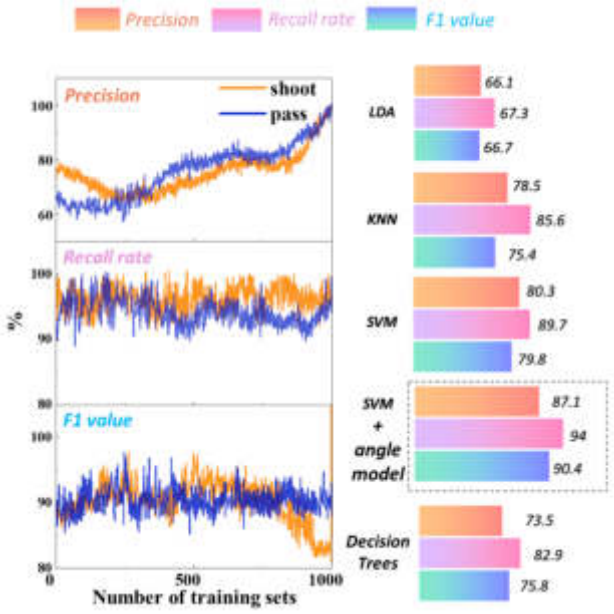

Fig. 4.2: Experimental results of different algorithmic models for soccer training movement recognition and movement quality assessment

5. Conclusion and discussion. The combination method of intelligent object type and support vector type recognition machine is used to recognize soccer training movements, and the designed data processing mode adopts posture angle pattern + SVM pattern classification algorithm to recognize different training movements. Through experiments, it is verified that the soccer training action recognition system based on attitude angle pattern + SVM has the highest recognition rate and the fastest computing speed, which significantly improves the performance over the traditional algorithm mode... The system allows for the migration change from an empirical type-driven approach to a data type-driven approach in the field of athletic training and, by extension, development to other applications of foot-based movement recognition and skill level assessment. In order to solve the problem of the framework's dependence on specific conditions or datasets, the following measures can be taken in the subsequent research: first, the framework is modularized to make it more versatile and extensible.

The method proposed in this paper combines attitude angle with SVM classification, which is efficient but at the same time has high computational complexity. The main challenges include real-time processing requirements and the efficiency of large-scale datasets. The application is promising, especially for scenarios such as soccer training movement analysis that require fast and accurate recognition.This makes it easy to replace or modify specific modules to adapt to different datasets and conditions. Second, migration learning and fine-tuning techniques are used when training the model to enable it to better adapt to specific tasks and data distributions. Finally, the framework is fully tested and validated to ensure its performance stability and reliability in different datasets and scenarios. Through these measures, the generalization problem of the framework can be effectively solved and its applicability in different real-world situations can be improved.

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FILM AND TELEVISION SPECIAL EFFECTS AI SYSTEM INTEGRATING COMPUTER ARTIFICIAL INTELLIGENCE AND BIG DATA TECHNOLOGY

YAO JU* AND GUOBIN WEI†

Abstract. Particle systems can achieve many scenarios that are difficult to achieve in the field or expensive in reality. In this paper, the requirements of 3D film special effects and the design process of particle systems are studied. Unity3D engine was used to simulate 3D movie special effects. Then, the motion trajectory planning of 3D video group animation characters based on particle swarm optimization is proposed. Then, the system models the animated characters' moving track to achieve the realism's dynamic effect. This project intends to use the gravity optimization method for particle swarm optimization. The aim is to overcome the optimization difficulty caused by particle swarm optimization, which is easy to fall into local extreme values. Finally, the generated trajectory information is input into the 3D simulation system for conflict detection and clustering tests. Experiments show that the proposed algorithm can effectively render memorable scenes such as movies and TV. The picture has a high real-time frame rate and is realistic.

Key words: Film and television; Special effects animation; Particle system; 3D special effects; Particle swarm optimization; Collision avoidance

1. Introduction. 3D special effects have been widely used in science fiction, martial arts, animation and other movies and TV series, and it has gradually developed into a significant sign to measure the visual quality of contemporary film and television works. For example, "Transformers 3", "Men in Black 3", "The Day after Tomorrow," and so on use particle technology to achieve three-dimensional special effects such as explosions, building collapses, fireworks and so on. The production team will integrate the three-dimensional film effect with the natural theme scene, which can not only fully mobilize the creative passion of the producer but also save a lot of production costs. Secondly, many memorable scenes are complex to be photographed in actual situations, which may also be because such scenes do not exist in reality. For example, human cell division, the process of seasonal changes in trees and flowers, is challenging to photograph in the same time and space. Real effects waves crashing into cities, volcanoes erupting, buildings exploding, smoke, etc., are costly. Particles are 2D images generated in 3D and then repeatedly drawn with various materials to create a 3D movie effect. Using particle systems to simulate memorable scenes that are impossible to achieve in reality is an integral part of the research and development of movies and television programs.

Reference [1] uses a fast simulated annealing algorithm based on hybrid particle swarm optimization. A model for solving high-dimensional optimal problems is presented. The particle swarm optimization algorithm determines the global optimization range, and FSM is used to refine the optimization range. Reference [2] A method integrating particle swarm optimization algorithm (PSO) and genetic algorithm (GA) is proposed to improve the adaptability of the system based on reference [1]. Given the problems in the current population evolution, such as complex coordination of local search ability and easy falling into local extreme values, SUANFA was improved using particle swarm technology in literature [3]. In this way, the algorithm model has fast convergence speed, high precision and strong robustness. In literature [4], an adaptive neural network algorithm based on weights was designed to solve problems such as low optimization accuracy and "premature convergence" in practical applications. Literature [5] studies the group behavior simulation method aiming at generating and propagating fear emotion under multiple disaster scenarios.

Unity3D is a 3D game engine. It supports Windows, MacOS desktop operating system platforms and mobile operating system platforms like Android and iOS. It includes graphics, sound, physical, network, particles and

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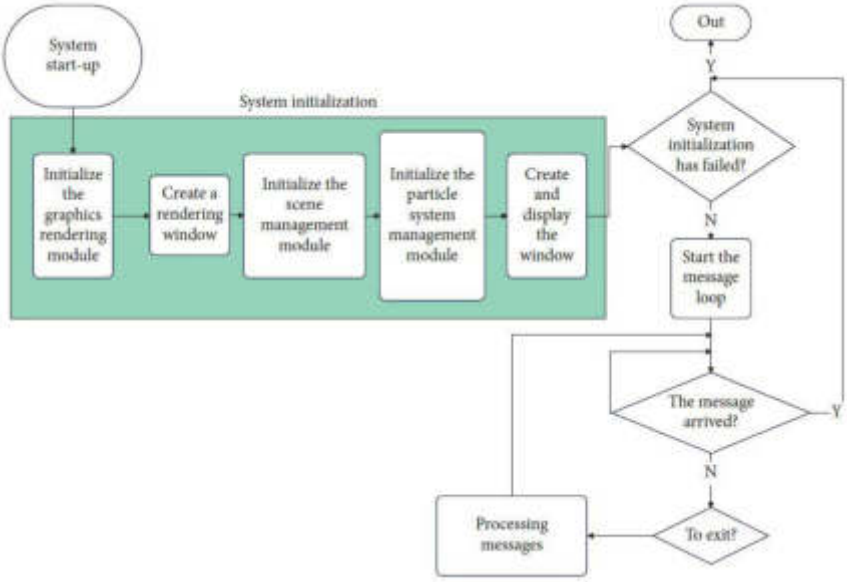

Fig. 2.1: *3D visual effects development process of the particle system.*

other functional components [6]. It uses scripting languages such as C# and JavaScript and can support most 3D model documents. The platform has a variety of light rendering systems such as soft shadow, baking and powerful graphics editing functions. This method can be used to simulate large-scale virtual environments and develop 3D online games. It can also realize the simulation of digital 3D movie effects such as smoke, smoke, flame, smoke, lightning, explosion, etc. This paper studies the requirements of 3D film special effects and the particle system design process. Unity3D engine was used to simulate 3D movie special effects [7]. Then, the motion trajectory planning of 3D video group animation characters based on particle swarm optimization is proposed. Then, the system models the animated characters' moving track to achieve a realistic dynamic effect.

2. Introduction to particle systems. Reeves et al. introduced the particle system 1983, which can simulate targets of any shape, such as smoke, waves, water currents, flames, rain and snow, clouds, explosions, forests, etc. Because the particles in the particle system have the characteristics of shape, size, color, transparency, moving speed, moving direction, life, etc., and have the characteristics of spatiotemporal dynamic distribution, it can simulate the motion effects of various motion rules [8]. Particle systems can simulate complex and varied objects or scenes in various shapes. According to the particle shape, it can be divided into fluid particles, smoke particles and broken particles. Flow particles are primarily used to simulate special effects such as water flow, wave, flame and magma. Smoke particles are dynamic particle effects [9]. It grows and dies over time. Pulverized particles are used to simulate the action of matter in the explosion process, usually accompanied by the formation of explosive fragments of matter. Figure 2.1 shows the development process of 3D visual effects for particle systems (figure cited in Scientific Programming, 2022, 202:1-11.).

3. Improved particle swarm optimization algorithm for 3D animation group trajectory optimization.

3.1. Key Issues. Group behavior requires not only the randomness of movement trajectories but also the global consistency. Only in this way can we produce actual group intelligence animation. To this end, this project will carry out research from the following aspects: (1) Each individual in the cluster has its scope of activity to prevent conflicts effectively. (2) The population is a whole. All the individuals in the population move in the same direction or for the same purpose. (3) The population can be divided into several smaller populations. According to certain conditions, it can form a large population by itself. (4) Enhanced track

authenticity. The individual's movement path not only has independence but also guarantees the unity of the whole, which conforms to the law of group movement. (5) Improving the coordination ability of the population. It enhances the intelligence of the cluster and speeds up the movement rate of the cluster.

3.2. Particle swarm optimization algorithm . Suppose the search space is N and all the particles sum is n. The PSO algorithm is explained by formula (3.1) and formula (3.2)

$$u_1(k+1) = u_1(k) + \varepsilon_1 \times \omega() \times [Q_2(k) - x_1(k)] + \varepsilon_2 \times \omega() \times [Q_3(k) - x_1(t)] \tag{3.1}$$

$$x_1(k+1) = x_1(k) + u_1(k+1) \tag{3.2}$$

In formula $1 \leq i \leq n, 1 \leq d \leq N.u_i(k)$ represents the speed of the i particle at the k iteration, and $x_i(k)$ represents the position of the i particle at the k iteration. d represents the size of particle $i.Q_2$ represents the optimal particle distribution and Q_3 represents the optimal location of the population of the i particle. ε_1 and ε_2 are positive values of the acceleration coefficient. $\omega()$ stands for any number from 0 to 1 .

3.3. Improved particle swarm optimization to solve the path planning of 3^{D} animation . Although the particle swarm optimization algorithm has many advantages, it is easy to enter the minimum point, which reduces the optimization accuracy [10]. In this project, gravity optimization (GSA) and particle swarm (PSO) technology are organically integrated to overcome the disadvantage that PSO can easily fall into local extreme values. In this way, the overall optimization ability of PSO is improved. The modified algorithm is determined by the following formula $(3 \cdot 3)$

$$u_i^d(k+1) = \lambda \times u_i^d(k) + \varepsilon_1 \times \omega() \times \delta_i^d(k) + \varepsilon_2 \times \omega() \times \left[H_{\text{best}} - x_i^d(k)\right] \tag{3.3}$$

$u_i^d(k)$ is the rate of particle i at time k in the d iteration. ε_1 and ε_2 are acceleration factors. Where λ is an inert component. $\omega()$ is any number in the interval $[0,1].\delta_i^d(k)$ is the acceleration of the particle i at time k in the d iteration. H_{bst} represents the best solution so far. Formula (3.4) is used to update theladaptive weighting to improve its search performance

$$\lambda = \lambda_{\max} - (\lambda_{\max} - \lambda_{\min}) \times \frac{g_{\text{clovert}} - g_{\text{worst}}}{g_{\text{best}} - g_{\text{worst}}} \tag{3.4}$$

g_{croren} stands for the current fitness function. g_{best} represents the optimal fitness of the particle. g_{worst} represents the worst fitness of the particle. This project intends to incorporate the natural characteristics of bird clusters into the method to improve its complexity and search range without local optimal solutions [11]. The new position of the agent after each repetition is updated according to formula (3.5)

$$x_i^d(k+1) = x_i^d(k) \tag{3.5}$$

In the later iteration process, the genetic variation of the genetic algorithm will gradually weaken so it can quickly enter the local extreme value. So, look carefully at the H_{best} value after each cycle. If the H_{best} fitness remains constant after several iterations, the particle is in A suboptimal state. The local movement process is then started to avoid stalling. This paper calls it global response [12]. The individual particles can be updated using formula (3.6) to explore a more extensive range of sites

$$\hat{x}_k = \overset{\mathrm{r}}{x}_k + \omega_1 \left(\frac{1}{6} \sum_{n \in N_i}^{\overset{\mathrm{r}}{x_n}} \right) (3.6) \tag{3.6}$$

$\hat{x}_k$ is the new position after the overall response to $\hat{x}_k$. The new positioning is determined by averaging the six closest points. Set N_i has an exponent of 6 adjacent particles $\overset{1}{x}_k$.

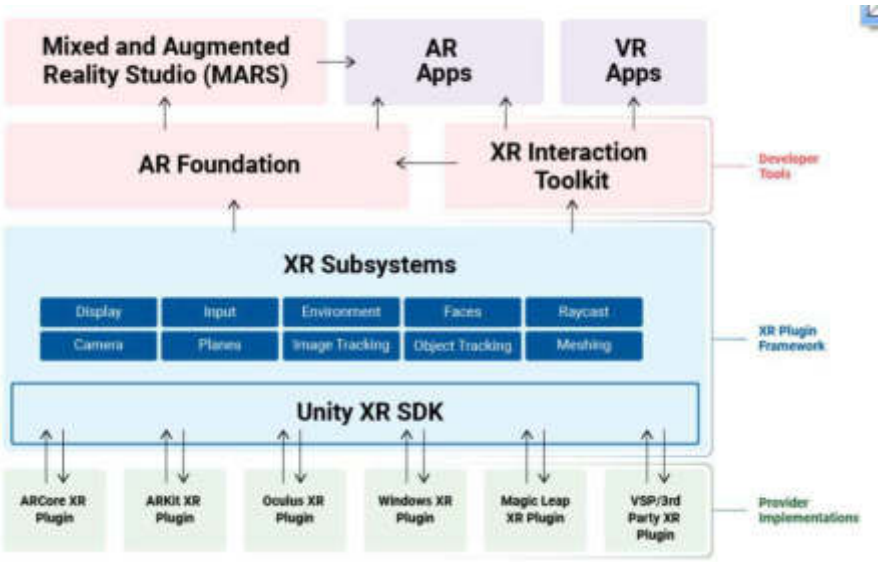

Fig. 4.1: *The overall structure of the special effects animation-assisted generation system.*

4. Realization of three-dimensional film and television special effects based on Unity3D technology . Particle animation in Unity3D comprises three components: particle generator and particle animator. A simple stationary particle system can be constructed using a particle generator and rendering method [13]. When the particle system interacts with other virtual objects, a particle impact device can be added to the object. In Unity3D, particle emitters are divided into ellipsoid and network structures. Ellipsoidal particle emitters can form a series of spheroidal regions of particles. The ellipsoidal characteristics are used to scale and expand the sphere. Particle generators generate particles from the surface of the grid and emit them around the grid. The software can move at multiple angles according to particle characteristics [14]. At the same time, the system can operate each particle to make it have more abundant effects. The particle rendering machine presents the graphics generated by the particle system on the display screen so the user can see the corresponding graphics directly. They are using particle collisions to interact with other objects. For example, it can achieve an explosive effect when the object is in contact with the explosive object. The overall structure of the special effects animation-assisted generation system is shown in Figure 4.1. The system is divided into three modules: front-end browser, back-end server and communication network. The front-end browsing subsystem can play, pause and stop the animation of movie special effects. In the display interface, the user can input the effect text of the animation and movie that he wants to make on the display screen. The system produces the effect of the movie according to the user's input [15]. The system uses a communication network to transfer information between the front browsing subsystem and the back terminal system, including database, text analysis, animation production, special effects production, and the other five modules. The system includes animation features and animation instructions. It can store a large number of anime and movie special effects materials. In the text analysis part, fuzzy semantic analysis is used to analyze the text and generate the corresponding animation. The film effect generation module uses particle technology to produce the film effect. The wavelet transform theory is applied to combine the animation and film effects produced by the system [16]. Through the communication network, the synthesized film special effects animation is transmitted to the front-end browsing subsystem to achieve the purpose of human-machine dialogue with users.

5. System inspection .

5.1. Experimental Detection. Select Windows 2010 operating system, Core i9 9100 processor, 8 GB memory as hardware configuration. Visual Studio 2018 and OGRE image engine were used to verify the designed system [17]. Two different database structures, MySQLServer5.0 and MySQL dB, are adopted. The

Table 5.1: Comparison results of collision detection.

Action name	Text system	Bounding box system	STM system
Displacement action	89	165	200
Joint action	79	169	191
Leg action	96	143	183
Hand movement	84	155	175
Rotating action	81	175	181
Jumping action	90	161	190
squat	95	180	160
brandishing	82	172	194

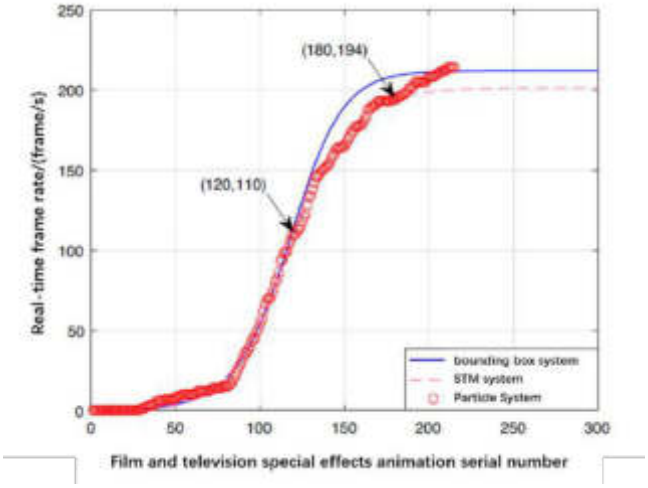

Fig. 5.1: *Real-time frame rate comparison of different systems.*

test results shown in Table 5.1 are compared with the closed frame and STM methods.

The conflict detection results in Table 5.1 show the conflicts between various behaviors when generating dynamic images. Compared with the scanning tunnel model, the conflict detection algorithm of this method is significantly reduced. The simulation results show that this method is fast and can meet the needs of a fast generation of film special effects animation [18]. This system helps to generate the actual time frame rate of 10 movie special effects animations. This system must meet 30 frames per second of video. At this time, the fluency of the film effect can be guaranteed. The wraparound and STM systems were selected to compare real-time frame rates (Figure 5.1). From the real-time frame rate comparison in FIG. 5.1, it can be seen that all three algorithms can achieve a speed of 30 frames/SEC. The real-time frame rate of PSO in this paper is much higher than that of the other two algorithms. The test proves that the designed software can meet the real-time processing requirements. It can be used for automatic synthesis of film animation effects.

The software of this paper is used to calculate ten different types of movie effects and compare them with the bounding box system and STM system. The results of the comparison are shown in Table 5.2.

The data in Table 5.2 shows that the number of vertices of movie special effects animation assisted by the software in this paper is more than that of the bounding box system and the STM system. This proves our software is more realistic and livelier than the other two systems [19]. It shows that the system in this paper has better assist in generating special effects animation.

5.2. Special Effects Detection. Add the rain instance system rain, which consists of an ellipsoid particle emitter, particle animator, particle renderer, particle collider, sound source and other components. The paper

Special effects animation serial number	Text system	
	Number of vertices	Face number
1	16081	13913
2	15878	14851
3	18295	16397
4	20151	19221
5	19234	17577
6	15934	14852
7	18183	16931
8	18806	17954
9	19442	18590
10	17176	16015
Special effects animation serial number	Bounding box system	
	Number of vertices	Face number
1	13069	10681
2	12003	13981
3	12871	11947
4	14043	13172
5	13596	12988
6	13901	12970
7	12560	12290
8	12346	10886
9	13175	11945
10	13410	12450
Special effects animation serial number	STM system	
	Number of vertices	Face number
1	14088	12931
2	13064	12452
3	14028	13511
4	14424	12138
5	14217	13202
6	13525	13376
7	12225	11297
8	13172	12049
9	14026	13331
10	13602	13277

Table 5.2: *Statistics of numerical comparison of special effects of film and television special effects.*

added rain and snow sound files to the sound source component to make rain and snow even better. Then, two-particle systems were built initially to simulate the wave and spray effects [20]. At the same time, text was added to the particle system to mimic the rippling and splashing effect of rain hitting the land. By controlling characteristic parameters such as texture mapping, particle size and particle emission velocity of the particle system, simulation of various rain and snow effects can be easily achieved (Figs. 5.2 and 5.3).

5.2. Special Effects Detection. 3D movie effects can mimic natural phenomena. It solves the difficulty of scene shooting and the time and space limitation of life growth. Swarm motion in 3D animation is studied by using a particle swarm optimization algorithm. A particle swarm optimization algorithm based on cluster behavior and gravity optimization is studied to overcome the optimization difficulty caused by local extreme values in PSO. Secondly, a solution strategy based on conflict detection and collision avoidance is studied. Finally, the obtained trajectory information is input into the 3D simulation platform and conflict and clustering tests are carried out. The results show that this system can satisfy the realistic sense of special effects animation. At the same time, its real-time expressiveness and flexibility can meet the system's requirements. The system

Fig. 5.2: *3D dynamic rain effects.*

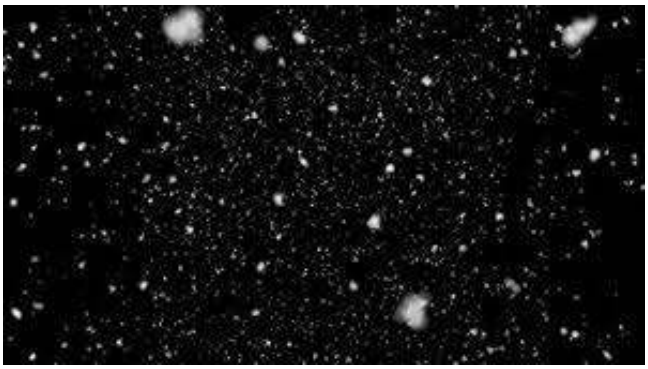

Fig. 5.3: *3D visual effects development process of the particle system.*

can make the movie's special effects animation more vivid and lifelike.

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COMPLEX EVENT INFORMATION MINING AND PROCESSING FOR MASSIVE AEROSPACE BIG DATA

LIN LI* AND LIBIN JIA†

Abstract. This paper intends to analyze the existing problems of remote sensing data from the perspectives of space remote sensing information data capacity and data types. Then, a framework for rapidly analyzing and processing space remote sensing information is constructed. Then, LSTM is used to realize the fault diagnosis of remote sensing data continuity, discrete sample mixing and strong correlation of sample variation. LSTM conducts a multimodal analysis of remote-control commands, which is applied to modeling. The multi-stage LSTM prediction model is established and integrated efficiently to improve its adaptive ability in complex space environments. In this way, the anomaly recognition of remote sensing information is realized. Experiments show that the algorithm can improve the anomaly detection rate of remote sensing data. Experiments show that the algorithm is feasible. It can provide reliable data interpretation function for space remote sensing information control system.

Key words: Space remote sensing; Big data; Integrated extended short-term memory network; Hadoop; Map reduce

1. Introduction. With the development and function of spacecraft, its development cycle is shorter and shorter, and the number of launches is increasing. Simply relying on conventional reliability engineering technology has been unable to meet the needs of data processing and analysis. Most of the current satellites are realized by ground-based telemetry. While working in orbit, the ground tone center needs to collect and process the remote sensing data of the satellite in orbit. In this way, the automatic judgment and early warning of the status monitoring parameters of the orbiting satellite can be realized. The obtained remote sensing data are saved in the database for subsequent analysis. The detection of anomalous phenomena in satellite remote sensing signals is one of the research hotspots in the world. The existing remote sensing monitoring technology can be summarized into three categories: statistical direction, distance direction and error direction. Most traditional statistical studies assume that the sample satisfies a specific distribution pattern. The data that does not conform to the distribution or the statistical characteristics that are not consistent are labeled as anomalies. And these samples are often difficult to describe by pre-set distributions. At this point, the relative positions between multiple samples are measured, and the samples close to them are found and labeled. Literature [1] uses density-based, supplemented by ranging technology for high-precision time series anomaly detection. Literature [2] studies the similarity measure based on the temporal features of remote sensing to eliminate the influence of correlation among parameters. This enables non-synchronous measurement.

An extended short-term memory network (LSTM) is a typical recurrent neural network. This method can infer and predict based on historical data while maintaining the advantages of traditional recurrent neural networks. Therefore, the anomaly recognition of time series data has become the focus of current research. In reference [3], National Aeronautics and Space Administration (NASA) integrated nonlinear modeling and automatic extraction characteristics of LSTM and constructed the LSTM model with remote control commands and remote sensing information as inputs. In this way, remote sensing information can be labeled efficiently.

However, the existing LSTM modeling methods have some problems, such as high overall prediction deviation and more variation, and their ability to identify situation and aggregation anomalies needs to be improved [4]. Therefore, this project intends to study the new satellite remote sensing data anomaly detection technology based on LSTM. The clustering idea is used to explore the differences among high dimensional remote-control commands efficiently. The LSTM prediction model is constructed for each control mode, and the prediction error threshold is integrated to improve the prediction performance of remote sensing data.

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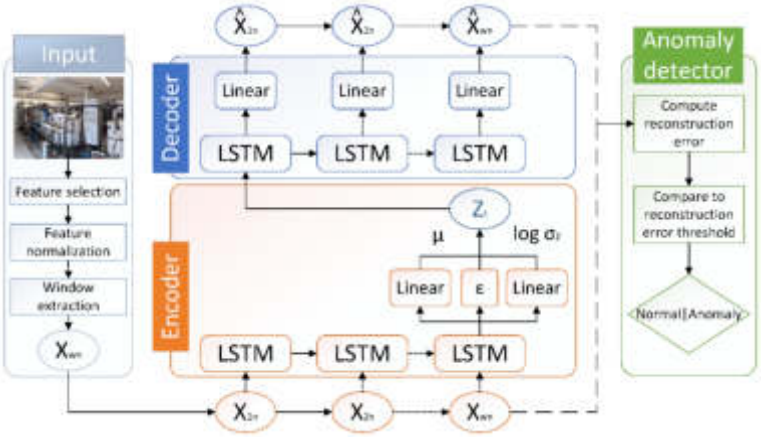

Fig. 2.1: *Anomaly detection method of telemetry data with integrated LSTM prediction model.*

2. Using LSTM integrated forecasting technology to detect space remote sensing data anomalies . When the spacecraft is working in orbit, the difference in the mode characteristics of the telemetry signal under the action of multiple remote-control commands is not considered [5]. This affects the ability to detect remote sensing parameters. This paper will combine LSTM for data processing and divide the workflow into three levels: 1) mining control commands, 2) Model training of multiple LSTMS, and 3) Telemetry data anomaly detection model. The anomaly detection method flow of remote sensing data integrated with the LSTM prediction model is shown in Figure 2.1 (the picture is quoted in Sensors 2022, 22(8), 2886).

2.1. Control guide pattern discovery. First, the algorithm preprocesses the learning process of LSTM. Then, it is classified by clustering based on the time sequence segmentation of fixed units [6]. In this way, the preprocessing of training samples and the discovery of the control mode of remote operation are realized.

2.1.1. Training data preprocessing. The training set D at time t can be viewed as the set of m dimensional vectors, $d^t = \{d_1^t, d_2^t, \mathrm{L}, d_m^t\}$. Here $\left\{d_1^t, d_2^t, \mathrm{L}, d_{m-1}^t\right\}$ is the multi-dimensional remote-control indication for time t. Let $\{d_m^t\}$ be the remote sensing data at time t, then the remote sensing data training set D containing a subsystem is represented as follows

$$D = \left\{ \begin{bmatrix} d_1^1 \\ \mathrm{M} \\ d_{m-1}^1 \\ d_m^1 \end{bmatrix}, \begin{bmatrix} d_1^2 \\ \mathrm{M} \\ d_{m-1}^2 \\ d_m^2 \end{bmatrix}, \mathrm{L}, \begin{bmatrix} d_1^t \\ \mathrm{M} \\ d_{m-1}^t \\ d_m^t \end{bmatrix}, \mathrm{L} \right\}$$

Then the paper reconstructs $D.B'$ is decomposed into multiple submatrices D_n^* containing continuous-time vectors [7]. Each submatrix contains c_t times of telemetry data and global remote-control commands, whose reconstructed input D' is expressed as:

$$\mathcal{D}^0 = \{\{D_1^*\}, \{D_2^*\}, \mathrm{L}, \{D_n^*\}, \mathrm{L}\}$$

Among them:

$$D_n^* = \left\{ \begin{bmatrix} d_1^n \\ d_2^n \\ \mathrm{M} \\ d_m^n \end{bmatrix}, \begin{bmatrix} d_1^{n+2} \\ d_2^{n+2} \\ \mathrm{M} \\ d_m^{n+2} \end{bmatrix}, \mathrm{L}, \begin{bmatrix} d_1^{c_i+n} \\ d_2^{c_i+n} \\ \mathrm{M} \\ d_m^{c_i+n} \end{bmatrix} \right\}$$

2.1.2. Excavation of remote-control mode. A spacecraft remote control method based on real-time monitoring is proposed to solve the incoordination problem in spacecraft remote control [8]. The total data in the sub-training set should not be too small to avoid overfitting and underfitting. Two examples of cluster classes are given, and the clustering method according to the dominant mode is illustrated. For example, remote command R_n^* is extracted from each submatrix D_n^* of B' to obtain the corresponding control command matrix R^* of D' :

$$R_n^* = \left\{ \begin{bmatrix} d_1^n \\ d_2^n \\ \mathrm{M} \\ d_{m-1}^n \end{bmatrix}, \begin{bmatrix} d_1^{n+1} \\ d_2^{n+1} \\ \mathrm{M} \\ d_{m-1}^{n+1} \end{bmatrix}, \mathrm{L}, \begin{bmatrix} d_1^{c_1+n} \\ d_2^{c_2+n} \\ \mathrm{M} \\ d_{m-1}^{c_i+n} \end{bmatrix} \right\}$$

R^* series of control mode characteristic vector $\|R^*\|_2$ is obtained by $C2$ norm operation on a submatrix.

$$\|R^*\|_2 = \{\|R_1^*\|_2, \|R_2^*\|_2, \mathrm{L}, \|R_n^*\|_2, \mathrm{L}\}$$
$$\|R_n^*\|_2 = \sqrt{\eta_{\max}\left(R_n^{*T} R_n^*\right)}$$

Reorder the numeric values in the control graphics feature vector $\|R^*\|_2$. Taking the middle value of $\|R^*\|_2$ as the threshold, the control command set is divided into two categories in the order similar to the control commands.

2.2. Multi-stage LSTM model training. The modal analysis of remote-control commands is carried out, and they are grouped into two sub-training groups. LSTM predicts it. The reconstructed training matrix D is used as input in the forecast of telemetry data [9]. The telemetry data for the next point in time is forecast based on the telemetry data for c_t times contained in each submatrix D_n^* and the corresponding global remote-control command. Assuming $t = c_t$, its prediction steps are:

$$D_n^* = \left\{ \begin{bmatrix} d_1^n \\ d_2^n \\ \mathrm{M} \\ d_m^n \end{bmatrix}, \mathrm{L}, \begin{bmatrix} d_1^{n+t} \\ d_2^{n+t} \\ \mathrm{M} \\ d_m^{n+t} \end{bmatrix} \right\} \rightarrow \begin{bmatrix} d_2^{n+t+1} \\ d_2^{n+t+1} \\ \mathrm{M} \\ \hat{f}^{n+t+1} \end{bmatrix}$$

$\hat{f}^{n+t+1}$ is the predicted value at the point $n+t+1$ in time. In constructing the prediction model, the absolute error function (MAE) is the loss function of the LSTM prediction model:

$$\mathrm{MAE}(f, \hat{f}) = \frac{\sum_{i=1}^{n} \left| f_i - \hat{f}_i \right|}{n}$$

n is the total number of all expected values. f_i is the i actual value. This project intends to adopt the LSTM prediction method based on Adam to enhance the sensitivity and accuracy of different control modes through repeated learning [10]. This article sets a specific number of memory modules in each hidden layer as part of the LSTM model to avoid overmatching. LSTM prediction models α and β were obtained after all the sub-training sets were trained.

2.3. Anomaly detection mode of remote sensing data. LSTM was used to train α and β prediction models to obtain two different sequences. Then, the two prediction sequences are weighted and integrated to form the final prediction sequence [11]. The test data is reassembled using a training set B' as an example. LSTM was used to recombine the remote sensing data of α and β, and two sets of remote sensing data prediction sequences $\alpha, \hat{f}_\alpha = \left\{\hat{f}_\alpha^1, \hat{f}_\alpha^2, \mathrm{L}, \hat{f}_\alpha^t, \mathrm{L}\right\}$ and $\beta, \hat{f}_\beta = \left\{\hat{f}_\beta^1, \hat{f}_\beta^2, \mathrm{L}, \hat{f}_\beta^t, \mathrm{L}\right\}$ were obtained. Finally, the weighted matrix $\hat{F}$ is used to integrate the models and obtain the final forecast sequence.

$$\hat{f} = \begin{Bmatrix} \hat{f}_\alpha^1 & \hat{f}_\alpha^2 & \cdots & \hat{f}_\alpha^t & \cdots \\ \hat{f}_\beta^1 & \hat{f}_\beta^2 & \cdots & \hat{f}_\beta^t & \cdots \end{Bmatrix}$$

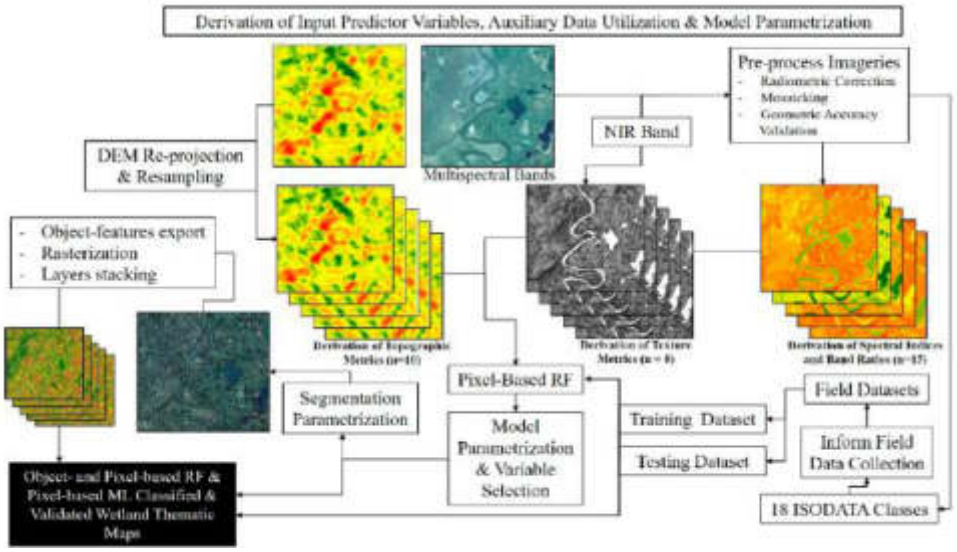

Fig. 3.1: *Remote sensing data processing flow.*

D_t^* is the input to time t, and the corresponding remote control command matrix R_t^* obtains the prediction value $\hat{f}_\alpha^{t+c_t+1}$ of time $t+c_t+1$ through the prediction mode D. The prediction value $\hat{f}_\beta^{t+c_t+1}$ is also obtained from the prediction model β of R_t^* to $t+c_t+1$. If the corresponding norm $C2\left\|R^*\right\|_2$ of R_t^* is the training set α, then:

$$\hat{f}^{t+c_t+1} = \varphi^{t+c_t+1}\hat{f}_\alpha^{t+c_t+1} + \left(1-\varphi^{t+c_t+1}\right)\hat{f}_\beta^{t+c_t+1}$$

If R_t^* corresponds to $C2$ norm $\left\|R^*\right\|_2$ belongs to training set β :

$$\hat{f}^{t+c_t+1} = \left(1-\varphi^{t+c_t+1}\right)\hat{f}_\alpha^{t+c_t+1} + \varphi^{t+c_t+1}\hat{f}_\beta^{t+c_t+1}$$

Gets the remote-control command matrix associated with the current forecast. Dynamically adjust the weights. Finally, A series of prediction sequence $\hat{F}$ is obtained.

3. Space remote sensing cloud processing technology. Remote sensing cloud technology aims to extract new information from massive data. Then, the data is analyzed, reasoned and processed. The Remote sensing data processing process is shown in Figure 3.1 (the image is quoted in Remote sensing, 2017, 10(1): 46). Data preprocessing includes three parts: "data depth processing," "orthographic correction" and "image fusion and conversion." Remote sensing data processing is a typical data-intensive computation. This puts forward higher requirements for data processing methods. In the existing cluster system, task division, task processing and network communication are hardware-based. At the same time, data-intensive computation requires freedom from traditional hardware programming patterns. This allows the application to be described using higher-level semantics [12]. Remote sensing cloud technology integrates the relevant technologies in remote sensing data processing into the cloud to realize the storage, processing and transmission of remote sensing data. With the advent of big data, massive remote sensing data has exceeded the existing storage and computing capabilities. Remote sensing cloud computing can provide storage and analysis tools for remote sensing big data. Cloud computing platform administrators use the cloud storage and computing functions provided by the Internet to users. Cloud computing services include Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS), and business intelligence. Amazon's EC2 is a type of IaaS. Google and Microsoft are PaaS. IaaS is the cornerstone of future IT industry development. The deployment of network and cloud computing and the storage and processing of massive data will promote the development of IaaS.

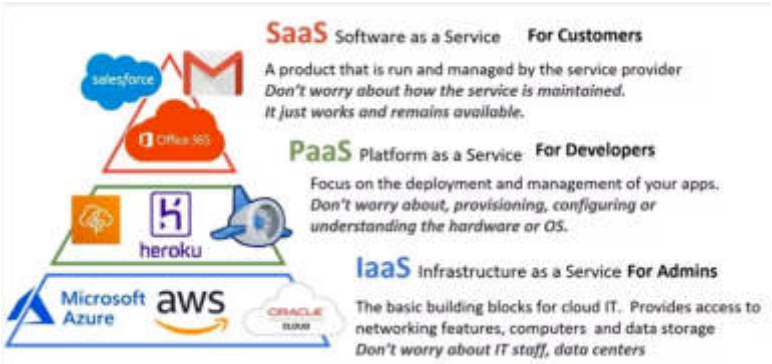

Fig. 3.2: *Cloud service pyramid model.*

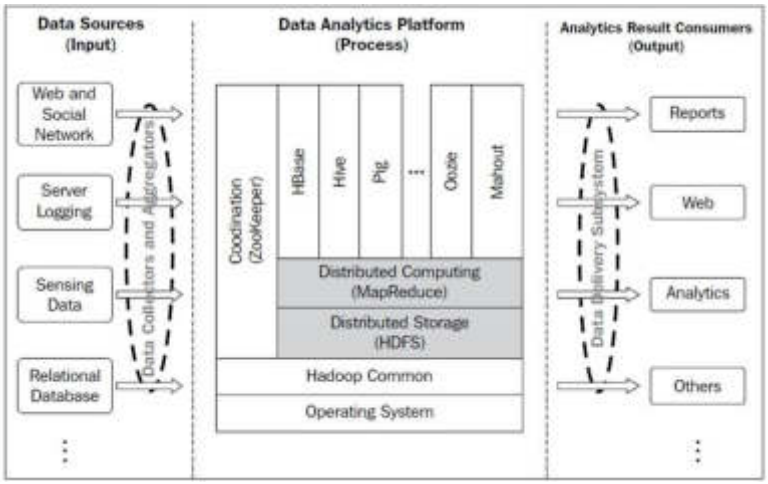

Fig. 3.3: *Hadoop ecosystem architecture.*

PaaS is considered the "operating system" of the future IT industry. SaaS plays a role in communicating with customers. The three service levels can also be re-split. Each tier contains many kinds of businesses, forming a cone pattern similar to the cloud computing services in Figure 3.2. Hadoop is the most popular large-scale data analysis platform based on the Map Reduce framework. Its core idea is the large-scale, data-intensive, parallel application based on the MapReduce framework. Data storage and processing are realized using the Hadoop distributed file system and Map Reduce programming model. The Hadoop ecosystem is shown in Figure 3.3. The typical cloud model can be divided into three levels: the low-level programming model, the base-valued programming model, and the generic parallel programming model. The underlying programming mode mainly includes OpenMP mode and Message Passing Interface (MPI) mode. Map Reduce, introduced by Google, is a typical Key-Value programming model. It uses the idea of divide and rule. The complex problem is divided into several subproblems by recursion until the subproblem can be solved directly. Standard parallel programming includes standard class libraries such as STL and QUAFF.

Among them, Hadoop-GIS is a platform for processing, retrieving and acquiring massive spatial data. ESRI Hadoop is a tool developed specifically for the Hadoop process. Spatial Hadoop uses Map Reduce mode to construct indexes for building spatial data. TTA REEG uses the Map Reduce system based on Spatial Hadoop, whose core is to process the data in OpenStreetMap. CG Hadoop extends Map Reduce to support polygon, boundary, convex set analysis, farthest point, nearest point and other geometric operations [13]. The space

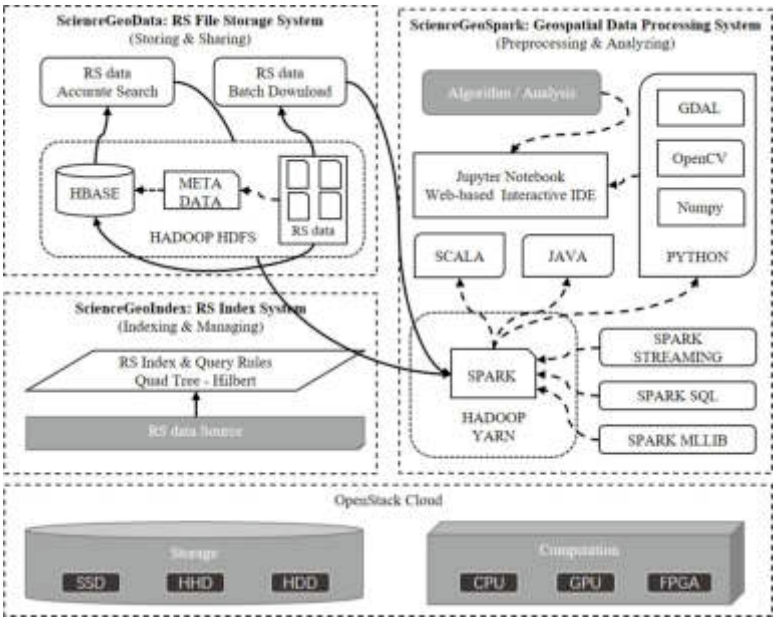

Fig. 3.4: *Remote sensing extensive data processing system based on cloud computing.*

Table 4.1: *Data parameters.*

	SMAP	MSL	Total
Total number of abnormal sequences	72	38	109
Total number of abnormal sequences	66	55	61
Context exception total	40	49	43
Total number of telemetry channels	57	28	49
Total telemetry data detected	447641	69489	517129

remote sensing extensive data processing system based on cloud computing technology is shown in Figure 3.4. The system consists of a remote sensing data acquisition system, a remote sensing data processing system, an extensive data analysis system and a cloud computing system. After the data is preprocessed, the collected data is transmitted to the earth's surface through the downlink, and the remote sensing data processing system is used to store, manage and serve the remote sensing data. Filter data based on availability and distribute processing requests to individual servers using load balancing. After mathematical and logical processing, the result of processing is produced. The paper can focus, edit, analyze, and decide on the data by analyzing the data.

4. System inspection. The confirmation data used in this paper comes from the ISA Report published by NASA, which includes the SMAP and MSL spacecraft models. By comparing with radial neural network (RBF), the detection effect of remote sensing anomaly detection algorithm based on LSTM on point and context is studied.

4.1. Experimental data. The observation data and corresponding remote-control commands of each channel of SMAP and MSL 12 subsystems are used for training and testing. Among these samples, 72 (66.06%) belonged to SMAP and 38 (33.94%) belonged to MSL. Each set contains a different amount of telemetry data and 24 sets of remote commands [14]. The total number of telemetry values for each set is 300-4000. The specific number of training data, the total number of abnormal sequences, the total number of test channels and the total number of test data are shown in Table 4.1.

Table 4.2: *Inspection and comparison of space telemetry anomaly data integrated with LSTM.*

			RBF	Integrated LSTM
SMAP	Point anomaly	Detection rate	88	99
		False alarm rate	10	37
	Context exception	Detection rate	80	92
		False alarm rate	41	56
MSL	Point anomaly	Detection rate	71	71
		False alarm rate	12	12
	Context exception	Detection rate	68	79
		False alarm rate	0	12
Total	Point anomaly	Detection rate	74	81
		False alarm rate	11	34
	Context exception	Detection rate	75	84
		False alarm rate	32	49

4.2. Space telemetry anomaly data inspection integrated with LSTM. Specific test data are shown in Table 4.2. It can be seen from the data in Table 4.2 that compared with the RBF network, the overall anomaly detection rate of the algorithm has increased from 74% to 81%, and the overall anomaly detection rate has increased from 75% to 84%. The algorithm in this paper can make the detection rate of single-point exceptions in SMAP reach more than 95%, while the context exception is stable at about 88%. MSL's single-point anomaly detection rate is about 73%, and the context anomaly is basically stable at about 74%. The single-point anomaly detection rate of Class 2 satellites is about 81%, and the context anomaly detection rate is about 84%. The results show that the point set and the content discovery have greatly improved.

5. Conclusion. A cloud computing platform for space remote sensing information is constructed. A new technique for anomaly detection of LSTM satellite remote sensing data is proposed. The technology is restricted by multiple control modes of remote command, which leads to the degradation of its overall forecasting performance. Multiple LSTM models are established, and the predicted values of each sub-model are weighted and integrated. An exception recognition method based on a dynamic threshold is established. The target can be identified effectively by analyzing the deviation between the data and the actual data.

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APPLICATION OF HIGH-DIMENSIONAL DATA VISUALIZATION AND VISUAL COMMUNICATION TECHNOLOGY IN VIRTUAL REALITY ENVIRONMENT

DAN LIU *

Abstract. How to efficiently find what you want from massive data has become a hot topic. It is precisely because network information is developing so fast that so many data-oriented software systems and pages are used to manage so much network information. Aiming at problems such as insufficient information mining of visual communication websites in ASPNET and poor visual communication effects, a design scheme for integrating high-dimensional data into visual communication websites is proposed. Its working architecture includes high-dimensional data integration, multi-type visual integration, and visual support services. The main functions of the website include comprehensive management, charts, data sources, projects, systems, etc. We have conducted specific design and Implementation of high-dimensional information integration on the website, completed the design and Implementation of integration of high-dimensional data, integration of multiple visualization types, and integrated access to visualization-supported functions. Use a deep web crawler to search the visual site. It uses a search-based approach to filter URLs and crawl valuable web pages. Practice has proved that the intelligent distribution network management page implemented by the solution proposed in this article has good performance. The system shows good performance in visualization implementation and the ability to discover information. The system achieved sound and visual communication effects.

Key words: High-dimensional data; Visual communication; Visualization; Virtual Reality Environment

1. Introduction. In today's society, with the continuous advancement of science and technology, network technology, software and hardware technology are developing rapidly. The amount of information available on the Internet has also increased significantly. How to efficiently find what you want from massive data has become a hot topic. It is precisely because network information is developing so fast that so many data-oriented software systems and pages are used to manage so much network information. The most important of these solutions is visualization. Its most outstanding feature is that it reads data in a form that users can directly receive, providing users with a convenient place for data analysis and learning [1]. Therefore, data visualization has gradually become an essential means of enterprise information management. The design scheme of the visual website based on ASPNET is characterized by rough information mining and poor visualization effects. For this reason, this topic plans to study the visualization page with the support of high-dimensional data to improve the information content and visualization performance of the visualization page.

2. High-dimensional data integration method in Visual Computing .

2.1. Operational Architecture for high-dimensional data integration . Use the JavaEE high-dimensional data integration platform to integrate multi-source data and realize visual expression pages. The integration of high-dimensional data, data visualization technology, and visualization support services integration realize the visualization and visualization of data [2]. When designing the page visualization, according to system integration needs, the visual page based on high-dimensional data can be combined to obtain system data, customize visualization effects and other functions. The web page running architecture is shown in Figure 2.1. The web operating architecture includes the following.

1) Integrate high-dimensional data: The page can integrate high-dimensional data. It provides the integration of various data and solves the integration methods of data files and other functions. The integration of data is completed by the identification and organization of data [3].
2) Multiple types of visualization integration: It enables the page to display the visualization results of different data so that the visualization technology is consistently integrated. This feature enables the integration of large-scale graphs and data visualizations.

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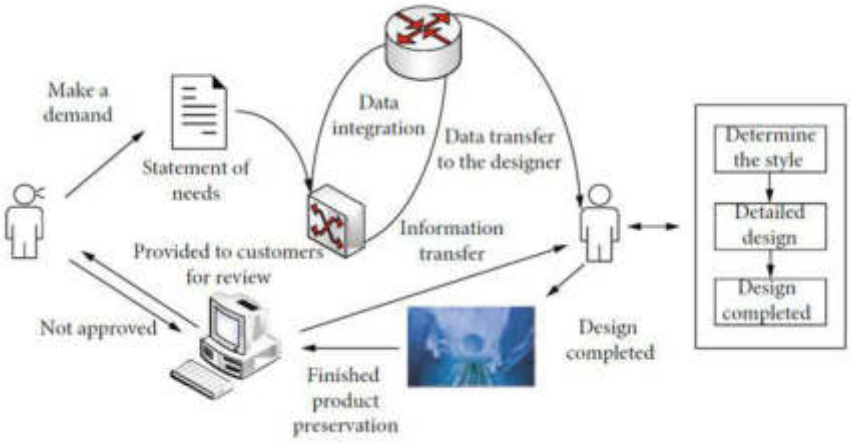

Fig. 2.1: Visual communication web page operation architecture diagram

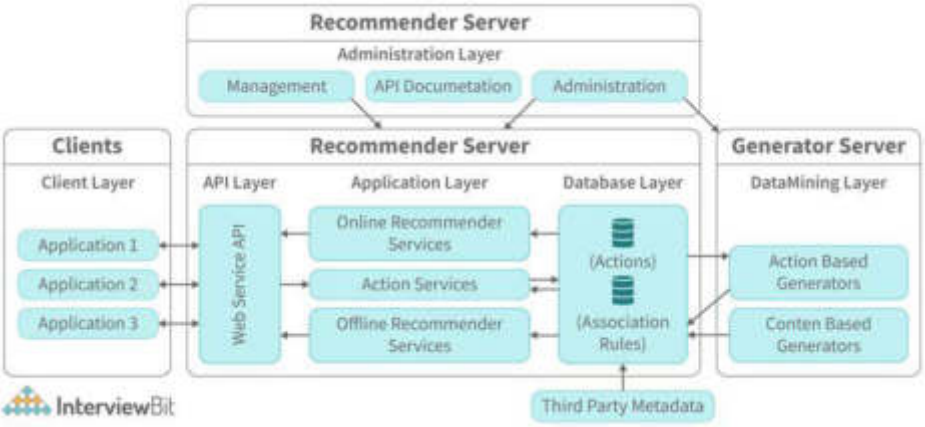

Fig. 2.2: Web page functional architecture diagram

3) Visual support service: It provides a unified visual information integration interface for information exchange between web applications and pages. This facilitates data exchange.

2.2. Web page functional architecture design. The page's overall function has five aspects (Figure 2.2). They are application system integration management, chart management, data source management, project management, and system management.

1) Application system integration management: When users decide on web system integration, data encryption, chart display, etc., online, the web page will summarize the user's various needs. Data can be visualized through a system parameter docking interface, visual comprehensive access and other means.
2) Graphical management: From the four perspectives of visual customization, data visualization and resource visualization integration, it helps users understand the page status presented after integrating data. This is an essential feature.
3) Data source management: Manage databases, files and metadata to determine the scope of use of the website. Its operation relies on the integration of data resources and business processing.
4) Entry management: Entry is a Web page's most basic management unit. In the same project, it can build multiple data sources, charts, application systems, etc. Data exchange is only possible within the same

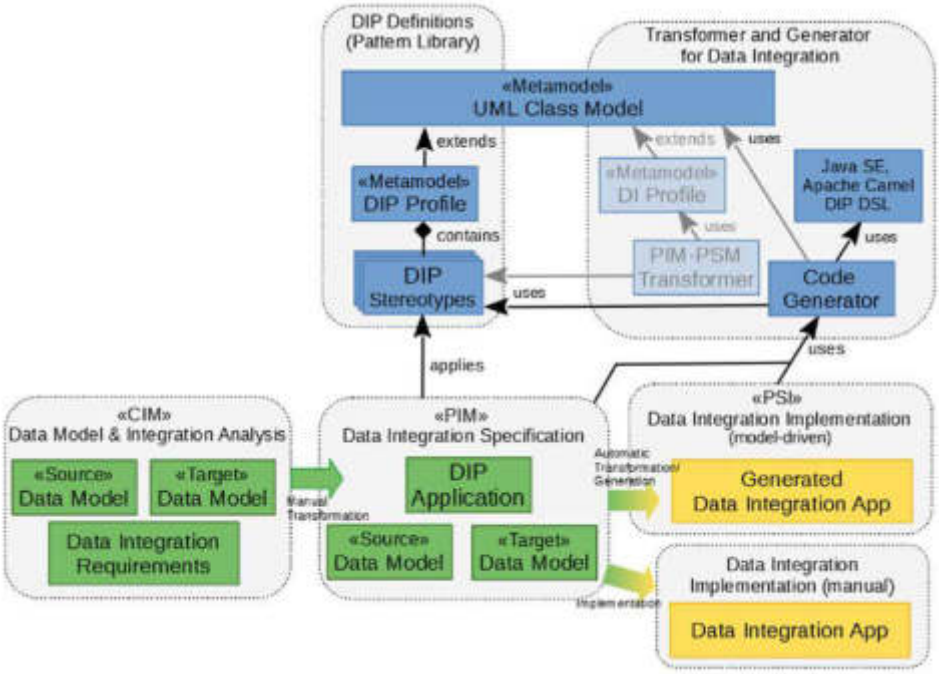

Fig. 2.3: High-dimensional data integration function design

project.

5) System management: System Management is the most basic management unit of the Web page. It has a user system, permission system, security management, and system monitoring to support page data management. And ensure that the work of the website can be carried out smoothly.

2.3. Design and Implementation of high-dimensional data integration function based on Web pages.

2.3.1. Integration function design of high-dimensional data. The visual expression page designed in this paper needs to have the function of high-dimensional data integration. The goal is to meet the growing need for data integration. A scalable and unified data fusion rule is proposed based on the characteristics of high-dimensional data fusion. Realized the normalization of online data integration, induction and classification [4]. Visual communication websites should also have the ability to exchange online data. The goal is to integrate various types of databases and to be able to read various types of data. The design of the integration function of high-dimensional data is illustrated in Figure 2.3.

Third-party technology is the technical support for integrating this information. This enables the most basic browsing and retrieval of data files. If you want to perform more difficult operations on data files and improve the utilization efficiency of data files, then introduce table management into the design to complete the table management of the database [5]. Users can perform complex string splitting or splicing operations on the database by sorting the data files into the database and then adding them to the database table.

2.3.2. Implementation of integration functions for high-dimensional data. High-dimensional data integration of web pages can be carried out from three aspects: input information of web pages, underlying data integration applications, and data integration. The page information to be entered includes database classification, connection address, user name, etc. The primary database application is for creating databases [6]. Data integration is to present data objects in JSON form based on the actions of web page data. High-dimensional data integration uses many input and output operations to complete long-term operations. It

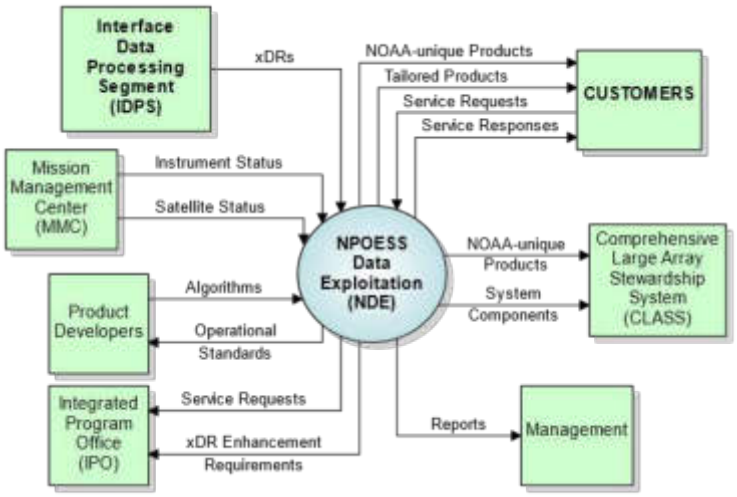

Fig. 2.4: Operation diagram of various visual integration functions

can withstand heavy network traffic. Use interface programming ideas and SOA application methods to make various data operations independent modules. Dubbox turns every module into a function in Zookeeper. The above operations further improve the efficiency of integrating high-dimensional data.

2.4. Implementation of multiple types of visualization integration functions. Achieve multiple visualization integrations, realize visualization technology integration, visual customization, visual data visualization and other functions. Various forms of visual integration are oriented to network technology users, network users, and application system users. Visual integration mainly includes visual technology integration services, visual customization services, data visualization, configurable resources, configurable integrated documents, etc. Its functional operation diagram is shown in Figure 2.4. Multi-type visualization integration generates the same integration rules based on integrated files, combining file integration with dynamic loading of services to expand the visualization scope [7]. This function supports visual technical information organization, visualization effect customization, and visual display, thereby expanding the scope of page visualization operations.

2.5. Integrated access design of Visual Service functions. The visibility support function is the most essential thing in the visibility communication of the website. The software can be customized to integrate information on visually communicated pages. The system presents visual data to users [8]. The system's primary functions include integrated management, system parameter interface, visual integrated access, etc. Integrated visibility access allows users to obtain results after processing the visibility page by executing the system parameter interface when receiving user instructions. Then, the data access, query and implementation analysis were carried out. This process is shown in Figure 2.5.

1. Users can use visual Web pages.
2. Visual Integration Access Visual effect check in Cache service based on integrating high-dimensional information.
3. Continue to use cache traffic to access permission information without visual effects being detected in the cache traffic.
4. Explore the various visual interfaces corresponding to it.
5. The results of the operation are visually stored. 6) Provide visual results to users.

2.6. Workflow of deep web crawler. Dark web scrapers are used to retrieve visual sites. Its crawling method is consistent with other crawlers. It crawls valuable web pages [9] after reducing the links to a list of URLs. Unlike other crawlers, this crawler will only crawl the website's content when crawling. The focus of its

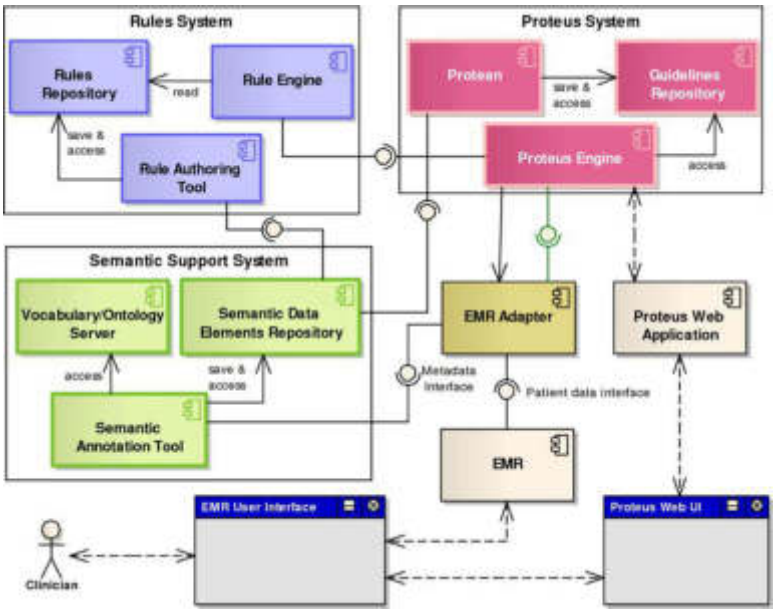

Fig. 2.5: Visual integration access process.

work is whether it exists on the Web page. This article uses the following method to change the page content into a crawler form. The whole process is like this:

1. A deep web crawler crawls this URL.
2. Construct a Web site retrieval form ontology through a deep web crawler.
3. Deep web crawler crawls the page in the retrieval form.
4. Download the pages captured by the Deep web crawler and parse the search form.
5. Pre-populate the required search form.
6. Submit pre-populated results.
7. Store the required forms and display results.

3. Visualization and rapid clustering of high-dimensional data. V_{ktij} represents the data block. $k = 1, 2, \mathrm{K}, q, q$ represents the number of variants of the category. q represents the number of all variants. $t = 1, 2, \mathrm{K}, T, T$ represents a known specific moment. $i = 1, 2, \mathrm{K}, m, m$ represents the meaningful number of times in a single variety. $j = 1, 2, \mathrm{K}, n, n$ represents the number of sequence values in the data grid [10]. If we only look at a single variety, these data $q = 1$ can be reduced to V_{tij}. If it is $m = 1$, the data can be represented by V_{tj}. At this time, if the calculation is performed in days, the data cube will be reduced to a sequence $\{V_t\}$.

We use $V_{kt} = (V_{ktij})_{m\times n}$ to express this matrix [11]. The vector $V_{kt}\varepsilon_n$ obtained by multiplying the variable ε_n by the righthand side is called a weighted average. For example, taking $\varepsilon_n = \left(\frac{1}{n}, \frac{1}{n}, \mathrm{L}, \frac{1}{n}\right)'$ as an example, $V_{kt}\varepsilon_n$ is the average of n days. When the left multiplied vector δ'_m corresponds to the left multiplied vector, the intermediate value $\delta'_m V_{kt}$ is obtained.

$$\mid u_{kt} = \delta'_m V_{kt}\varepsilon_n$$

This leads to the order of k and $\{u_{kt}\}$. $\{u_{kt}\}$ sequences can be found in a huge dynamic database. Multidimensional data patterns require analysis of data based on data cubes [12]. Select an orthogonal function system $\{\sin t, \cos t, \sin 2t, \cos 2t, \mathrm{L}\}$ on $[-\pi, \pi]$ and establish the following mapping:

$$\begin{aligned} &Z = (z_1, z_2, \cdots, z_m) \to g_z(t) = \\ &z_1 \sin t + z_2 \cos t + z_3 \sin 2t + \\ &z_4 \cos 2t + \cdots - \pi \le t \le \pi \end{aligned}$$

1. Maintain linearity.
2. Euclidean distance.
3. It represents a oneto-one relationship from D^m to S^m.

If each component of Z has nothing to do with homoskedasticity ε^2, then if m is an even number, there is the following equation

$$\operatorname{zar}\left(g_z(t)\right) = \frac{m\varepsilon^2}{2}, -\pi \leq t \leq \pi$$

When m is an odd number

$$\frac{(m-1)\varepsilon^2}{2} \leq \operatorname{zar}\left(g_z(t)\right) \leq \frac{m\varepsilon^2}{2}, -\pi \leq t \leq \pi$$

If $Z \sim N_q\left(\lambda, \varepsilon^2 A_q\right)$, then it is possible that $1-\beta$

$$\left|g_z(t) - g_\lambda(t)\right|^2 \leq \frac{\varepsilon^2(m+1)}{2} x_m^2(\beta), -\pi \leq t \leq \pi$$

Here $x_m^2(\beta)$ is the chi-square distribution quantile β. Triangular polynomial graphs with infinitely many projection directions are proposed. That's what makes it unique. If $z, \varphi \in D^m$, then the Euclidean distance between z, φ is

$$d_{z,\varphi}^2 = (z-\varphi)'(z-\varphi)$$

Because $g_z(t)$ and $g_\varphi(t)$ are both multipliable squares on $[-\pi, \pi]$. The following parameters can determine the Euclidean distance

$$d_{g_z g_\varphi}^2 = \int_{-\pi}^{\pi} \left|g_z(t) - g_\varphi(t)\right|^2 dt$$
$$d_{g_z g_\varphi}^2 = \int \pi d_{z\varphi}^2$$

$d_{g_z g_\varphi}^2$ has at most level $W\left(n^2\right)$ complexity. The definition of Euclidean distance is as follows:

$$g_{g_z g_\varphi}^0 = \int_{-\pi}^{\pi} \left|g_z(t) - g_\varphi(t)\right| dt$$

In specific numerical simulations, two different approximation methods can be used. Its operational complexity is $W\left(n^1\right)$! a. $g_{g_z g_\varphi}^0 \approx \sqrt{\pi} \sum_{i=1}^m |z_i - \varphi_i|$ b. $d_{g_z g_\varphi}^0 \approx \frac{2\pi}{\zeta} \sum_{i=1}^{\zeta} \left|\sum_{j=1}^m \gamma_{ij}\left(z_i - \varphi_i\right)\right|$

All γ_{ij} here are unchanged. For each i there is the following formula:

$$\begin{aligned}&(\gamma_{i1}, \gamma_{i2}, \cdots, \gamma_{im}) = (\sin(-\pi + 2\pi i/s),\\ &\cos(-\pi + 2\pi i/s),\\ &\sin 2(-\pi + 2\pi i/s),\\ &\cos 2(-\pi + 2\pi i/s), \cdots)\end{aligned}$$

This equation effectively controls accuracy. Because $d_{g_z g_\varphi}^0$ represents the area of the two curves g_z and g_φ. Compared with the Euclidean distance of g_z and g_φ, it is not only more robust, but its geometric characteristics are also more significant. First divide segment $[-\pi, \pi]$ into ζ segments:

$$\underset{n\to\infty}{\tilde{d}_{g_z g_\varphi}^*} = \frac{2\pi}{\zeta}\left|g_z\left(-\pi + \frac{2\pi}{\zeta} i\right) - g_\varphi\left(-\pi + \frac{2\pi}{\zeta} i\right)\right|$$

Let z and φ be two points on the $2q$ dimension,

$$
\begin{aligned}
&g_z\left(-\pi+\frac{2\pi}{n}i\right)=(z_1,z_2,\cdots,z_{2q})\left(\sin\left(-\pi+\frac{2\pi}{n}i\right),\right.\\
&\cos\left(-\pi+\frac{2\pi}{n}i\right),\cdots,\sin q\left(-\pi+\frac{2\pi}{n}i\right),\\
&\left.\cos q\left(-\pi+\frac{2\pi}{n}i\right)\right)^T\ i=1,2,\cdots,n\\
&g_\varphi\left(-\pi+\frac{2\pi}{n}i\right)=(\varphi_1\varphi_2,\cdots,\varphi_{2q})\left(\sin\left(-\pi+\frac{2\pi}{n}i\right),\right.\\
&\cos\left(-\pi+\frac{2\pi}{n}i\right),\cdots,\sin q\left(-\pi+\frac{2\pi}{n}i\right),\\
&\left.\cos q\left(-\pi+\frac{2\pi}{n}i\right)\right)^T\ i=1,2,\cdots,n\\
&g_x\left(-\pi+\frac{2\pi}{n}i\right)-g_u\left(-\pi+\frac{2\pi}{n}i\right)\\
&\cos\left(-\pi+\frac{2\pi}{n}i\right),\cdots,\sin q\left(-\pi+\frac{2\pi}{n}i\right),\\
&\left.\cos q\left(-\pi+\frac{2\pi}{n}i\right)\right)^T\ i=1,2,\cdots,n\\
&g_x\left(-\pi+\frac{2\pi}{n}i\right)-g_u\left(-\pi+\frac{2\pi}{n}i\right)\\
&=(x_1-u_1,x_2-u_2,\cdots,x_{2q}-u_{2q})\times\left(\sin\left(-\pi+\frac{2\pi}{n}i\right),\right.\\
&\cos\left(-\pi+\frac{2\pi}{n}i\right),\cdots,\sin q\left(-\pi\left(\frac{2\pi}{n}i\right),\right.\\
&\left.\cos q\left(-\pi+\frac{2\pi}{n}i\right)\right)^T\ i=1,2,\cdots,n\\
&d^0_{g_{z}g_{\varphi}}=\frac{2\pi}{\zeta}\sum_{i=1}^{\zeta}\left|\sum_{j=1}^{m}\gamma_{ij}\left(z_i-\varphi_i\right)\right|
\end{aligned}
$$

4. Experimental results and analysis.

4.1. Development of intelligent power grid dispatching system in the network environment. This software has been widely used in the operation management, equipment management and user services of electric power enterprises. It has real-time monitoring, calculation analysis, information exchange and other functions [13]. The page has very little traffic. Figure 4.1 illustrates the overall trend effect of the intelligent allocation management page designed in this way through experiments (picture cited in Designs 2022, 6 (5), 88). The entire analysis page can be applied to calculate the company's electricity consumption during each period. Calculation is performed based on the data configured according to the device number, and the overall power trend is displayed with dynamic data. Through case analysis, it is proved that the intelligent distribution network management page implemented by this method has sound effects in practical applications [14]. It is a compelling power distribution management web page.

4.2. Visualization implementation effect inspection. In this way, when working with other application systems, the operation of other application systems can become more convenient. Among them, high-dimensional data fusion, multi-type visualization fusion, and visualization support are critical [15]. Through

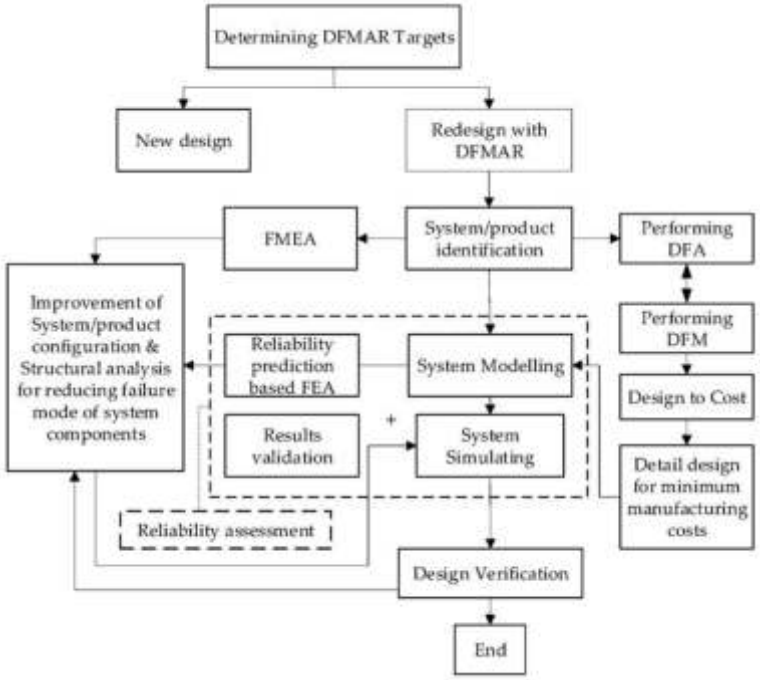

Fig. 4.1: Deep in web crawler operation process.

Table 4.1: Comparison table of visualization tools

Contrast item	**Methods of this article**	**Jaspei Report**	**Pentabo Reporting**	**DataV**
Multiple data sources	support	not support	support	not support
Online customization and maintenance	support	not support	not support	support
Visualization source	Open source	Independent research and development	Open source	Independent research and development
Compatibility with other visualization technology architectures	compatible	Not compatible	Not compatible	Not compatible
Seamless integration	easy	complex	complex	difficulty

experiments, the method in this article and other visualization methods are compared in terms of each function's support, compatibility and difficulty when designing intelligent power distribution management pages. These results are illustrated in Table 4.1. Compared with other visualization methods, we can see that this solution can provide multiple data sources, online customization and maintenance functions. It is compatible with other visualization technology architectures. Easy to seamlessly integrate the system. This method shows good results in page visualization.

4.3. Data mining performance testing. By comparing with the traditional ASPNET algorithm, the application of this algorithm in "food" and "games" is verified [16]. The experimental data are given in Table 4.2. It can be seen that this algorithm obtains more data than the conventional ASPNET algorithm. It shows that this algorithm has a better retrieval effect in food and game retrieval. It can better uncover more helpful information. The list of all sites obtained by experimental statistics is shown in Tables 4.3 and 4.4. The site list obtained this way is more detailed and richer in content. The results show that this algorithm has good results in information mining.

Table 4.2: Mining data

Project	The data obtained by this method	Data obtained by ASPNET method
Number of visits to the site	41.7	26.0
Number of forms that have been processed	129.2	102.1
Number of forms submitted	46.9	33.3
Maximum number of forms submitted	78.1	62.5
Minimum form size	2.1	1.0
Minimum assignment merge level	0.6	0.5

Table 4.3: List of websites obtained by this method

Website name	URL
meituan.com	https://www.meituan.com/
Are you hungry	https://www.ele.me/
Ctrip	https://hotels.ctrip.com/
Public comment	https://m.dianping.com/
Tik Tok	https://www.douyin.com/
Taobao	https://taobao.com/
quick worker	https://www.kuaishou.com/

Table 4.4: List of websites obtained by traditional ASPNET method

Website name	URL
meituan.com	https://www.meituan.com/
Are you hungry	https://www.ele.me/
Ctrip	https://hotels.ctrip.com/

5. Conclusion. A multidimensional fast clustering algorithm is proposed based on the visual processing of multidimensional data. The paper also provides a comprehensive design method for visual communication websites. Then, an improved Web page data analysis method is proposed. The experimental simulation found that this algorithm achieved better results.

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CROSS-BORDER E-COMMERCE LOGISTICS OPTIMIZATION ALGORITHM FOR COLLABORATION BETWEEN THE INTERNET OF THINGS AND LOGISTICS

SHILING PAN* AND JUAN CHENG†

Abstract. This paper proposes the shortest path optimization algorithm for domestic and overseas e-commerce logistics based on a bilateral search method. This paper uses the logistics distribution route optimization algorithm based on the shortest path to set the collaborative parameters. Then, it builds an adaptive optimization model for the grid planning of domestic and overseas e-commerce logistics path. The route is optimized. Then, the PSO and genetic algorithm are integrated to establish the logistics path planning model of domestic and overseas e-commerce. The superiority of the proposed route optimization algorithm in domestic and overseas e-commerce logistics distribution is verified through simulation experiments. This algorithm has high spatial positioning efficiency and high transportation efficiency.

Key words: Internet of Things; Bilateral search method; Logistics collaboration; Domestic and overseas e-commerce; Transport route; Path planning algorithm

1. Introduction. With the rapid development of domestic and overseas e-commerce, consumers have an increasingly high demand for e-commerce at both the economic and real-time levels. Whether goods can be delivered to users on time and economically is essential for consumers to obtain satisfaction. Under the premise of meeting customer needs, delivering goods to the specific location required by customers with the lowest cost and shortest time has been the essential requirement of transnational e-commerce business. Logistics distribution has higher cost efficiency and better real-time performance. Customers want to know the status of their goods in real-time with minimal cost. At the same time, the customer expects the goods to be delivered within the expected delivery time. How to meet the customer's time demand for products to reduce the logistics and distribution costs is an essential topic in the current international research. But the cost of international trade is also increasing, making it difficult for e-commerce companies to bring high-quality services to customers. With the deepening of domestic and overseas e-commerce business and the broad application of the Internet, a diversified global logistics system has developed rapidly. This has led to diverse options for how goods move around the world. Currently, China is in a dilemma of mutual penetration of domestic and overseas e-commerce and logistics, and it is urgent to find countermeasures and optimization ways for their mutual integration and mutual development.

Literature [1] studies the cooperation decision of domestic and overseas e-commerce and transnational logistics enterprises. However, there is no in-depth research on how to improve customer satisfaction. Literature [2] analyzes the growth process of international trade and cross-border business from the supply chain perspective. Then, based on the "alienation law," this paper discusses how to enhance the competitiveness and profitability of transnational e-commerce enterprises. However, this method does not establish the relevant mathematical model or have the relevant mathematical theory support. Literature [3] takes refrigerated container transportation as the research object and establishes a mathematical modeling method for the comprehensive cost minimization of cold chain logistics to minimize freezing, transportation and transit costs. The path planning is solved as a parameter. It is calculated that there are differences in the optimal routes between cold storage and conventional containers under different conditions. However, optimizing the optimal route is not included because of the cost. This results in the inefficiency of the whole system. From shipper route selection, literature [4] established freight organization optimization methods in the port area of the upper reaches of the Yangtze River. However, this distribution route optimization method is based on a genetic algorithm. Its poor adaptive

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optimization ability leads to poor effect of transportation path planning. Therefore, this paper proposes the bilateral search method for domestic and overseas e-commerce logistics route planning. Firstly, the path characteristics of transnational e-commerce logistics are optimized using path information clustering. The model is solved by particle swarm optimization [5]. The simulation results are verified and analyzed. The simulation results show that this method can effectively improve the traffic route planning ability of transnational e-commerce systems.

2. Design of domestic and overseas e-commerce logistics management system . This paper builds a domestic and overseas e-commerce logistics service system under the mobile Internet [6]. The aim is to effectively control and monitor it through the mobile Internet to achieve satisfactory information management.

2.1. Domestic and overseas e-commerce integrated service architecture . The overall structure of the domestic and overseas e-commerce logistics service system based on the mobile Internet can be divided into a logistics monitoring system, mobile Internet system and mobile user terminal system. Its core is to use B/S architecture to manage each module [7]. The monitoring center of the logistics service system is mainly composed of the database, GPS server, mobile communication server, etc. It can monitor and collect each networked mobile terminal in real-time and pass the corresponding information to logistics transportation and distribution employees. At the same time, it can also pass the instant message of the logistics business to the management so that all aspects of the logistics activity become an organism. Mobile communication network uses radio as a data transmission medium to build a bridge between the monitoring center and mobile phone users. Due to the continuous development of domestic mobile communication technology, the 5G communication network has been quite popular [8]. The distance used and the speed of transmission have been greatly improved. The wireless network can provide stable and reliable transmission service for the logistics support system. Mobile terminal equipment is also a critical link in the logistics service system. Most mobile phones and tablet computers currently have GPS positioning and wireless networking functions. It can collect and transmit logistical information.

2.2. Functions of domestic and overseas e-commerce logistics service system. Figure 2.1 shows the functional architecture of the domestic and overseas e-commerce logistics service system. The system collects the task order, scans the items, sends and signs for receipt, and deals with anomalies and service statistics [9]. The task command extraction function is to transmit the distribution information to the mobile phone operation platform through the mobile phone network to improve employees' work efficiency. The function of item scanning is to encode and scan the item so that the item corresponds to the number one by one. The scanned data is transmitted to the monitoring center, which is convenient for managers to search and deploy. The delivery signature of the Courier company is to facilitate the inspection of the cargo information between the Courier and the recipient. Abnormal processing refers to various abnormal conditions (such as loss and damage to items) that occur in the logistics process and are stored in the system's database [10]. The business statistics function can calculate transport-related business information in the logistics process, such as the number of delivery employees, transportation plans, etc. Logistics supervision and operation systems are essential data management functions, logistics distribution management functions, distribution management functions, and operation report database management functions [11]. Database management realizes the functions of customer information management, goods distribution management, transportation route planning, logistics information collection and statistics. Among them, the logistics distribution monitoring system can realize the functions of GPS position and navigation for the mobile terminal equipment and collect and upload relevant information, such as the traffic status and route of the goods, in real time. This is convenient for operators and customers to inquire. Enterprise report database management realizes the summary of various types of reports of various types of enterprises and stores them in a dedicated database.

The mobile Internet module uses mobile phone communication technology. It can interact with the Internet and has a wide range of uses. It can achieve seamless connections in fast motion [12]. At present, the main communication networks, such as 4G and 5G, are relatively mature, which can ensure the efficient and stable data transmission of mobile terminals. It has laid the foundation for upgrading and transforming China's domestic and overseas e-commerce logistics management system.

A modern logistics management mode system based on mobile Internet is proposed. It gives full play to

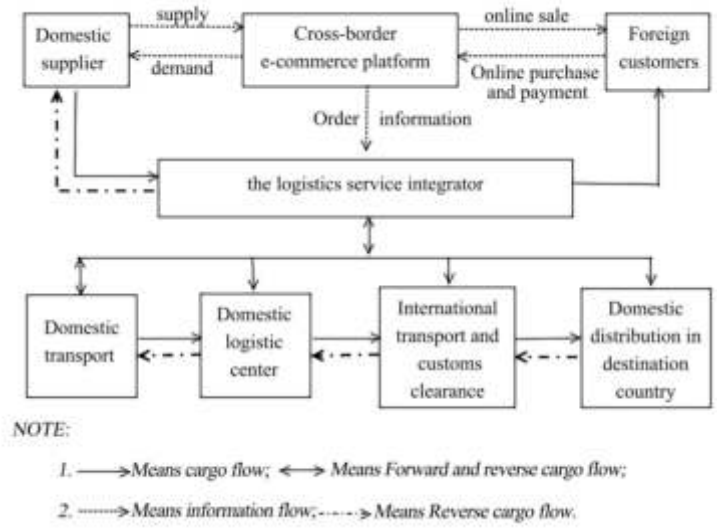

Fig. 2.1: *Functional architecture of domestic and overseas e-commerce logistics service system.*

the advantages of mobile Internet, real-time collection and processing of logistics information, which is helpful to alleviate the problem of poor real-time logistics information in our country [13]. It points out a new way for the informatization development of our logistics industry to enhance the core competitiveness of our logistics enterprises.

3. Grid division and feature matching of e-commerce logistics distribution routes.

3.1. Rasterization of traffic routes . The optimization method of domestic and overseas e-commerce logistics distribution routes based on linear programming is established.

$$\min K = \sum_{m=1}^{M}\sum_{i=1}^{l} u_{i,i+1}^{m} K_{i,i+1}^{m} + \sum_{m=1}^{M}\sum_{n=1}^{M}\sum_{i=1}^{l} f_{i}^{m,n} K_{i}^{m,n}$$

$$\min Z = \sum_{m=1}^{M}\sum_{i=1}^{l} u_{i,i+1}^{m} Z_{i,i+1}^{m} + \sum_{m=1}^{M}\sum_{n=1}^{M}\sum_{i=1}^{l} f_{i}^{m,n} Z_{i}^{m,n}$$

K represents the total time spent in the entire delivery process. Z is the total expense. $u_{i,i+1}^{m}, f_{i}^{m,n}$ is the determining variable. $u_{i,i+1}^{m} = 1$ is the choice of the transport mode of m between i and $i+1$.$f_{i}^{m,n} = 1$ is the transport mode from node i mode m to another transport mode $n.l = (l_i)$ is the transport mode, which is the set of alternative paths of all traffic nodes [14]. Where M is the distribution characteristic of the transport vehicle set. From this, the number of global circulation paths of goods in transnational n commerce is obtained. The time and space parameters $N_1,\ \mathrm{L}, N_n$ and $Q_1^{\min}, \mathrm{L}, Q_n^{\min}$ of road flow are obtained by linear fusion of road flow characteristics. An optimization algorithm based on the network topology structure is proposed to obtain the weighted coefficient $S^K = [s_1, S_2,\ \mathrm{L}, S_n]$. The optimal route parameter set of the node is obtained by block-matching the traffic distribution on each node.

$$u_i^m + u_{i+1}^n \geq 2 f_i^{mn}$$
$$Z_{i,i+1}^m, Z_i^{mn}, K_{i,i+1}^m, K_i^{mn}, \sigma \geq 0$$

$[0, \sigma]$ is the delivery time limit suggested by the customer. The shortest path optimization method is used to design domestic and overseas e-commerce logistics route parameters [15]. An adaptive optimization model based on a grid is established. The uniform rectangular grid obtained by grid planning of the domestic and overseas e-commerce logistics transportation path is shown in Figure 3.1.

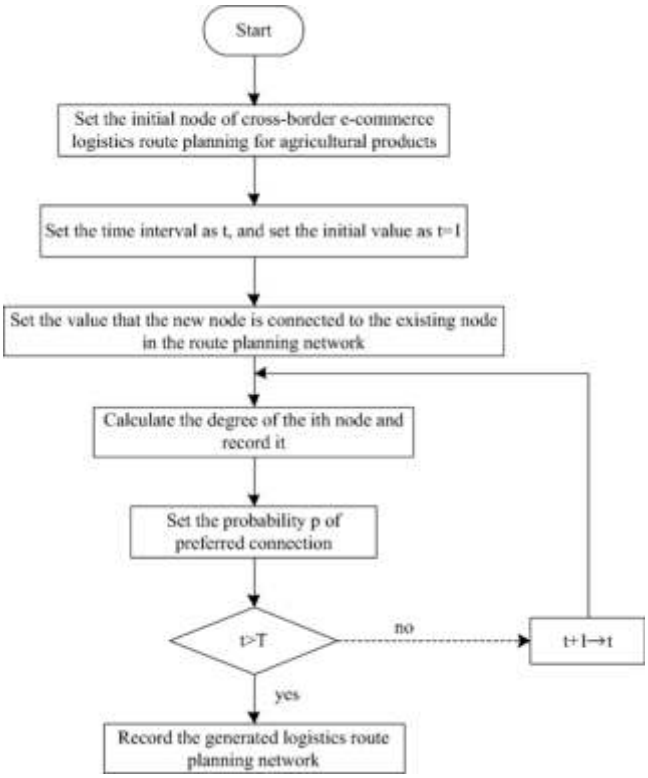

Fig. 3.1: *Grid planning of domestic and overseas e-commerce logistics transportation paths.*

3.2. Transport path feature matching. The path of domestic and overseas e-commerce logistics transportation is optimized using the path information cluster analysis based on raster data. It is assumed that the block characteristic matching matrix of the network node can be expressed as:

$$Q(u) = \begin{pmatrix} \frac{\partial r_1(u)}{\partial u_1} & \mathrm{L} & \frac{\partial r_1(u)}{\partial u_n} \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ \frac{\partial r_M(u)}{\partial u_1} & \mathrm{L} & \frac{\partial r_M(u)}{\partial u_n} \end{pmatrix}$$

$\frac{\partial r_M(u)}{\partial u_n}$ represents the balanced distribution of domestic and overseas ecommerce transport routes in the road network. The quadratic gradient method $\nabla^2 Q(u)$ is used to describe the problem of cargo traffic route planning in domestic and overseas e-commerce [16]. Suppose that the number of nodes E of the associated properties of each path is constant. In state $t < \eta$, the matching of the traffic route characteristics of domestic and overseas e-commerce is expressed as follows:

$$S_i = \int_{1 \le i \le E} \frac{1}{r(t)K_{i,j+1}^m - d(t)K_i^{mn}} dt Q(u)$$

t is the time of the planned international freight route. $r(t)$ and $d(t)$ represent the volume and density of goods along the transit route of domestic and overseas ecommerce.

4. Dual-path query optimization of goods distribution routes in domestic and overseas e-commerce.

4.1. Dual-path optimization Query. The bidirectional search optimization algorithm is used to realize the shortest route planning of domestic and overseas e-commerce logistics distribution routes [17]. Different

road network structures are constructed by optimizing input, output, and intermediate layers. At this time, the compressed output of traffic flow characteristics is expressed as

$$H = \sum_{m=1}^{M}\sum_{n=1}^{M}\sum_{i=1}^{l} u_{i,i+1}^{m} f_i^{m,n} Z_i^{m,n} + \min \sum_{m}^{M}\sum_{i=1}^{l} \left(K_{i,i+1}^{m} - ES_i\right)$$

$M = \{m_1, m_2,\ \mathrm{K}, m_N\}$ is a parameterized distribution scheme for transnational e-commerce distribution routes. N is the metric distance. Where l is the number of routes that goods in domestic and overseas e-commerce travel on the road. Assume that the optimal control is between each solution and the ideal solution. The traffic flow set of the whole road network is built based on the discrete sampling of group n with various traffic flows. The expressions of tensor dimension and output tensor obtained during path optimization are as follows:

$$\phi(i,t) = \sum_{i\in E} \nabla^2 Q(u) H + Z_{i,i+1}^{m} K_{i,i+1}^{m}$$

Node i has n adjacent nodes j. The following fuzzy iterative formula can be obtained by optimizing the cargo transportation routes in transnational e-commerce:

$$S^* = \frac{(z_1 - z_2)\, u_{i,i+1}^{m} - d(t)\delta_i}{K_{i,i+1}^{m}\phi(i,t)}$$

z_1 and z_2 are the learning coefficients of the sections. The optimal logistics transportation path of transnational e-commerce is $(X_1(0), X_2(0), \mathrm{L}, X_N(0))$. The distribution route planning and route allocation of domestic and overseas ecommerce is expressed in the diagonal matrix.

$$G = \begin{pmatrix} u_{i,i+1}^{m} Z_{i,i+1}^{m} & \mathrm{L} & 0 \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ 0 & \mathrm{L} & u_{i,i+1}^{m} K_{i,i+1}^{m} \end{pmatrix}$$

The hesitating fuzzy set of intuitive duality is defined as d. The overall control factors of logistics distribution routes of transnational e-commerce based on unaffiliated metrics are proposed. Its expression is:

$$d_i^m = \frac{\bar{d}_i S^*}{\sum_{n=1}^{n} \bar{d}_n}$$

The loading information of node i, which is arranged by domestic and overseas e-commerce logistics and transportation modes at time t, is as follows:

$$\bar{d}_i = \left(\prod_{n=1}^{n} p_{in}^{m}\right)^{\frac{1}{n}}$$

p_{in}^{m} is the hesitation-ambiguity weighting of the intuitive dual. At this time, the formula for optimizing the distribution route of transnational e-commerce logistics can be obtained:

$$D = \sum_{m=1}^{n} G d_i^m \cdot \bar{d}$$

4.2. Path planning optimization model. A feature decomposition algorithm based on non-membership degree is proposed. The transportation path optimization node is $Q_M = (u_M, f_M)$. In this paper, a traffic flow density formula based on the direct dual hesitant fuzzy set model is proposed to solve this problem:

$$g_D(i) = \frac{|M_E Q_M| + |M_R D_i|}{M_D}$$

M_E, M_R and M_D are the number of nodes of international logistics transportation path planning under time conditions E, R and D. Assume that the maximum iteration time is $E_{\max}$ to increase the coverage of the entire network. The current iteration algebra is E_z. Then, an adaptive weight algorithm based on the local ant colony algorithm is proposed.

$$p_{ij}^m = \frac{\sum_{i=1}^n g_D(i) - \sum_{j=1}^n l_{nj}}{2n}$$

A domestic and overseas e-commerce distribution network model based on a spatial planning matrix is proposed. The error measurement parameters obtained in the road vertical coordinate system are:

$$y_i = \sum_{m=1}^{n} \sum_{i \in E} \nabla^2 Q(u) \frac{(z_1 - z_2)\, u_{i,i+1}^m - Z_{i,i+1}^m}{p_{ij}^m}$$

The double hesitation fuzzy unit describes the transport route of goods in domestic and overseas e-commerce.

$$J_i\left(g_i(j)\right) = \int_1^{\infty} \frac{g_d(i) y_i}{r(t) Z_{i,i+1}^m - d(t) Z_i^{mn}} dt$$

This paper proposes an optimization algorithm based on Hamming distance to optimize the transportation path of domestic and overseas e-commerce logistics. The fuzzy membership function of the traffic route planning problem of transnational ecommerce enterprises is expressed as follows:

$$\kappa = \sum_{m=1}^{M} \sum_{i=1,j=1}^{M} J_i\left(g_i(j)\right) p_{ij}^m$$

The optimization model of transnational e-commerce logistics distribution route based on particle swarm optimization algorithm is proposed:

$$\Phi(u) = \frac{\sqrt{2}\tau \left\| g_i(d) p_{ij}^m \right\| \kappa}{r(t) Z_{i,i+1}^m - d(t) Z_i^{mn}}$$

τ is the route planning method of domestic and overseas e-commerce logistics based on the geographical coordinate system. Where κ is the frequency characterization of freight route allocation of goods in transnational e-commerce.

5. Simulation test analysis. Finally, taking the goods purchased by a customer and the logistics distribution optimization model of the product as an example, the mathematical model and solution method are empirically studied. Table 5.1 shows the information on the goods purchased by this customer. Table 5.2 is the price information table for each logistics company to send the goods to the location specified by the customer. The customer's expected logistics distribution time is 3.5 working days. The ideal distribution of shipping costs is $1354. In the objective function of logistics distribution optimization, the two weight values $\alpha\beta$ are respectively 0.5.ε is 0.000001 . The algorithm is iterated 100 times, and its optimal effects are listed in Table 5.3 below. The algorithm is optimized in this paper. The shipping cost of this order is $1250.52. The transportation cycle of the entire cargo is 3.5 days. From the optimal effect, the transportation time of the whole goods is close to the customer's expectation of 3.5 days. But the cost of transporting the entire cargo was much lower than customers expected.

Through the analysis of Figure 5.1, we can see that the model established in this paper can plan the logistics route of transnational e-commerce. The resulting data is shown in Figure 5.2.

Through the analysis of Figure 5.2, we can see that the traffic predicted by the model established in this paper is consistent with the actual traffic. The model established in this paper has good optimization performance and higher accuracy in optimizing and determining domestic and overseas e-commerce logistics distribution routes, and its convergence is shown in Table 5.4. The method proposed in this paper has a good convergence performance for traffic route planning in transnational e-commerce.

Table 5.1: *Commodity information table.*

Product	Quantity	Weight per piece (kg)
1	21	0.10
2	5	6.77
3	13	1.56
4	17	0.52
5	6	8.33
6	8	7.81
7	16	0.52
8	9	1.04
9	3	9.90
10	16	1.82

Table 5.2: *Logistics distribution unit price quotation information table ($).*

Logistics company	m 1kg	1kg m 5kg	5kg m 10kg	Time (d)
1	5.21	9.90	26.56	3.13
2	5.73	10.16	27.86	3.65
3	6.25	10.42	31.25	2.60
4	5.16	9.11	30.21	4.17
5	5.36	10.05	33.33	4.69
6	5.47	9.74	31.51	2.60
7	4.95	11.20	30.99	3.13
8	5.89	9.53	31.25	3.65
9	5.78	10.26	32.29	3.65
10	5.99	10.57	34.38	2.08

Table 5.3: *Results of logistics distribution optimization.*

Product	Logistics distribution company	Logistics distribution cost	Logistics Delivery time (d)
1	2	114.58	3.65
2	1	132.81	3.13
3	1	118.75	3.13
4	9	92.50	3.65
5	1	159.38	3.13
6	5	266.67	4.69
7	10	89.84	2.08
8	5	90.47	4.69
9	2	83.59	3.65
10	5	101.93	4.69

Table 5.4: *Convergence performance test of model path planning.*

Model	Minimum capacity	Maximum capacity	Mean value
ARMA	2.900	6.026	3.633
PC	0.566	2.653	2.024
ANN	2.558	5.783	3.575
MB	3.586	4.571	3.463
ALR	2.580	3.578	2.860
Road network TS	1.502	4.732	3.586

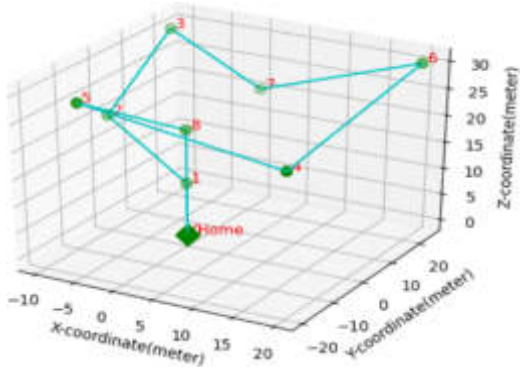

Fig. 5.1: *Optimal path planning results.*

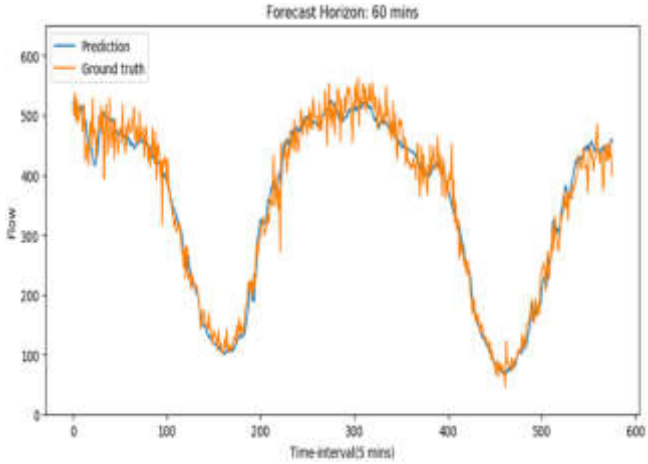

Fig. 5.2: *Forecast results of logistics transportation traffic flow.*

6. Conclusion. This paper first establishes the grid-parameterized model of domestic and overseas e-commerce logistics distribution trajectory. Then this paper analyzes the linear programming of traffic flow data. The shortest path in the domestic and overseas e-commerce logistics transportation path planning is planned. Finally, this paper uses a standardized Hamming distance measurement algorithm to optimize domestic and overseas e-commerce logistics networks. The simulation results show that the method established in this paper has achieved good results in optimization.

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STOCK QUANTITATIVE INTELLIGENT INVESTMENT MODEL BASED ON MACHINE LEARNING ALGORITHMS

KANGYI WANG*

Abstract. In order to cope with sudden changes in market style, the author designed and implemented an investment system. In response to the inability to cope with sudden changes in market style, the author proposed an improved scheme when using a classifier for training, using a hidden Markov model to select time points in the same market state as the training samples for the classifier. The results of backtesting and real market testing show that the improved investment system can capture changes in market style, and during the testing period, the test results obtained higher returns compared to the pre improved classifier. At present, the investment system implemented by the author has become the core backend module of the officially launched intelligent investment advisory product Zhiyu Liangtou APP, providing strong investment decision-making suggestions for small and medium-sized investors. In the future, we can provide backend support for more user end products.

Key words: Machine learning algorithms, Stocks, Quantification, Intelligent investment model

1. Introduction. In recent years, with the continuous growth of people's wealth and the improvement of financial awareness, stock investment is receiving more and more attention. People investing in stocks can not only achieve diversified asset allocation, but also share the dividends of the development of the real economy. In the investment process, people try to obtain the highest possible returns while taking the smallest possible risks [1]. The use of manual methods for stock trading has many drawbacks, which can greatly discount the investment results. For example, human emotions during manual operations, the speed and ability of the human brain to process information, and the ability to evaluate risks and returns all limit the level of investment.

With the development of computer tools, people are trying to use computers to automatically discover investment opportunities, calculate risk indicators, and place orders. Quantifying the use of trading rules in investments, allowing the system to execute without emotion, overcomes human weaknesses, and this is called quantitative investment. Quantitative investment is widely welcomed due to its advantages such as discipline, systematicity, accuracy, and timeliness [2]. The most widely circulated quantitative investment case is Renai ssance Technologies in the United States, a fund under the company called Medallion. The industry speculates that it used hidden Markov models to guide investment, with an annualized return of 35.6% between 1988 and 2008. The Chinese stock market started relatively late and has characteristics such as a large number of retail investors and being greatly influenced by policies. According to the efficient market hypothesis, the Chinese market is far from reaching an efficient state, but because of this, the profit margin of the Chinese market is very large, which also attracts people to continuously make quantitative investment attempts.

In order to achieve success in quantitative investment, the key lies in establishing effective mathematical models or directly predicting stock prices, choosing to buy stocks when they are about to rise or sell stocks when they are about to fall, or indirectly predicting which stocks will perform relatively well in the future, in order to buy these stocks and form an investment portfolio to obtain higher returns than market benchmarks.

A major test criterion for the success of quantitative investment is that the return on investment portfolio should be higher than the benchmark return, which is generally represented by market indices such as the Shanghai and Shenzhen 300 Index, representing the weighted average return of the market [3,4].The reason for requiring the return of an investment portfolio to be higher than the benchmark return is because investors can directly purchase index funds in the fund market and obtain the benchmark return. If the return on the

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investment portfolio is lower than the benchmark return, investors can directly give up active investment and purchase index funds. In response to these issues, the author starts from domain knowledge, places equal emphasis on financial background and statistical significance, filters a large amount of data, and establishes a feature library. When using these factors as features, the author uses hidden Markov models to improve, identify market styles, and adjust the samples used for training, so that the classifier can adapt to the new style as soon as possible.

2. Methods.

2.1. Market Style Recognition Method Based on Hidden Markov Model. The author uses Hidden Markov Model (HM) to improve the Adaboost multi factor model. The main method is to divide the implicit states of the past period of time through some indicators, select historical data that is in the same state as the current time as the training set, and then use a classifier to screen for stocks with high future returns [5].

There are several main reasons for choosing HMM:

1. There are fewer HMM parameters. When HMM learns parameters, the only parameter that needs to be manually selected is the number of implicit states.
2. The number of hidden states in HMM has some explanatory power in the application scenarios of financial time series data. Although the implicit state is assumed, after analysis, a posterior explanation can be made based on experience. For example, assuming there are three hidden states, after training, obtain parameters, and then use these parameters to predict features, it is likely to find that the three hidden states correspond exactly to the three states of rise, fall, and consolidation in the stock market. This is different from some other black box models. With explanatory power, the model becomes more convincing and safer to use. The number of states needs to be determined by oneself. For example, the market can be divided into two states: up and down, or three states: up, down, and consolidation. It can also be subdivided into five states: Big up, small up, consolidation, small down, and big down, etc. [6,7]. The setting of the number of states needs to be weighed: if the number of states is small, then the average number of samples per state is larger, containing more information, and the model has higher stability. However, the description of different window conditions may become weaker, especially in some extreme market situations, which may not be covered, but are only included in ordinary states. If the number of states is large, then the average information per state is less, there may be a situation where a certain state has only been present for a few days in the past few years, and the model's stability may decrease, but the model can differentiate between extreme market states.
3. The meaning of HMM's implicit state is somewhat consistent with the real stock market. In the minds of subjective investors or mainstream investment methodologies, the stock market itself has some implicit states. Names such as "bull market" and "bear market" refer to people's classification of stock market conditions. Although different people may have different definitions of bull and bear, most investors acknowledge the existence of a state in the stock market.
4. HMM is different from other stochastic process or time series models. Models such as Black Scholes assume that stock prices follow a lognormal distribution, but use historical data to fit mean p and volatility unable to characterize short-term characteristics, because the fitting result will bring the p-value closer to the long-term mean, it is easy to overlook the short-term trend. HMM can use different states to represent different distributions, and the mean returns and volatility of different states are different[8]. For example, in a bull market, the mean returns of all stocks are larger, in a bear market, the mean returns of all stocks are smaller, and in a volatile market, the absolute logarithm of the mean returns of all stocks is very small, this way, the explanatory power of the actual situation is stronger, that is, as long as different states are given, different distributions can be used for different states.
5. Hidden Markov models can consider a relatively moderate time span. Other time series models, such as the exponential mean EMA, typically set parameters of a few days or more, and give more weight to recent data, while the impact of long-term data gradually converges over time. That is to say, if the parameter is set to 20, the data over the past 30 days has almost no impact. If there is a long-term trend in the stock market, the EMA moving average may not be considered. But HMM is a probability graph model that assumes that the state transition matrix remains unchanged throughout the entire period and is calculated entirely based on historical data using maximum likelihood. It also uses equal weights

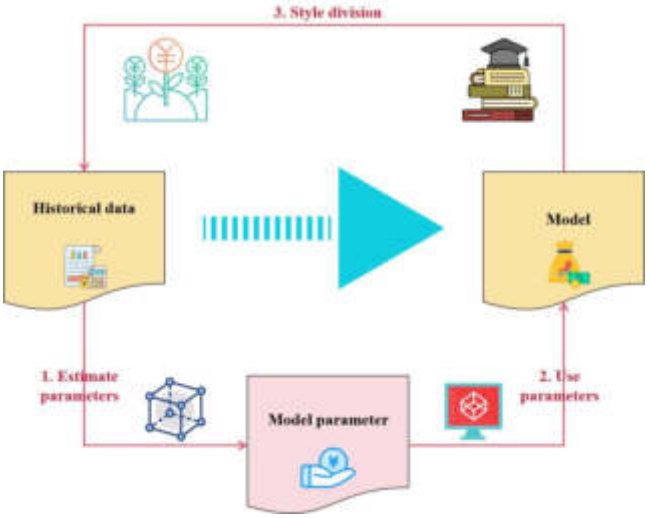

Fig. 2.1: Flow Chart of Hidden Markov Model Style Identification

for long-term data. The parameters of the state transition matrix in the stock market are generally believed to be determined by many exogenous variables, and their changes will not be sudden, and the time span of the change process will not be in the tens of days. Therefore, using a hidden Markov model here is appropriate.

HNM also has some drawbacks in its application. The first-order Markov property may not be satisfied. If there is indeed a clear state division in the stock market, then the true state of a certain day is likely to depend not only on the state of the previous day, but also on the state of the previous time. The model is still a black box. After conducting style recognition, a state sequence is obtained, and even if corresponding with relevant background knowledge, it is likely that it cannot be explained. The main process of style recognition is to first estimate the model's parameter $\lambda = (A, B, \pi)$ using historical data (features) after establishing the model, by using these parameters again, the most likely implicit state sequence to generate historical data is calculated, resulting in a style sequence. This is equivalent to clustering past time based on some indicators. The entire style recognition process is shown in Figure 2.1 [9].

After completing the style division of the market, it is possible to sample time points under the same style, instead of using a systematic sampling method every 20 days to form a training set for training. This style recognition method also needs to be based on the assumption that the market style at the current time point can find the same situation in the past period of time. If there is a fundamental and permanent change in the market, starting from the current time and completely entering a new market style that cannot be found in the past, then the model cannot be effective [10].

However, on the one hand, the possibility of fundamental and permanent changes in the market is extremely low, and China's stock market policies are gradually beginning to stabilize. On the other hand, even if fundamental changes occur, it may still be possible to identify past styles that are similar to the new style to some extent, and may still have a certain effect. Therefore, the use of this model is interpretable.

2.2. Specific steps for style recognition. Taking the warehouse adjustment date on January 3, 2022 as an example, explain the specific operation of using HBM for style recognition. Firstly, determine which features to use as observation variables. HM assumes that the distribution of observed variables is determined by implicit states, which correspond to some states of the stock market. Therefore, the features used for style recognition should correspond to the entire market, not to individual stocks. The feature library constructed above is not applicable [11].

Because the purpose of the author's use of this model is to distinguish which type of feature is more effective, the features used should also be able to demonstrate the strength of a certain type of feature in the

market, and the features should be as orthogonal as possible to each other. Drawing inspiration from the five factor model, this section also uses market factor RM, market value factor SMB, book to market ratio factor HML, profit level factor RMW, and investment level factor CMA as features. As these five factors have already described the market from different dimensions and have low correlation with each other, therefore, it can meet the requirements. The market factor RM is used to measure the systemic risk of the entire market, that is, whether the current market situation is good or not. The author will directly use the Shanghai and Shenzhen 300 index return as the daily market factor RM value. The market value factor SMB represents the size of the risk premium given by the market to a company's size [12,13]. The theory of corporate finance holds that the smaller the asset size of a company, the greater the risk, and this view is also confirmed by the behavior of investors. Therefore, stocks with smaller market capitalization should have higher returns. The market value factor SMB is used to determine how strong the small market value effect is in the entire market. The construction method of the factor is to select the stocks with the lowest market value on the previous day, calculate their average return on that day, and then subtract the average return on that day of the stocks with the highest market value on the previous day, in order to obtain the value of the market value factor SMB for that day.

The book to market ratio factor HML describes the estimated risk premium of the market on the company's additional financial risks. The book to market ratio B/M of a company is the owner's equity divided by the total market value. The higher the book to market ratio, the lower the market's valuation of the company, and the market is not optimistic. Therefore, such a company needs higher stock returns to compensate, in order for investors to be willing to invest. The book to market ratio factor HML can be used to measure how much compensation a company with a high market to market ratio should have compared to a company with a low market to book ratio. The specific calculation method for the factor value is to calculate the average daily return for companies with the lowest book to market ratio of B/M in the entire market, subtracting the average daily return for companies with the lowest book to market ratio of B/M in the entire market, to obtain the value of the HML factor [14].

The profit level factor RMW measures the market's premium on a company's profitability. The author directly uses the return on equity (ROE) to measure a company's profitability. The calculation method for the RMW factor is to calculate the average daily return for companies with the highest one-third of the total market ROE, minus the average daily return for companies with the lowest one-third of the total market ROE, to obtain the value of the RMW factor.

The investment level factor CMA represents the market's premium on investment risk. The level of investment can be measured by the reinvestment rate. Generally speaking, companies with lower investment rates have higher risks, and their stocks should have higher returns. Otherwise, they cannot compensate for the risks they bring, and vice versa. In practical operation, the reinvestment ratio can generally be calculated using the annual growth rate of total assets. The calculation method for the investment level factor CMA is also similar, using companies with the lowest one-third of the annual growth rate of all market assets to calculate the average daily return, subtracting the average daily return of companies with the highest one-third of the annual growth rate of all market assets, in order to obtain the value of the investment level factor CMA. Next, we need to make the factors reflect the situation of the next 20 days, so for each factor, we will take the geometric average of the values of the next 20 days at each time point. In the last 20 days before January 3, 2022, due to the inability to obtain data on January 3 at that time point, if the data is less than 20 days in the future, the geometric average of the factor values until the last day will be taken. After this operation, each factor contains information about how a certain style will last for 20 days.

Due to the fact that the state switching of the stock market is not very frequent, if measured in days, it is likely that there will be frequent switching of states in one or two days, and switching back and forth, which is also contrary to the starting point of this article. Therefore, the author takes 5 days as the dimension, calculates the geometric mean of the 5 factors every 5 days, divides 240 trading days into 48 5 days for training, and obtains an implicit state sequence. Then, each 5 day is the same state [15]. How many implicit states are self assumed. According to prior knowledge, there are often classification methods for styles such as large/small cap, value/growth, and the five selected features are also good indicators to reflect these styles. If the time span is too long, it may make the style transformation too complex, such as the transformation probability matrix

and other parameters may also change. Therefore, the author chose a short time span and a small sample size. When the sample size is not large, selecting too many categories can result in too few days for some categories. For the above reasons, the author directly assumes that there are four categories of implicit states [16].

Before the opening of the market on January 3, 2022, select the data of the above 5 features from the previous 240 trading days, assuming there are 4 hidden states, and use the Baum Welch algorithm to estimate the parameters of the model. The estimated state transition matrix is as follows:

$$\begin{bmatrix} 0.42 & 0.35 & 0.23 & 0 \\ 0.10 & 0.40 & 0.50 & 0 \\ 0.16 & 0.39 & 0.40 & 0.05 \\ 0 & 0.53 & 0.47 & 0 \end{bmatrix} \tag{2.1}$$

2.3. Sampling Method Based on Style Identification. December 30, 2019 belongs to implicit state 2, so what needs to be done is to count the number of time points in the entire sequence that are not the last 20 days and belong to state 0. The reason for removing the last 20 days is because the "future 20 day yield" cannot be obtained from the last 20 days and cannot be added as a sample to the training set of the classifier. The statistical result is that a total of 95 days belong to implicit state 2. Next, they will be sampled and some time points will be selected as training samples. Next, conduct sampling over these 95 days. The specific method is to first remove the time points less than 20 days before January 3, 2022, as from January 3 onwards, these time points cannot obtain the stock returns for the next 20 days. Then filter the duration of each entry into implicit state 2. If the duration is less than 10 days, skip this period and only sample in stages with a duration of at least 10 days. The sampling method is to sample on the 1st, 6th, and 11th days (if any) at each stage that lasts at least 10 days. If the total number of sampling days is less than 6 days, it is considered that the data volume is too small, and the system sampling method in the previous chapter is still followed, which is to extract a total of 12 samples from the 20th day before the current time, the 40th day before the current time, and the 240th day before the current time. If it is greater than 6 days, it indicates that the data volume is sufficient, and the filtered date data is used as the training sample for the classifier.

This sampling has two benefits:

1. Sampling should be conducted as much as possible at each stage of entering the corresponding hidden state, and periods where the hidden state does not last long enough or is not stable are excluded [17]. Guaranteed sample size. If the number of samples is too small, it will affect the performance of the classifier. After sampling using the above algorithm, a time series is obtained, at which the stock market belongs to the same state. Use the data at these time points as the training set, and use the Adaboost algorithm based on Decision Stamp classifier from the previous chapter to train the model. At the time point of January 3, 2022, using this sampling method, the training set data was obtained from 6 time points, including February 5, February 19, October 17, October 24, November 7, and November 14, 2019. From the distribution of data, it can be seen that under the new sampling method, the data from February 19th to October 17th was discarded because the style during this period was not very close to the latest style, and only data consistent with the latest time point style was used. The sample size for this sampling is 6328, with 3164 positive and negative samples each.
2. Using 16 weak classifiers, cross validation was conducted multiple times on January 3, 2022, with an average accuracy of 61.93%, which is 58 The 12% cross validation results increased by 3 81%, significantly improving the classifier performance. If we adhere to this investment method, the advantages will continue to accumulate, and ultimately we can obtain very considerable excess returns.

3. Retrospective testing and production environment testing. Adjust positions every 20 days. On each adjustment day, HBM is used for style recognition, and then data samples from the same style are used as the training set. The Adaboost method based on Decision Stump classifier is used for classification training. The 50 stocks that are most likely to hit the top 25% of all stocks in the next 20 days are selected for equal weight buying, and this process is repeated for backtesting. From March 16, 2022 to October 31, 2022, production environment testing was conducted using its own funds, and the net worth curve was concatenated after the backtesting curve. The yield curve for backtesting and production environment testing is shown in Figure 3.1, with the benchmark being the Shanghai and Shenzhen 300 Index [18].

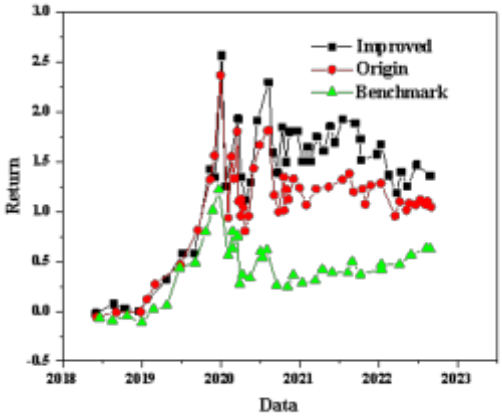

Fig. 3.1: Comparison of Net Worth Curve before and after Improvement

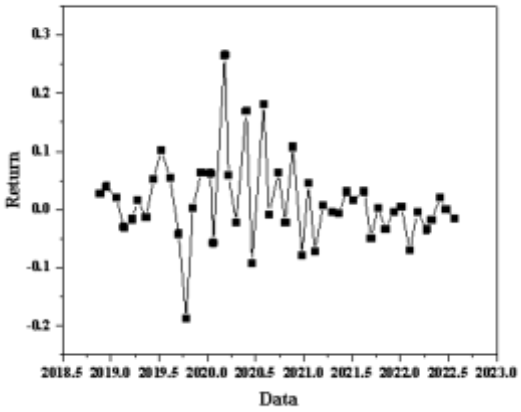

Fig. 3.2: Improved strategy with excess returns for each period

In Figure 3.1, the vertical line represents March 16, 2022, followed by the actual test curve. The improved investment strategy has defeated the benchmark in 27 out of 47 adjustment cycles (including 39 backtesting cycles and 8 real cycles), and overall remains the same as before. The performance in each specific cycle is shown in Figure 3.2.

The period with the maximum excess return has increased excess return, while the period with the lowest excess return has increased negative excess return. This phenomenon to some extent indicates that the improved strategy may amplify the effect of a certain style while increasing the overall effect. In addition, the overall style switching in 2022 is relatively frequent, and the improved investment strategy performs better than the previous strategy, indicating that the ability to follow style switching has become stronger after the improvement.

During the period from March 16 to October 31, 2022, only 2 out of 8 issues defeated the benchmark, and in the improved production environment testing, it was increased to 4 issues. And it can be clearly seen from the curve that although there are unfavorable factors in the production environment such as sliding points and market shocks that cannot be truly simulated in the backtesting environment, the improved strategy

Table 3.1: Comparison of Investment Strategy Evaluation Indicators before and after Improvement

Index	Before improvement	Improved
Total return rate	114.33%	144.42%
Benchmark return rate	71.99%	71.99%
Annualized rate of return	22.72%	27.11%
α	0.071	0.135
ρ	0.995	0.820
sharpe ratio	59.9%	79.6%
Maximum withdrawal rate	50.636%	39.99%
Information ratio	41.4%	50.4 %
Strategic volatility	31.3%	29.1%

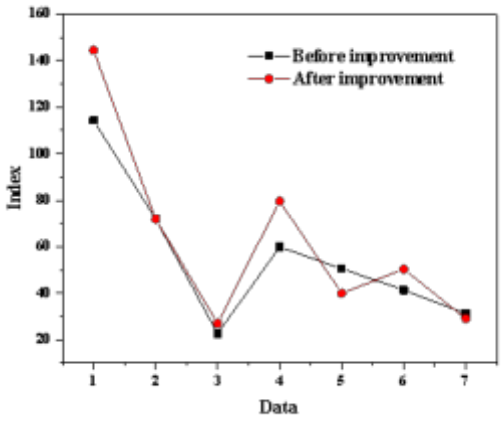

Fig. 3.3: Comparison of investment strategy evaluation indicators before and after improvement

still performs strongly. The comparison between the improved strategy and the evaluation indicators before improvement is shown in Table 3.1 and Figure 3.3 [19].

It can be seen that after improvement, a small increase in prediction accuracy will significantly improve the effectiveness of the entire strategy, with an annualized yield increase of nearly 3%, while other indicators also become better [20].

4. Conclusion. The author improved the investment strategy of the Adaboost multi factor model and improved the performance of the classifier. Firstly, a hidden Markov model is used to partition the stock market style, and then a sample is taken from dates that are consistent with the current date style. The factor values of the sampled dates are used as features, and then the Adaboost algorithm based on Decision Stump is trained and predicted. From the results of backtesting and real market testing, it can be seen that the method proposed by the author has improved the return on investment strategies. The author's work also comes with some other achievements. If a feature library is established, the features can be used in machine learning algorithms. When using other methods to research new topics, new features can also be selected from the library and directly used. In addition, the market style segmentation method based on hidden Markov also has the function of monitoring market style. The author's work has improved some of the shortcomings and innovations in the application of machine learning in quantitative investment in the past, mainly including the following points: For feature selection, the author starts from domain knowledge and uses a large amount of fundamental data to select the most predictive features. The author did not predict the financial time series, but instead classified

the relative quality of stocks at each time point, and predicted whether the future rise and fall of stocks were within the highest range. The advantage of this is that it can avoid the influence of many other factors, such as macro factors, policy factors, etc., by simply identifying relatively strong stocks.

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THE DIGITAL MEDIA ART AND DESIGN SYSTEM UNDER THE INTEGRATION OF COMPUTER BIG DATA CHATGPT TECHNOLOGY

ERHUA ZHANG*AND SHENGWEN LU†

Abstract. Traditional digital media art and design systems take a long time to run and cannot handle a large number of objects simultaneously. Therefore, the author proposes a digital media art and design method based on ChatGPT technology. ChatGPT technology is an important part of networking.Prepare to provide conference support for various applications such as customer service, personal assistant, robotic interview, and so on. ChatGPT can not only answer the question that is set, but also solve the question openly.The comprehensiveness and intelligence of ChatGPT have attracted widespread attention since its launch. TThe hardware system adopts dual core TMS320C6657 and DDR3Thel1333 series processors as the core circuit, together with high speed external storage, to expand the image transmission line of multi-data; System software uses module architecture to design image modules, video modules, and voice modules, all of which are integrated into the core of the system as modules.In this experiment, 10 images were transferred and the running time was tested. Experimental results showed that, the traditional digital media art and design system had three errors, which took more time to run.

Key words: Computer big data, ChatGPT technology, Digital media, Art and Design System

1. Introduction. The emergence of ChatGPT technology has brought significant changes to the development of intelligence. With the rapid development of technology, education is facing unprecedented challenges, and there is an urgent need for profound reform. Teachers should carefully study the effects and challenges that intelligence brings to education and teaching, and find solutions to them. With the rapid development and development of artificial intelligence technology, its application has become more extensive, and its performance in various aspects exceeds human potential [1]. ChatGPT technology, as the latest product of artificial intelligence, can quickly respond to users' input needs in chat boxes. Within a few seconds, a unique and clear thinking article that combines a large amount of information will be displayed to users. If you are not satisfied with it, users can continue to add requirements in the chat box. ChatGPT will make every effort to modify, improve, and update it, and the waiting time will not exceed one minute. In the future, ChatGPT may replace many traditional jobs. What talents should educators cultivate to meet this challenge? Therefore, the direction of talent cultivation is the primary issue that education needs to clarify to ensure that they have sufficient competitiveness and potential for future development [2,3]. ChatGPT technology enables learners to easily access various course resources, which brings the disadvantage that learners need to learn what artificial intelligence is not easy to achieve in order to gain an advantage in future competition. So, in order to meet future challenges, what course content do learners need to master to help them adapt to the development of artificial intelligence? How should courses be arranged in the future to meet the growing teaching needs? As mentioned earlier, ChatGPT technology can provide intelligent and complete solutions, effectively providing learning guidance for learners, which to some extent weakens the role of traditional teachers. How educators seize the opportunity, utilize ChatGPT technology and combine it with other artificial intelligence technologies to improve teaching methods, improve teaching experience and quality, is also a key issue that teachers are currently facing that urgently needs to be solved [4].

In order to meet people's aesthetic demands for the indoor and outdoor space environment of buildings, digital media is integrated into architectural design, and communication technology is used to meet the personal needs of different audiences. Digital Information System is a kind of information transmission system based on digital technique. It has good interaction and can enhance the real-time performance of drawing and designing.

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For this reason, we put forward an artistic design system of digital media based on ChatGPT. The focus of traditional digital media art and the design quality is not good. To solve this problem, the author used a pre- processing method to reconstruct 3D images, using the TMS320C6657 processor as the core of the system to handle related algorithm operations. Due to differences in DSP related circuits, some improvements have been made in the core processor, memory, and bus interface. In terms of software design, in order to repair the visual effects of art design, the development of a digital media art design system is implemented on the MapInfo development platform.

2. Methods.

2.1. ChatGPT: Emerging New Artificial Intelligence Technology. In recent years, chat robot technology has developed rapidly, and many enterprises and organizations have adopted them to provide more convenient and efficient customer service. However, although traditional chat robot technology has made some progress, there are still some challenges that need to be overcome, such as uncoordinated dialogue content and inaccurate answers [5]. In order to effectively address the current challenges and challenges, researchers have developed a new chat robot technology called ChatGPT. ChatGPT is a discussion of the intelligent language design system developed by OpenAI, one of the world's leading research fields in intelligence. The architecture of ChatGPT is based on the Transformer network, which is an integrated system of encoder and decoder blocks used to process large amounts of text data, improving the accuracy and reliability of the model through training. The encoder block extracts information from the input, converts it into various hidden formats, and then processes it by the decoder block to ultimately generate the output format. The Transformer network can extract contextual information from more text, thereby gaining a deeper understanding of input content, making analysis more accurate, comprehensive, and effective [6]. Therefore, one of the key features of ChatGPT is its ability to generate continuous feedback that is closely related to the context. In addition, ChatGPT model technology is based on a proprietary "self attention mechanism", which can achieve advanced functions in natural language processing (NLP) tasks, and is considered a high fidelity embodiment of "emotional intelligence plus intelligence". On the basis of pre trained language model operation, the received input is generated into a natural language response and given to the chat robot for feedback to the user. This is the core idea of ChatGPT technology. Specifically, ChatGPT technology is supported and operated by artificial intelligence services such as natural language processing (NLP) technology, deep learning technology, automatic speech recognition (ASR) technology, automatic machine translation (MT) technology, automatic text generation technology, automatic question answering system (QA) technology, automatic dialogue system (DS) technology, automatic document summarization technology, automatic text classification (TC) technology, automatic text retrieval (IR) technology, etc, and through the development and alternation of these technologies, we continuously improve the accuracy of chat robots' answers.

2.2. Hardware structure design. Taking into account the developing period of the system, this paper uses some key technologies to realize the artistic design system of digital media. Figure 2.1 illustrates the hardware configuration diagram [7,8].

Choose dual core TMS320C6657 and DDR3-1333 series processors: apply to digital media art and design course, DDRS controller of the chip only support DDR3-1333 series processors.This combination will greatly enhance the system's ability in art and design. Due to different input and output interfaces, it is necessary to improve the core processor, memory, and bus interfaces. The following is a description of the capacity structure design of each power supply and memory. When selecting a circuit, it is necessary to add a certain margin according to Table 2.1. The necessary conditions must be met: a certain margin can be provided for emergency needs; Current ripple and noise need to be within an acceptable range [9].

In order to meet the above conditions, it is necessary to calculate the system power consumption reasonably. If the power consumption is too low, it can cause system crashes; If the power consumption is too high, it will increase the difficulty of power supply design. In order to apply AC-DC circuits for this purpose, it is necessary to convert the evaluation indicators of output accuracy and noise before use, in order to shorten the design cycle. Using the MUA30-220S05 power module, the conversion efficiency can reach up to 75%, the output voltage conversion accuracy is $< \pm 1\%$, and the noise is<50mV [10]. Each layer of memory structure should have a larger capacity than the previous layer of memory, as shown in Figure 2.2. There are four levels of memory

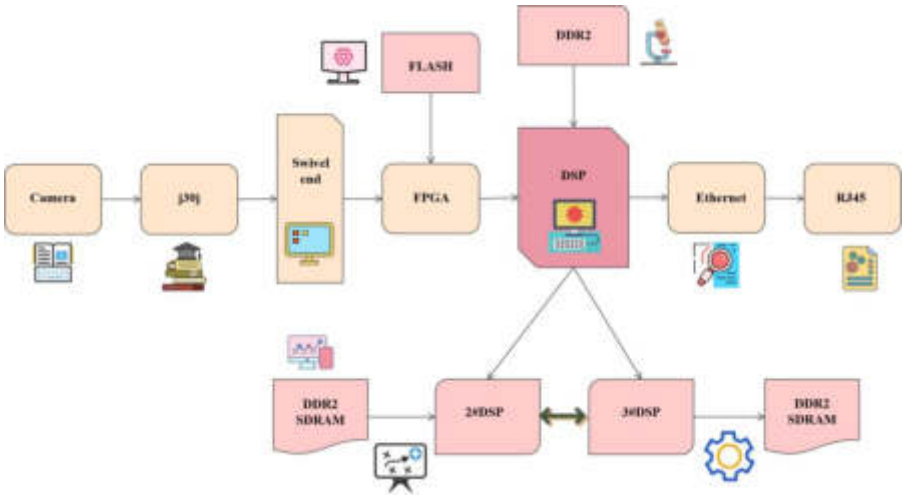

Fig. 2.1: Hardware Framework of Digital Media Art Design System

Table 2.1: Power consumption estimation of main circuits in digital media art design system

system circuit	Voltage/N	Current/A	Power consumption/W
DSP	1.36	4.7	5.63
FPGA	2.4	0.7	0.51
DSP	1.7	0.3	2.46
SRIO	1.6	0.9	0.55
DDR2	1.4	0.6	0.86
EMAC	1.3	1.7	2.81
Clock	3.4	0.7	1.63

capacity, with one level being on chip SRAM, which is slow and has a large capacity; The second level is off chip DRAM, with slightly slower speed and larger capacity; The third level is FLASH memory, which is the slowest and has the highest capacity; The fourth level is Web distributed storage, which is an indispensable part of the system. The SRAM inside the chip contains a Cache; The external DRAM of the chip contains BlockRAM. FLASH, as the system program boot, is responsible for uploading image data to the upper computer disk.

2.3. Software Function Design. Establish the whole software function in the form of plugins to simplify integration with the main system framework to achieve the design of digital media art design systems. The design features of each plugin are as follows. This image plugin is designed based on MapInfo platform, and the management functions include OpenCV library function to implement image processing related to digital media art design [11].Content used: Image led control: responsible for taking image data, using the loaded image as the image led control. Image management: responsible for the integration of input and output models, processing and managing internal affairs. Image transformation: Select CV threshold mode to provide information and choose different processing methods for processing. The design of the video module is divided into three types, which are responsible for the transformation of the image into the 3D virtual image. Using VR technology to store the image data, then call the video source to produce CvCapture objects, which include camera data and video files. Once you've done all of this, loop the CvQuery frame function to retrieve the frame data from the CvCapture object. The loop ends and exits the program. To guarantee the precision of the query, the new frame data is transmitted by C code. Only new deep data can be called after processing. You have to restart the camera at this time.

Sound plugin design: Select BASS to complete the sample file operation. BASS supports platforms such

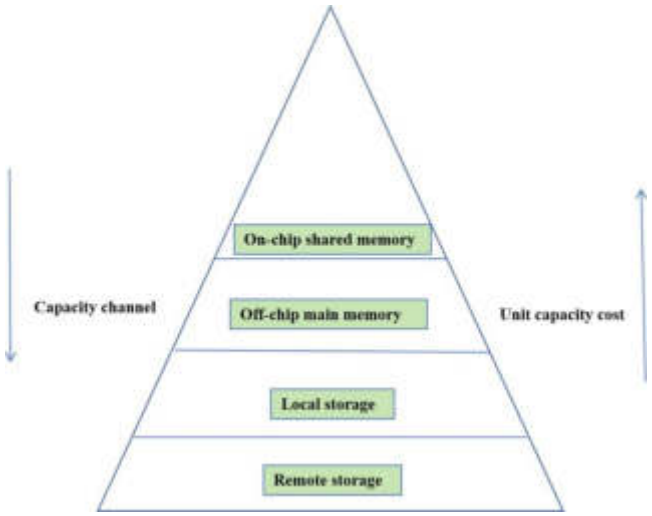

Fig. 2.2: Memory Capacity Structure

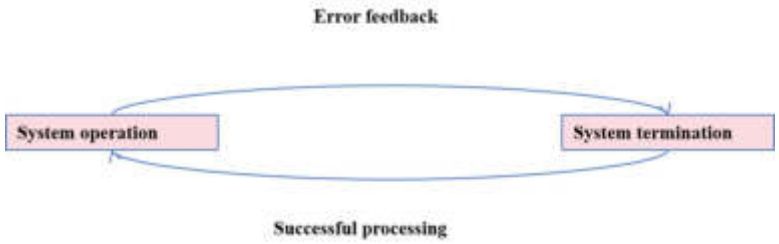

Fig. 2.3: Finite State Structure of System Operation

as XP and I0S.

The work programme is as follows:

(1) Audio part: Using the bass loader control to guide the audio, using input input as the way, responsible for extracting audio data; The output is the handler responsible for displaying floating-point numbers [12].

(2) Mathematical part: Choosing the camera network provides the frame information for the camera, applying the image quality control and motion control to extract the image contours. In order to prevent a system from sending error reports, it is necessary to create an error message, with the process running the system diagram shown in Figure 2.3.

The following steps will be taken when the error report is shown in the system: When the user makes a mistake, the system will open the box automatically and disable the current error. In order to provide timely feedback, we use the Nonupdate Box to record the errors that happened in the process.If there is an error message while the test is being executed, the system will send an error message; if it is finished, the system will continue; if there is an error message, the system will jump to a stop state. Based on the virtual reality technique, a digital media art design system has been developed with the combination of software and hardware.

3. Simulation experiments.

3.1. Experimental Environment. For the sake of simplicity of experiment description, we used the numerical simulation method to compare the time contrast of traditional digital media art and the design with this system. Various measurement results were used in the experiment, and rich experiment data were obtained, providing the reference basis for the next work [13-14].The core of the VFD is TMS320C6657 processor. Based

Table 3.1: Comparison of System Operation Time

number	data size/B	Number of targets	Traditional systems		This article system	
			run time/ms	test result	run time/ms	test result
lmage-I	512×300	8	13.266	Incorrect	11.556	correct
lmage-2	512×300	2	2.366	correct	1.585	correct
lmage-3	512×300	6	8.597	correct	7.233	correct
lmuge-4	512×300	10	10.255	correct	9.266	correct
Image-5	512×300	2	3.266	Incorrect	1.266	correct
lmage-6	512×300	5	5.625	correct	4.266	correct
lmage-7	512×300	6	11.266	Incorrect	10.266	correct
Image-8	512×300	4	10.543	correct	9.563	correct
Image-9	512×300	6	7.266	Incorrect	6.266	correct
lmage-10	512×300	2	3.626	correct	1.266	correct

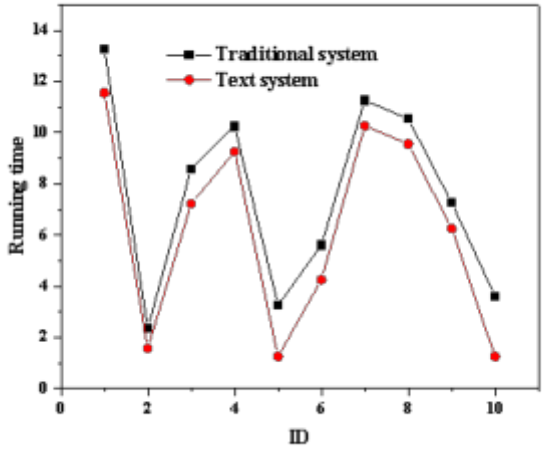

Fig. 3.1: Comparison of System Operation Time

on this, a test environment is created, and the image module is used to send 10 or more image data. Then, the data is sent to the system.

3.2. Experimental Results and Analysis. Test results of the calculation time required for digital media art design during the debugging process of the two machines are shown in Table 3.1 and Figure 3.1 [15].

The test results show that the system has the advantages of short running time, accurate target, and stable realization, and satisfying the system's quality requirements. There are three errors that require more time when using traditional digital media art and design to measure goals [16,17,18].

4. Conclusion. With the rapid progress of technology, today's educational concepts and models are constantly evolving and innovating. ChatGPT is a new artificial intelligence technology based on natural language processing. The emergence of this technology has also brought challenges and opportunities to education and teaching. Many input devices are important parts of the artistic and design platform of digital media, and they are also important parts of the system. In the art and design of digital media, the input device consists of the input device and the user's data pre-processing.So in terms of software design, in addition to commonly used

devices such as keyboards and mice, image plugins, sound plugins, and video plugins have also been designed to capture image information.In the aspect of hardware design, the dual-core TMS320C6657 and DDR3-1333 series technology were used to analyze the data. Processing of data. Based on virtual reality technology, a digital media art design system is developed by combining hardware and software. In the experimental part, it is proved that the method has a shorter time and better performance compared with the design by comparing the experimental results.

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INTELLIGENT ADVANCED ATTACK DETECTION TECHNOLOGY BASED ON MULTI-MODAL DATA FUSION

FEILU HANG[*], LINJIANG XIE[†], ZHENHONG ZHANG[‡], AND JIAN HU [§]

Abstract. This paper proposes an adaptive Wedman intrusion detection algorithm (AID-DFS) for data fusion. Firstly, feature extraction of abnormal text detection is carried out using a BI-gated loop (Bi-GRU). Multi-branch convolutional recurrent neural network (CNN-RNN) extracts hierarchical features from abnormal images. The multi-mode dynamic fusion uses the intermodal and intramodal attention mechanisms. In this way, a joint representation of multiple modes is obtained. The visual perception mechanism is used to realize multichannel integration and strengthen the function of original information in multichannel. The experimental results show that the proposed method has 99.6% accuracy and 94.9% accuracy. Compared with other algorithms, the proposed method can improve the performance of the intrusion system by about 10.2%.

Key words: Wireless sensor network; Information fusion; Intrusion detection; Convolutional neural network; Anomaly information extraction

1. Introduction. In recent years, wireless sensor network (WSN) has been applied increasingly and has become an essential technology in smart grid, rail transit, manufacturing and other major engineering fields. Detecting abnormal services, such as network attacks, is a prerequisite for long-term continuous critical infrastructure monitoring. The popular methods currently include data mining, game theory, traffic prediction, and computational intelligence technology. Literature [1] uses a negative selection algorithm in immunology to monitor the behavior of wireless sensor networks. Literature [2] uses the K-means method to learn and classify massive network information collected in wireless sensor networks to detect various types of network attacks. In reference [3], a game theory intrusion detection algorithm is designed to solve the abnormal phenomena in wireless sensor networks. A cluster-structured hybrid intrusion detection method (CHH-IDS) is studied in reference [4]. This method can detect both existing and non-existing attacks at the same time. Literature [5] combines kernel self-grouping mapping technology and PSO algorithm (KSOM-PSO). It can effectively improve the recognition accuracy of wireless sensor networks. Literature [6] constructs a WSN network intrusion detection model based on multiple stages. This algorithm updates the posterior information of subsequent nodes based on the Bayes criterion, thus significantly improving the detection accuracy of clustered WSNs. Given the problems of high and low false alarm rates in network security, most of the existing intrusion detection methods are based on data mining. Although these methods can ensure the regular operation of the network, they are still vulnerable to various types of network intrusion attacks. Therefore, how to use the abnormal behavior in the network to improve the security of sensor networks is the core goal of wireless sensor networks. Literature [7] proposes a multi-protocol hierarchical IDS (T-MPNID) algorithm based on the fusion of trust and noise detection. An intrusion detection model based on a neural network is proposed, aiming at the abnormal behavior in wireless sensor networks. Intrusion detection is a security protection technology with positive significance. It distinguishes common from intrusion in a binary way. The core of the attack is the information fusion processing of each subsystem.

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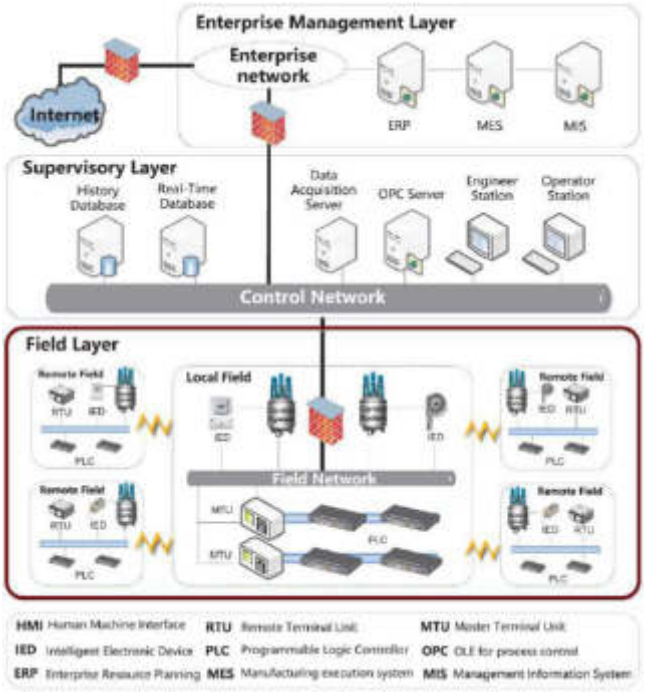

Fig. 2.1: System intrusion detection system architecture based on attention mechanism.

2. Multi-modal data fusion algorithm. Call $O = \{o_1, o_2, \mathrm{L}, o_n\}$ a pseudo data set. Where o_i is the i post. n represents the number of articles published in the data set. The K and S in any post $o = \{K, S\}$ represent its corresponding text and picture, respectively. The error message detection problem can be represented by the function $f(K, S) \rightarrow y$. The number $y \in \{0, 1\}, 0$ marked here represents the actual information. 1 indicates a system intrusion [9]. The method includes four parts: text feature extraction, image feature extraction, multi-modal fusion and error detection (Figure 2.1 cited in International Journal of Distributed Sensor Networks, 2018, 14(8): 1550147718794615).

2.1. Abnormal text feature extractor. The method takes Bi-GRU as the primary research object. It describes long-term sentence dependencies and contextual information between words [10]. Each word vector is pre-trained and word embedding is carried out in Word2vec. The BTH word of text K initializes the vector $K_i \in R^t$. t represents the algorithm dimension. i text with m words is represented as $K = \{K_1, K_2, \mathrm{L}, K_m\}$. Bi-GRU is calculated as follows:

$$\vec{g}_i = \overrightarrow{GRU}\left(K_i\right); i \in [1, m]$$
$$\overleftarrow{g}_i = \overleftarrow{GRU}\left(K_i\right); i \in [1, m]$$

At time i $\vec{g}_i \in R^t$ represents the implied feature of K_i acquired by the positive GRU. $\overleftarrow{g}_i \in R^t$ represents the implicit characterization of K_i obtained by the reverse GRU. The implicit representation $g_i, g_i = [\vec{g}_i, \vec{g}_i], g_i \in R^{2t}$ is constructed by the connection of $\vec{g}_i$ and $\overleftarrow{g}_i$. The feature matrix $K_n \in R^{m \times 2t}$ of the abnormal text is obtained by the implicit representation superposition of m time steps in turn [11]. The most recent hidden layer vector $\vec{g}_m$ on the current GRU and the first hidden layer vector on the backward GRU are used to characterize the result of $\overleftarrow{g}_1$ bar concatenation, and a complete data set $K_f \in R^{2t}, K_f = [\vec{g}_m, \vec{g}_1]$ is obtained.

2.2. Abnormal image feature extractor. The anomaly image feature extractor method is centered on multiple branches of CNN-RNNs (Figure 2.2 cited in Sensors 2020, 20(22), 6592). The algorithm comprises 5CNN branches, each corresponding to VGG19, and the feature vector $s_t \in R^t (t \in [1, 5])$ can be obtained

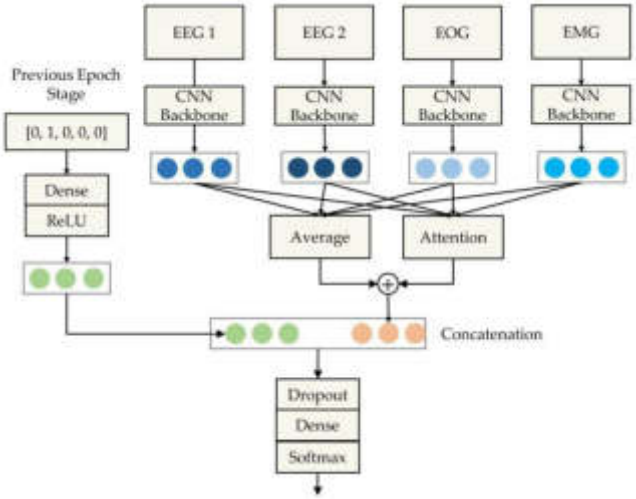

Fig. 2.2: Multi-branch CNN-RNN structure.

by three methods: convolution layer, planarization and complete connectivity [12]. There is a significant dependency relationship between the functions of each level. For example, the texture of a mid-level structure is hierarchical, with low-level feature lines and high-level structural goals. The Bi-GRU model is used to model the sequential dependence between features:

$$\vec{d}_t = \overrightarrow{GRU}\left(s_t\right); t \in [1,5]$$
$$\overleftarrow{d}_t = \overleftarrow{GRU}\left(s_t\right); t \in [1,5]$$

Using A method similar to the text anomaly feature extraction algorithm, the anomaly image feature matrix $S_n \in R^{5\times 2t}$ and the original anomaly image representation $S_f \in R^{2t}, S_f = \left[\vec{d}_5, \overleftarrow{d}_1\right]$ are obtained.

2.3. Multichannel Fusion.

2.3.1. Attention patterns between models. This paper will use the attention mechanism to analyze the degree of correlation between the modes [13]. The purpose is to capture the interaction between the abnormal text and image and realize the correction of the text and image correlation. The attention mechanism is as follows:

$$\text{Attention}(W,T,S) = \text{soft}\max\left(\frac{WT^K}{\sqrt{h}}\right)S$$

Attention $(\cdot)$ is the operating function of the attention module. W,T,S is the query matrix, the critical matrix, and the numerical matrix respectively. h is the scaling factor used to avoid excessive molecular dot multiplication, and its value is the dimension of the input property. The abnormal text update matrix K_{update} and image correction matrix S_{update} are obtained by paying attention between models.

$$K_{\text{update}} = \text{Attention}\left(K_n E_{q1}, S_n E_{t1}, S_n E_{s1}\right)$$
$$S_{\text{update}} = \text{Attention}\left(K_n E_{q2}, S_n E_{t2}, S_n E_{s2}\right)$$

Where $K_{\text{update}} \in R^{m\times 2t}; S_{\text{update}} \in R^{5\times 2t}; E_{q1}, E_{t1}, E_{s1}, E_{q2}, E_{t2}, E_{s2} \in R^{2t\times 2t}$. Concatenate K_n and K_{update} into the exception literal property matrix $K_{n1} \in R^{m\times 4t}$:

$$K_{n1} = \left[K_n, K_{\text{update}}\right]$$

Similarly, the anomaly image property matrix $S_{n1} \in R^{5\times 4t}$ can be obtained:

$$S_{n1} = [S_n, S_{\text{update}}]$$

2.3.2. In-mode attention module. The internal connection of a single model is a kind of complement to the interaction between various models. The internal attention model establishes the internal relationship between single patterns. The calculation process is as follows:

$$K_{n2} = \text{Attention}\left(K_{n1}E_{q11}, K_{n1}E_{t11}, K_{n1}E_{s11}\right)$$
$$S_{n2} = \text{Attention}\left(S_{n1}E_{q21}, S_{n1}E_{t21}, S_{n1}E_{s21}\right)$$

$K_{n2}R^{m\times 4t}$ and $S_{n2} \in R^{5\times 4t}$ are the feature matrices of the final intrusion system exception text and exception picture respectively. $E_{q11}, E_{t11}, E_{s11}, E_{q21}, E_{t21}, E_{s21} \in R^{4t\times 4t}$. 2.3.3 Fusion Module. Average pooling of the above obtained K_{n2} and S_{n2} to obtain the final feature description $R_K, R_S \in R^{4t}$ of the abnormal text and image:

$$R_K = \text{AvgPool}\left(K_{n2}\right)$$
$$R_S = \text{AvgPool}\left(S_{n2}\right)$$

AvgPool$(\cdot)$ is average pooling. The text representation R_K and image representation R_S are joined to form abnormal text and image to represent $R'_f \in R^{8t}$ and $R'_f = [R_K, R_S]$ together. Through the linear transformation of the model, the joint representation $R_f \in R^{2t}$ of the multiple modes is obtained.

2.4. System Intrusion Detector. The information between the original text and the original image is always missing when merged. The attention mechanism is constructed to represent the K_f of each channel. S_f and multichannel commonfeature R_f are reintegrated to strengthen the original signal. The calculation process is as follows:

$$c_t = \tanh\left(E_w g_t + b_w\right); t \in [1, 3]$$
$$\beta_t = \frac{\exp\left(c_t^T c_w\right)}{\sum_t \exp\left(c_t^T c_w\right)}$$
$$f = \sum_t \beta_t g_t$$

E_w stands for weighting matrix. b_w refers to a biased term. g_1, g_2, g_3 stands for $R_f, S_f, K_f \cdot c_1, c_2, c_3$ is a nonlinear transformation of g_1, g_2, g_3. In the training phase, the situation vector c_w is randomly initialized and co-learned. Where β_t is the normalized weighting of the t eigenvalue. f is an indication of a higher level of entry into a position [14]. The probability distribution is obtained by projecting the advanced representation f into a binary target space using a fully connected layer with softmax activation:

$$o = \text{soft}\max\left(E_c f + b_c\right)$$

E_c stands for the weighted parameter. b_c refers to a biased term. The mutual entropy difference between the predicted probability distribution and the actual label defines the loss function:

$$D = -\sum_{i=1}^{n} \left[y_i \log o_i + (1 - y_i) \log\left(1 - o_i\right)\right]$$

n indicates the number of abnormal texts. $y_i \in \{0, 1\}$ is the value of the actual flag. 1 is system intrusion, o is accurate information. o_i stands for the probability of being predicted to be attacked by the system.

3. Performance analysis. NS_3 simulator was used to simulate AID-DFS. The simulated WSN has 25 nodes. It is distributed in the range of 100 mx100m.This paper divides it into four clusters and is communicated through the hierarchical dynamic source routing mechanism [15]. The algorithm's performance is compared and analyzed using the KDDCUP 1999 database. Other parameters of the simulated WSN are listed in Table 3.1.

Table 3.1: Simulation parameters.

Parameter	Value
Simulation time/s	660
Communication radius /m	100
Packet size /B	250
Scope of trust score	[0,1]
Weight parameter	0.7
Types of intrusion attack	DoS/Probing/U2R/R2L

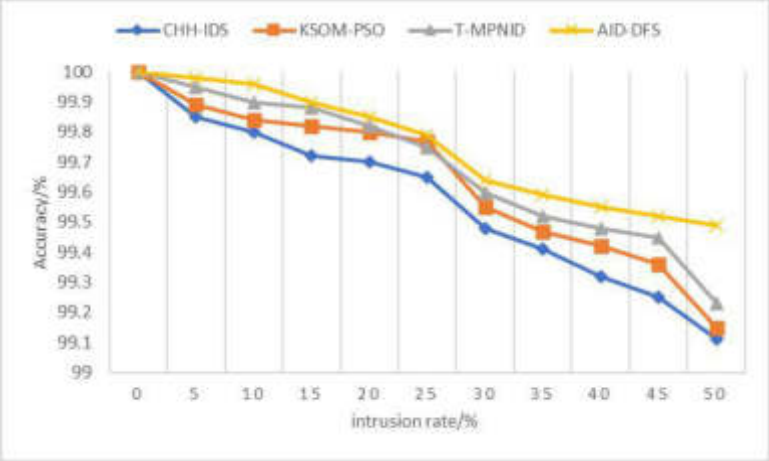

Fig. 3.1: Comparison of the accuracy rates of intrusion detection of four schemes.

3.1. Accuracy. Accuracy rate (AR) is the probability of accurately distinguishing between intrusion attacks.

$$R_A = \frac{P_T + N_T}{P_T + N_T + P_F + N_F}$$

N_F is the false negative ratio. Where N_T is the actual negative ratio. Figure 3.1 shows the change of recognition accuracy of AID-DFS, CHH-IDS (reference [4]), KSOM-PSO (reference [5]), and T-MPNID (reference [7]) algorithms for different attack modes, where $\Delta R = 0.25$. It can be seen from Figure 3.1 that the recognition accuracy of the four methods for different attack modes is reduced to different degrees, among which the recognition accuracy of CHH-IDS is the largest. The identification accuracy of CHH-IDS, KSOM-PSO, T-MPNID and other intrusion methods reaches $99.80\%, 99.86\%$ and 99.93%, respectively, when the intrusion speed is 20%. When the intrusion rate is 50%, the identification accuracy of CHHIDS reaches $99.20\%, 99.33\%$ and 99.52%, respectively. AID-DFS has a recognition accuracy of 99.33% and 99.70% for different species, respectively.

3.2. Detection rate. Detection rate (DR) is the probability that an intrusion can be correctly detected:

$$R_D = \frac{P_T}{P_T + P_F}$$

Figure 3.2 shows the difference in detection rates of AID-DFS, CHH-IDS, SOMPSO and T-MPNID algorithms under different attacks. As shown in Figure 3.2, the detection speed of the four methods decreases with the increase in the intrusion rate, significantly decreasing the detection speed of CHH-IDS. The detection rates of the AID-DFS method were $93.69\%, 94.49\%$ and 96.60% at $31.25\%, 97.92\%$ and 99.27%, respectively. In $50.05\%, 88.99\%$ and 91.59% cases, the AID-DFS method can achieve a 98.85% detection rate.

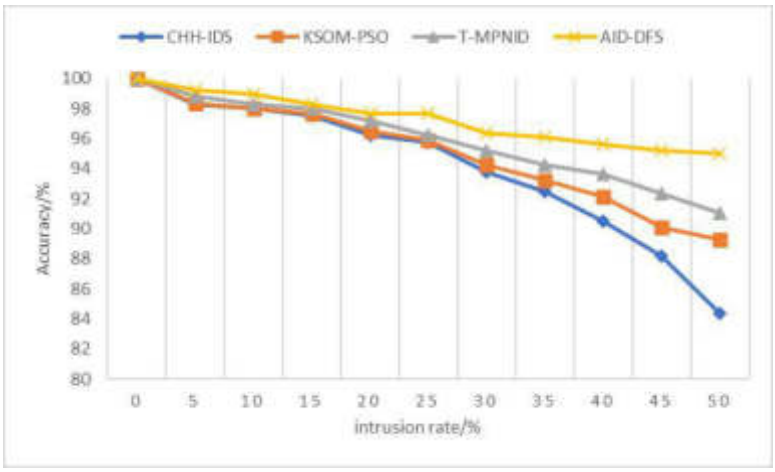

Fig. 3.2: Comparison of intrusion detection rates of the four schemes.

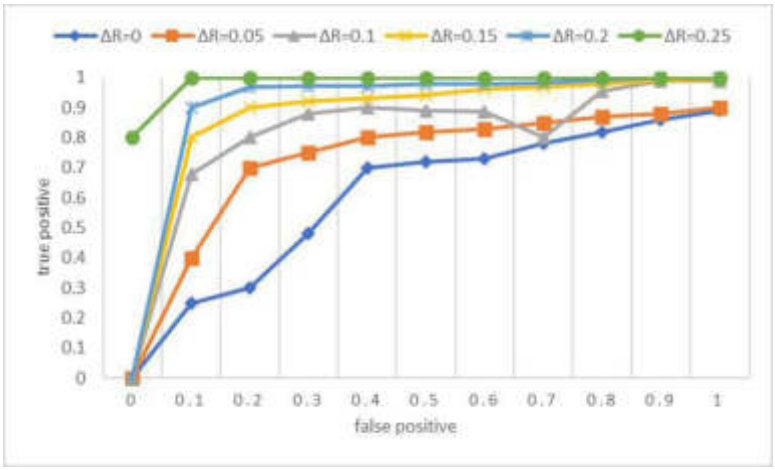

Fig. 3.3: ROC characteristics under different ΔR.

3.3. ROC Characteristics. FIG. 5 shows that the total transmission time of the AID-DFS system changes with the change of FP under different transmission regulation ratios ΔR. This performance is mainly used to analyze the ROC characteristics of the AID-DFS intrusion detection scheme [16]. With the increase of FP, the total attack rate of the AID-DFS system increases with time (Figure 3.3). When the time delay coefficient is 0, the time delay of the AID-DFS system is the lowest. The intrusion algorithm using AID-DFS has the maximum TP value when ΔR=0.25. The AID-DFS system has the best ROC characteristic at ΔR=0.25.

3.4. Precision rate curve. As the recall rate changes, the accuracy of the system changes. The higher the correct rate, the better the performance. This strategy has the best performance when the correct rate tends to 1 . The recall rate here is defined as $P_T/(P_T + N_F)$. Figure 3.4 shows the change in the precision rate curve of AIDDFS at different transfer adjustment ratios ΔR. The DFS algorithm has the lowest accuracy when $\Delta R = 0$; the DFS intrusion detection algorithm has a high accuracy rate when $\Delta R = 0.25$. In the case of $\Delta R = 0.25$, the intrusion detection algorithm using AIDDFS can obtain the best performance. The recall rate and accuracy of the AID-DFS intrusion detection scheme reached 99.98% and 90.19%, respectively.

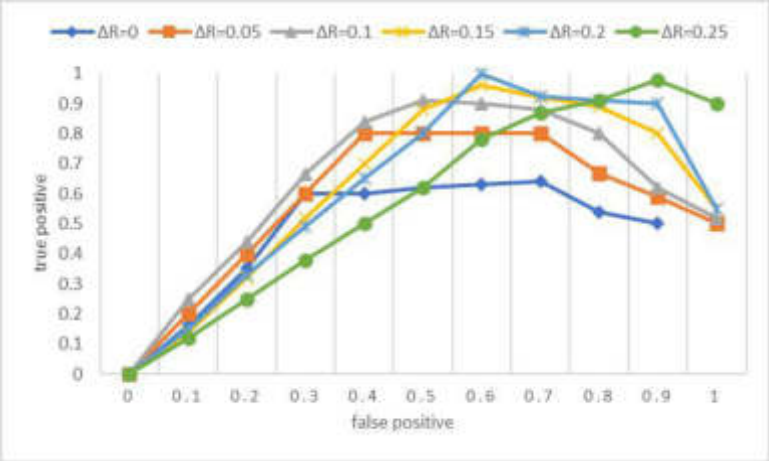

Fig. 3.4: Accurate rate curves under different ΔR.

4. Conclusion. Wireless sensor network (WSN) is the most essential infrastructure monitoring technology currently used. This paper presents an adaptive intrusion detection scheme in the data fusion phase of wireless sensor networks. The interrater-based attention mechanism is proposed to reintegrate the multichannel common expression in different modes and strengthen the original information. Through simulation tests, the algorithm proposed in this project has strong robustness in practical application, with an accuracy of 99.69% and a detection rate greater than 94.99%, which is about 0.5% higher than other traditional methods. In the case of ΔR=0.25, the algorithm proposed has the best reception and operation characteristics, and the recall rate and accuracy rate can reach 99.90 and 90.20%.

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RESEARCH ON THE APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN THE BANKING INTERNET FINANCE INDUSTRY

TIANHAO ZHANG*

Abstract. This paper presents a collaborative filtering algorithm based on reinforcement learning theory. Then, the personalized bank financial recommendation system for users is constructed in the massive data environment. Tags mimic different types of user interest points to build a representative personalized data set. The collaborative screening of bank financial products is realized using the simulation results and users' historical access records. The ranking calculation of related financial products is added to the general bank financial product recommendation system. This method can more accurately express the query results for a specific user. It is found that the collaborative filtering algorithm based on enhanced learning theory can improve the efficiency of collaborative screening of bank financial products. The best results can be obtained by combining the two organically. This paper proposes that the recommendation algorithm of reinforcement learning bank financial products based on user preference and collaborative filtering is feasible.

Key words: Bank financial products; Reinforcement learning; Feature extraction; Vector space; Adjacency matrix; Collaborative filtering; Artificial intelligence

1. Introduction. Under the background of business optimization and industry reform in the financial industry, Chinese banks and various financial organizations have developed various financial products according to market needs to meet the needs of various customers. However, due to the increasing number and types of financial products, the quality and evaluation of various financial products have also appeared uneven. Customers often spend a lot of energy searching for the goods they want, affecting their shopping experience and significantly impacting the bank's operating income. Customers can quickly and accurately search and select the goods they need in many financial commodities, an essential problem the banking industry needs to solve.

Scholars use the recommendation system as a means to analyze users' consumption habits and interests in the past to discover the potential preferences and needs of customers. In this way, the customer is presented with the most suitable product information. Literature [1] proposes a model based on the interaction between users and products. Compared with other content and mixed recommendation methods, combined filtering recommendation is convenient and fast and does not require additional business knowledge. It can assist users in exploring new commodity needs and is more suitable for the e-commerce environment. However, this method faces the problems of data sparsity and cold start, which reduces the recommendation accuracy. Literature [2] introduces features and evaluation information such as user and commodity attributes. It can solve problems such as sparse data and cold start to improve the product's recommendation performance. User preference is a data analysis method that focuses on customers and products. The historical interaction information of customers is used as a link to establish the relationship between customers and products. Use the differentiated semantic construction to explore the potential needs of customers. This improves the recommendation system's accuracy, variety, and comprehensibility [3]. In this paper, the bank financial product recommendation system is established based on user preferences and collaborative filtering reinforcement learning.

2. Design of bank financial product recommendation application system under multi-source big data environment. A personalized visualization solution for big data is built based on the Hadoop processing platform and MapReduce computing architecture [4]. The system's primary functions include data acquisition, fusion, algorithm realization and business service (fig. 2.1).

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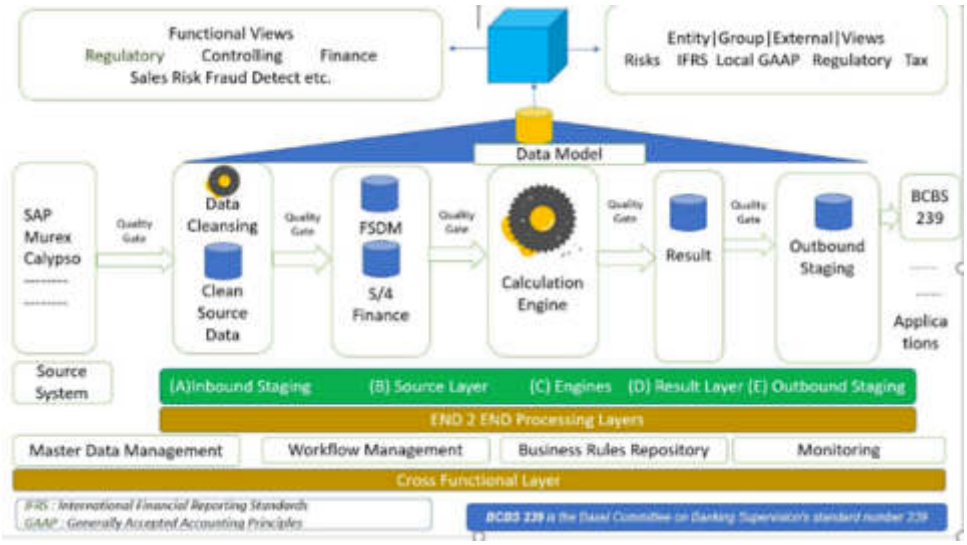

Fig. 2.1: *Architecture of bank financial product recommendation system for multi-source data.*

2.1. Data Collection. The low-cost HDFS distributed file system can process and update data from terminals such as PCS, mobile, cloud, and sensors in real-time. HDFS includes a file structure that exists in the form of inheritance. The different file systems are very similar [5]. Users can save files to their created folder or transfer files to another folder and rename them. The DFS Shell interface in HDFS enables users to access its data. This high throughput feature allows easy access to programs with large data sets.

2.2. Data Fusion. The MapReduce algorithm is used to merge the collected multi-source data. Erase user data, filter noise, and remove excess information. The standardization process is carried out to make the system's data structure get a unified specification [6]. Through the interactive analysis of the characteristics of each data to complete the transformation and synthesis of information. MapReduce can create a different number of nodes by using a standard server. It can realize the automatic segmentation and processing of the operational data in the cluster through the system of data positioning, fault tolerance optimization and other small and tedious content in the calculation work. This makes the system developer's job easy. According to the Lisp programming idea, a simple operation interface is established. Integrate Map and Reduce to complete large-scale data-oriented programming and parallel computing.

2.3. Algorithm implementation. This project intends to use Hadoop as a platform and combine visual analysis technology to discover user data from multiple sources. A large-scale data mining method based on attributes is proposed. Big data mining algorithms mainly include six types: 1) They can combine various data items into corresponding categories. It is mainly used in data classification, preference prediction and so on. 2) The classification problem faced by clustering is uncertain. The correlation between different categories of data is minimal, but the correlation between the same type of data is very high. 3) The degree of correlation between the variables was obtained through multiple linear regression of the data. It can be used in the research of forecasting, error control and so on. 4) The result of association rules is to mine the interaction between data items. From a single piece of data, infer the implied goal of the association. It is often used to predict user requirements. 5) Neural networks are artificial intelligence technologies that mimic human thinking. It is characterized by a network system composed of multiple neurons, which can independently self-process and decentralize data storage. It has higher advantages in learning and promotion. 6) Web data mining uses mining methods from the vast network data to find hidden valuable information and patterns. Then, it comprehensively analyzes and processes the structure and behavior of web pages. The main advantages of this method are high parallelism and real-time solid dynamics.

2.4. Application Services. The front-end application of the platform is the personalized service of bank financial products. It realizes personalized recommendations, push, search and other functions. A personalized recommendation is based on the collected information for its corresponding opinions. Help customers find the right product and make a decision [7]. The content of the suggestion should be consistent with the user's immediate situation. It can accurately sense the user's movements. It is both novel and timely. For example, if a user has recently and frequently viewed skin care products on the site, the recommendation function can be implemented based on the user's age, income and past spending habits. Personalized push refers to using mobile platforms to recommend potential financial products to consumers. Personalized search means that users can obtain the exact needs in the search results and present the relevant knowledge content to users.

3. Collaborative filtering algorithm of reinforcement learning. First, establish the user interest vector associated with the tag. $\lambda_t \Theta_c^T$ represents the value function of the user c at time $t.\lambda_t$ is the proportion of different labels in the user c. It represents the area that each tag occupies in the user. Θ_c is the ratio of the frequency of each tag occurring in a user c to that tag occurring in many users [8]. It reflects the significant differences of individual marker vectors λ_t in the population. The results show that the influence of users on the evaluation results of network resources decreases with the development of the network. It tracks the user's most recent interest vector. A method based on linear approximation of function is proposed to study the user's interest vector. The following formula can express the reinforcement learning weighted correction algorithm:

$$\Lambda_{i+1,k} = \Lambda_{i,k} - \frac{1}{2}\eta\mu^{n-i}\frac{M_k}{\sum_{j=1} M_j}\nabla_\lambda \left[\varphi^\beta(c) - \varphi_i(c)\right]$$
$$\nabla_\lambda \left[\varphi^\beta(c) - \varphi_i(c)\right]^2 - 2\left(S_{i+1} + \delta\hat{Y}\left(c_{i+1}\right) - \hat{Y}\left(c_i\right)\right)\nabla_\lambda \hat{Y}_i(c)$$

So, formula (1) can be transformed into

$$\Lambda_{i+1,k} = \Lambda_{i,k} + \eta\mu^{n-i}\frac{M_k}{\sum_{j=1} M_j}\left(S_{i+1} + \delta\hat{Y}\left(c_{i+1}\right) - \hat{Y}\left(c_i\right)\right)\nabla_\lambda \hat{Y}_i(c)$$

$\Lambda_{i+1,k}$ is the weight that the $i+1$ dimensional tag has for the Step user $i+1$ after accessing the data. M_k is the number of k dimensional tokens that occur for that user. $\sum_{j=1}^{n} M_j$ shows the number of displays of all tags in the n dimension [9]. Where S_{i+1} is the value of the resource assessed by the user at time $i+1$. The value function of user c at the i time is

$$\hat{Y}_i(c) = \Lambda_i \Theta_S^T$$

So $\nabla_\lambda \hat{Y}(c) = \Theta_c^T$. Here, each dimension of Θ_c under the Laplacian correction is represented as follows

$$\psi_c\left(x_j\right) = \frac{1 + x_{c,j}}{\sum_{c=1}^{N} 1 + x_{c,j}}$$

$x_{c,j}$ is the number of j dimensional tabs displayed for the user $c.N$ is the number of users. Resources with different access times are graded using μ. The gradient learning algorithm extracts the intrinsic weights of representative eigenvalues [10]. The current vectors of interest are affected by the two factors λ_4 and Θ_c. Calculate the distance between the user group that has historically accessed the predicted resource and the current user. Use K users closest to the current user to estimate the value of future users.

4. TDIDF and text classification. 4. TDIDF and text classification. TFIDF is often used to calculate text weights in vector space models. In text recognition, domain weighting functions involve two fundamental learning modes: K-nearest neighbor and support vector machine. The components were weighted by the TFIDF method. z particular research area z may consist of a vector s of the individual files it contains. Suppose s represents the vector of file $s'.s'$ and the corresponding category vector z have a cosine distance [11]. It represents how close a file is to a particular category. It represents how similar the document is to a particular class. The value is the largest. It is the class z to which s' belongs.

4.1. PageRank. After the corresponding search results are obtained through the query, they must be appropriately calculated to be sorted according to the degree of importance. One of the best ways to do this is to use the web page's links. Google is an example of this [12]. This method uses the link operation method proposed by Brin and Page. If you think of A Web page and its connections as a directed graph $R = Q($ Page,Link $)$. This can be illustrated by the adjacent matrix Q. The element of Q can be defined as

$$Q_{ij} = \begin{cases} 1, \text{ Link } i \rightarrow \text{ jexists} \\ 0, \text{ Otherwise} \end{cases}$$

$i, j \in (1 \text{ L}n), n$ represents the number of web pages. If the probability of starting from one page to another is 1 , the elements of the Q matrix are operated with $Q_{ij} = Q_{ij}/\deg(i)$. It can represent the possibility of sending from one web page to another. $\deg(i)$ refers to the page outlet point. Q is called an arbitrary matrix of lines [13]. From the characteristics of Web page connection, Q and Markov chain are consistent. Modify the Q matrix. Replace all rows of zeros in the matrix with $u = \left(\frac{1}{n}\right) e^T \cdot n$ is the number of web pages. e^T is the vector of all 1 line. Q is changed to $Q' = Q + s \cdot u^T$. The $s = \begin{cases} 1, \text{ if } \deg(i) = 0 \\ 0, \text{ otherwise} \end{cases}$ here is called the jump page indicator [14]. It proves that Q is a random matrix of columns. Q is an arbitrary transfer matrix for R. So, PageRank can be used as the limit value for the following recursive procedure

$$a_j^{(t+1)} = \sum_i Q'_{ij} a_i^{(t)} = \sum_{i \rightarrow j} a_i^{(t)} / \deg(i)$$

The above formula can transform the cost vector to find Q'. Since A contains an element of o, it does not ensure that Q' is the largest eigenvector. The reason for this is that Q' can be simplified. Q' can include several subgraphs that are disconnected from each other.

$$W = zQ + (1 - z)eu^T, e = (1, 1, 1 \text{ K}, 1)^T$$

$z \in (0, 1)$. In most literature it is set as $z \in [0.85, 1).z$ is known as the Ding ling coefficient. Processing W allows $W_{ii}^{(t)} > 0(i, t \in (1 \ldots n))$ to be tested. So W is not periodic. We can think of Q' as a non-periodic irreducible positive row type random matrix. The convergence of $a^{(t+1)} = W^T a^{(t)}$ in some respects is obtained from the Perlen-Frobenis law. Its maximum intrinsic property vector is positive.

4.2. Re-calculation of the value of the website.

4.2.1. Keyword extraction. In the system covered in this paper, it is necessary to extract domain-specific keywords. Some scholars have proposed a lexical weighting method to classify specific categories. This formula ensures that the weight of certain irrelevant words is low. This ensures that the intrinsic properties of the eigencharacters are fully reflected in the classification [15]. This article uses a top-n keyword method called option value. The selected file source is a separate domain file and has been manually categorized. Each key word is weighted. Suppose that the particular class is represented by the vector $S_i = \{(t_j, \lambda_j), j \in (1, m)\}, i \in (1, n)$. Here n represents the total number of classes. m represents the number of class keywords in a particular class. (t_j, λ_j) represents the specific keyword that has its weight. File $s_i : s_i = \{(t_j, \lambda_j), j \in (1, m)\}, i \in (1, n)$ is represented by vector $s_i.n$ stands for the number of files. m indicates the number of keywords in the file. (t_j, λ_j) indicates the weight of the keyword in the file.

4.2.2. Download Link. The user access sequence of the system is obtained through the analysis of server login records. This sequence lets you download the user's visited page from the Internet (Figure 4.1).

4.2.3. Construction of web connection matrix. This system has two kinds of web connection: the host link and the primary link. The two are linked in different proportions. Set the weight of the internal link to 3/4. Link weight between hosts 1/4. Then the connection matrix Q is represented by

$$Q_{ij} = \begin{cases} \frac{3}{4*/\deg(\text{ in tra })}, i, j \in G_m \\ \frac{1}{4*/\deg(\text{ in tra })}, i \in G_m, i \in G_n, m \neq n0, \text{ O therwise} \end{cases}$$

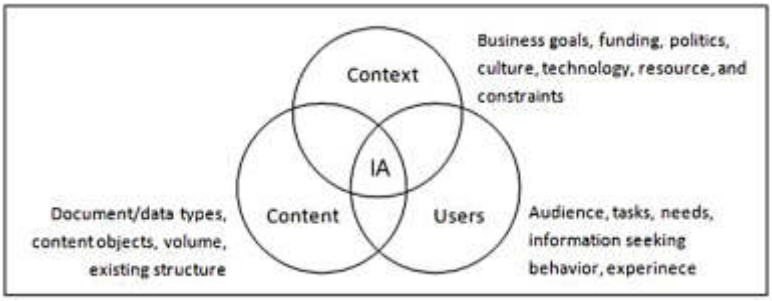

Fig. 4.1: *Hierarchical information structure of a Web site.*

Table 5.1: *Experimental data set.*

Data set	User number	Test the number of financial products	Number of labels	Average number of user tests	Average number of user tags	Average label users
1	786	2976	16663	3.938	22.063	0.049
2	779	2985	16663	3.990	22.271	0.048
3	808	3093	16663	3.979	21.469	0.050
4	807	3145	16663	4.052	21.500	0.050
5	807	2963	16663	3.917	22.063	0.049

4.2.4. PageRank calculation. The following data are stored in the local database: 1) The pages downloaded from the web page according to the login history. 2) Use categories to describe the vector of the web page. 3) Associate the link information of the page and keep two sequences: the sequence of the page is arranged according to the cosine distance of the page to the category. The PageRank formula calculates it. The two queues may consider using different weights to determine the importance of files in a particular category.

$$\text{score}(s) = \eta^* \,\text{sim}(s, S) + (1 - \eta) * PR(s)$$

s is used to store partial pages. $\text{sim}(s, S)$ is the cosine from class D to class s. $PR(s)$ is the level of the page on page $s.\eta \in (0, 1)$ is the weighting factor. The result is a new sequence. It represents s ranking of pages from high to low importance for a particular S level.

5. Experiment.

5.1. Test data set. The empirical data comes from the customer data of Santander Bank. Santander Bank is the second-largest bank in Europe and the largest bank in Spain. The bank generates a large amount of customer behavior data monthly and continues expanding new financial products. It includes the user's number, gender, age, tag data, type of financial product purchased, customer level, etc. There are 74,549 users and 11,126 financial products. Among them, 10,416,723 people purchased financial products, including 99,563 marks. Five samples were drawn from the sample set to ensure the stability of the experiment. Each data set is selected from 1,000 randomly selected users, and each set of data is selected from 1,000 randomly selected users who have purchased at least three financial products. Table 5.1 lists the characteristics of the data.

5.2. Evaluation criteria. The training samples are evaluated by the actual scores of each user on the training set and the predicted results. The difference between the score and the actual score is used as the evaluation criterion to predict the selected M financial products. The mean square error of evaluating system

Table 5.2: *Experimental results.*

Algorithm	**1**	**2**	**3**	**4**	**5**	**Avg**
random	2.402	2.343	2.370	2.331	2.300	2.349
user-based	1.285	1.314	1.247	1.329	1.367	1.308
item-based	1.422	1.436	1.350	1.477	1.465	1.430
Collaborative filtering algorithm for reinforcement learning	1.098	1.108	1.063	1.075	1.111	1.091

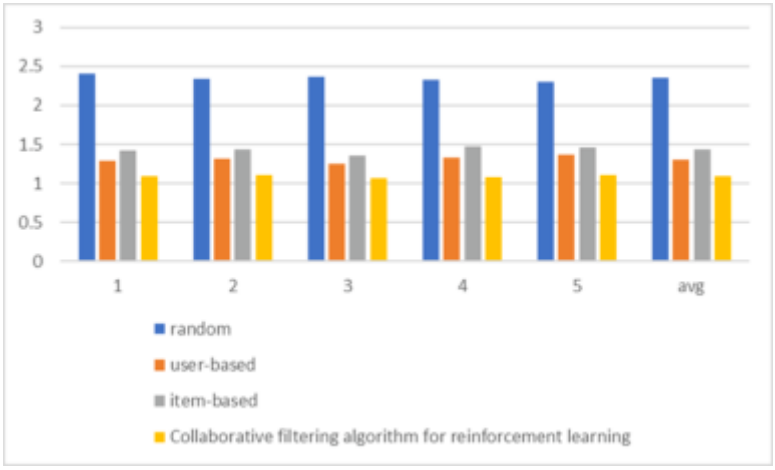

Fig. 5.1: Graphical representation

effect in the field of information retrieval is used as the evaluation standard:

$$\text{errors} = \sqrt{\frac{\sum_{j=1}^{N}[\text{prediction}(j) - \text{real}(j)]^2}{N}}$$

prediction(j) is the expected value of i financial product. real(j) is the objective evaluation of j financial products. N is the estimated number of wealth management products.

5.3. Results and analysis. The three methods are compared and analyzed. Firstly, an evaluation method for calculating random numbers is presented. An evaluation method based on probability distribution is proposed. The method is based on the worst-case baseline. Secondly, user-oriented collaborative filtering (user-based CF) is designed. Then, the resource cooperative filtering method (item-based CF) is proposed. During the experiment, 80% of the video score was scored, and then the collaborative filtering algorithm of reinforcement learning was trained. The top five resources in each user candidate set are predicted using the existing collaborative filtering algorithm of reinforcement learning. And compare it with the actual evaluation value of the user. All nearest neighbor values are 20 when executing both the regular user base CF and item-based CF methods. The information prediction of reinforcement learning collaborative filtering algorithm is presented. Table 5.2 shows the results of the mean deviation test of five different algorithms.

The elements in Table 5.2 represent the mean deviation of the corresponding algorithm in the corresponding data set. Avg is the average score of the five tests. Figure 5.1 gives a graphical representation of Table 5.2. The test results of the five data sets can all show a stable effect. The result shows that the mean value of the random variable is 2.349. A conventional user-based collaborative filtering approach can bring the average down to 1.308. The resource collaborative filtering algorithm can reach 1.430. The collaborative filtering algorithm of reinforcement learning can reduce the mean-variance to 1.091. Two kinds of recommendation accuracy based on collaborative filtering are further improved. The experimental results show that the method is very stable

on various samples. In addition, tag information is added to the cooperative filtering. It can improve the user's ability to predict network resources to improve the recommendation accuracy of the network.

6. Conclusion. This paper proposes that the recommendation algorithm of reinforcement learning bank financial products based on user preference and collaborative filtering is feasible. This overcomes the inaccuracy caused by the scarcity of user data. Then, an improved reinforcement learning method is proposed, which can effectively improve the system's performance. Then, use the learned user interest vector and the collaborative filtering method to realize the personalized recommendation to the user. Experimental results show that the enhanced learning method with tags is superior to the conventional collaborative filtering method in recommendation accuracy. Efficient financial product recommendation can also be applied to electronic financial product networks and information searches.

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VERIFICATION AND OPTIMIZATION OF NETWORK SECURITY DEFENSE SYSTEM FROM THE PERSPECTIVE OF BLUE ARMY IN ACTUAL OFFENSIVE AND DEFENSIVE EXERCISES

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Abstract. From the point of view of signal camouflage, this paper proposes an active network defense system. Then, the optimal camouflage target selection scheme is proposed. Its goal is to solve the problems existing in the information construction of Chinese military equipment support. This method establishes a multistage game model based on weapon support information network attack and defense. The attack and defense benefits are quantitatively calculated based on the cost of signal concealment. The solution to the refined Bayesian balance problem is given. Then, a multistage optimization algorithm for camouflage signal selection is proposed. Finally, experimental research proves the proposed algorithm to be reasonable and practical.

Key words: Actual combat offensive and defensive exercise; Information network; Multistage signal game; Optimal camouflage signal

1. Introduction. In the attack and defense confrontation of the weapon support system, if the appropriate concealed signal can be selected and the concealed signal can be used to interfere with the attacker's behavior, the defensive efficiency can be effectively improved. This is a veritable form of active security defense. However, how to accurately depict the attack and attack behavior of the weapon support information network and what kind of camouflage signal to deal with the attack is a complicated problem. Current research results are scarce. A game is a mathematical model to study two competitors' optimal strategies for mutual constraints. It accords with the characteristics of network attack and defense. In recent years, the problem of information security models based on game theory has been paid more and more attention. Literature [1] establishes a mathematical model of attack and defense based on a non-zero-sum attack game. At the same time, the optimal defense decision selection algorithm is given. Literature [2] organically integrates Markov's decision with game theory to understand security situations in equipment support information systems. Literature [3] established a mathematical network attack and defense model based on Bayesian game theory. This paper proposes an information security risk assessment model for complex environments. Literature [4] established a theoretical framework of network attack defense behavior based on the signal countermeasure theory to make the attack defense countermeasure closer to the network reality. Although this method overcomes the shortcoming that the conventional countermeasure requires the joint action of attack and defense, it can only be applied to single-stage attack and defense, not multistage network attack and defense. In this paper, a multilevel signal game model is established. From the perspective of "signal concealment," the active defense problem of the "weapon support information network" is studied. Before facing network security risks, defenders can use hidden signals to trick or deceive attackers to achieve active defense. This is the key to improving China's equipment support information construction level.

2. Complex network security defense diagram.

2.1. Security Defense Diagram. The defense map is made up of six units, $DG = (R, \xi, R_1, R_2, R_\alpha, R_\beta)$ .R represents the set of nodes on the defense map. Each node represents the state of the network. $\xi \subseteq R \times R$ represents the transitional relationship of the network. $R_1 \subseteq R$ stands for initial network security. $R_2 \subseteq R$ refers to

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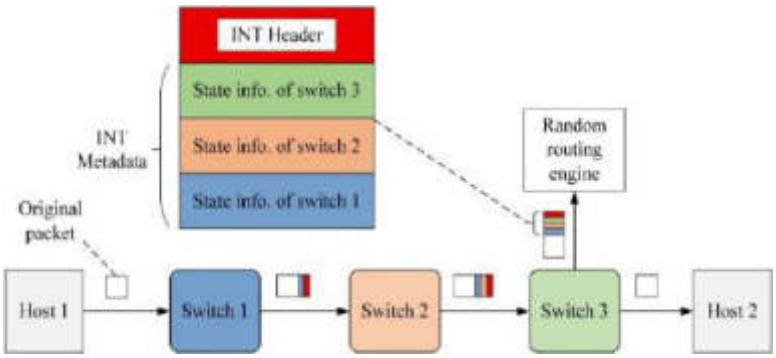

Fig. 2.1: *Randomly generated defense diagram example.*

Table 2.1: *Attack policy classification.*

Sort	Description	Attack lethality
Root	Get Administrator action rights	10
User	Obtain movement permission from network users	5
Data	Illegal access to or reading of data	3
DOS	Denial of service attack	2
Probe	Search attack	0.5
Other	other	*

the attack target set. $R_\alpha = (r_1^\alpha, r_2^\alpha, \mathrm{L}, r_m^\alpha)$ stands for strategic mix of objectives. Where $R_\beta = \left(r_1^\beta, r_2^\beta, \mathrm{L}, r_m^\beta\right)$ represents the policy set in the defense system [5]. Defensive maps are one of them. The nodes in the figure cannot only depict the current running status of the network but also reflect the sharing characteristics of the network and the resistance to external attacks. Directed edges describe the change process from one node to another after an atomic attack. R_α represents all of the attacker's attack routes, each an atomic attack [6]. The atomic attack sequence and attack strategy each have their corresponding defense strategies, and these defense measures are combined to form R_β. Figure 2.1 is a randomly generated defense diagram (image cited in Digital Communications and Networks, Volume 8, Issue 3 , June 2022, Pages373-387). In this graph, the directed side represents the transformation of two different security conditions in the corresponding block. $R_\alpha = \{1, 2, 3\}, R_\beta = \left\{r_1^\beta, r_2^\beta, r_3^\beta\right\}$ represents the corresponding defense strategy.

2.2. Creating a Defense Diagram. An attack on a complex network usually causes significant damage to the network. Therefore, it is necessary to take measures such as security detection and security hardening. A defense map is a typical security protection method that can effectively protect it before the attacker attacks it or does not cause heavy losses [7]. In this way, the "passive" information system is transformed into an "active" to achieve the purpose of "high security." The defense chart is detailed in Figure 2.2 (Computers & Security, 2024, 136:103534). The defense diagram contains vital information, such as the data processing and database modules. According to these data, the attacker can search for one or more attack routes to achieve a cost-effectiveness analysis based on offensive and defensive principles and strategies to develop a defensive map.

2.3. Attack and Defense Strategy classification. It is necessary to study the offensive and defensive strategies to achieve accurate network protection [8]. Two aspects should be paid attention to in the division of attack and defense strategies: 1) The complexity of the environment and active defense mode should be comprehensively utilized in establishing the division space of attack and defense strategies. Too much spacing makes the defense mode more complex, while too little spacing makes it difficult for the algorithm to resist various attacks. 2) The attack and defense strategies division must match most current attack patterns. The categories of offensive strategies are listed in Table 2.1.

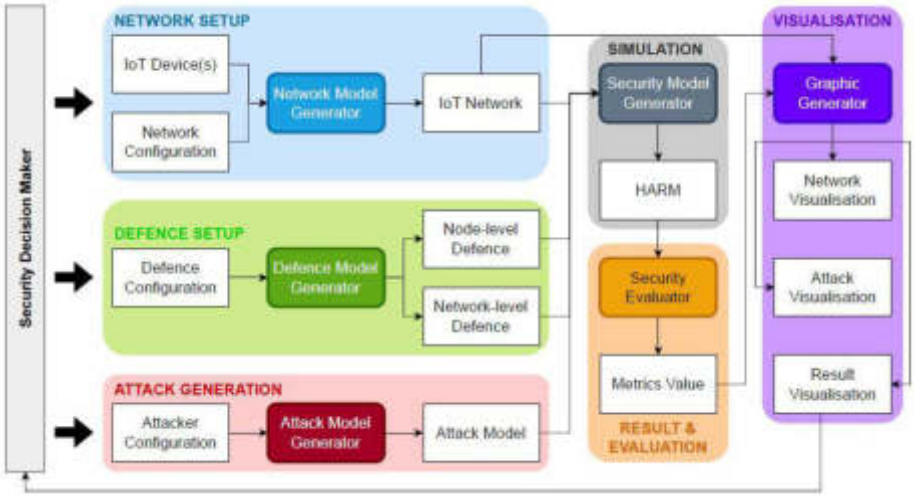

Fig. 2.2: *Defense diagram generation module diagram.*

Table 2.2: Host-based defense policies.

Subclass	Description	Operating cost
End procedure	Close the hacked program or all programs	DE1
Remove file	Delete files that have been changed or attacked	DE1
The account information has been removed	Removal of suspected user account information	DE1
Stoppage service	Terminate programs that are vulnerable to attack	DE2
Restrictions on user movements	Restrict and authorize suspected users	DE2
Shut down the host	Shut down the attacked host	DE2
Restart the host	Restart the attacked host	DE2
Install updater	Update the defective software to the latest version	DE2
Computer virus scanning	Antivirus detection technology	DE3
Document authenticity check	Application software checks the integrity of system files	DE3
Install updater	The system has been updated to the latest	DE3
Reinstall the system	Reinstall the system that was attacked or affected by the virus	DE3
Change account password	Change all system account information	DE2
Set the disk file format	Format the disk and remove the malicious code	DE3
Back-up device	Back-up data	DE3
other	*	*

This project will delve into the types of invasion strategies and the temporal and spatial characteristics of active defense [9]. The defense policies are divided into two categories: host and network. A class contains several subclasses. Details are shown in Table 2.2 and Table 2.3.

DE1 means passive defense. DE2 means medium-strength defense. DE3 stands for active defense. The security protection of complex networks has become the focus of current research [10]. Active defense can conduct security early warning and deep defense and strengthen the defense of information systems to change from passive defense to active defense. This network-based protection method can exclude standard software and trojans. Let users decide whether they can operate or perform a given job according to their wishes. ”Defense” is the process of monitoring and intercepting users, which has a positive protection function for complex network security.

3. Network security active defense model. It is necessary to establish the active protection mode of the information system and choose effective protection measures. When an individual is subjected to a single attack, its protection measures can be optimized at a lower cost. When multiple attack targets are

Table 2.3: *Network-based defense strategies.*

Subclass	Description	Operating cost
Isolated host	Isolate the attacked host from the NIC	DE2
Discard suspicious groupings	Discard suspected packets using IDS or Firewall	DE2
Network outage	Make the attacked system disconnected from the outside world	DE2
TCP reset	Send a reset packet to reset the session	DE2
Blocked port	Close the port through the software	DE2
Blocking IP address	The IP address of the software is blocked. Procedure	DE2
Establishing a black hole path	Use Firewire to change the routing table to an inaccessible IP	DE2
other	*	*

attacked, one attack is effective but ineffective due to the constraints of protection measures [11]. This makes the selection of protective measures more difficult. In this paper, the game theory method is used to solve it. The network security protection diagram $DG = (R, \xi, R_1, R_2, R_\alpha, R_\beta)$ is generated at the input end of the model, and the corresponding optimal protection scheme R_{st} is given. The selection process for face R_{st} is detailed below. 1) Initialize the protection diagram $ADG = (Q_\alpha, Q_\beta), (R_\alpha, R_\beta), (W_\alpha, W_\beta)$. Q_α, Q_β stands for offensive ontology and defensive ontology. W_α, W_β stands for the benefit of attacking and defending agents when appropriate defensive means are used to fend off an attack. 2) If the mode of the offensive and defensive game is $(W_\alpha = -W_\beta)$, only one of W_α, W_β needs to be solved. W_β is used in this paper. 3) r_i^β is the defense in Plan R_β. The defense cost of $r_i^\beta De_{\cos t}(\beta)$ is calculated using formula (3.1):

$$De_{\cos t}(\beta) = E_{\cos t} + M_{\cos t} = E_{\cos t}(\beta) + G_{\cos t} \times s(\alpha, \beta) + B_{\cos t}(\alpha) \times \varepsilon(\alpha, \beta)$$

E_{cost} represents the operational cost of defense. $M_{\cos t}$ stands for passive defensive cost. Y_{cost} stands for remaining defensive strength. G_{cost} represents the cost of adequate system protection. s is a negative defense cost factor. $s(\alpha, \beta)$ describes the adverse consequences of protective action β against the attack mechanism α. $B_{\cos t}(\alpha)$ represents the cost of defending against the actual value β against offensive strategy α.ε stands for residual loss factor [12]. $\varepsilon(\alpha, \beta)$ is the effect of residual loss on the entire system when protective measure β resists offensive measure α. After the operation, the efficiency function set matrix W is generated, and the index system at each level in the matrix has a close relationship [13]. It's a multilevel index system. The index evaluation and the realistic function comprehensive evaluation of the complex network security active protection mode determine the weight. The evaluation index weight is based on the premise of complex network security. The importance degree of each level factor is evaluated. The result of the composition matrix is as follows:

$$W = [w_{ij}] = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{m1} & w_{m2} & \cdots & w_{mn} \end{bmatrix}$$

w_{ij} represents the degree of subordination to the Class j evaluation set of the Class i use function of the total matrix method index. Evaluation sets integrate views into a complex network security proactive defense model but cannot change the nature of the differences between comments [14]. An evaluation method of attack defense countermeasure based on information entropy is proposed. 4) When the attack and defense strategy mode is $(W_\alpha \neq -W_\beta)$, choose one of the attack plans r_1^α in R_α. Use formula (2.3) to calculate the attack cost of r_1^α $De_{\cos t}(\alpha)$:

$$De_{\cos t}(\alpha) = \sum_{m=1}^{n} G_m \times C_m \times (F_{\cos t} \times Q_i + C_{\cos t} \times Q_c + G_{\cos t} \times Q_v)$$

G_m represents the number of networks attacked. C_m for risk of attack. F_{cost} is the full cost of an attack. Q_i represents the weighted total cost of offense. $C_{\cos t}$ refers to the confidentiality cost of an attack. Q_c is

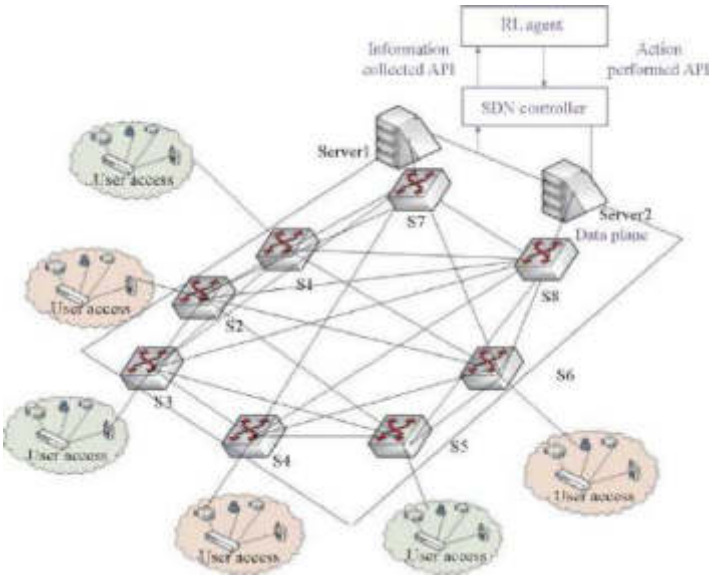

Fig. 4.1: *Network topology of the experimental environment.*

Table 4.1: Attack policy set of the attacker.

Serial number	Attack operation	Cost	Attack strategy	
			Attack 1	Attack 2
Attack 1	Steal the account and crack it	2	Y	Y
Attack 2	Trojan horse activity	3	Y	
Attack 3	Remote buffer overflow	5		Y
Attack 4	Deface a website	4	Y	Y
Attack 5	TCP-SYN flood	7	Y	Y
Attack 6	Oracle TNS listener	6	Y	

weighted by the confidentiality cost of the attack. G_{cost} stands for cost of attack effectiveness. Q_v represents the weighted value of the cost of offensive effectiveness. 5) This paper studies how to choose the target and method of attack. The attacker has local permissions. The attacker must be connected to a host on the target network [15]. The target of the attack can often hit the target in both dimensions of space and time and solve the attack in the fastest and easiest way. To minimize defensive explosion. Choose the best forward defense scheme R_{st} to obtain the best value to establish the active defense mode of the whole complex information system.

4. Simulation experiment and analysis. A test platform is set up to analyze the simulation results. Network security attacks are mainly targeted at external networks. The military firewall insulates the enterprise's internal and external networks. Only a single external host can access the mail server, the network server, and the internal host. Enterprise mail servers, network servers, host servers, and file servers can access the database server [16]. The attacker cannot initially gain direct access to the database but can conduct atomic attacks to achieve this goal. Various network attack programs, such as low Orbit Ion Canon, UDP Flood and Acunetix, are used to automate the test system (fig. 4.1) partially.

The network topology of the attacker is studied, and the attack strategy is obtained. This paper chooses only two ways of attack [17]. It can be seen from Table 4.1 that "Y" represents the offensive actions included in the selected offensive strategy, and the cost of the attack is set according to the difficulty of executing the attack.

According to the difference of defense effectiveness and cost that "defense behavior" may produce, the

Table 4.2: Defense policy set of the defender.

Serial number	Defensive action	Cost	Defensive strategy	
			Defense1	Defense2
Defense1	Delete suspicious accounts	2	Y	Y
Defense2	Restrict packets coming from ports	1	Y	
Defense3	Uninstall and delete Trojan Horse	6	Y	
Defense4	Correct home page	4		Y
Defense5	Repair database	5	Y	Y
Defense6	Restrict SYN/ICMP packets	3	Y	

Table 4.3: Parameters related to attack operations.

Serial number	μ_m	$(W(Z_1), W(Z_2), W(Z_3))$	ε
Attack 1	0.9	(0.7, 0.4, 0.5)	0.1
Attack 2	0.8	(0.5, 0.6, 0.6)	0.4
Attack 3	0.8	(0.5, 0.8, 0.6)	0.4
Attack 4	0.7	(0.5, 0.7, 0.8)	0.3
Attack 5	0.9	(0.4, 0.8, 0.6)	0.3
Attack 6	0.8	(1, 1, 1)	0.4

"defense strategy" database is constructed. Two typical "defense measures" of "high defense" and "weak defense" are selected and studied. The camouflage signal space is $\phi = \{\varphi_1, \varphi_2\}$.φ_1 is high level camouflage. φ_2 is a low-level camouflage signal. Table 4.2 sets out the defense strategy [18]. The "Y" here means that the defense strategy includes the following defense measures, and the defense cost is determined according to the difficulty of defense implementation. When the offensive side chooses the defensive side's strategy, its prior cognition is $(\gamma_1, \gamma_2) = (\gamma_1, 1-\gamma_1) = (0.3, 0.7)$. The parameters related to offensive operations are listed in Table 4.3.

Use $(10, 15, 15)$ to represent the security attribute value of the Intranet server. Use $(18, 16, 18)$ to indicate the security attribute value of the network service. Use $(20, 20, 22)$ to represent the security property values of the file server. Use $(18, 20, 22)$ to represent the security property values of the file server. Use $(25, 28, 30)$ to represent the security attribute value of the database server. Use $(2, 3; 4, 1)$ indicates the cost of signal hiding [19]. The strategy combination of defense and attack and the corresponding parameters are put forward to get the network defense countermeasure tree. Various information sets are analyzed, and the posterior probability is $p^* = 0.353, q^* = 0.447$. From the process of refined Bayesian Nash equilibrium solution, it can get: $p > p^*, q > q^*$ is Attack$^*(\varphi_1) =$ Attack$_1$, Attack$^*(\varphi_2) =$ Attack$_1$, The defender φ^* (Defen $_1$) $= \varphi_1, \varphi^*$ (Defen $_2$) $= \varphi_2$ chooses defense Defens s_1. The defensive option is to hide φ_1, and the offensive option is to attack Attack $_1$. The defender chooses a defensive strategy Defens $_2$. Use the covert signal " φ_1 " as a defense [20]. The attacker adopts the offensive strategy Attack $_1$. The refined Bayesian Nash equilibrium is the confusion equilibrium $S_1 = \{(\varphi_1, \varphi_1) \rightarrow (\text{ Attack }_1, \text{ Attack }_1), p = \gamma_1, q > q^*\}$. The paper studies the refined Bayesian Nash equilibrium for other cases.

When $p > p^*, q > q^*$ is the mixed equilibrium, call it $S_2 = \{(\varphi_1, \varphi_2) \rightarrow (\text{ Attack }_1, \text{ Attack }_1), p = \gamma_1, q > q^*\}$.

When $p < p^*, q > q^*$ is the separate equilibrium, call it $S_3 = \{(\varphi_2, \varphi_1) \rightarrow (\text{ Attack }_2, \text{ Attack }_1), p = 0, q = 1\}$.

When $p < p^*, q < q^*$ is the mixed equilibrium, call it $S_4 = \{(\varphi_1, \varphi_1) \rightarrow (\text{ Attack }_2, \text{ Attack }_2), p = \gamma_1, q > q^*\}$

For $\gamma_1 = 0.3 < p^*, \gamma_2 = 0.7 > q^*$, then, the refined Bayesian Nash equilibrium B is proper. In terms of defense, the high level of defense plan Defens s_1 chooses the lower level of covert signal φ_2. The benefit is most significant when the higher cover signal φ_1 is chosen in the weaker defense strategy Defens $_2$. Turning a low-level defense into an advanced one can keep attackers at bay. The choice of the covert signal can effectively enhance the secrecy performance of the military intelligence system so that it can better play its active defense role.

5. Conclusion. This paper analyzes the attack and defense of military intelligence networks and proposes the optimal choice scheme of camouflage signal based on game theory. Simulation results show that the algorithm can be applied to the covert system to achieve active network defense. Therefore, enhancing the security protection level of our military information network is of great practical significance.

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DYNAMIC SECURITY RULE OPTIMIZATION BASED ON DEEP LEARNING AND ADAPTIVE ALGORITHMS

FEILU HANG*, LINJIANG XIE†, ZHENHONG ZHANG‡, YUTING LIU§ AND JIAN HU¶

Abstract. Compared with traditional computer network security identification techniques, deep learning algorithms are based on their own distributed network structure for storage, processing, classification, comparison, and automatic identification functions. The distribution and dynamism of cloud databases increase the difficulty of route prediction and recognition in the cloud, affecting the efficiency of cloud computing. In response to the above issues, the author proposes a dynamic path optimization process for cloud databases based on adaptive immune grouping polymorphic ant colony algorithm. By setting up two states of ant colony, reconnaissance ant and search ant, and introducing an adaptive polymorphic ant colony competition strategy, the defect of general ant colony algorithms being prone to falling into local optima is improved; On this basis, an artificial immune algorithm with fast global search capability is further integrated to improve the search ant path optimization process, improving search speed and accuracy. Simulation experiments show that the IPANT algorithm outperforms the other three algorithms, maintaining a throughput of 1000 kbps and relatively stable; The data of OSPF, SPF, and FR are not significantly different, significantly lower than IPANT. The immune polymorphic ant colony algorithm (IPANT) has the lowest time delay for packet routing and performs better than the other three algorithms, with FR and SPF having higher latency. It has been proven that this algorithm can better solve convergence speed and global optimization problems, and can quickly and reasonably find the database to be accessed in the cloud.

Key words: Adaptive polymorphic ant colony competition strategy, Immune polymorphic ant colony algorithm, Cloud database, Dynamic path optimization

1. Introduction. With the rapid development of artificial intelligence, internet technology, and automated recognition technology, more deep learning methods such as decision tree classification algorithms, gradient classification algorithms, neural network algorithms, convolutions, etc. are gradually being rapidly applied in computer network security recognition. Compared to traditional computer network security identification technology methods, deep learning algorithms make up for the shortcomings of computer network security intelligent management information ability, intuitive, and nonlinear data information adaptive ability based on their own distributed structure storage, processing, classification, comparison, and automatic recognition functions, thereby improving the network security data calculation ability and data information efficiency value, expanded the application scope of computer network security under deep learning mode[1]. On the basis of deep learning, in order to achieve efficient, accurate, and high-quality computer network security identification and management technology, the algorithm feature advantages of deep learning algorithms such as feature vector extraction, recognition, information combination optimization, and classification are applied to computer network security identification management. Through systematic analysis of its principles, architectural functional features, and platform application implementation, a set of security, economy, and intelligence is designed and constructed, provide a scientific reference for the design, implementation, and application of computer network security identification management system diagrams for deep learning algorithms.

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In order to scientifically and comprehensively grasp the characteristics and functions of computer network security identification management technology based on deep learning algorithms, the design and application of the technology platform in security identification management are based on the principles of scientificity, intuitiveness, security management, and scalability. Furthermore, based on the basic principles of design and application, enhance the functionality of network security identification technology in the context of deep learning, and enhance the application of deep learning methods and identification management core technologies. In the basic principles of design, scientific prediction and evaluation of computer network security forms are carried out through neural networks and convolutional learning methods. Compared with traditional security management methods, deep learning methods improve the accuracy of security evaluation prediction results and overall management efficiency; In terms of information scalability, machine learning presets the scalability of security protection tools in the security design process based on the current situation of computer systems, enabling the expansion and upgrading of new functions in security protection situations, and achieving full coverage of computer network security management[2].

As shown in Figure 1.1, the design process of computer network security identification management technology in the context of deep learning is presented. In the computer network security management technology platform, interactive mechanism structure is mainly used to achieve the sharing and co construction of interpretation mechanism, deep learning method inference, and data knowledge acquisition. At the same time, the functions of each module and important components are as follows: In terms of interpretation mechanism, coding data quantification evaluation is implemented for computer network security, and relevant predictions are made based on the evaluation results for the collected data information and situation values; In terms of deep learning methods and inference mechanisms, conduct situation assessment based on selected data, generate the required format data, and then predict and evaluate the current computer network security situation through neural network algorithms or convolutional algorithms to ensure computer network security[3]. The advantages of computer network identification security management mechanisms are mutually collaborative. When realizing the interoperability and sharing of mechanism functions, deep learning algorithms are used to demonstrate the current computer security situation and strengthen the technical capabilities of network security management. From the above scholars' research, it can be analyzed that polymorphic ant colony algorithms can basically solve the defects of ant colony algorithms in the path optimization process, and are suitable for cloud environments. However, during the search cycle, the number of the two ant colonies is not adjusted at any time, which can easily cause the search process to be too slow or stagnant, and the search ants still need to improve in terms of global search. Therefore, the author utilizes a grouping polymorphic ant colony algorithm with social morphology, and introduces an adaptive polymorphic ant colony competition strategy based on this. The strategy function Pg is used to reasonably adjust the number of reconnaissance ants and search ants, better improving the shortcomings of premature and local optima in general ant colony algorithms; In response to the shortcomings of the global search ability of search ants in polymorphic ant colony algorithms, an artificial immune algorithm with fast global search ability is organically integrated to further improve its optimization process: each search ant is regarded as an antibody based on the reconnaissance element and the path that may be the optimal solution, and the shortest path in reality is regarded as an antigen to solve the matching degree between the two, forming a new adaptive immune polymorphic ant colony algorithm, simultaneously solving the problem of global optimal solution and algorithm convergence speed, thereby optimizing the path of cloud databases. Finally, simulation experiments were conducted from three perspectives: Adaptive polymorphic ant colony competition strategy, immune polymorphic ant colony algorithm, and cloud database throughput and grouping delay to demonstrate the effectiveness of the algorithm.

2. Deep learning polymorphic ant colony algorithm and adaptive competition strategy.

2.1. Basic Polymorphic Ant Colony Algorithm Model. There are three main types of ant colonies in polymorphic ant colony algorithms: Reconnaissance ants, search ants, and worker ants. Among them, the task of the worker ant colony is only responsible for feeding back from the confirmed optimal path, and the author did not consider it when designing the cloud database path optimization algorithm[4]; Reconnaissance ants are mainly responsible for local reconnaissance, searching around each node in the cloud database and leaving reconnaissance results (reconnaissance elements) to provide assistance for searching ants; Search ants are mainly responsible for global search. At each node, they select the next node based on the reconnaissance

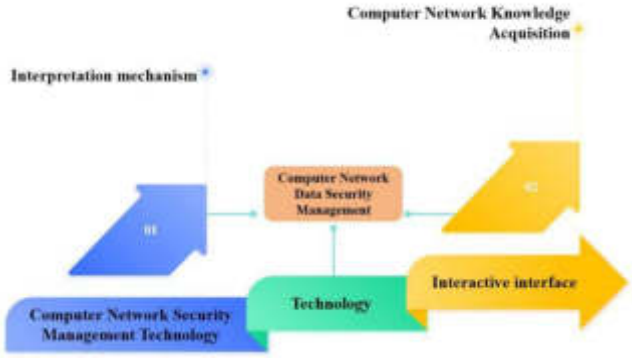

Fig. 1.1: Schematic diagram of computer network security identification management using deep learning algorithms

elements left by the reconnaissance ants and the original information elements of each path, until the best path is found and marked.

1) Reconnaissance ants place m reconnaissance ants on n nodes, with each reconnaissance ant scouting n-1 other nodes centered around its node. The reconnaissance results are combined with existing MAXPC (prior knowledge) to form reconnaissance elements, denoted as s [i] [j], marked on the path from node i to j, the search ant colony can calculate the state transition probability $P_{ij}^{k}$and adjust the amount of information on each path based on the marked detection elements and existing pheromones[5]. The calculation formula for s [i] [j] is shown in Equation 2.1.

$$s[i][j] = \begin{cases} \overline{d_{ij}}/d_{ij} & \text{If node j is within MAXPC of i} \\ 0 \quad otherwise \end{cases} \tag{2.1}$$

Among them, $\overline{d_{ij}}$ represents the minimum distance from node i as the center to other (n-1) nodes.

The amount of information on each path at the initial time is

$$\tau_{ij}(0) = \begin{cases} C \times s[i][j] & \text{if s[i][j]} \neq 0 \\ C \times \overline{d_{ij}}/\overline{\overline{d_{ij}}} & otherwise \end{cases} \tag{2.2}$$

Among them, $\overline{\overline{d_{ij}}}$ represents the maximum distance from node i as the center to other (n-1) nodes, and C represents the initial concentration of pheromones on each path.

2) The probability of state transition from node i to node j during the movement of ant k (k=1,2,...,m) is $P_{ij}^{k'}(t)$, and its value is

$$P_{ij}^{k'}(t) = \begin{cases} \frac{\tau_{ij}^{\alpha}(t) \times \eta_{ij}^{\beta}(t)}{\sum\limits_{s \neq tabu_k} \tau_{is}^{\alpha}(t) \times \eta_{is}^{\beta}(t)} & \text{if j} \neq tabu_k, \text{and s[i][j]} \neq 0 \\ 0 \quad otherwise \end{cases} \tag{2.3}$$

After an iteration, the pheromone concentrations on each path need to be readjusted:

$$t_{ij}(t+1) = \begin{cases} (1-\rho) \times \tau_{ij}(t) + \rho \times \Delta\tau_{ij} & \text{ifs[i,j]} \neq 0 \\ (1-\rho) \times \tau_{ij}(t) \quad otherwise \end{cases} \tag{2.4}$$

Among them, $\Delta\tau_{ij}$ is the sum of the information released by all ants on the path (i, j) in this cycle, $\Delta\tau_{ij} = \sum\limits_{k=1}^{m} \Delta\tau_{ij}^{k}$. The amount of information left by k ants on paths (i, j) in this cycle is $\Delta\tau_{ij}^{k}$, and the calculation

formula is shown in Equation 2.5.

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q\times(\overline{d_{ij}}/d_{ij})}{L_k} & \text{If ant k passes through (i,j) and afters[i,j]} \neq 0 \\ 0 \quad otherwise \end{cases} \tag{2.5}$$

According to Equation 2.5: each search ant only leaves an appropriate amount of pheromones (local information $(\overline{d_{ij}}/d_{ij})$ combined with global information L_k) on the path that may be a component of the optimal solution based on the reconnaissance element. Is it a component of the optimal solution determined by s [i, j] Decision[6].

2.2. Adaptive Polymorphic Ant Colony Competition Strategy. In order to fully leverage the roles of search ants and reconnaissance ants, promote better integration of polymorphic ant colony algorithm and immune algorithm, and ensure the optimality of the improved algorithm, an adaptive polymorphic ant colony competition strategy is introduced, which reasonably allocates the number of two ant colonies and adjusts them at any time based on the cycle results. Firstly, set the competition strategy function, as shown in Equation 2.6.

$$P_g = F(X) = \int_{-\infty}^{X} f(x)\,dx \tag{2.6}$$

where f (x) is the normal distribution probability density function, that

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \tag{2.7}$$

Among them: σ is the standard deviation, μ is a mathematical expectation. Due to compliance with standard normal distribution $\mu = 0$ $\sigma = 1$.At the beginning of the search, if the number of reconnaissance ants $m_0 = m \times P_g$ is the same as the number of search ants $m_1 = m \times (1 - P_g)$, then the variable $X = 0, P_g = 0.5$. For each iteration completed, X in Equation 2.6 is updated based on the search results[7].

Then set the adjustment method. Among them, APL (average path length) is used to represent the average path length of ant colony search, and a constant of $k_0(1 < k_0 < 1.005)$ is set.

a) When $APL_{\text{Reconnaissance ant}} < k_0 \times APL_{\text{Search for ants}}$ is reached, it can be seen that the average path length searched by reconnaissance ants is shorter, and their ability to search for the best path is better than that of search ants. According to Equation 2.8: update X:

$$X = X + \frac{\sigma}{(\sigma + b_1)} \tag{2.8}$$

Among them, b_1 is a constant, and b_1 is taken as 100. At this point, as X increases and P_g also increases, the number of reconnaissance ants will increase in the next round.

b) When $APL_{\text{Reconnaissance ant}} < k_0 \times APL_{\text{Search for ants}}$ is reached, it can be seen for the best path, and update X according to Equation 2.9.

$$X = X \tag{2.9}$$

Just keep the number of two ant colonies consistent with the previous generation.

In order to avoid the complete disappearance of one of the ant colonies, AA regulation is used.

$$P_g = \begin{cases} P_{gmin} \quad if \quad P_g \leqslant P_{gmin} \\ P_g \quad if \quad P_{gmin \leqslant P_g \leqslant P_{gmax}} \\ P_{gmax} \quad if \quad P_g \geqslant P_{gmin} \end{cases} \tag{2.10}$$

Experimental simulation shows that the introduction of polymorphic ant colony algorithm and adaptive competition strategy can significantly improve the search performance of ant colony and improve the defect of general ant colony algorithms being prone to falling into local optima; And apply it to the improved new algorithm in the following text to further improve the dynamic path optimization effect of cloud databases.

3. Cloud Database Dynamic Path Optimization Process Based on Immune Polymorphic Ant Colony Algorithm.

3.1. Algorithm design concept. The basic idea of immune polymorphic ant colony optimization algorithm is to divide ants used for dynamic path planning in cloud databases into two categories according to the idea of group polymorphic ant colony algorithm. Among them, reconnaissance ants use each node placed in the cloud database for local reconnaissance and leave reconnaissance elements. The speed of global search based on polymorphic ant colony algorithm is relatively slow, and the artificial immune algorithm with fast and random global search ability is integrated to improve the functional part of ant search in the ant colony algorithm. Search ants use artificial immune algorithms to conduct global searches based on the reconnaissance elements left by the reconnaissance ants[8]. Consider the path that the search ant considers to be the possible optimal solution as an antibody, calculate the affinity (matching degree) between the antibody and the antigen, select the one with good affinity as the new antibody, obtain the optimal feasible solution, and generate the initial distribution of pheromones. Search for ants and optimize them based on reconnaissance elements and pheromones to improve solution efficiency. The improved model is conducive to finding optimal feasible solutions and improving solution efficiency. It can effectively improve the convergence speed of algorithms and the globality of optimal solutions that need to be solved in dynamic path queries of cloud databases, and achieve load balancing of computing resources.

3.2. Steps for optimizing dynamic paths in cloud databases. The steps of immune polymorphic ant colony optimization algorithm are as follows:

a) Before starting the search, place m reconnaissance ants on m nodes of the cloud database. Each reconnaissance ant evaluates the resource utilization rate of its neighboring cloud database nodes within the local range of the database node, and combines prior knowledge to form the reconnaissance element s [i] [j], among them, s [i] [j] represents the probability that node S chooses to use node j's resources through node i. The calculation formula for s [i] [j] is shown in equation (12): where i, j=0, 1, 2,..., m-1, $i \neq j$, η for neighbor Table.

$$s[i][j] = \frac{\sigma_{ij}}{\delta_{ij}} \tag{3.1}$$

b) Whenever user U searches on the platform, submit a search task Q to the source node N_s. The source node N is detected in the neighbor table n. If no neighbor nodes are found, task Q is temporarily placed in N_s.

c) Set the amount of information on each path at the initial time.

$$t_{ij}(0) = \begin{cases} C \times s[i][j] & if s[i][j] \neq 0 \\ C \times \overline{\sigma_{ij}}/\overline{\overline{\sigma_{ij}}} & otherwise \end{cases} \tag{3.2}$$

d) Before the search starts, the $P_g = F(X) = \int_{-\infty}^{X} f(x)\,dx$ will adjust the number of two ant colonies at any time by introducing the designed competition strategy.

e) The ant scheduling module AS of N_s generates search ant ANTs. The search ants select the most likely optimal path based on the reconnaissance elements left by the reconnaissance ants on m cloud database nodes, and roughly calculate the calculation amount of information search task Q, which is recorded as $\sigma(Q)$. Assuming the search period TTL is 0, calculate the grid size to obtain the longest period TTL_{max}. Calculate the available search ability of the source node N_s born as search ants and the estimated time T_l for N_s to start the next information search task, and then place them in the tabu(ANT_s) of ANTs.

f) Design the search part of search ants from the perspective of artificial immunity. If the path traveled by the ANTs search ants (m ants) in the taboo Table (i.e. the path that the search ants believe may be the optimal solution) is considered as antibody a, then the antibody population Ab can be expressed as $Ab = [a_1, a_2, ..., a_m]$, and m is the number of antibodies, i.e. the number of search ants; The antigen is the antibody with the shortest path length, which is the actual fastest path to reach the cloud database during the ant search process. The parameter that represents the degree of matching between antibodies and antigens is affinity. The affinity

function is defined as

$$affinity(a_i) = \frac{[F - dist(a_i)]}{[\sum_{j=1}^{m}(F - dist(a_j)) + \varepsilon]} \tag{3.3}$$

Among them, dist (ai) is the path length of antibody a; F is the longest path among all antibodies, $F = max(dist(a_1), dist(a_2), ..., dist(a_m))$. In order to prevent the shortest path from becoming the same and intimacy saturation in later search tasks, coefficients are added to the denominator $\varepsilon(0 < \varepsilon < 1)$. The larger the affinity (ai): the greater the degree of matching between the antibody and antigen, and the more likely it is to be the shortest path.

g) Optimize the antibodies in the taboo list to generate new antibodies. The process of selecting new antibodies is as follows: Based on the calculated affinity, the antibodies with a high degree of matching are placed in the memory antibody library N_{Ab}, and the optimized antibodies are compared with the original antibodies. If the path length is shorter, the original antibodies are replaced.

h) Antibody selection. The newly generated antibodies are arranged in the taboo table according to their affinity matching degree from high to low. The first four antibodies are selected to form a new antibody group, and then proceed to step f) for cyclic optimization.

i) Simultaneously initializing parameters τ_C, τ_G, m_1, m_2. Follow step e) to obtain a shorter search path and update the pheromone. Among them, τ_C is the pheromone constant τ_G is the conversion value of the pheromone of the immune polymorphic ant colony algorithm result, m_1 is the current number of detected ants, and m_2 is the current number of searched ants[9]. Update pheromones while forming a new antibody population:

$$\tau_{ij}(0) = \begin{cases} \tau_C + \tau_G & m_1 \neq m_2 \\ t_c & otherwise \end{cases} \tag{3.4}$$

j) After n hours, m only searches for ants and ends searching for various nodes in the cloud database. Calculate the final function value Lk (h=1,2,..., n) of the antigen to output the optimal solution.

4. Simulation experiments. In order to better validate the effectiveness of the improved immune polymorphic ant colony algorithm in the dynamic path search process of cloud databases, the author selected an example from the internationally recognized TSPLIB test library for simulation experiments. Simulate and analyze the introduction of adaptive polymorphic ant colony competition strategy in polymorphic ant colony algorithm, the improvement of immune polymorphic ant colony algorithm using artificial immune algorithm, and the comparison of immune polymorphic ant colony algorithm with other algorithms in average throughput and group delay in cloud database path search. The experimental simulation software of the first two systems is MATLAB 7.0; the latter chose NS-2 from the ISI Institute of the University as the experimental simulation platform.

4.1. Simulation analysis of adaptive polymorphic ant colony competition strategy. The author selected datasets from four typical examples of the TSP problem, Att48, St70, Lin105, and Ch150, and conducted 40 tests based on different Pg values to verify whether polymorphic ant colonies and adaptive competition strategies can effectively improve search capabilities, among them, $\alpha = 1, B = 5, Q = 50$. $P_g = 0$ represents a polymorphic ant colony algorithm with only search ant colonies, $P_g = 1$ represents a polymorphic ant colony algorithm with only reconnaissance ant colonies, and adaptive PR represents a polymorphic ant colony algorithm with adaptive polymorphic ant colony competition strategy. The initial value of P_g is set to 0.5, and the maximum number of cycles is set to 4 times the number of cities[10]. The specific experimental results are shown in Table 4.1. In the table, N_{best} is the number of times the optimal solution was obtained within the experimental iteration number;.

From the comparative data shown in Figure 4.1 and Table 4.1, it can be seen that the polymorphic ant colony algorithm using adaptive P_g has improved convergence speed and accuracy, and is superior to the polymorphic ant colony algorithm with $P_g = 0$ and $P_g = 1$, because it combines the advantages of reconnaissance ants and search ants, and applies adaptive competition strategies to reasonably adjust the number of the two ant

Table 4.1: Test examples based on different Pg values (40 tests)

Problem S_0	Method	N_best	MTL	MITL	METL	σ/%
	P_g=0	4	23794	32515	33641	0.39
Att4833524	P_g=1	2	23794	32515	33602	0.25
	Adaptive P_g	7 23792	32515	33565	0.16	
	P_g=0	5	676	666	670	0.32
St70678.5975	P_g=1	6	677	666	669	0.21
	Adaptive P_g	7	676	666	668	0.07
	P_g=0	2	14563	14372	14447	0.51
Lin10514382.996	P_g=1	2	14571	14372	14436	0.44
	Adaptive P_g	8	14471	14372	14387	0.10
	P_g=0	0	6273	6114	6180	1.32
Ch1506110.9	P_g=1	0	6288	6167	6278	1.75
	Adaptive P_g	2	6243	6100	6150	0.8

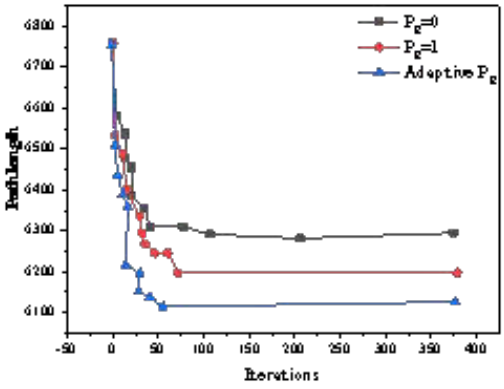

Fig. 4.1: Comparison of Convergence Process

colonies, ensuring global and local balance[11]. MTL (maximum value of tour length) is the longest path value; MITL (minimum value of tour length) is the shortest path value; METL (mean value of tour length) is the mean path length; σ is the average error (%): $\sigma\frac{\sum_{i=1}^{30}(S_{Ti}-S_0)}{30S_0}\times 100\%$ (where S_{Ti} is the shortest path for the i-th time and S_0 is the known shortest path). Figure 4.1 shows the comparison of convergence processes based on different P_g in the Ch150 instance.

4.2. Simulation analysis of immune polymorphic ant colony algorithm path optimization. Regarding whether the improved immune polymorphic ant colony algorithm can achieve faster search for global optimal solutions, the author selects Oliver 10 in the TSP problem as a simulation example, which is often used to verify the effectiveness of a certain algorithm. The coordinate data of Oliver 10 is as follows:

Abscissa x=5 10 8 20 6 1 21 9 30 25;

Ordinate y =20 2 12 16 3 20 30 35 20 8.

Its known shortest path length is 106.740.

Simulate the improved immune polymorphic ant colony algorithm and basic ant colony algorithm using MATLAB 7.0. In the experiment, take $\alpha = 1, \beta = 3, \rho = 0.3, Q = 50$. The experimental results are shown in Table 4.2, and the comparison of path evolution between the two algorithms is shown in Figures 4.2 and 4.3. The result of the number of iterations is a conclusion drawn after 10 experiments[12].

Table 4.2: Comparison of the experimental results of the basic polymorphic ant colony algorithm

The maximum short circuit strength length	Number of iterations(immune polymorphism)	Number of iterations(basic polymorphism)	Time ratio (Immune polymorphism /basic polymorphism)
108.324	9	18	1:1
107.746	14	29	1:3
107.193	28	47	1:3
106.740	32	58	1:4

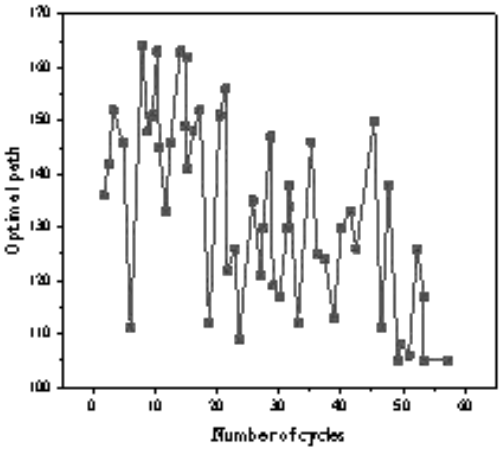

Fig. 4.2: Pathway evolution curve of basic polymorphic ant colonies

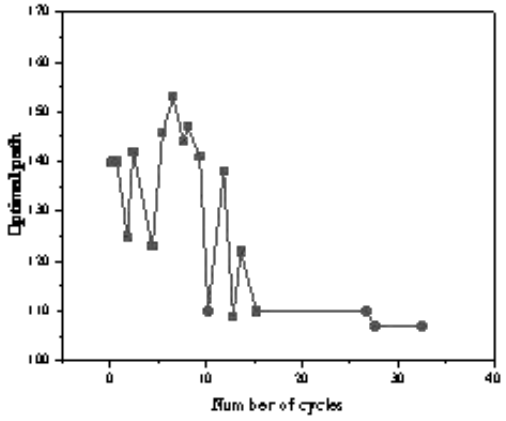

Fig. 4.3: Pathway evolution curves of immunopolymorphic ant colonies

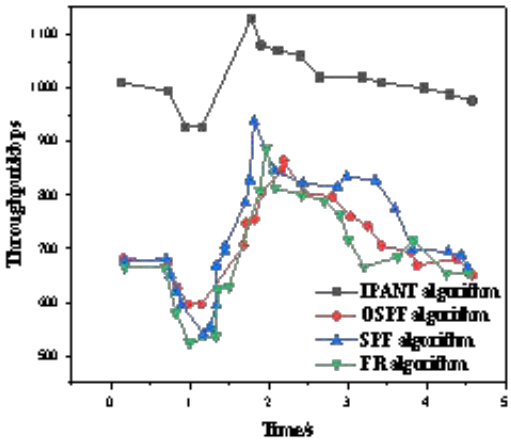

Fig. 4.4: Average throughput

From Table 4.2, it can be seen that using the immune polymorphic ant colony algorithm, an average of 32 generations can obtain the optimal solution of 106.740; Using the basic polymorphic ant colony algorithm, an average of 58 generations can be obtained, and the time is much longer than the immune polymorphic ant colony algorithm. From Figures 4.2 and 4.3, it can also be seen that the basic polymorphic ant colony algorithm has unstable iterations and multiple iterations; The improved immune polymorphic ant colony algorithm significantly reduces the number of iterations, is stable, easy to converge, and can quickly find satisfactory solutions. So the improved immune polymorphic ant colony algorithm can effectively solve the convergence speed of the algorithm and the global optimization problem of the optimal solution.

4.3. Cloud Database Throughput and Packet Delay Simulation Analysis. Due to the fact that the author's research object is cloud databases rather than general databases, simulation needs to further consider the characteristics of cloud databases. However, the role of a data network depends on many components that interact in nonlinear and unpredictable ways, so choosing a meaningful testing environment is very difficult[13]. The method followed is to define a finite set of adjustable components composed of various classifications. The experimental model selected NS-2 from the South California University ISI Research Institute as the experimental platform. Throughput and data packet delay were selected as the evaluation criteria for the effectiveness of the new algorithm, and three representative excellent routing algorithms in communication networks were selected, namely the open shortest path first algorithm, the shortest path first algorithm, and the flow based routing algorithm, to compare with the immune polymorphic ant colony algorithm. Take the average of 30 experiments as experimental data, and each simulation time is 1000 virtual seconds.

The average throughput is shown in Figure 4.4. From the experimental results in Figure 4.4, it can be seen that the IPANT algorithm outperforms the other three algorithms, maintaining a throughput of 1000 kbps and relatively stable; The data of OSPF, SPF, and FR are not significantly different, significantly lower than IPANT[14-15].

The empirical distribution of packet delay is shown in Figure 4.5. From the experimental results in Figure 4.5, it can be seen that the immune polymorphic ant colony algorithm (IPANT) has the lowest time delay for packet routing and performs better than the other three algorithms, with FR and SPF having higher latency.

5. Conclusion. In order to solve the problem of difficult route prediction and recognition in the cloud due to the dynamic instability of cloud databases, the author proposes an adaptive immune polymorphic ant colony algorithm for path optimization in cloud databases. By combining the group polymorphism ant colony intelligent search algorithm with cloud database search with strong global search ability, and integrating artificial

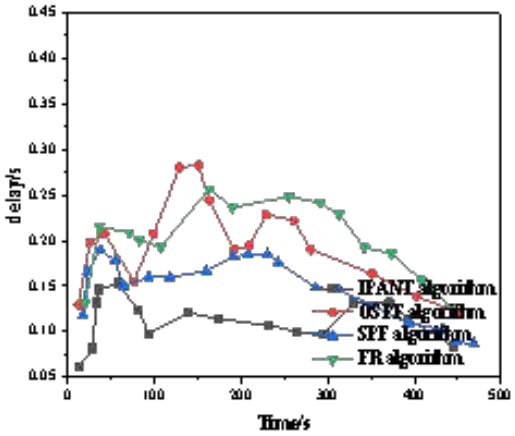

Fig. 4.5: Empirical distribution of grouping delays

immune algorithm in the process of polymorphism ant colony optimization, it effectively solves the problems of abundant and dynamic resources in cloud databases, slow convergence speed of traditional optimization algorithms, and falling into local optima, achieving load balancing. Compared with other routing algorithms, good experimental results and effects were obtained. However, the new algorithm has some shortcomings in improving the grouping delay of cloud databases. Although it has significant advantages compared to SPF and FR algorithms, it has little difference in latency compared to OSPF algorithm, and the experimental effect needs to be improved. However, due to the complexity of the testing environment and the limitations of experimental conditions, the author's current research is only conducted in simulated cloud environments. In the future, it will be applied to real cloud databases for experiments, in order to better improve algorithms and improve the efficiency of path optimization. In addition, the next step of work is mainly focused on designing and developing cloud platforms that can truly apply the designed algorithms to practice.

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CONSTRUCTION OF POWER SYSTEM NETWORK SECURITY DEFENSE BEHAVIOR DECISION-MAKING MODEL BASED ON ARTIFICIAL INTELLIGENCE TECHNOLOGY

FEILU HANG[*], LINJIANG XIE[†], ZHENHONG ZHANG[‡], AND JIAN HU[§]

Abstract. According to the needs of power grid monitoring architecture and information security cooperation protection, this project builds a multi-level, deeply distributed active security cooperation defense mode. A complete implementation method is proposed from the perspective of model architecture and function mechanism. The optimal defense strategy based on grey correlation is studied according to the characteristics of cooperation between regions. In this way, the coordination between the equipment is realized to achieve multi-level protection from the host layer to the security equipment layer and then to the network layer. Multiple detection mechanisms are used to realize the comprehensive detection and integrated judgment of abnormal documents in the cloud environment. This provides maximum protection for cloud users. Experiments show that this method can effectively suppress the malicious attacks of malicious users and reduce the damage caused by viruses. In this way, both the cloud and the customer are protected.

Key words: Power system; Multi-level cooperative protection; Cooperative protection mode; Network security; Grey relational decision

1. Introduction. With the popularization of the computer, network, communication and other scientific and technological means, the modern power system has formed a complex system composed of a physical power supply and communication network. The power monitoring system is a commercial and intelligent device with computer and Internet technology as the core, which is the primary support for monitoring and controlling the production and supply of electric energy [1]. Power grid monitoring is critical to ensure the power supply's safety and stability. At present, information attacks on the power grid are frequent, showing the characteristics of specialization, high risk, internationalization, and strong continuity, which makes the security protection problem of the power grid monitoring system rise to a certain height. Relevant agencies have proposed the need for a common defense of "multiple vertical lines of defense." Some scholars intend to introduce the concept of cooperative defense into the system from the traditional information security perspective [2]. In theory, the cooperative defense model, system or mechanism is constructed to lay the foundation for the cooperative defense model and method. However, compared with the conventional information system, the security protection means of power grid monitoring is very different. General information security protection means cannot be well applied to the power grid [3]. The research on the security protection of power grid monitoring information at home and abroad mainly focuses on constructing a depth protection system suitable for the power grid, analyzing defense technology and the methods and means to deal with extreme accidents. However, the above research does not focus on the security protection architecture and application of multi-level collaborative information systems in power systems and also lacks comprehensive, detailed and efficient research on its collaborative mechanism and implementation [4]. Therefore, this project intends to study the safe and efficient network security cooperation protection mode and its implementation method to provide a theoretical basis and technical support for improving network security accidents' response and control level in power grid security monitoring.

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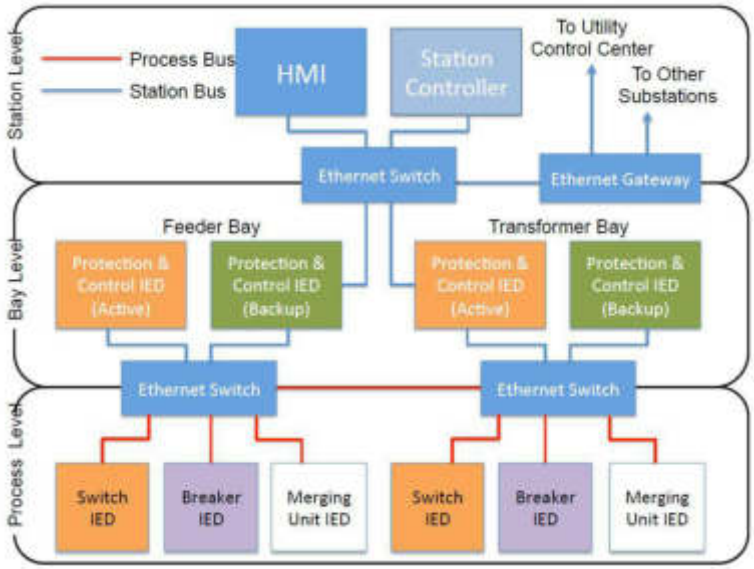

Fig. 2.1: *Architecture of electric power Active security defense system.*

2. Active security defense model.

2.1. Active security defense architecture. The focus of secondary security protection of the power grid is to ensure the safety of the power grid. Defend against hackers, viruses and other attacks to ensure the availability and regular operation of the network [5]. This ensures the confidentiality and integrity of critical data stored and transmitted. Authenticates application systems and devices to prevent unauthorized access. Auditable and secure management of SPDnet and applications. This paper establishes a physical layer-based information security protection method (Figure 2.1 cited in IEEE Transactions on Industrial Informatics, 2017, 14(6): 2442-2451).

The structure of the active security defense system is as follows: 1) Horizontally, the basic level of legal management can be divided into laws and regulations, policies and regulations, security management and ethical guidelines. 2) Technical mechanism The Technical support layer can be divided into security communication protocol, network defense strategy, defense mechanism, and security service. 3) Multi-level protection includes preparatory protection, enhanced protection, detection of feedback, response to blocking, backup recovery, and summary improvement. You can configure the resources of various systems by configuring security protection policies, defense mechanisms, technologies, and services at different levels [6]. A more efficient in-depth defense strategy, mechanism and implementation method with independent intellectual property rights will be established from the three levels of border defense, network defense and management platform.

2.2. Deployment and implementation of power safety protection system. Many large power companies at home and abroad have encountered network security problems in the secondary system, which shows that it is difficult to achieve the safety of the power secondary system only by relying on conventional and passive protection means and only by effectively integrating and configuring it can its comprehensive performance be fully utilized [7]. New technologies such as defense-in-depth strategy mechanisms, unified threat management platforms, intelligent intrusion prevention systems, authentication and encryption and separation technology replace some of the inefficient security management and negative security detection technologies. The active defense strategy mechanism and active defense Security defense System described in this paper are used for practice (Figure 2.2 cited in Challenges in Power System Information Security). According to the layout of the active safety defense system of the power secondary system, the integration method is adopted to supplement each function module [8]. Then, the implementation and management of each security policy are

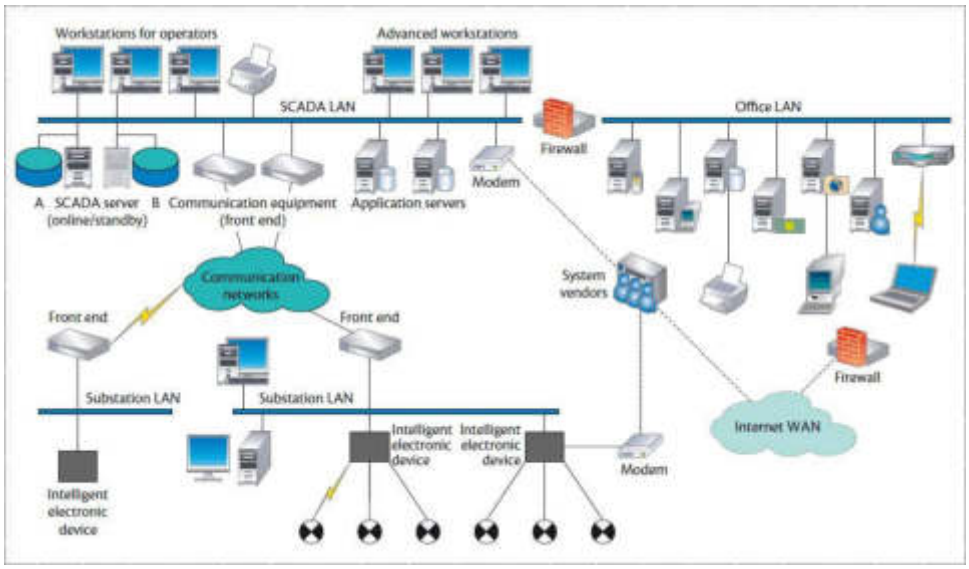

Fig. 2.2: *Architecture of active safety protection system for secondary power supply.*

unified to build a set of effective three-dimensional protection systems. As shown in Figure 2.2, a host-based intrusion prevention system is configured to monitor, defend against, and respond to abnormal behavior of the network and server. The monitoring and prevention of scheduling MIS and SPInet, DMIS internal access and DMIS access are emphasized. The network intrusion detection center can be managed, controlled, and unified. In combination with local server cluster response, cache support and synchronization of enterprise cloud computing servers, the client/server-side distribution is configured to the server side using function integration [9]. An access control mechanism based on the acceptable behavior of users is proposed to realize the comprehensive detection, protection and maintenance of users. At the same time, IPsec VPN technology establishes several VPNs with different logic based on CISCO routers.

3. Issuance of relevant decisions. Factors such as the impact degree, threat degree, reliability and timeliness of defense behavior, frequency and correlation degree of information security incidents are considered comprehensively. Construct a decision set, an assignment reference sequence, a correlation coefficient and a weight correlation degree [10]. The correlation between various factors and defense strategies in information security incidents is studied. For specific and consistent information security incidents, select relevant defensive measures and publish and implement them.

3.1. Decision Set. According to the specific information security accident, the relationship between each factor and protective measures is analyzed and established [11]. The data for Group n factors are listed in the following matrix. m is the number of defensive actions that can be taken.

$$(U_1', U_2', \cdots, U_n') = \begin{pmatrix} U_1'(1) & U_2'(1) & \cdots & U_n'(1) \\ U_1'(2) & U_2'(2) & & U_n'(2) \\ \vdots & \vdots & & \vdots \\ U_1'(m) & U_2'(m) & \cdots & U_n'(m) \end{pmatrix}$$

U_n is the set of m defense measures corresponding to the n impact shadow of a network security event. $U_n(m)$ is the m defense measure of the B impact factor of the event.

3.2. Assign a value to the decision set and determine the reference sequence. By assigning a value to the initial index of Class m possible protection measures corresponding to n factors in the above

Table 3.1: *Examples of information security incident prevention strategies based on relevancy.*

USB wireless card access event	Business impact degree	Security level	Frequency of policy reliability occurrence	Duration	Correlation with other events	Correlation degree
Disable network card	104	104	626	0	104	96.81
The front switch port is powered off	94	104	83	83	94	82.53
Tunnel blocking	73	83	94	52	73	64.24
The primary route is blocked	42	52	104	10	42	52.05
Specific gravity distribution	21	21	16	21	36	-

formula (3.1), the more significant the value, the greater the correlation. The optimal value of each influence factor is taken as the criterion to establish the corresponding reference sequence of various influence factors:

$$U_0' = (U_0'(1), U_0'(2), \cdots, U_0'(m))$$

U_0 is the reference sequence of a security risk index that occurs for a specific information system. Where $U_0'(m)$ is the expected security risk of Class m protective means.

3.3. Correlation coefficient. The binding factors of the corresponding elements of the decision group and the reference series are calculated separately from the equation (3.3), and the correlation factor matrix is formed:

$$L_i(t) = \frac{\min_i |U_0'(t) - U_i'(t)| + \gamma \times \max_i |U_0'(t) - U_i'(t)|}{|U_0'(t) - U_i'(t)| + \gamma \times \max_i |U_0'(t) - U_i'(t)|}$$

$$L_i(t) = \begin{pmatrix} L_1(1) & L_2(1) & \cdots & L_n(1) \\ L_1(2) & L_2(2) & \cdots & L_n(2) \\ \vdots & \vdots & & \vdots \\ L_1(m) & L_2(m) & \cdots & L_n(m) \end{pmatrix}$$

where $i = 1, 2, \cdots, n; t = 1, 2, \cdots, m; U_i(t)$ and $U_0(t)$ are the safety index t of each safety protection countermeasure under the i level factor of determining matrix and reference matrix [12]. The normalized minimum and maximum value are obtained by calculating each safety index's relative difference and each decision set's benchmark index. Finally, the matrix of correlation coefficients is obtained. γ is the analytic factor, $0 < \gamma < 1$. When the γ value is low, the larger the distance between the correlation coefficients, the larger the conclusion. In the calculation of the correlation degree of defense decision, the median value of γ is 0.5 to keep the deviation of the correlation coefficient consistent.

3.4. Weighted correlation degree. Through a comprehensive evaluation of the importance of various influencing factors in this information security accident. According to formula (3.5), the correlation system matrix calculates each factor's protection measure's security index and the average correlation coefficient between each factor. This reflects the correlation between various protective measures and the baseline sequence [13]. The correlation degree between the information security accident and various protection schemes is given.

$$p_i = \frac{1}{m} \sum_{t=1}^{m} \varphi_t \times L_i(t)$$

$i = 1, 2, \cdots, n; t = 1, 2, \cdots, n; \varphi_t$ is the weight of each factor in their respective influence. p_i' is the weighted mean of the i defense measure in this incident [14]. This paper takes the USB wireless card of a service device to access a specific network security problem as an example to analyze. Table 3.1 Uses the maximum relevancy evaluation algorithm to test this example and concludes that the correlation coefficient of the "network card disabled" processing method is significant.

4. Simulation experiment and result analysis.

4.1. Experimental simulation and description. The test environment comprises three servers, one router, and six clients. Using .NET to develop identity authentication authorization, behavior evidence standardization, document discovery mechanism, credibility evaluation and other modules [15]. The abnormal file was operated on a VMware virtual workstation, and the dynamic analysis was carried out. On a small-scale cloud storage platform, use Net Flow Tracker to monitor the status of each service in real-time. 1) Build customer trust $D = \{0.3, 0.6\}$. The user is then asked to authenticate. A small-scale cloud storage system $L = \{L_1, L_2, L_3\}$ can be divided into three layers. L_1 indicates a rejection of the service. L_2 means that only the file can be read. L_3 is for files that can be edited and downloaded. C between $[0, 0.3)$ is a customer with a poor credit rating and enjoys the business of grade L_1.C between $[0.3, 0.6]$ is a general honor customer. All its business is grade L_2. C between $[0.6, 1)$ are customers with higher credit, who enjoy L_3 type of service. Set the credibility level of the suspicious file to $T = \{0.4, 0.5\}$. Ci has good document credibility in the range $[0, 0.4)$.Ci has A trust level of unknown in the range [0.4, 0.5). Ci has a trust level of Trusted in the range $[0.5, 1]$. 2) In the interaction between users and cloud computing, BM constantly monitors users' behaviors and records them in the behavior database as user behaviors. The trust evaluation model evaluates users' credibility [16]. And give early warning to potential emergencies. The user's business level is given real-time early warning so that the user can dynamically adjust the business level according to their own needs.

4.2. Operation of confidence evaluation cases. The Performance Monitoring Center collected 12 types of evidence from users within 30 minutes. The average evidential value, $Q = \{Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, Q_7, Q_8\}$

$$= \{0.62, 0.51, 0.88, 0.83, 0.74, 0.67, 0.73, 0.54\}$$

$L = \{L_1, L_2, L_3, L_4\} = \{0.33, 0.28, 0.15, 0.08\}$ is obtained by normalizing it. Determine the weights for performance and security features [17]. The following uses performance features as an example. Experience shows that IP packet response time, IP transmission rate, throughput rate and bandwidth occupancy can best reflect the performance characteristics of users. $[d(Q_1) = d(Q_4) = d(Q_6) = d(Q_7)] > [d(Q_2) = d(Q_8)] > [d(Q_3) = d(Q_5)]$. Build the initial judgment matrix:

Determine the weight of performance characteristics and safety characteristics [18]. The practice has proved that in the network, the response time of IP packets, IP data transmission rate, traffic and occupancy rate are the best indicators.

$$[d(Q_1) = d(Q_4) = d(Q_6) = d(Q_7)] > [d(Q_2) = d(Q_8)] > [d(Q_3) = d(Q_5)]$$

Generate a preliminary decision matrix:

$$EP = \begin{bmatrix} 0.5 & 1 & 1 & 0.5 & 1 & 0.5 & 0.5 & 1 \\ 0 & 0.5 & 1 & 0 & 1 & 0 & 0 & 0.5 \\ 0 & 0 & 0.5 & 0 & 0.5 & 0 & 0 & 0 \\ 0.5 & 1 & 1 & 0.5 & 1 & 0.5 & 0.5 & 1 \\ 0 & 0 & 0.5 & 0 & 0.5 & 0 & 0 & 0 \\ 0.5 & 1 & 1 & 0.5 & 1 & 0.5 & 0.5 & 1 \\ 0.5 & 1 & 1 & 0.5 & 1 & 0.5 & 0.5 & 1 \\ 0 & 0.5 & 1 & 0 & 1 & 0 & 0 & 0.5 \end{bmatrix}$$

Calculate $\varphi_{\underline{Q}}^T = \{0.161, 0.107, 0.071, 0.161, 0.071, 0.161, 0.161, 0.107\}^T$ weighted vector for evidence related to performance characteristics: A. The importance of evidence related to safety features is $[d(L_3) = d(L_2)] > d(L_1) > d(L_4)$ in pairwise comparison. And similarly, the weight vector is going to give us $\varphi_L^T = \{0.208, 0.333, 0.333, 0.125\}^T$. If the importance of the user's behavioral feature is $d(Q) < d(L)$, then the feature weight is $\varphi_g^T = \{0.25, 0.75\}^T$. The user behavior characteristic evaluation value $G = K \times \varphi^T = (0.656, 0.222)^T$ is obtained by formula (3.4). Find out the user behavior of the evaluation result $C = 0.67$. The user has a high reputation and can edit and download files in a small-scale cloud storage system. Figure 4.1 shows the overall level of trust change caused by the gradual increase of undesirable actions, such as illegal connections and critical port scanning, when users interact with the cloud [19]. When there are a lot of malicious activities in the network, the trust value obtained by the fuzzy analytic hierarchy process (AHP) decreases faster than that by AHP and is closer to the cognitive law of human beings. This method can detect low credit users earlier

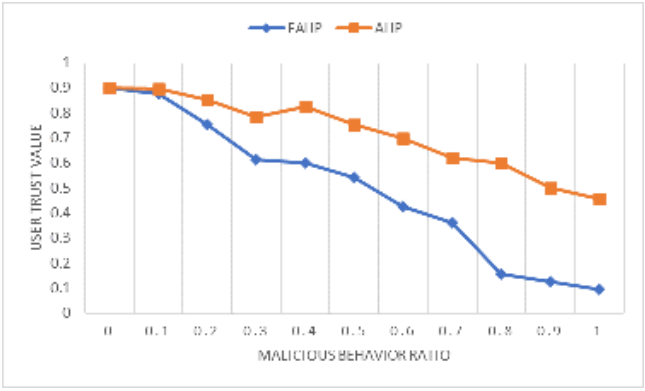

Fig. 4.1: *Changes in trust values of customer machines.*

and faster than the analytic hierarchy process and help verify the rights management system to upgrade the customer's business level in real-time, thus reducing the security risks in the cloud.

When constructing the decision matrix, the analysis should be carried out according to the specific situation of customers. Security features become more important if the user is in a non-security situation. Therefore, even if the same evidence is obtained for the same customer, its judgment matrix is different under different circumstances.

5. Conclusion. A multi-level safety protection system of power monitoring system has been established. This project plans to start from three levels: the host layer, security equipment layer and network layer. Security risks at different levels are classified and actively defended through self-defense and cross-domain cooperation. The experimental results show that the proposed method can adapt well to the security protection requirements of the current power grid monitoring system, enhance the security protection level of the power grid, and make the power grid change from the traditional passive defense to the active defense. The research work of this project has crucial academic significance and practical application prospects.

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FAULT TOLERANCE ANALYSIS AND OPTIMIZATION OF CENTRALIZED CONTROL PLATFORM BASED ON ARTIFICIAL INTELLIGENCE AND OPTIMIZATION ALGORITHM

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Abstract. To enhance the reliability and self-healing of the system, the research on fault tolerance of the reconfigurable modular centralized control center is its development trend. Most of the previous research has focused on hardware redundancy. Improving fault tolerance performance is an essential topic in the research of centralized control platforms. Firstly, the problem of centralized fault tolerance in the working configuration of a reconfigurable manipulator is studied. The effect of each hinge on fault tolerance in the existing configuration is studied with the criterion of manoeuvrability and tolerable space. The fault module was first modelled to represent the system architecture information. A modular motion rule based on autonomous recombination technology is proposed. A self-organizing deformation algorithm with fault tolerance is studied. The fault tolerance of the motion pairs is compensated by adding a small number of motion pairs to ensure the configuration characteristics. With the addition of a failure compensation device, the joint's range of motion was reduced, and the fault tolerance rate was enhanced. After the failure of the robot arm, the fault tolerant control method can still ensure that the robot arm can perform work in its tolerable working space. The test results show that the fault tolerance analysis method is practical and feasible. It lays a theoretical foundation for the application in aerospace, industry and other fields.

Key words: Reconfigurable robot; Fault tolerance; Configuration design; Fault-Tolerant Control

1. Introduction. Self-reassembling robot is a new kind of robot technology developed in recent decades. The self-assembling robot, also called a self-transforming robot, is formed by organically connecting several modular robots with certain intelligent and essential functions. Self-reassembling robots can realize self-adaptability through their form. It can adjust its configuration in a complex environment and work to achieve self-adaptability to the environment and task. This method can effectively reduce the construction and fabrication cost of the robot arm and improve the function and construction of the robot arm. Its diversified structure has the advantages of high reliability, good flexibility, strong self-assembly and self-repair [1]. The system highlights high adaptability in terms of fault tolerance. The first autonomously reassembled robotic prototype system is from the perspective of the space station. Some scholars have researched self-reassembling robot technology [2]. This will provide technological support for variable space vehicles such as satellite dishes, solar panels, adaptive operators, and new ways to explore the planet. The self-reconfigurable robot has a flexible global topological configuration. Through the independent docking and disconnection between the components, the whole or part of the configuration change is completed [3]. According to the function of each component in the whole robot construction process and the construction of the object system, it can be divided into link type and lattice type.

The chain-linked robot arm includes a flexible arm, snake, foot and other open-loop and closed-loop walking machinery. Such as flexible arm, snake, and foot walking robots, PolyBot, and Conro robots are chain-connected systems. The components in the lattice system can be combined in any shape in two or three dimensions, thus giving it a hexagonal modular structure: molecular robots and crystal robots produced by Kotay KD, RusDL and other companies. Yoshida et al. 's three-dimensional crystal structure robot also adopts a lattice crystal structure. In this project, the fault tolerance performance of a self-assembling robot platform is studied based on the configuration determined by the task [4]. Moreover, fault tolerance and compensation are added to ensure the configuration can perform the work correctly and reliably.

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2. Fault-tolerant obstacle climbing rules. The first case is first to identify the system's objects and then transform the existing objects. The second case is given the object's shape but does not understand its specific shape information needed to extract the shape information of the object from the external environmental conditions to form the target shape [5]. The third case studies the movement from the initial to the predetermined point in an unstructured environment. It involves problems such as obstacle avoidance and path optimization. Among them, the first two types of deformation problems can be summarized as the deformation problem of static mechanism, and the third type of deformation problem is how to obtain better action through deformation [6]. No matter what kind of variant work is performed, it must be able to learn rationality and fault tolerance by itself. This means that a particular link's failure will not impact the entire system [7]. This method is to replace the component with other non-critical parts if the component fails due to the failure of the component. Or the component can be separated from the system to achieve the purpose of self-healing [8]. At the same time, the system can also carry the fault module and make it move or deform to achieve fault tolerance management [9]. This project will study the fault-tolerant deformation method of two-dimensional square lattice robot crossing obstacles.

3. Research on the wrong description of the structure of the reconfigurable robotic arm. The corresponding parameters evaluate the fault tolerance of the mechanism configuration. Selecting a tolerable performance index is an essential aspect of tolerable configuration design. Assume that the total motion rate of the manipulator in the workspace is $\dot{v}_1$. The connection rate is $\dot{v}_2$.K is the Jacobian matrix of the manipulator. The corresponding relationship between $\dot{v}_1$ and $\dot{v}_2$ is:

$$\dot{v}_1 = K\dot{v}_2$$

There is $K = \begin{bmatrix} k_1 & k_2 & \cdots & k_n \end{bmatrix}$ in the formula. In this project, the minimal singularity of the failure configuration is used to measure the fault tolerance in the failure process. As the amount of singular point computation required is too large, it is challenging to meet the real-time requirements [10]. This project will take the degree of operation as the evaluation standard of destruction resistance. The following is a definition of the operability of the current robotic arm configuration:

$$\lambda = \sqrt{\det\left(KK^T\right)}$$

The physical meaning of this method is to characterize the volume of the operation ellipsoid, which can reflect the dexterity of the fault-tolerant mechanism configuration.

3.1. Relative operability. At present, simply using the operating degree of the failure configuration to measure the fault tolerance of the robot arm can not reflect the loss caused by the failed robot arm [11]. Therefore, comparing the dexterity of the failed robot arm before and after failure is necessary. Relative operability is used to characterize the system's fault tolerance before and after configuration. In the case of failure, if d node fails, the performance of the manipulator is reduced as follows:

$$\lambda_{i_1,i_2,\cdots,i_d} = \sqrt{\det\left(K_{i_1,i_2,\cdots,i_d} K^T_{i_1,i_2,\cdots,i_d}\right)}$$

$$K_{i_1,i_2,\cdots,i_d}$$

$$= \begin{bmatrix} k_1 & \cdots & k_{i_1-1}k_{i_1+1} & \cdots & k_{i_d-1}k_{i_d+1} & \cdots & k_n \end{bmatrix}$$

$K_{i_1,i_2,\cdots,i_d}$ is the degraded Jacobian matrix obtained by removing the corresponding column vector of the failed joint by Jacobi K of the robotic arm. Then the relevant operation is:

$$L_{i_1,i_2,\cdots,i_d} = \frac{\lambda_{i_1,i_2,\cdots,i_d}}{\lambda}\lambda \neq 0$$

Since $K_{i_1,i_2,\ \mathrm{L},i_d}$ is a subclass of $K_{i_2,\ \mathrm{L},i_d}$, there is the following relationship:

$$0 \leq L_{i_1,i_2,\cdots,i_d} \leq L_{i_2,\cdots,i_d} \cdots \leq L_{i_d} \leq 1$$

3.2. Fault tolerance space. Relative maneuverability can only reflect the degree of flexibility of the mechanism configuration after the failure and locking of the robot arm but cannot reflect its effect on the working environment. At the same time, the working environment is also a critical factor in measuring work quality. Therefore, the expandability design method is proposed in this paper [12]. When one or more nodes in the robot arm fail, the redundant robot arm can still perform the desired task. The fault-tolerant space measures the fault-tolerant capacity of each node in the mechanism configuration. The node with the smallest error tolerance space is found. The inclusion degree of fault-tolerant space is calculated by joint compensation. The robot has the following workspace:

$$W = \{\varphi_1, \varphi_2 \cdots \varphi_n \mid \varphi_{1\min} < \varphi_1 < \varphi_{1\max}, \varphi_{2\min} < \varphi_2 < \varphi_{2\max}, \cdots, \varphi_{n\min} < \varphi_n < \varphi_{n\max}\}$$

The fault-tolerant space for the d joint is represented as follows

$$\begin{aligned} W_{\varphi_d} = \{&\varphi_1, \cdots \varphi_{d-1}\varphi_{d+1} \cdots, \varphi_n \mid \varphi_{1\min} < \varphi_1 < \varphi_{1\max}, \cdots \\ &\varphi_{d-1\min} < \varphi_{d-1} < \varphi_{d-1\max}, \varphi_{d+1\min} < \varphi_{d+1} < \varphi_{d+1\max}, \cdots \\ &\varphi_{n\min} < \varphi_n < \varphi_{n\max}\} \end{aligned}$$

The standard space volume describes the relationship between the fault-tolerant space and the task space of the d joint. Then, determine the d fault-tolerant space evaluation function as:

$$\psi_d = \frac{M\left(W_{\varphi_d} \mathrm{I} W_\lambda\right)}{M\left(W_\lambda\right)}$$

$M\left(W_{\varphi_1 \cdots \varphi_{d-1}\varphi_{d+1} \cdots \varphi_n} \cap W_\lambda\right)$ is the volume of joint space of fault-tolerant space and task space in the section $d.M\left(W_\lambda\right)$ represents the volume of the work area [13]. Because $W_{\varphi_1,\varphi_2\ \mathrm{L}\varphi_d} \subset W_{\varphi_2,\varphi_3\ \mathrm{L}\varphi_d}\ \mathrm{L} \subset W_{\varphi_d}$, the following relationships exist:

$$0 \leq \psi_{1,2\cdots d} \leq \psi_{2\cdots d} \cdots \leq \psi_d \leq 1$$

3.3. Comprehensive fault tolerance performance. In this project, the fault tolerance characteristics related to the configuration of reconfigurable robots and the fault tolerance ability of moving pairs are studied [14]. Through the integrated research of the two, the fault-tolerant ability of the multi-degreeof-freedom motion mechanism is compared and analyzed. Then, the evaluation function of the integrated fault tolerance performance of the d joint is:

$$C_d = L_d + \psi_d$$

From formula (3.6) and formula (3.10), it can be obtained:

$$0 \leq C_{1,2,\cdots,d} \leq \cdots C_d \leq 2$$

Currently, the simplest fault tolerance compensation method is to connect the compensated hinges in series, but this will affect their original topology and reduce their working characteristics. The optimal configuration generated by a specific task can simultaneously meet the higher performance requirements, so the existing configuration cannot be modified while ensuring system reliability [15]. An adaptive control method based on a robotic arm is proposed in this paper. The compensation hinge does not affect the topological structure of each hinge under the closed condition. The designed motion pair accords with the dynamic characteristics of the system. The worst one or two nodes are compensated according to the order of the effect of each node on the fault tolerance of the system, which can significantly improve the fault tolerance of the system.

4. Case analysis. The endpoint of the robotic arm reaches a point in the basic coordinate system (Figure. 4.1a). In this project, the 4-DOF manipulator is first constructed, and then the system's fault tolerance is studied. Its fault tolerance ability is found weak in the whole operation process, the maneuvering degree is only the order of A, and the fault tolerance working area is narrow [16]. It cannot accommodate mission points.

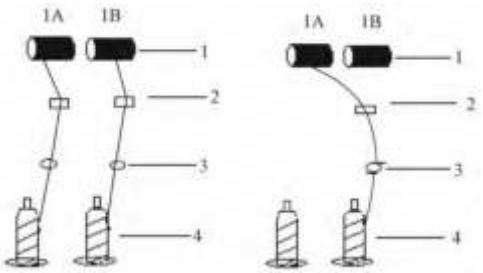

Fig. 4.1: Configuration of the robotic arm.

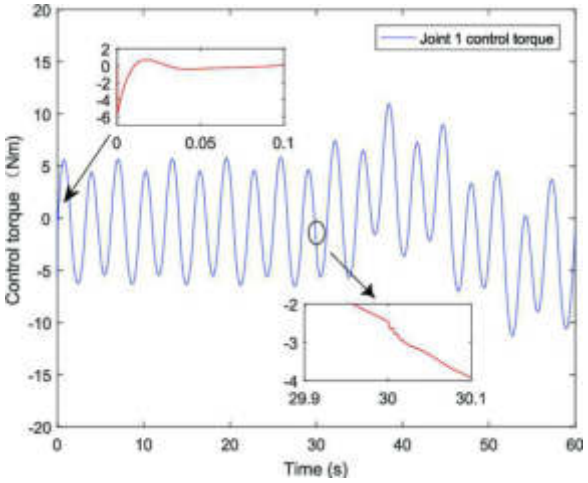

Fig. 4.2: Maneuverability of the fault-tolerant robot configuration.

The robotic arm will lose its function if something goes wrong. According to the effect of the operation on each joint, find out the joints that are easy to fail. Although joint 1 is the lowest joint, its load-bearing capacity and torque in the direction of movement are much smaller than joint 2. Joint 2 has ample working space for the whole robot configuration. So, joint 2 is a failure-prone node. Fault tolerance compensation was applied to the model to construct the robot structure (Figure 4.1b).

The fault-tolerant design of the constructed mechanism is carried out. The fault-tolerant capability and fault-tolerant gap in mechanism configuration were studied. Figure 4.2 shows the configuration maneuverability of the arm during the operation during the 10-second movement. The effectiveness of this method is proved by simulation experiments [17]. The shaded part in Figure 4.3 is the fault-tolerant workspace of mechanism 2 of the fault-tolerant operation. It's not much different from its working space. And its working point is in the fault-tolerant working space.

In this paper, a 5-DOF manipulator configuration is established, in which the configuration of 4 a is the addition of the fault-tolerant compensation joint, and the swing joint 2 is the fault-tolerant compensation joint [18]. In fault-tolerant control, it can reach a certain point in the fault-tolerant space regardless of the state of the end-swing node (figure 4.4). The motion equation of the robot at the target point is established. The compensation node is added. The motion Angle of oscillating node 1 is 154.24° when oscillating node two does not participate in the action. At this time, the moving Angle of oscillating node 3 is 95.12°. At this time, the movement Angle of oscillating joint 1 is substantial, which has exceeded its moving distance, so the robot can not reach the destination [19]. When joint two is moved, the target point is in the flexible working space, which can achieve a particular pose requirement. When the manipulator's end center faces the target vertically,

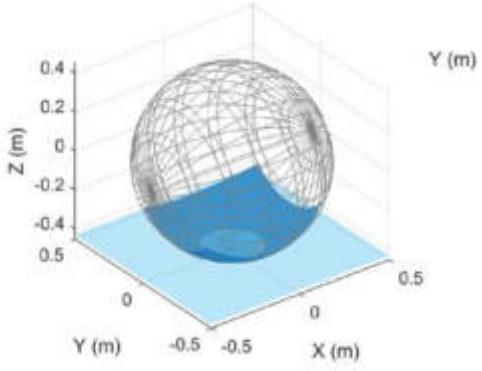

Fig. 4.3: Fault-tolerant workspace of joint 2.

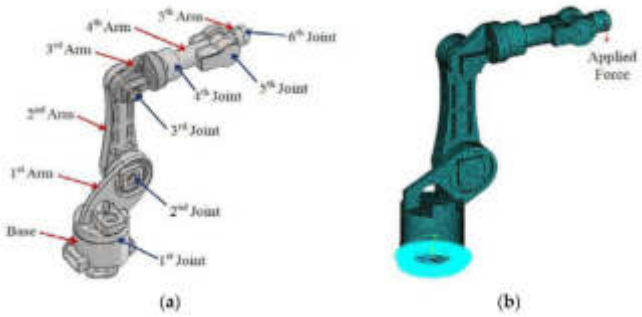

Fig. 4.4: Robot configuration.

the moving angles of the shaking joints 1, 2 and 3 are 51.245°, 64.211° and 67.145°, respectively. At this time, the range of motion of the joints prone to failure is significantly reduced, thus reducing the chance of their failure. The robot arm, which is easy to fail, is simulated, and the fault tolerant control test is carried out. The mechanical arm prone to failure fails when moving to 28, as shown in Figure 4.5. The robot's end can still reach the target point while the other joints continue to move. During this period, the moving Angle of moving node 2 is 51.24°, and the moving Angle of swinging node 3 is 64.35°. The failure occurred when swing node 1 moved to 47.21°. You can see this in Figure 4.6. The robot's end reaches the target point when the moving Angle of swinging node 2 is 44.56 ° and the moving Angle of swinging node 3 is 80.15°.

The test results show that the displacement amplitude of the failed joint and the failure rate of the joint can be reduced effectively by adding the failure compensation joint. A fault-tolerant controller is adapted to enable the robot arm to perform work in the fault-tolerant working space after the failure of the easily failed robot arm.

5. Conclusion. This project studies the reliability of reconfigurable manipulator configuration under operational conditions. The evaluation theory of configurational integration fault-tolerant performance of relative operability and fault-tolerant space is established. The fault tolerance compensation method is given for the joints which are easy to fail. Then, a method to reduce the flexible manipulator's failure times and application range is proposed to improve the fault tolerance of the manipulator configuration. The machine's path is replanned because of various joint failure phenomena during operation to ensure it can perform the job smoothly. The research results of this project will lay a foundation for the application of aerospace, industrial robots and other fields.

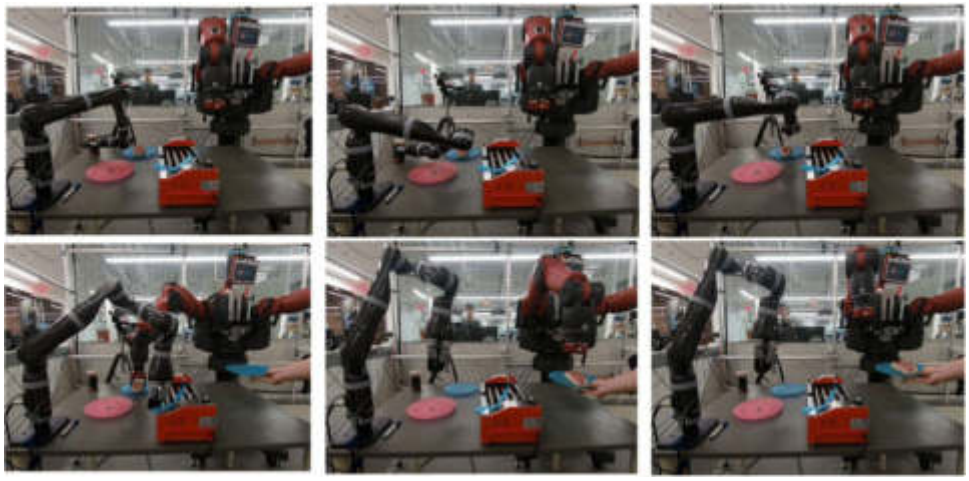

Fig. 4.5: Fault tolerance experiment of mechanical arm 1.

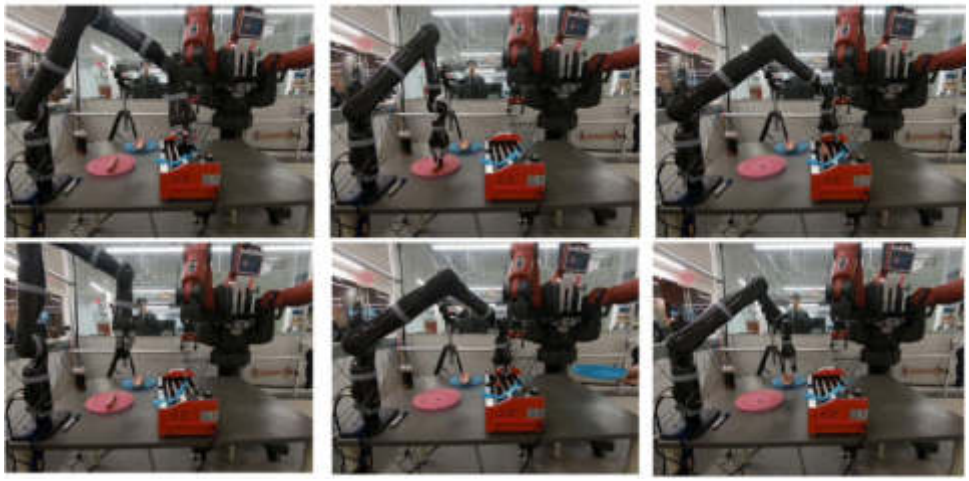

Fig. 4.6: Fault Tolerance Experiment 2.

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ARTIFICIAL INTELLIGENCE RETRIEVAL SYSTEM BASED ON COMPUTER BIG DATA TECHNOLOGY

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Abstract. In order to achieve automatic retrieval of library literature, the author proposes a robot retrieval method based on intention recognition for library literature automatic retrieval. Firstly, propose a robot retrieval approach; Then, the keywords of the user's question are automatically extracted, and the intention of the user's question is identified. Finally, combined with intention recognition, the semantic similarity between the intention recognition literature and the search literature is calculated. The latest results indicate that: The accuracy of keyword automatic extraction based on KL and TF-IDF for each sentence keyword is 98.3%, indicating that this extraction method performs better. The retrieval accuracy of the automatic retrieval robot reaches 98%, indicating that this method can accurately achieve accurate retrieval of user intentions and candidate literature.

Key words: Artificial intelligence, Automatic retrieval, Intentional identification, Semantic similarity calculation

1. Introduction. Currently, as we enter a new stage of social development, people can search through the internet to obtain the information they need [1]. Although online information retrieval has enormous advantages compared to traditional paper-based information retrieval methods, there are still problems such as information classification defects, partial information invalidity, huge amount of information, and difficulty in distinguishing true from false [2,3]. On this basis, using artificial intelligence for information classification can provide true and accurate information according to users' habits, thereby promoting information retrieval. Network information retrieval is actually based on the network as a platform, allowing users to search for relevant information using network search engines.

By using allocation storage technology, massive amounts of data information can be distributed to corresponding servers. For users, they can use terminals to query and view pre stored data. Therefore, all information can be retrieved and utilized on the Internet, and providing information search methods or means for network users can be called network information retrieval. Artificial intelligence is a type of technology that allows robots to simulate and perceive people's feelings during the process of doing things through machinery, and then make the right decisions, thereby giving them a specialized technology to solve problems. Therefore, the essence of artificial intelligence also revolves around the human mind. Its biggest feature is to reconstruct and apply knowledge in a relatively complete logical system based on a correct understanding of the problem.

At present, artificial intelligence can be divided into the following schools: distributed school, cognitive school, connected school, logical school, and knowledge engineering school. Although the research of different schools is different, the goal in the construction and function of artificial intelligence is the same, that is, artificial intelligence should be composed of an intermediate database, interpreter, knowledge collector, user interface, knowledge base, and inference engine. Taking the knowledge base as an example, it is an important component of the artificial intelligence system and an important storage technology. There are facts, information, common sense, and rules in the knowledge base. Some specific systems also include databases. Next is the inference engine, also known as the inference engine, which includes control strategies and various types of task searches. As a special database, it plays a very important role in providing query support. The content of the user interface includes the transmission of the system and related information. The inference engine is a bridge connecting external and internal information, which can not only display the final processing effect to the user, but also transmit the user's wishes to the computer. In this case, the use of non natural language can alleviate the psychological pressure of users and play a role in storing intermediate results and data during work and logical operations. In practical use, the system will display the problem on the blackboard and present the

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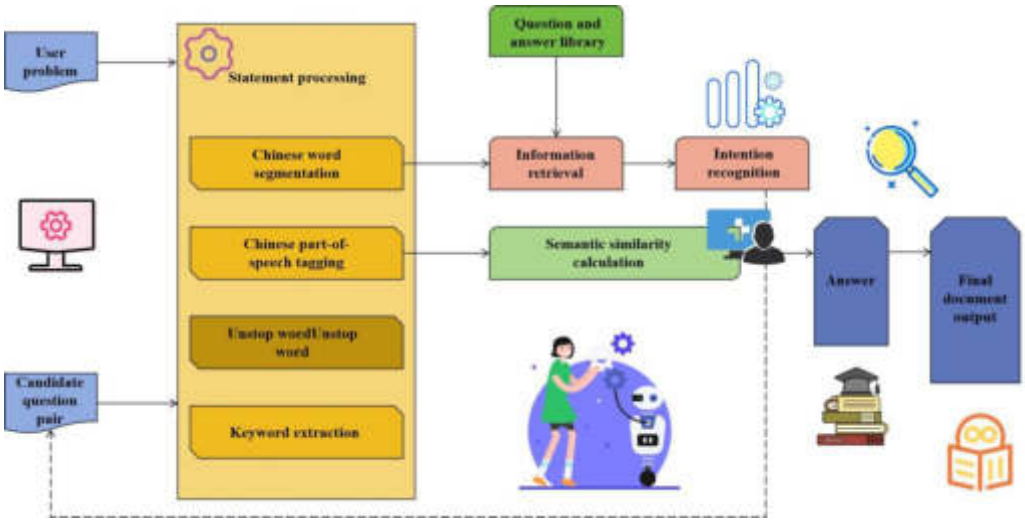

Fig. 2.1: Retrieval Ideas of Library Document Automatic Retrieval Robot

initial status of the problem. Then, the expert system will analyze the information in the knowledge base and analyze the information on the blackboard. If necessary, we will also seek advice from customers to supplement and address knowledge gaps. Therefore, in a sense, the blackboard can also be seen as a dynamic knowledge foundation, playing a crucial role in the operational process. Finally, there is a knowledge collector, whose main function is to update the actual operation of the knowledge base to ensure the stable operation of the entire system. The task of the analyzer is to answer users' questions and provide them with operational paths related to the system's results. In short, artificial intelligence is the use of scientific and virtual methods to solve human problems.

With the rapid development of natural language, utilizing natural language to achieve autonomous interaction between humans and robots has become a trend in artificial intelligence [4]. Some scholars have also conducted extensive research on the application of natural language in robot interaction scenarios. For example, Pang Hui proposed using natural language understanding technology to achieve interaction with customer service robots, thereby achieving control of customer service robots; Miao Haifeng proposed the use of natural language object retrieval technology to meet the requirements of different users for robots [5]. In the field of literature retrieval and intelligent robots, combining natural language with different retrieval methods is an important way to improve their application scenarios. However, in library robot retrieval, although natural language and literature retrieval methods are used, the user's intentions are ignored. Therefore, adding more dimensional factors to improve the accuracy of library robots in literature retrieval has become a hot topic and an innovative point of this study. Therefore, based on the above analysis, the author proposes an intention recognition library literature automatic retrieval robot to better promote the intelligence of university libraries [6,7].

2. Methods.

2.1. Automatic Retrieval Robot Retrieval Ideas for Image and Literature. The robot literature automatic retrieval constructed in this study is based on the FAQ question answering system, and intention recognition is added to this foundation to better improve the accuracy of literature automatic retrieval. The specific idea is shown in Figure 2.1 [8].

As shown in Figure 2.1, this robot retrieval mainly includes three modules: statement processing, information retrieval, and literature push [9]. The main function of sentence processing is to segment students' search questions and candidate question and answer pairs, label part of speech, remove stop words, and extract keywords; The main function of the information retrieval module is to retrieve literature categories that are highly

relevant to student search questions from the stored literature dataset, and output candidate literature; The literature push module includes intention recognition and semantic similarity calculation. Intention recognition filters candidate literature that has different intentions from the student's search content; Semantic similarity calculation calculates the similarity between candidate literature and student search content to obtain candidate literature with high similarity, and ultimately outputs the final literature by the library's automatic retrieval robot.

2.2. Design of automatic literature retrieval module for intention recognition.

(1) The process of extracting keywords from user questions. In order to achieve automatic retrieval of literature by robots, it is first necessary to extract keywords from user questions in order to correctly understand user needs. Therefore, various keyword automatic extraction methods such as KL divergence, TF-IDF, word length and part of speech are introduced [10]. KL divergence value is a relative entropy that reflects the degree of deviation between two different probability distributions P and Q, and its calculation formula can be expressed as:

$$D_{KL}(P|Q) = \sum_i P(i) \log \frac{Q(i)}{P(i)} \tag{2.1}$$

If P and Q represent the distribution of continuous random variables, the calculation formula for KL divergence can be expressed as:

$$D_{KL}(P|Q) = \int_{-\infty}^{\infty} p(x) \log \frac{p(x)}{q(x)}\, dx \tag{2.2}$$

Consider whether two texts are similar as two different probability distributions, and label similar ones as 1 and dissimilar ones as 0. Calculate the degree of deviation between the two probability distributions using KL divergence. If each word in the text is treated as a separate one-dimensional feature, the KL divergence calculation result represents the importance score of each feature [11].

TF IDF: TF represents the frequency of a word appearing in a given text, abbreviated as word frequency, and its statistical formula is:

$$TF_{i,j} = \frac{n_{i,j}}{\sum\limits_k n_{k,j}} \tag{2.3}$$

In the formula, $n_{i,j}$ represents the frequency of the i-th word appearing in the jth text; $\sum\limits_k n_{k,j}$ represents the total number of words contained in the jth text; The higher the frequency of a word, the greater the likelihood that it is a keyword in the jth text [12]. However, in long texts and documents, some words may have high frequency but are not keywords, which can easily lead to incorrect keyword extraction. Therefore, based on the overall corpus, inverse document frequency (IDF) is introduced to calculate the universal importance of each word. The calculation formula can be expressed as:

$$IDF_I = \log \frac{D+1}{\{j : t_i \epsilon d_j\} + 1} + 1 \tag{2.4}$$

In the formula, D represents the total number of texts; t_i represents the i-th word in the text; d_j represents text containing t_i ; J represents the quantity containing t_i text. The calculation formula for comprehensive TF-IDF keyword extraction can be expressed as:

$$TF - IDF_i = TF_{i,j} * IDF_i \tag{2.5}$$

TF-IDF combines the advantages of word frequency and inverse frequency, making it simple and effective for keyword extraction and suitable for library automatic retrieval robots.

Word length: The length of a word itself is called a word length feature, and the word length of a keyword is usually 2-3, which has good distinguishability compared to other words [13].

Part of speech: Based on the distribution of part of speech of keywords, the part of speech is transformed into multidimensional Boolean features and selectively combined. This method not only improves keyword distinguishability, but also solves the problem of high and sparse dimensions of part of speech features, thereby improving the performance of automatic extraction of text keywords. Automatic keyword extraction preprocesses user search problems, and extracts keyword features using KL divergence, TF-IDF, word length, etc. to obtain feature vectors and labels; Secondly, XGBOOST algorithm is used to construct multiple feature keyword automatic extraction models, and the scores of each word are calculated; Finally, output the words with the highest scores as keywords [14].

(2) Intention recognition. Intention recognition is a method of identifying requirements based on the content of a user's search question and dividing their types of requirements. Intention recognition is a multi classification model that extracts intent features. This model takes user search content as input and preprocesses student search content using Chinese word segmentation, part of speech tagging, and removal of stop words; Subsequently, domain word judgment and sentence Word2vec2 were used to extract features from the search content, and they were matched with the intentions in the intention classification template; Finally, Softmax classifier was used to achieve intention recognition [15].

(3) Semantic similarity calculation. Semantic similarity calculation mainly calculates the similarity score between the user's search content and the candidate literature after intention recognition and classification, and takes the highest score literature as the final output of the robot. Semantic similarity calculation is based on the input of two sentences of search content and candidate literature for users with labels 1 or 0, where 1 represents similarity between the two sentences and 0 represents dissimilarity. Firstly, two sentences are preprocessed, followed by feature extraction using methods such as domain word judgment and sentence Word2vec cosine distance; Finally, a semantic similarity model is constructed using the XGBOOST algorithm, and the similarity score between user search content and candidate literature is calculated to enable the library literature automatic retrieval robot to obtain the final output answer.

(4) The overall process of robot literature automatic retrieval. Based on the above implementation, the overall steps for designing automatic literature retrieval are as follows: Students input search questions into automatic search robots [16]; The automatic retrieval robot first performs word segmentation, part of speech tagging, removal of stop words, and keyword extraction preprocessing on student search questions; The information retrieval module retrieves candidate literature containing keywords in the database based on the extracted keywords; Identify the intentions of student search questions and filter out candidate literature that does not match the student's search intentions; Calculate the similarity between student search questions and candidate literature filtered through intention recognition through semantic similarity calculation, and obtain the literature with the highest similarity; Take the candidate literature with the highest similarity as the final output result.

2.3. Application Countermeasures of Artificial Intelligence in Network Information Retrieval in the Era of Big Data.

(1) Network Intelligent Knowledge Service System. Usually, a network intelligent knowledge service system consists of four parts, including a knowledge processing system, a knowledge collection system, a knowledge service system, and a knowledge base.

The knowledge processing system is to transfer the knowledge downloaded from the network to intelligent communication devices, classify the knowledge, search based on keywords, and finally transfer the approved knowledge to the database. Generally speaking, there are four points to streamline knowledge processing [17]. Firstly, intelligent knowledge classification. Implement classification based on relevant standards by combining data types and content, and then pass it into the intelligent matching process. Secondly, the intelligent knowledge matching process. In this process, knowledge in the database can be classified, and then downloaded using the internet. The downloaded knowledge can be compared and analyzed to avoid data overlap. The intelligent matching results can be transmitted to the intelligent update process. Once again, intelligent knowledge updates. Use the matching results to clarify which knowledge base the corresponding information is stored in, and then replace the original data or overlap the newly downloaded information with the original

information to form a new information concept. Finally, intelligent knowledge cleaning. The intelligent database needs to be cleaned regularly, and internal knowledge and network knowledge matching work should be done to achieve internal knowledge replacement and cleaning, so as to ensure the smooth operation of the entire system.

In order to enhance the richness of internal knowledge in the database, it is also necessary to do a good job in knowledge collection and updating. In other words, it means knowledge collection and processing, achieving the transformation and supplementation between knowledge and knowledge. Usually, the collection system involves two parts, one is the collection of printed knowledge, and the other is the collection of data knowledge. Among them, the collection of printed knowledge mainly involves scanning paper knowledge and using artificial intelligence technology to transform data, transforming text indices into digital form. The data knowledge system collects it, making network data resources more abundant. In the process of information collection, there are four processes that need to be followed. Firstly, site mirroring refers to downloading the internal information of a site like a mirror, usually copying some websites with abundant resources, and comprehensively copying the content into the system to improve information collection efficiency. Secondly, intelligent information monitoring. Intelligent monitoring of target information can be achieved to ensure the rationality of target information changes, and internal system information can be exchanged with the actual situation. Thirdly, intelligent resource discovery. The system can search for new resources and discover new data that meets network requirements. In the event of new data appearing, the system can automatically collect it. Fourthly, intelligent knowledge resource transformation. In this process, digital resource collection and allocation can be achieved, and a new meaning can be formed afterwards.

The preservation system is an indispensable part of the knowledge base and also serves as a basis for ensuring the quality of information retrieval. Usually divided into hardware retrieval, software retrieval, and system retrieval. Among them, hardware serves as the basis for storing data, while software is an information storage management system that can ensure efficient storage of various information. The retrieval system relies on hardware storage and software management, which is the foundation of intelligent retrieval systems. On this basis, the entire system can be redeveloped to make it more comprehensive and provide users with good services.

(2) Intelligent Agent Technology. In the context of big data, IA intelligent agent technology, as a major component in the field of intelligence, has emerged with the comprehensive development of the internet. IA intelligent agent technology has been widely applied in various fields and is also a key research topic in China's intelligent technology exploration. By applying IA intelligent agent technology to network information retrieval functions, various problems in traditional retrieval can be addressed, effectively improving the level of network information retrieval. The application structure of intelligent technology in information retrieval applies intelligent agent technology to information retrieval work, which can form a new retrieval agent tool that sets corresponding services according to the needs of each user. By combining the user's network application habits and needs, information retrieval methods can be classified. For example, if the user will frequently collect relevant information for a period of time, under the action of intelligent agent technology, the user's collection situation can be recorded, and the type of information that the user is interested in can be analyzed. At the same time, corresponding reference schemes can be set based on the key situation of other users in collecting this type of information, provide a basis for users to search for relevant information. For example, centralized push of relevant information, etc. Under the influence of intelligent agent technology, relevant information can be pushed according to user needs, which helps users better understand themselves. Assuming that the user is not satisfied with the pushed information, they can record the feedback results in the system based on the actual situation, and the system will automatically make changes to make the system more accurate in the next information matching process. The emergence of intelligent retrieval tools can better meet user needs and make network information retrieval work more rational and intelligent.

Firstly, network management. This function allows users to monitor the distribution of network resource points and promptly handle resource failures when searching for corresponding site resources. When downloading the same data, it is convenient for users to choose sites with wide resource areas and ideal server operation, and select corresponding information transmission networks based on their actual situation, this can reduce the significant consumption of time resources by users due to network congestion. Secondly, information manage-

Table 3.1: Distribution of keyword automatic extraction training and testing sets

Data set	Sentence	Terms	Keyword
Training Set	4000	17000	3500
Test Set	1000	6000	1000

Table 3.2: Automatic Extraction Results of Two Kinds of Keywords

Model	Accuracy (%)
KL+TF-IDF+XGBOOST	98.325
Logistic	95.216

Table 3.3: Literature search results for semantic similarity calculation

Model	Accuracy (%)
Semantic Similarity Model Test Results	98

ment. This service function can clearly understand the distribution of user required data in the network, and provide a basis for keyword search by users. It can select target information and delete invalid information. In addition, based on user application habits, information push plans are set to promote interface optimization, allowing users to choose corresponding interfaces according to their own network application habits, making intelligent technology more personalized and targeted.

3. Experimental verification.

3.1. Experimental Data and Evaluation Indicators. Extract 5000 sentences from the user search question set, and after preprocessing with Chinese word segmentation, annotation, and removal of stop words, obtain 23000 words, including 4500 keywords. Divide the above data into training and testing sets, as shown in Table 3.1.

3.2. Automatic keyword extraction results. In order to verify the performance of the keyword automatic extraction method designed in this study, both KL+TF-IDF based keyword automatic extraction and logistic regression based keyword automatic extraction were trained and tested to obtain the accuracy of extracting N keywords from each sentence. The test results are shown in Table 3.2 [18].

From Table 3.2, it can be seen that the accuracy of keyword automatic extraction based on KL and TF-IDF for each sentence keyword is 98.3%, indicating better performance of this extraction method.

3.3. Literature retrieval results based on intention recognition. Classify the keywords extracted above and obtain a total of 175 different user intentions. In order to verify the performance of the intention recognition model, training and testing were conducted on the basis of the obtained data, and the test results were evaluated through evaluation indicators such as accuracy, recall, and F1 value. The evaluation results are shown in Figure 3.1.

Analyzing Figure 3.1, it can be seen that the accuracy of the original intention recognition model is close to 95%, indicating that it can improve the accuracy of library automatic retrieval robots in identifying user intentions.

3.4. Accuracy of Literature Retrieval Based on Semantic Similarity Model. Using accuracy as the evaluation indicator for model performance, semantic similarity was used to calculate the test results of 100 users on 50 candidate literature, as shown in Table 3.3 [19].

As shown in Table 3.3, the accuracy of semantic similarity calculation reaches 98%, indicating that this method is good and suitable for library literature automatic retrieval robot systems.

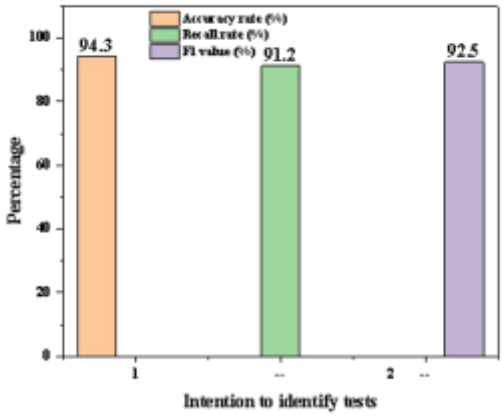

Fig. 3.1: Intention Recognition Test Results

Table 3.4: Automatic retrieval results of library literature retrieval robots based on intention recognition

Model	Accuracy (%)
A Robot System for Library Document Automatic Retrieval Based on Intention Recognition	98

3.5. System Verification. In order to further verify the retrieval effect of the automatic retrieval robot, the results of 100 students' automatic literature retrieval were collected, as shown in Table 3.4. As shown in Table 3.4, the designed automatic retrieval robot has a retrieval accuracy of 98%, indicating good performance [20].

4. Conclusion. In order to achieve automatic library literature retrieval based on artificial intelligence, the author designed a library literature automatic retrieval robot retrieval method based on intention recognition, and tested the retrieval method. The results show that the automatic retrieval robot has a retrieval accuracy of 98% for user search content. However, due to time and manager constraints, the classification of students' search intentions in this study is not detailed enough, and the design of the semantic similarity calculation module is not yet perfect, requiring further exploration and improvement.

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HETEROGENEOUS HIGH PERFORMANCE DATA MINING SYSTEM FOR INTELLIGENT DATA

XINKE WANG*, KAI LI†, AND XIAOLING LI‡

Abstract. In order to improve the utilization rate of internet data under heterogeneous distribution, increase the diversified usage functions and data transmission rate of the internet, and reduce the running time of the internet, it is necessary to mine internet data under heterogeneous distribution. The author proposes an ontology based optimization method for internet data mining under heterogeneous distribution; This method first preprocesses and selects data features from internet data under heterogeneous distribution, and uses a feature selection decision system to select features from the mining data. Based on this, information entropy is used to filter internet data under heterogeneous distribution. During the filtering process, the theoretical values filtered by information entropy are reduced to obtain the optimal data filtering value, finally, based on the various data information obtained in the preprocessing, the iterative calculation results of the information gain value in the decision tree generation algorithm are used to high-precision mine internet data under heterogeneous distribution; The simulation experimental results demonstrate that the proposed method improves the flexibility of internet data operations under heterogeneous distribution, increases the recyclability of internet data, and makes internet operations under heterogeneous distribution more concise and efficient, providing a strong basis for research and development in this field.

Key words: Heterogeneous distribution; Internet; Data mining methods; Optimization research

1. Introduction. Since the 1990s, "informatization", "networking", and "globalization" have become several main characteristics of human socio-economic development in the new era [1]. Information and data have become important resources that support human socio-economic development after material and energy, and are also changing the allocation of social resources, as well as human values, work, and lifestyle. With the rapid development of information technology, fundamental changes have taken place in various industries driven by information technology. Various information systems are abundant, and governments, enterprises, and research institutions have established a large number of information systems.

Data is growing at an annual rate of 200%, with most of it coming from the application of new technologies. Due to differences in business and functions, as well as the impact of factors such as stage, technical, and human factors on the informationization construction of various departments and institutions, the established information systems are isolated from each other, forming multiple "information islands". These "information silos" make the internal data of enterprises exhibit obvious characteristics such as distribution, self-control, and heterogeneity. With the development of information technology, information and data have become important assets in today's society and a major driving force for its development. It is in this situation that research on information and data is also increasing, and the breadth and depth of research are further deepened. Enterprises are not satisfied that the system can only provide business data for local business processes, but increasingly need to achieve information sharing among multiple businesses distributed in different locations on the network to improve the efficiency of enterprise collaborative operation. Therefore, in order to ensure the sharing, maintenance, and management of information within and between enterprises, it is necessary to find a unified operation method for multi-source and heterogeneous data. Heterogeneous data integration is a key problem that must be solved in information integration applications.

Heterogeneous data integration has important characteristics, mainly manifested as not only shielding the distribution and heterogeneity of heterogeneous data, but also fully maintaining the autonomy of heterogeneous data. The ultimate result is that users do not have to worry about the physical storage location of heterogeneous

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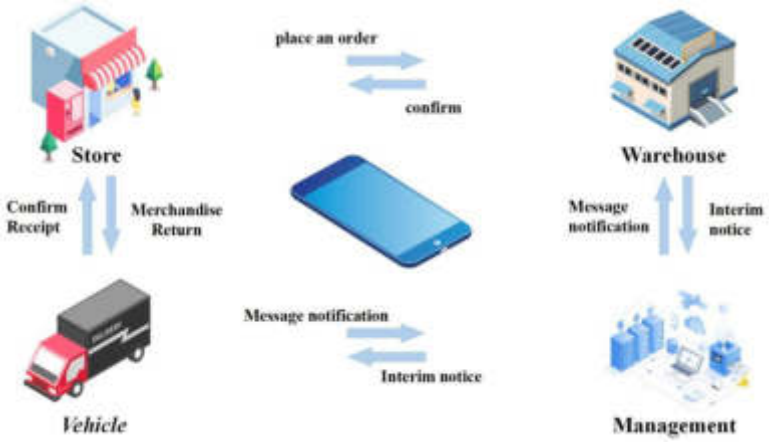

Fig. 1.1: Data integration method for multi-source heterogeneous massive data

data, only need to operate and use heterogeneous data through an integrated environment, and do not need to worry about the structural differences between data. At the same time, the integrated system does not affect various local application systems. Heterogeneous data integration systems provide a solution for enterprises to integrate multiple platforms, applications, structures, and semantic data. Through such an integrated system, not only can various relevant data resources within the enterprise be integrated, but also external information can be collected for data mining to provide support for enterprise decision-making. Therefore, heterogeneous data integration systems are receiving increasing attention, and research in this area has become a hot topic. Figure 1 shows a data integration method for multi-source heterogeneous massive data.

With the continuous development and popularization of computer science and internet technology, internet data under heterogeneous distribution is distributed in office automation, electronic data exchange, remote exchange, remote education, electronic bulletin board system BBS, electronic banking, securities and futures trading, broadcasting packet exchange, information superhighway, enterprise network, etc Intelligent buildings and structured cabling systems are widely used in social platforms and systems [2]. Therefore, the development of internet data under heterogeneous distribution has received widespread attention and high attention from people. The internet under heterogeneous distribution can not only support different applications of different protocols and combine advantageous products or systems, but also meet the diverse needs of network business and improve the utilization rate of various multi-functional platforms and systems in the internet. Due to the characteristics of uncertainty, diversity, and flexibility of the internet under heterogeneous distribution, it is necessary to mine internet data under heterogeneous distribution [3,4]. Most internet data mining methods under heterogeneous distribution are unable to quickly, effectively, and accurately mine data, resulting in high packet loss rates, complex data operation processes, and computational errors during operation or operation of the internet under heterogeneous distribution. In this situation, how to reduce the packet loss rate of internet data mining under heterogeneous distribution and improve the accuracy of internet data mining has become an urgent problem to be solved. The optimization method of in ternet data mining based on ontology under heterogeneous distribution can perform flexible, convenient, reliable, and high-precision data mining on it. It is a feasible way to solve the above problems [5]. In response to the aforementioned issues, the author proposes an ontology based optimization method for internet data mining under heterogeneous distribution. This method first preprocesses the internet data under heterogeneous distribution to achieve higher mining accuracy and faster mining speed. Then, the decision tree generation algorithm is used to mine the internet data under heterogeneous distribution. Simulation experiments have shown that the proposed method can efficiently and accurately mine internet data under heterogeneous distribution, and has good implementability.

2. Optimization Method for Internet Data Mining under Heterogeneous Distribution.

2.1. Internet Data Preprocessing under Heterogeneous Distribution. Using ontology to mine internet data under heterogeneous distribution, the first step is to preprocess internet data under heterogeneous distribution. In data preprocessing, it is necessary to determine the data target attribute set and data condition attribute set of the internet original dataset under heterogeneous distribution, secondly, the value range of the attribute set is divided into several cells, and a discrete symbol of internet data corresponds to a data attribute set between cells. This results in a feature selection decision system for internet data under heterogeneous distribution. The same data records in the feature selection decision system are merged and recorded as (R, CRD) to establish a feature selection decision system for internet data under heterogeneous distribution, it is an optimization of the traditional data mining methods that directly conduct internet data mining without data feature selection [6,7].

Before data feature selection, the features of the data need to be extracted, and the author uses the maximum interval algorithm to extract features from internet data under heterogeneous distribution. Assuming that internet data follows a certain feature distribution P, the similarity value ω of internet data feature extraction under heterogeneous distribution is calculated using the maximum interval algorithm as follows:

$$\omega = arg_{\omega}\omega_q^0 \tag{2.1}$$

Among them, 0 represents the predefined threshold for feature extraction from internet data under heterogeneous distribution, and q represents the dimensionality of internet data feature extraction. Based on the extraction of similarity value ω from internet data features under heterogeneous distribution, it is known that the extraction process of internet data features is as follows:

Input F,G,h.
Output: $\omega_1, \omega_2, \omega_3$.

Among them, F represents the internet data feature extraction dataset under heterogeneous distribution, G represents a feature parameter in the internet data feature extraction under heterogeneous distribution, and h represents the dimensionality of the features to be extracted from the internet data under heterogeneous distribution, $\overline{o}$ represents the feature attribute mapping values in internet data feature extraction [8]. This completes the feature extraction of internet data under heterogeneous distribution. Applying ontology to feature selection of internet data under heterogeneous distribution aims to extract the most essential features that reflect the essence of internet data mining under heterogeneous distribution from the original internet data under heterogeneous distribution. The following is the specific process of feature selection methods for internet data under heterogeneous distribution:

Assuming input: internet data condition attribute set A, data decision attribute set B, and data decision system (R, CRD) under heterogeneous distribution.

Output: Internet data generation resolution matrix H and data reduction set X (A, B) under heterogeneous distribution [9].

(1) If n represents the number of attributes in the internet data decision-making system, then:

$$X(A, B) = \phi \tag{2.2}$$

Among them, X represents the internet data reduction value under heterogeneous distribution, ϕ represents the internet data reduction set under heterogeneous distribution [10].

(2) Assuming an nXn internet data attribute set matrix N;

(3) According to the discernibility matrix in ontology, the data discernibility matrix is generated, and the internet data attribute set matrix N recorded in (2) includes:

$$for(j = i + 2; i < n; j + +) \tag{2.3}$$

$$ifB(x_1), N_{ij} \leftarrow \phi \tag{2.4}$$

Among them, i represents the number of data condition attributes, j represents the number of data decision attributes, and N represents the internet data attribute set matrix.

(4) Add each internet data attribute subset in (2) to XLop (A, B);
(5) Output internet data attribute set matrix N, reduction set XLOP (A, B) [11].

In summary, using the feature selection decision system established above for internet data under heterogeneous distribution, the process of feature extraction and data feature selection for internet data under heterogeneous distribution is completed. In order to improve the quality of data mining in internet data mining under heterogeneous distribution, it is necessary to filter internet data. The optimization method of internet data mining under heterogeneous distribution based on ontology uses information entropy to filter internet data, and the filtering theory value of information entropy is used to input the filtering condition value IT of internet data:

$$IT = (U, A_t, V_x, I_x) \tag{2.5}$$

The output is:

$$IT = (U, A_t, V'_x, I'_x) \tag{2.6}$$

Among them, U represents the set of data attribute values corresponding to each attribute on the internet, V represents the expected information value of internet data mining samples under heterogeneous distribution, V 'represents the expected information value of internet filtered data mining samples, I represents the information function value during the internet data filtering process, I' represents the theoretical value of information entropy during the internet data filtering process, t represents the mean value of internet data attributes, and x represents the internet data attribute value. Sort the attribute values of in ternet data under heterogeneous distribution by making each internet data attribute value $x \epsilon A_t$.

For non internet data attribute values, assuming its attribute values are in an ordered relationship, it can be transformed into data numerical ordering. This step has been optimized in the internet data value sorting process under heterogeneous distribution, so that non in ternet data attributes can also be sorted [12]. After sorting, perform the following steps based on the filtering information function of information entropy for each internet data attribute value $x \epsilon A_t$.

$$fori = 1toK - 1 \tag{2.7}$$

Among them, K represents the maximum specified filtering value for filtering internet data under heterogeneous distribution using information entropy. Using information entropy to filter inter net data under heterogeneous distribution can be defined as:

$$H(C/X; V_1, V_2, ..., V_t) = \sum_{j=1}^{i+1} p(U_j) \sum_{d \epsilon V_D} p(d/U_j) log(d/U_j) \tag{2.8}$$

Among them, H represents the defined value of information entropy for filtering internet data under heterogeneous distribution, and p represents the probability distribution value of internet data attributes. When the amount of internet data under heterogeneous distribution continues to increase and the theoretical value of information entropy data filtering changes little, the optimal filtering value is output to complete the filtering of internet data under heterogeneous distribution. In summary, internet data preprocessing under heterogeneous distribution mainly consists of data feature selection and data filtering. Data preprocessing improves the quality of data mining and reduces data mining time [13,14].

2.2. Internet Data Mining under Heterogeneous Distribution . After completing the data preprocessing of internet data mining under heterogeneous distribution based on cost body theory, decision tree algorithm is used to mine internet data under heterogeneous distribution. The specific methods are as follows: The decision tree algorithm constructs an in ternet data mining decision tree under heterogeneous distribution in a top-down manner, which is divided into internet data decision tree generation and internet data decision tree pruning. The author does not study internet data decision tree pruning. The internet data decision tree generation algorithm utilizes information gain to select the best mining attributes in internet data under heterogeneous distribution. The specific calculation method for information gain is as follows:

Assuming there are m pieces of information, the probability distribution of the data attributes mined is:

$$p = (p_1, p_2, ..., p_m) \tag{2.9}$$

The expected information value of internet data mining sample S under this heterogeneous distribution:

$$V(S) = V(p) = \sum_{1}^{m} p_i log_2 p_i \tag{2.10}$$

Among them, S represents the total number of samples in internet data mining under heterogeneous distribution, and m represents the number of information in the information gain [15]. Given the heterogeneous distribution of internet data mining samples $s_i \epsilon S$, the total number of in ternet data mining samples is s_i, based on the attribute values of internet data mining categories s under the heterogeneous distribution; Divide into z subsets of data category attributes, and the number of internet data mining samples under heterogeneous distribution contained in each subset of data mining categories is s_{ij}. Therefore, the probability distribution of internet data mining attributes is shown in Equation 2.11:

$$p = (S_{i1}/S_i, S_{i2}/S_i, ..., S_{iz}/S_i) \tag{2.11}$$

According to Equation 2.10, the expected information value of internet data mining sample s_i is $I(s_i) = I(p)$. The entropy of the internet data mining sample set S under heterogeneous distribution is:

$$E(S) = \sum_{1}^{z} \frac{S_i 1 + S_i 2 + ... + S_{im} I(s_i)}{S} \tag{2.12}$$

The information gain value of internet data mining sample S under heterogeneous distribution is:

$$Y(S) = I(S) - E(S) \tag{2.13}$$

Among them, Y represents the information gain value of internet data mining under heterogeneous distribution, and E represents the entropy of internet data mining sample set under heterogeneous distribution. Perform iterative calculations on the above process until one of the following conditions is met: all samples of a given internet data node belong to the same classification; There are no additional internet data attributes that can be further divided into data attribute samples; The internet data branch attribute sample under heterogeneous distribution is empty. So far, we have completed the internet data mining under heterogeneous distribution [16,17].

3. Results and Analysis. In order to demonstrate the effectiveness of internet data mining optimization methods based on ontology and heterogeneous distribution, a simulation experiment is required. Build an internet data mining experimental simulation platform under heterogeneous distribution in the environment of Visual C. The experimental data was taken from the SPSS Elementinell. 1 data mining system. In this experiment, ontology was used to high-quality mine internet data under heterogeneous distribution in the SPSS Elementinell. 1 data system. Table 3.1 and Figure 3.1 describe the relationship between the amount of feature selection data (10000) and its selection efficiency (%) in the optimization method of internet data mining under heterogeneous distribution based on text theory.

It is evident from the various data in Table 3.1 that the internet data mining optimization method based on text theory under heterogeneous distribution is safe and reliable. Although the efficiency of data feature selection in the table fluctuates continuously with the increase of feature selection data volume, the selection efficiency is basically above 90%, which further demonstrates the overall effectiveness of internet data mining optimization methods based on text theory under heterogeneous distribution. Table 3.2 and Figure 3.2 describe the relationship between the amount of filtered data (10000 pieces) and the filtering time (s) in the optimization method of internet data mining under heterogeneous distribution based on text theory.

In Table 3.2, the relationship between the amount of filtered data and the time it takes in the optimization method for internet data mining under heterogeneous distribution based on text theory is described. The time

Table 3.1: Relationship between Data Feature Selection and Selection Efficiency in Internet Data Mining

Number of feature selection data (10000)	Data selection efficiency (%)
1000	92.7
2000	93.4
3000	95.3
4000	92.5
5000	94.6

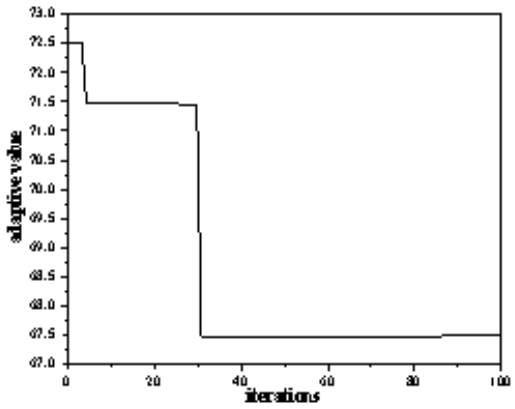

Fig. 3.1: Relationship between Data Feature Selection and Selection Efficiency in Internet Data Mining

Table 3.2: Relationship between Data Filtering and Time Used in Internet Data Mining

Filtered data volume (10000)	Time taken for filtering (s)
100	3.12
200	3.64
300	4.11
400	4.57
500	4.9

it takes to filter data fluctuates relatively little with the increase of filtered data, indicating that the data mining optimization method proposed by the author consumes less time, further proving the feasibility of the optimization method for internet data mining under heterogeneous distribution based on text theory. Figure 4 shows a comparison of the mining efficiency (%) between the fast mining method for hidden data and the author's method. The efficiency of the fast mining method for hidden data in Figure 3.3 fluctuates greatly with the increase of data volume. The mining efficiency of the data mining optimization method proposed by the author is in a stable fluctuation state, and the mining efficiency is relatively high, which is significantly better than the fast hidden data mining method. This is mainly because when using the author's proposed method for data mining on internet data under heterogeneous distribution, the maximum interval algorithm is used for feature extraction on internet data Based on the feature selection decision system of internet data, feature selection is carried out on internet data, as well as the preprocessing work of internet data mining under heterogeneous distribution using information entropy to filter internet data. This has laid a solid foundation for internet data mining under heterogeneous distribution, which is conducive to efficient mining of internet

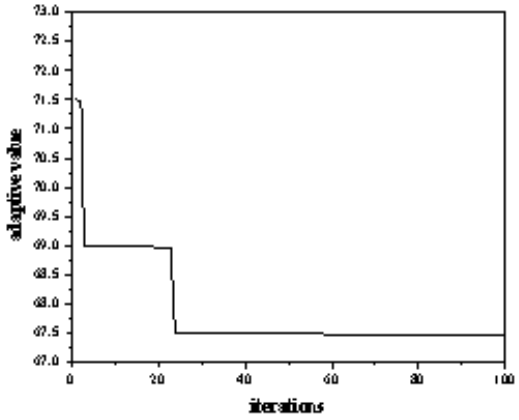

Fig. 3.2: Relationship between data filtering and time used in internet data mining

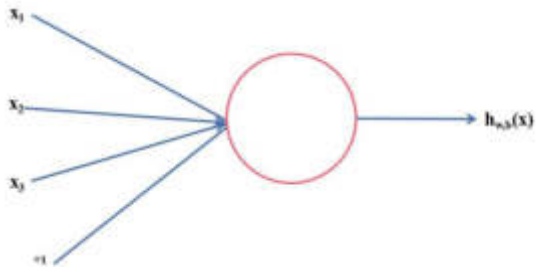

Fig. 3.3: Comparison of Mining Efficiency under Different Methods

data under heterogeneous distribution. Figure 5 shows the comparison of the error rate (%) between the hot topic data mining method and the author's proposed method [18].

The error rate of the internet data mining optimization method based on text theory and heterogeneous distribution proposed by the author in Figure 3.4 is significantly lower than that of the hot topic data mining method. The error rate of the data mining method proposed by the author fluctuates relatively steadily with the continuous increase of the rated number of data mining, and remains below 5%. The main reason is that the generation of internet data decision trees plays an indispensable auxiliary role in the process of data mining, improving the accuracy of internet data mining under heterogeneous distribution, and effectively increasing the feasibility and optimization of the method proposed by the author. Simulation experiments have shown that the optimization method for internet data mining under heterogeneous distribution based on text theory proposed by the author can accurately mine internet data under heterogeneous distribution, ensuring the overall effectiveness of internet data mining, improving the speed of data mining, and providing a reliable basis for research and development in this field [19,20].

4. Conclusion. When using current methods for data mining on the internet under heterogeneous distribution, it is not possible to achieve high-precision and efficient data mining on the internet under heterogeneous distribution, resulting in high mining error rate, slow speed, and insecurity. The author proposes an optimization method for internet data mining under heterogeneous distribution based on text theory. Through simulation experiments, it has been proven that the proposed method can accurately mine in ternet data under heterogeneous distribution, and has good application value and is practical and feasible.

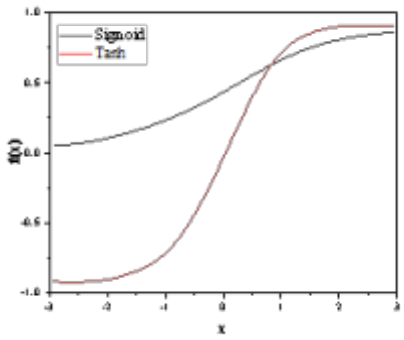

Fig. 3.4: Data Mining Error Rate

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RESEARCH ON COMPUTER INTELLIGENT COLLABORATIVE FILTERING ALGORITHM FOR PERSONALIZED NETWORK DATA RECOMMENDATION SYSTEM

YONG YU *

Abstract. In order to meet the protection needs of user privacy data in social networks, this paper proposes a computer intelligent collaborative filtering algorithm for personalized network data recommendation systems. This algorithm predicts user preferences for specific items by utilizing user evaluation information on groups of similar feature items, thereby achieving personalized recommendations. The experimental results show that as the number of project feature selections N increases, the MAE, RMSE, and NDCG5 of the algorithm gradually improve. This is mainly attributed to increasing the number of features under a fixed similarity threshold, which makes the data granularity finer and helps to describe project features more accurately. In the case of a fixed number of project feature selections N, the impact of the number of nearest neighbors s in similar groups on algorithm performance was further studied. The results showed that with the increase of s, MAE, RMSE, and NDCG5 showed a decreasing trend. Although the algorithm suffers from certain losses in recommendation accuracy, it is still within an acceptable range. It is worth noting that due to the system only using generalized data as input, user privacy data is effectively protected. Based on the comprehensive experimental results, this algorithm has significant value in practical applications.

Key words: Social networks, Collaborative filtering recommendation algorithm, User privacy data, User similarity

1. Introduction. With the development of the times, the internet has gradually entered the daily life of the public, and obtaining information through the internet has become routine [1]. In recent years, internet data and information have shown an exponential explosive growth, with massive amounts of information flooding the internet, making it increasingly difficult for users to find the information they need. As an information demander, finding what one needs and is interested in from a large amount of information is often not an easy task; For information providers, it is also very difficult to make their information accessible to everyone. The recommendation system is the main tool to solve this contradiction.

The extraordinary ability and practical value demonstrated by recommendation systems in dealing with information overload have increasingly attracted the attention of the academic community. In recent years, research on recommendation systems has made rapid progress, with significant progress in recommendation effectiveness and accuracy. However, there are still some unresolved issues, such as data sparsity and cold start in collaborative filtering algorithms, in order to address these issues and improve recommendation accuracy as much as possible, it is necessary to consider integrating other information into collaborative filtering algorithms. Due to the widespread development of social networks, user social network information has been applied to many websites. As early as the last century, scholars began researching social network information. Nowadays, with the rapid development of the Internet, it has become a research hotspot. The current research on social network analysis has achieved significant results in data mining tasks such as link based node sorting, node classification and clustering, link prediction, and subgraph discovery [2,3]. However, in the research of recommendation systems, there are not many mature algorithms that apply social network analysis to assist in recommendation system research. One of the author's research topics is to consider using social network analysis methods and combining machine learning with collaborative filtering algorithms in recommendation systems to form a new type of effective and practical algorithm. On the other hand, the personalized recommendation methods currently used in internet applications are based on collecting user personal information and behavioral data. Although these internet applications anonymously process user data when personalized recommendations are made to users, the original data of user information is often retained in the databases of various internet companies, due to some vulnerabilities in various systems, incidents of user data leakage often occur. This may

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cause incalculable losses to users and businesses.

2. A User Privacy Data Protection Recommendation Algorithm Based on Project Feature Grouping.

2.1. Privacy issues in recommendation systems. In a recommendation system, recommendation effectiveness and user privacy data protection are a contradiction. In order to achieve better recommendation effectiveness, it is necessary to obtain sufficient personal and behavioral information of users, which is the risk of exposing user privacy issues [4]. The main ways to expose user privacy information in personalized recommendation are as follows: The server in the personalized recommendation system automatically obtains and monitors user behavior information; The recommendation system has been attacked by network hackers, and user information has been leaked; Users submit their own privacy information independently; Resale of user private information; Among them, automatic monitoring of user behavior information is the most common and covert.

In personalized recommendations, the user's privacy behavior information mainly includes the following information:

Personal information: Mainly includes information submitted by users during registration or subsequent self submission. These include name, gender, birthday, email, interest preference, work, location, and even ID card number. These are personal privacy information for users [5,6]. Personal behavior information: mainly includes user access frequency, time, messages posted by users on social networks, @ friends, comments, search records, etc. Personal customization information: This includes users customizing their own homepage, profile, etc. according to their own habits. Currently, it is not uncommon for news to be leaked due to ineffective protection of user data, and users are increasingly paying attention to their privacy protection issues. Therefore, various privacy protection technologies have emerged. Common privacy protection technologies mainly include cryptography based techniques, anonymity, and data perturbation.

Cryptography based technology is a relatively traditional privacy protection method, mainly applied to the security protection of information data transmission processes in centralized or distributed scenarios. Among them, applications in distributed environments are the most widespread, such as distributed privacy queries, distributed data mining, etc. This technology typically requires communication points to be trusted and secure. The commonly used methods in cryptography based technologies include secure multi-party computation (SMC) homomorphic encryption algorithms, etc. Both secure multi-party computation and homomorphic encryption algorithms require complex cryptographic computation support. Due to the extremely large number of users and information in recommendation systems, cryptography based methods are not suitable for privacy protection in recommendation systems.

K anonymity technology, as the name suggests, is to remove some identifiers and directly hide the user's identity information, in order to prevent locating the user through the published information and obtaining further privacy information from the user. The technical principle of this anonymous method is simple, but there are also some security issues, such as its inability to effectively resist link attacks [7]. Link attack refers to the use of other relevant resources by users to locate relevant users after data is published. There are two main ways to achieve anonymity: generalization and removal. These two methods can effectively protect users' privacy data. The basic idea of generalization is to replace an attribute value with a universal value or interval. The basic idea of removal is to protect user privacy by removing sensitive information. The application of removal technology has led to a reduction in data in the data table. Anonymous technology in k often combines generalization and removal simultaneously. For particularly sensitive information, direct deletion is adopted, while others are generalized.

Data interference technology is the most fundamental privacy protection technology. Data interference technology is the use of certain algorithms to modify and interfere with raw data in order to protect user privacy data. Even through published information, raw data and statistical information cannot be obtained. Common data interference techniques mainly include data cleaning, randomized interference, etc [8,9]. The research goal of data interference technology is to ensure the accuracy of data mining under the condition of reaching a certain level of data interference, so that the accuracy of data mining results is infinitely close to the original data mining results without interference. Random interference technology is the most common technique in data interference technology. It hides data by adding other noisy data to the original data, and the

main methods of adding noisy data include additive and multiplicative addition. Although random interference technology has changed the original data, it can still obtain data features that are similar to the original data. Data cleaning and data exchange are also important data interference technologies. Data cleaning mainly reduces the support of frequent itemsets by removing or modifying data. And data exchange technology hides data by exchanging partial data in the dataset.

2.2. Establishment and analysis of recommendation models. In traditional personalized recommendation systems that rely on weights, there is a drawback of users' privacy information being easily leaked [10]. Because personalized recommendation systems need to obtain user preference information to construct user models, obtain user interest preferences, and recommend content information that interests them to users, recommendation systems need to collect detailed information about user behavior to analyze user interests. In a weighted network, user information can easily be fully exposed to the recommendation system through weights, such as obtaining the user's purchase record through the user's rating records. With the increasingly serious issue of privacy exposure, most users are concerned about the protection of their privacy information and therefore unwilling to provide private or sensitive information, therefore, in order to provide better personalized services and meet user concerns, current recommendation systems must provide an effective mechanism for protecting user privacy data.

Currently, many studies are committed to effectively protecting user privacy data without compromising recommendation accuracy [11]. In the personalized recommendation industry, collaborative filtering is a widely used and mature technology that has been applied in many practical application systems. The commonly used privacy protection technologies for collaborative filtering recommendations include encryption based technology, k anonymity technology, and random perturbation technology. Encryption based technology is mainly applied to privacy protection data mining research in distributed data storage. K-anonymity technology achieves privacy protection by generalizing and hiding user data, while random perturbation technology is commonly used in centralized data storage. In a recommendation system, any item can be divided into different groups based on its characteristics. For example, for music, it can be divided into corresponding groups based on the characteristics and attributes of the singer, style, and so on. The user's evaluation of a specific project can be inferred from the user's evaluation of the group in which the project is located. Based on the user's interaction behavior with these groups, it can to some extent reflect their preference for a specific project. And the division of these groups needs to be determined by the feature division of the project, each project has its own feature information and exists as an attribute of the project itself. These feature information implicitly contain user preference information for a project, because when a user makes a selection or evaluation of a project, their evaluation of projects with similar project features should be similar. Therefore, it can be considered to partition groups based on project features for recommendation. As the recommendation is only based on the feature information of the project itself and the evaluation information of the user's project feature group, without collecting user privacy information, it achieves the protection of user privacy data at the root.

The traditional item based collaborative filtering recommendation algorithm (1tem based Collaborative Filtering) predicts a user's rating for a target item based on their rating for similar items. It is based on the assumption that if most users have similar ratings for certain items, the current user's rating for these items is also similar [12,13]. The project-based collaborative filtering recommendation system uses statistical methods to find several sets of nearest neighbors of the target item. Due to the similarity between the current user's rating of the nearest neighbor and the target item's rating, the current user's rating of the target item can be predicted based on the current user's rating of the nearest neighbor, thus achieving recommendation. Similar to the analysis of user based collaborative filtering algorithms, it can be seen that the key to traditional project-based collaborative filtering recommendation algorithms lies in the determination of the nearest neighbor set of the project. The calculation of nearest neighbors cannot be separated from the measurement of similarity and the calculation of nearest neighbors. However, traditional project similarity calculation methods, whether they have Pearson correlation similarity, cosine similarity, or modified cosine similarity, are difficult to obtain accurate results when the evaluation data is very sparse. Similar to the improvement of user based collaborative filtering in Chapter 3, which takes into account the user's feature information, while considering the protection of user privacy data, the system needs to collect as little personal privacy information as possible. Therefore, starting from the analysis of project feature information, a collaborative filtering algorithm based on project

feature model is adopted. We have comprehensively considered the project's own attributes and user evaluation information. Firstly, a project feature similarity matrix is constructed based on the attribute feature vectors of the project, and combined with the existing user project rating matrix, the nearest neighbor project group set about the project is obtained. Furthermore, the filling matrix is predicted to obtain the predicted score and ultimately achieve recommendation.

The process of establishing a project feature similarity model mainly includes quantifying project feature data, calculating project feature similarity, and forming project neighbors based on feature similarity. Vector representation is generally used to quantify the feature attributes of a project, for example, dividing a project set into n mutually independent features, and forming an n-dimensional vector representing n important feature attributes of a specific project as $(c_{i1}, c_{i2}, ..., c_{in})$, among them, c_{in}represents the characteristic value of the nth attribute of the item i [14]. The eigenvalues of attributes can be numerical or descriptive, and different similarity calculation methods should be used for different types of eigenvalues. Numerical data can be divided into two forms: fixed values and interval ranges. For the form of interval ranges, the proportion they occupy can be used for calculation. Descriptive data can be represented using a commonly used TF-IDF formula to calculate the frequency of keywords appearing in the text as eigenvalues. The calculation formula for project feature similarity is:

$$sim(i,j) = \frac{|n_{ij}|_C^{t_i=t_j}}{|n_{all}|_C - |n_{ij}|_C^{t_i \neq t_j}} \tag{2.1}$$

Among them, t_i, t_j represents the feature groups of project i and project j, C represents all feature sets, and $|n_{ij}|_C^{t_i=t_j}$ represents the number of identical features that project i and project j have, $|n_{all}|_C$ represents the number of all features, and $|n_{ij}|_C^{t_i \neq t_j}$ represents the number of features that neither item i nor item j has. After calculating the similarity, the process of establishing the project feature similarity model is completed. In response to the problem of inaccurate calculation in traditional similarity measurement methods when the user rating matrix data is extremely sparse, a novel similarity measurement method is used to calculate the similarity between items. The main idea is that if you want to calculate the similarity between project i and project j, first count all users who have evaluated these two projects. Users can evaluate either one of them or both at the same time, if $r_{ui} = 0$ here indicates that user u did not evaluate project i, then these user sets are recorded as:

$$U_{ij} = \{u | u \epsilon U \cap (r_{u,t} \neq 0 || r_{u,j} \neq 0)\} \tag{2.2}$$

Then, pre score the items that have not been evaluated by users based on the scores of items in the project feature similarity group; Finally, the Pearson correlation coefficient method is used on the user set U_{ij} to calculate the similarity between terms i and j, and ultimately form the nearest neighbor of the target term. Among them, the rating of all users u on item i in U_{ij} is:

$$R_{ui} = \begin{cases} r_{ui}, r_{ui} \neq 0 \\ p_{ui}, p_{ui} = 0 \end{cases} \tag{2.3}$$

When user u has evaluated project i, the rating is equal to their actual rating r_{ui}. When user u has not evaluated project i, the rating is the predicted value p_{ui} obtained based on the rating of project i's characteristic neighbors. The calculation formula for the predicted value p_{ui} is:

$$p_{ui} = \frac{\sum\limits_{j \epsilon C_i} sim(i,j) * r_{uj}}{\sum\limits_{j \epsilon C_i} |sim(i,j)|} \tag{2.4}$$

Among them, C_i is the characteristic neighbor of project i. After the above processing, the data sparsity of items i and j has been alleviated, and the user set for joint evaluation of the project has increased. This can ensure the accuracy of the nearest neighbor set of the calculated items [15]. In addition, for the analysis of

algorithm efficiency, considering that the feature model of the project can be established offline, the calculation of feature similarity between each project can also be done offline, and the calculation results can be saved in the database. Therefore, the above prediction process will not have a significant impact on the operational efficiency of the recommendation system. The author's recommendation model is based on the feature matrix of users, projects, and groups with similar project features, and uses the calculated feature vectors to predict users' predictive ratings for specific projects. Although the graph model of the method proposed in the previous chapter is similar, their research objectives are not the same. The focus of the method proposed in the previous chapter is to combine social network analysis methods and fully utilize user social network information data, with the aim of improving recommendation accuracy; Although the recommendation model in this chapter also considers the direct relationship between users and projects, it focuses more on protecting user privacy while implementing recommendations. The author's algorithm can be used as an anonymous algorithm from the perspective of privacy protection calculations. We know that the classic k-anonymity algorithm is based on the construction of attribute hierarchy, and then the hierarchical structure of this construction is generalized to achieve the purpose of anonymity protection privacy. There are various ways to construct the hierarchy of k-anonymity algorithms when applying them, but obtaining the optimal k-anonymity is an NP challenge, which is also a major obstacle to the application of k-anonymity algorithms. For the author's recommendation model, it is a hierarchical structure, and its generalization method does not have strict limitations. Just like music, projects can be generalized based on the style of the music or the performers of the music. Based on this premise, the granularity selection of generalization will ultimately determine the implementation effect and recommendation accuracy of the recommendation model. If the granularity of generalization is coarse, the less user privacy data information will be included in the feature partition in the project group. This is helpful for protecting user privacy data, but it will have a negative impact on the accuracy of the system's implementation effect; On the contrary, if the granularity is too fine, although the accuracy of the system is improved, user information will become easily exposed, which clearly violates the principle of protecting user privacy data. So in practical model applications, it is necessary to constantly try to change the granularity division and find a balance point that effectively protects user privacy data with good implementation results. In addition, we do not actually generalize the recommended main users. On the one hand, this is because user privacy protection is something we must pay attention to, so we should try to obtain user information as little as possible. On the other hand, considering that the number and status of users change much faster than the speed of project changes, it is also difficult to generalize users.

2.3. System Implementation Framework. Figure 2.1 is an overall description of the algorithm framework. In practical recommendation system applications, the main steps are: (1) The system background collects relevant data generated by users, that is, input data. Here, the system collects user's pan data, which refers to the behavior and preference data of users acting on project feature groups. This is different from traditional recommendation algorithms [16]. For example, a user's music trial record of a certain genre, track information in a playlist created by the user, etc. By processing the user's pan behavior data, obtain the user group evaluation matrix and the relationship between the group and the project; (2) Quantify the project set based on project features, calculate the similarity of project features, and obtain the group division of project features. Fill in the rating matrix of user projects; (3) Predict users' preferences or ratings for specific projects based on their group ratings for projects with similar characteristics; (4) The recommendation system makes top-n recommendations based on the predicted score. The steps with high computational complexity throughout the entire system implementation process are concentrated in steps (1), (2), and (3). In order to improve the operational efficiency of the system, it is considered to process these steps offline. Firstly, the feature vectors of the user matrix and product feature matrix are calculated offline from existing data. Online, the recommendation results are mainly calculated based on the feature vectors, thereby improving the system's operational efficiency. On the other hand, the system then transfers data such as the user's behavior towards the recommended item to the storage system. After the data is updated, the updated recommendation model is obtained through offline calculation steps (1), (2), and (3). In addition, we can see that this recommendation model not only achieves privacy protection, but also makes the system more convenient to implement because the implementation of the system only requires user evaluation information on project feature groups. Compared to traditional recommendation systems that need to collect user evaluation information on specific projects, this type of user evaluation data

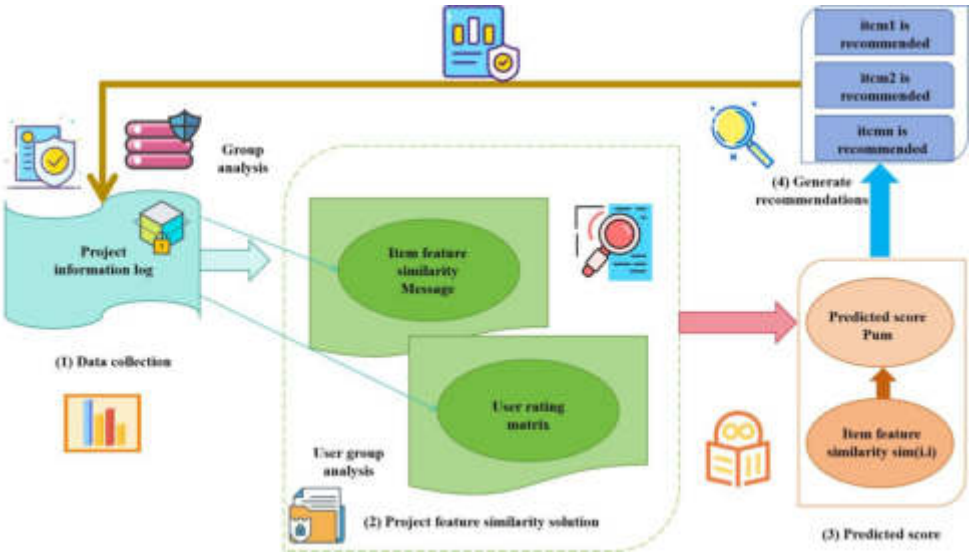

Fig. 2.1: Recommendation Framework

Table 3.1: Experimental Dataset Statistics

User data	Item Quantity	Number of ratings	Project category
944	1683	100 000	21

for groups is easier to collect because users rarely evaluate a large number of specific projects. Secondly, due to the coarse-grained macro evaluation information collected by the system, this data is relatively less noisy.

3. Experimental Results and Analysis.

3.1. Experimental Plan Design. The experimental data adopts the MovieLens dataset provided by the GroupLens project team at the University of Minnesota in the United States. The MovieLens movie recommendation system is a web-based research type that allows users to rate movies they have watched. Based on the user's historical rating information, the system predicts their ratings for other movies they have not watched and recommends movies with high predicted scores to users, I believe these movies are the next ones that users are interested in. The data of its system is also a commonly used dataset for experimental analysis by researchers. The MovieLens dataset contains 100000 rating data from 943 users on 1682 movies. The rating score is an integer from 1 to 5, and the larger the value, the higher the user's preference for the movie. Each user has rated at least 20 movies. The basic information of the dataset is shown in Table 3.1 [17].

The author randomly selected rating data from 300 users on 600 movies from the MovieLens dataset and compiled a feature description matrix for these 600 movies based on the website's demographic information. All experiments by the author will use this dataset, and 80% of it will be used as the training set and 20% as the testing set. Considering that the algorithm proposed by the author is based on the project feature model, it is necessary to first establish a film feature model. The feature attributes of the film are selected from the original data source, including 18 types such as Action, Adventure, Animation, Children's, Comedy, Crime, Documentary, Drama, Fantasy, Horror, Musical, Mystery, Romance, Sci-fi, Thriller, War, Western, Film noir, etc, Each film may have multiple attributes mentioned above at the same time [18]. For the given feature attributes mentioned above, it is first necessary to quantify them and convert them into computable data formats. Determine the value of the vector component based on whether it exists in the project. For the MovieLens movie dataset used by the author, for example, if movie a is both an action film and a crime and war film, the feature vectors of movie a are sorted according to the familiar movie features mentioned earlier.

The first, sixth, and sixteenth components of the feature vector are 1, and the other unfamiliar components are set to zero, i.e. (1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0). After quantifying the feature attributes of all test items, the project feature similarity matrix can be obtained. The similarity between projects can be calculated using formula (5), and the project group information can also be obtained by setting the number of groups to Ng and the number of items contained within the group to s (for this dataset, one project is also a movie). The author categorizes projects based on project feature categories, but using this classification method results in a fixed number of project groups Ng, where the number of projects s can be adjusted and determined by setting a similarity threshold.

$$sim(i,j) = \frac{|n_{ij}|_C^{t_i=t_j}}{|n_{all}|_C - |n_{ij}|_C^{t_i \neq t_j}} \tag{3.1}$$

In addition, for the author recommendation model, in its practical application, it only utilizes user rating data information for project feature groups, and does not require user ratings for specific projects. In this experiment, the selected dataset already includes specific ratings of user projects. In order to verify the effectiveness of the model, we used the above method to process project rating data in the experiment. In practical applications, only user behavior data about the group needs to be collected. This experiment mainly used three evaluation criteria, namely the root mean square error (RMSE) index to measure the accuracy of recommendation scoring, the mean absolute error (MAE) to measure the degree of deviation, and NDCG (Normalize Discounted Cumulative Gain) to measure the accuracy of recommendation item ranking. Mean Absolute Error (MAE) is the average absolute value of the deviation between all individual observations and the arithmetic mean. Its definition is:

$$MAE = \frac{\sum_{i \epsilon I} |\hat{r_i} - r_i|}{|I|} \tag{3.2}$$

I represents the test set, $\hat{r_i}$ represents the predicted score, and r_i represents its actual score.

The expression for root mean square error is defined as follows:

$$RMSE = \sqrt{\frac{\sum_{u,j \epsilon T} (r_i - \hat{r_{ui}})^2}{|T|}} \tag{3.3}$$

The symbol in the equation represents the actual score as r_{ui}, and the system predicted score as $\hat{r_{ui}}$.

NDCG is an indicator used to measure the quality of sorting. NDCG is a numerical evaluation of whether the ranking of recommendation lists provided by a recommendation system is reasonable, in other words, it evaluates whether the ranking of recommendation items is similar to the order of actual ratings. For example, NDCGp represents the NDCG value for the top p item positions in the recommendation list, calculated as follows:

$$NDCG_p = \frac{DCG_p}{IDCG_p}, DCG_p = rel_l + \sum_{i=2}^{p} \frac{r_i}{log_2 i} \tag{3.4}$$

r_i represents the user's rating on item i, and IDCG (ideaDCG) is the ideal DCG. In this experiment, the actual ranking result is calculated based on the actual rating of the test set, and then DCG_p is calculated to obtain $IDCG_p$.

3.2. Comparative experiments. Two comparative experiments were used in this experiment:

1. The user project rating matrix is filled in with an average score (Baseline), which is the average of the existing user ratings for the project [19].
2. Using the Probability Matrix Decomposition Algorithm (PMF), the principle of PMF is to reconstruct the rating matrix by utilizing the feature vectors of users and projects, thereby achieving recommendations.

Table 3.2: Comparison of Results

D	5		10		18	
Model	RMSE	$NDCG_5$	RMSE	$NDCG_5$	RMSE	$NDCG_5$
Baseline	1.0513	0.6953	1.0513	0.6953	1.0513	0.6953
PMF	0.9239	0.8162	0.9254	0.8156	0.9249	0.8178
Consider privacy algorithms	0.9878	08122	0.9663	0.8126	0.9669	0.8126

Table 3.3: Comparison of Loss Rates

D	5		10		18	
Model	RMSE	$NDCG_5$	RMSE	$NDCG_5$	RMSE	$NDCG_5$
Loss rate	4.23%	0.48%	4.43%	0.34%	4.44%	0.36%

If analyzed theoretically alone, the PMF algorithm will have higher accuracy than the author's algorithm that uses coarse-grained information based on user project feature similarity division as the training set, as it uses a training dataset with user ratings for specific projects and has finer granularity. After comparing the recommendations of Baseline, it is not difficult to find that the implementation effect of Baseline is actually relatively poor. This is because Baseline recommendations only consider the average rating of users on the project and do not conduct specific learning on the project.

3.3. Experimental Results and Analysis.

(1) Experiment 1: Selecting Different Project Feature Dimensions to Calculate Project Feature Similarity. This experiment compared the implementation effects of various algorithms under different feature vector dimensions. In the experiment, the feature vector dimensions D=5, 10, and 18 were selected. Regarding the algorithm proposed by the author, all other parameters are set to achieve optimal values for each algorithm. In order to intuitively evaluate the difference between the author's algorithm and the PMF algorithm in the actual accuracy of recommendations, a loss rate indicator has been defined, and its expression is as follows:

$$\delta = \frac{|a_{PMP} - a|}{a_{PMP}} \tag{3.5}$$

Table 3.2 shows the comparison of RMSE and NDCGs calculation results for each algorithm under different feature matrix dimensions, while Table 3.3 shows the comparison of loss rates for each algorithm under different feature matrix dimensions. The comparison of experimental results is shown in Tables 3.2 and 3.3 below.

From the experimental results, we can analyze and draw the following conclusions: As the dimension D of project features increases, there is a certain improvement in the accuracy of each algorithm, but the impact on the Baseline algorithm is not significant. The reason for the analysis is that the increase in the dimension D of the feature vector makes the description of project features more specific, which can effectively reduce errors. However, it must be noted that the increase in the dimension D of the feature vector can lead to an increase in computational complexity, so it is necessary to balance efficiency and accuracy. It can be seen that the privacy based collaborative filtering algorithm proposed by the author has poor implementation performance compared to PMF, with a loss rate of over 4%. The main reason for the analysis is due to the selection of training datasets. The training set of PMF is the user's evaluation data of the project, with finer granularity; The privacy based collaborative filtering algorithm proposed by the author uses a dataset of user evaluation data for grouping project feature similarity, with coarse granularity, resulting in insufficient accuracy. However, compared to the Baseline algorithm, privacy based collaborative filtering algorithms still have significant advantages, which also demonstrates the effectiveness of the privacy based collaborative filtering algorithm proposed by the author.

From the comparison of NDCGs indicators, combined with the results in Table 3.3, compared to the PMF algorithm, the privacy based collaborative filtering algorithm proposed by the author does not show significant changes in this indicator as the feature vector dimension decreases. This indicates that the impact on sorting

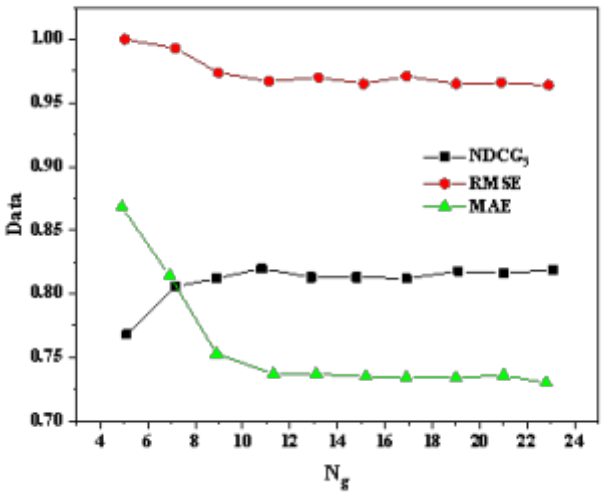

Fig. 3.1: N_g impact of AA on Algorithm

accuracy is not significant. In practical applications, the recommendation system for two-dimensional user data collects user behavior data, which is also simple "like" or "pop" information. In response to this situation, sorting accuracy has better measurement significance, and NDCG should be used as an evaluation indicator. Overall, the implementation effect of the recommendation model proposed by the author is acceptable and has practical application value.

(2) Effect of Different Data Granularities in Experiment 2. Data granularity refers to the level of granularity of data. When the number of items in each feature group is fixed, there are two main parameters that affect data granularity: The number of feature selections N and the number of nearest neighbors. Figures 3.1 and 3.2 respectively illustrate the variation of experimental results with the two parameters.

From Figure 3.1, it can be observed that as the number of feature selection N in the project gradually increases, MAE Both RMSE and NDCG5 are gradually improving, mainly due to the fact that increasing the number of feature selections N to a certain extent reduces the granularity of the data when s is fixed. The increase in the number of target feature selections will make the project feature description more specific. The calculation of project feature similarity obtained from this is more accurate, and the accuracy of similarity evaluations made by users based on similar project feature preferences is also higher, resulting in better results. However, this will also have a certain impact on the privacy protection effect of the recommendation model. It is worth noting that simply increasing the number of feature selections for a project does not result in a continuous improvement in MAE, RMSE, and NDCG5. However, when the number of feature selections for a project increases to a certain value, the measurement indicators do not show a significant improvement. This is mainly because an increase in the number of feature selections for a project can cause overfitting to a certain extent.

Figure 3.2 shows the impact of the number of nearest neighbors s within a similar group of project feature selection on the algorithm. It can be seen from the figure that, under a fixed N, MAE, RMSE, and NDCGs continuously deteriorate with the increase of s [20]. This is mainly due to the increase in the number of items within the group, resulting in larger data granularity. The reduction of useful data makes it more difficult to "purify" the data, that is, an increase in s will increase the bias of inferring users' preferences for specific items.

4. Conclusion. Currently, more and more recommendation systems are being applied to various internet applications, and users' enthusiasm for participation is constantly increasing. With this, there are issues with user privacy data security. The author extends the foundation of the proposed recommendation model to achieve

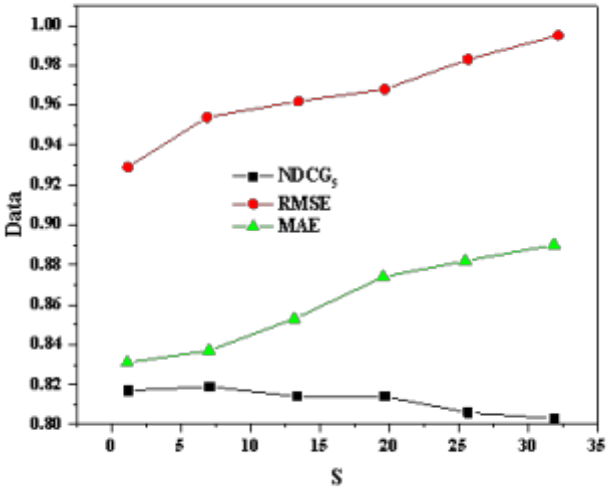

Fig. 3.2: The impact of s on the algorithm

a privacy protected recommendation model. In summary, the proposed recommendation model that considers privacy protection only collects "coarse-grained" information from users, while in terms of projects, projects are divided by calculating the project degree of project features, and these data are recommended to achieve the effect of protecting user privacy data. Firstly, the recommendation framework of collaborative filtering algorithm based on privacy protection was introduced, and the implementation principles were analyzed and derived; Subsequently, corresponding verification was conducted through experiments. It was found that although the privacy protection based collaborative filtering algorithm caused a certain degree of accuracy loss due to only utilizing coarse-grained data from users, it achieved privacy protection function and its implementation effect was also acceptable.

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CONSTRUCTION AND ANALYSIS OF INTELLIGENT ANALYSIS AND DISPOSAL MODEL FOR INTERNET SECURITY EVENTS IN POWER SYSTEM

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Abstract. The reliability of nodes is rugged to determine, and the global accuracy is low in identifying secure access nodes of ubiquitous power network gateways. Therefore, this project intends to establish a universal power grid gateway security access node identification model. Sensor technology collects secure access nodes of IoT gateways and evaluates their reliability. It is integrated with the security level of the network to form a virtual security domain. Then, the access node is searched and controlled twice. The access node identification of the universal power IoT gateway is realized according to the reliability calculation. Simulation results show that under the same parameter conditions, when the node size increases and the number of malicious nodes increases, the proposed method can obtain higher accuracy of secure access to nodes. This proves the advantages of the proposed method.

Key words: Power Internet of Things; Internet security incidents; Intelligent analysis; Internet of Things gateway; Secure access node

1. Introduction. With the continuous development of the intelligent grid, higher requirements are put forward for the security, aggression and vulnerability of power communication networks. The electric power communication network is a crucial link in the power grid, divided into different levels according to different business categories. In the whole system, the node is a very critical link. The failure of the node may cause particular interference to many services and even lead to the paralysis of some services. In the power communication network environment, node failure may interrupt higher-level power communication network services or lead to transmission delay problems. This has a significant impact on the operation of the entire power grid. Therefore, to reduce the vulnerability and danger in the network, it must be effectively identified and protected.

Many researchers at home and abroad are studying the problems related to the power grid. Literature [1] proposes a 5G-based distributed test system for power communication networks. The performance parameters of the network, transport, and application layers are measured. The probe detects each parameter to evaluate the whole power grid's operation comprehensively. However, this method does not measure the importance of critical nodes in the power network. According to the degree of shortest route selection, literature [2] gives the routing scheme of the power communication network. Then, they propose a link bandwidth utilization prediction method based on convolutional networks on graphs. The triangle module operator calculates the optimal path selection degree. Then, perform link optimization configuration. Document [3] A routing optimization method for power communication networks using PageRank. The research includes establishing the topology of the communication network and obtaining its characteristics. The PageRank algorithm is used to identify the critical nodes in the communication network. Set communication paths and metrics to maximize the use of information resources. Reference [3] studies the power system alarm signal fusion algorithm based on noise suppression. The alarm model of each node's message-receiving status is constructed based on each node's operation status and information-receiving status in the power network communication network. Literature [4]

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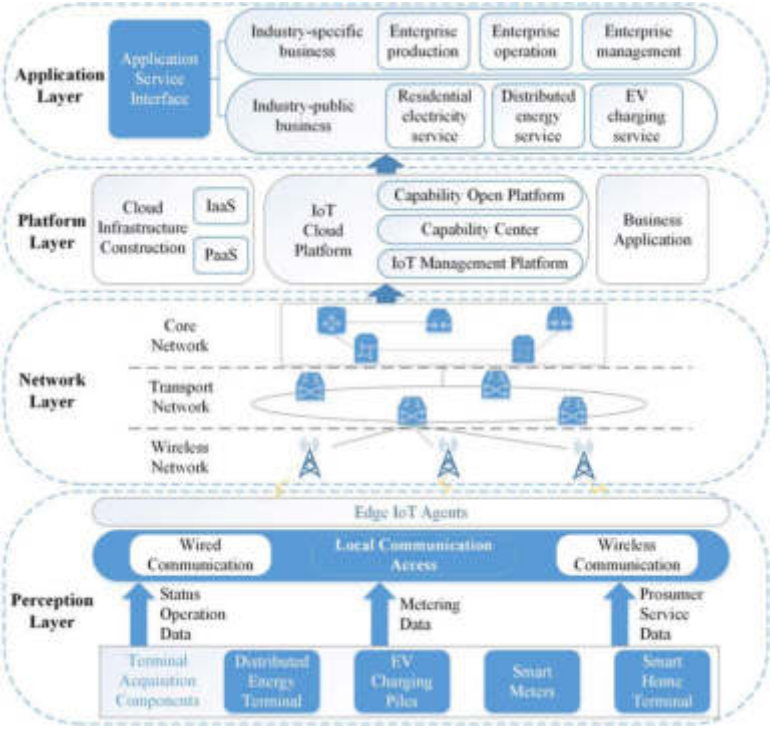

Fig. 2.1: *Data sensing mode in a ubiquitous electrical IoT.*

puts forward a cross-domain fusion framework applicable to power systems under the framework of IMS. After connecting different cross-domain websites, the access layer transforms them through the control protocol of the gateway to achieve the purpose of cross-domain IP access. The power communication service passes through the transport layer's Go interface, NGN packet core network and media gateway.

Transfer the multimedia Explorer to the control function of the media gateway in the session layer. The above research only discusses the influence of the shortest circuit and the optimal route composed of network nodes on the network topology. In the power system, if the critical node only carries many standard services but does not undertake the main business, the importance of this node is not high. Even if this node fails, it will not cause too much shock to the entire grid. Therefore, it is necessary to evaluate each node's importance in the power network comprehensively. This project intends to build a multi-level node importance identification method that includes the transport, physical topology, and service layers to improve the identification accuracy of critical nodes in the power grid.

2. Identify secure access nodes that are ubiquitous on the network gateway. In the universal power Internet of Things, all kinds of information must pass through the network nodes. This project proposes a multi-source heterogeneous information fusion technology [5]. The use of multiple channels to achieve the transmission of various data is the most common. Usually, because each channel's service information processing requirements are different, it is necessary to analyze the access node entering the gateway and determine whether it is safe when transmitting information. This ensures the safe and reliable operation of the universal electrical IoT. Unlike traditional power grid architecture, the universal power grid gateway can provide secure access to all nodes. Intelligent sensing technology collects data from the power grid [6]. The specific power ubiquitous IoT data perception model is shown in Figure 2.1 (image cited in Frontiers in Energy Research, 2022, 10:918998).

3. Multi-level node importance identification method. This paper intends to establish a multi-level identification method of node importance. The importance of nodes at each level is merged to find the nodes with higher importance. The correlation analysis of the correlation nodes in each network level obtains the

reliability and essential measurement. Finally, the critical degree of each node is measured comprehensively. A power communication network composed of M nodes is established. It contains three layers: physical topology, transport, and service. $F_t(i)$ represents the importance of the node i on level t, where $t \in [1,3], i \in [1,M]$ represents its importance. As the $F_t(i)$ level increases, there are more critical nodes i on the t level, giving it a higher subordinate status [7]. Use n_{ti} to determine the membership degree of node i in hierarchy t, then:

$$n_{ti} = \frac{F_t(i) - \min(F_t)}{\max(F_t) - \min(F_t)}$$

After evaluating the critical indicators of a single node, each level of fundamental indicators is proposed to reflect the credibility of each level. Let σ_t represent the underlying metric credibility of level t, and let σ_t conform to the following equation:

$$\sum_{t=1}^{n} \sigma_t = 1$$

where n is the number of logical layers used in the power communication network, in the power system, the importance of power supply is the most direct reflection of power supply interruption to the state of the grid. Since the importance of each business varies greatly, the first consideration should be the level of service [8]. However, if the importance of services in the power communication network is similar or equal, it is necessary to master the corresponding services carried by each node. Therefore, the transport layer is the second consideration. In addition, network services can be placed later if they have the same bandwidth and importance. An adaption-based reliability index for essential measurement is presented to take full advantage of the importance of the three levels:

$$\begin{cases} \sigma_1 = 1 - e^{\delta_{\min} - \delta_{\max}/\delta_{\max}} \\ \sigma_2 = (1-\sigma_1)\left(1 - e^{\lambda_{\min} - \lambda_{\max}/\lambda_{\max}}\right) \\ \sigma_3 = (1-\sigma_1)\, e^{\lambda_{\min} - \lambda_{\max}/\lambda_{\max}} \\ \sigma_1 + \sigma_2 + \sigma_3 = 1 \end{cases}$$

$\delta_{\min}$ and $\delta_{\max}$ are the minimum and maximum importance levels at the service level. $\lambda_{\min}$ and $\lambda_{\max}$ are the minimum and maximum bandwidth of the network layer, respectively. If $\delta_{\max}$ is much larger than $\delta_{\min}$ then σ_1 is very close to 1 . The use of service-level metrics to verify network criticality is entirely correct. Conversely, if $\delta_{\max}$ is close to $\delta_{\min}$ then σ_1 is close to o. The method of service level verification of its critical degree is not highly reliable, so evaluating other levels highlights the reliability. When σ_1 is very close to o, if $\lambda_{\max}$ and $\lambda_{\min}$ are very different then σ_2 is very large. It shows reliable measurements in the transport layer, which can characterize the node's key. On the contrary, when $\lambda_{\max}$ approached $\lambda_{\min}$, it means that the critical degree of the association node is related to the size of the topological layer dimension.

In the multi-level node importance identification model, the measurement of nodes at each level includes two aspects: First, the geometric mean value of each node can be measured at each selected level. The second aspect is to measure the credibility of the indicators [9]. That is, the level of importance of the chosen level is the product of the level of distrust at the bottom of the non-chosen level. The metric for any x logical layer node i is defined as follows ($x \in [1,n], n$ is the total number of logical layers in the power communication network):

$$n_{\psi i} = \sqrt{\prod_{t \in \psi}^{x} n_{t\Omega}}$$

$n_{\psi i}$ measures node $i.\psi$ is the selected logical level. The credibility of the second measure is defined as follows:

$$Q_\psi = \prod_{t \in \psi}^{x} \sigma_t \times \prod_{\Omega \in \Theta}^{n-x} (1 - \sigma_\Omega), \psi \mathrm{I} \Theta = \phi$$

The formula Θ is the logical layer that is not selected. The measurement of a node i in the power communication network of formula (3.5) and (3.6) can be calculated as follows:

$$g_\psi(i) = n_{\psi i} \times Q_\psi$$

$g_\psi(i)$ is a measure of node i in a power communication network. The $2^n - 1$ scheme is adopted when the power grid contains n class logic. Let $G(i)$ be the critical degree of node i, determined by the sum of $g_\psi(i)$ in ψ. To obtain $G(i)$ value, binary array $\alpha, \alpha_t \in \{0, 1\}, t \in [1, n]$ is introduced in this paper. If $\alpha_t = 1$, select t layers from the set ψ. Q indicates that the t layer is unselected [10]. The above $G(i)$ can perform the following calculations:

$$G(i) = \sum_{[\alpha]\neq 0} \left[[\alpha] \sqrt{\prod_{\alpha_t=1}^{[\alpha]} n_{ti}} \times \prod_{\alpha_t=1}^{[\alpha]} \sigma_t \times \prod_{\alpha_t=0}^{n-[\alpha]} (1 - \sigma_\Omega) \right]$$

σ_t is based on t level measurement reliability; $[\alpha]$ is the number of 1 in series α. As $G(i)$ increases, there will be more critical nodes.

4. Access node identification technology of gateway. With the continuous development of the Internet of Things technology, its security issues have attracted more and more attention. A credible evaluation model oriented to user behavior is studied to provide reliable technical support for promoting the healthy development of the Internet of Things. Access nodes are divided into several levels based on an assessment of trustworthiness [11]. Each level of resources is stored in the corresponding security zone of the trust level to prevent hackers from stealing or cracking the high-performance service gateway. Observe the change in the trust level between users according to the interaction evaluation list between users so that users with high trust can interact with each other in different areas. This can improve the network's security performance and prevent data leakage in the power system. Use the A-Node control mode to re-identify nodes that do not meet the security requirements [12]. It is also excluded to reduce the possibility of low-performance nodes attacking high-performance nodes.

All-access nodes associated with the universal power grid access gateway have security risks such as viruses and trojans. A secure access node identification model is necessary to prevent malicious intrusion [13]. The preemptive loading method is adopted to remove the "hidden channel's security effectively." It promotes the whole network's operation and achieves the gateway's secure access requirement. Identifying the secure access nodes of the universal power grid gateway is a vital part of improving the security defense capability of the power grid and ensuring the safety level of the power grid operation.

Due to the network's large number of access nodes and diverse service requirements, it is difficult to grasp its security accurately. By analyzing the reliability of the access node, the network control model of the access node is established to realize the identification of the access node. To obtain the best access control results, it is necessary to organically integrate the functions of access node automatic update and access control [14]. A gateway access node control model based on access control is proposed in this paper. The primary security monitoring method is used to realize the security check of the access node. Implement authorization control for some nodes with low trust. The specific function design of the gateway access node control model is shown in Figure 4.1.

Analyzing the attached Figure 4.1 shows that in the ubiquitous Internet of Things, the core of network monitoring is the host's network behavior and the host's status, and the background database realizes the exchange of monitoring information. The method uses the monitoring background database and identifies the access nodes in the network by analyzing the confidence of access nodes. An access node identification model for defect detection is proposed [15]. For the access nodes that have completed the preliminary identification, the vulnerability detection of the network is started. The work module is divided into five parts. First, the vulnerability database is modeled. Then, a console panel was added for the user terminal device. Then, scan access nodes. Scan the currently active knowledge base. The vulnerability scanning process is shown in Figure 4.2.

During vulnerability detection, it is necessary to ensure that the credibility database of the access node can be updated in time and it can identify whether the access node has security risks. The nodes identified for the

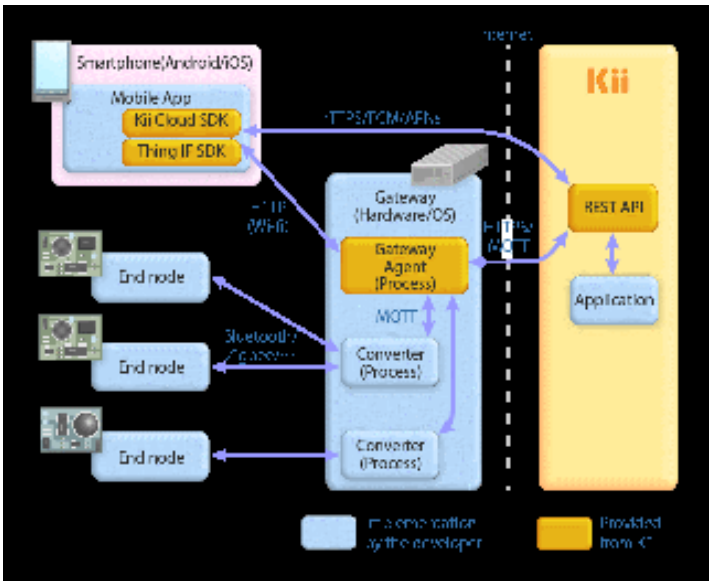

Fig. 4.1: *Functional design of Gateway Access Point Control Model.*

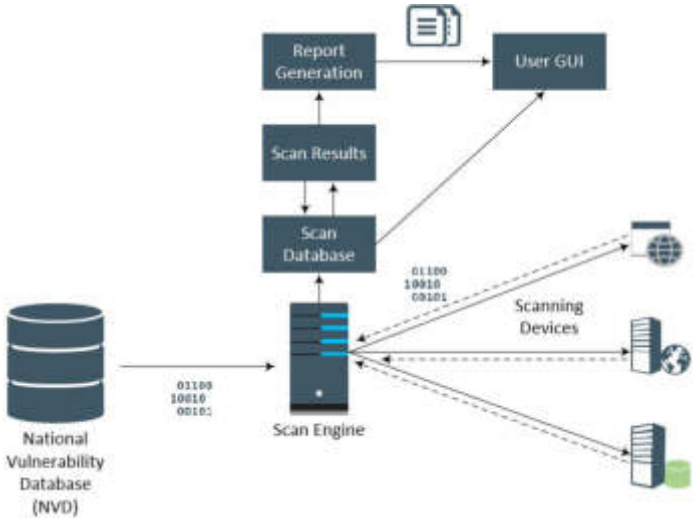

Fig. 4.2: *Vulnerability scanning process.*

first time are re-detected using the network vulnerability scanning technology [16]. The process is to process the access node according to the access request and determine its credibility change. After virus detection is complete, a detection report is sent to the background. Finally, the trusted access function is introduced to monitor the degree of trust of IoT network access nodes. By analyzing the behavior of access users, collect their business requirements. And according to the required information to generate the resolved results.

5. Simulation test. Simulation software is used to test the security of the proposed universal grid gateway. The universal power grid gateway is simulated by simulation software. The model is verified by adding different access nodes to the network. This project intends to adopt two common recognition patterns: network access recognition pattern based on near neighbor discovery and network access recognition model based on D-S

Table 4.1: *Comparison of precision under fixed parameters.*

Times	**This article model (%)**	**model 1 (%)**	**model 2 (%)**
1	97.46	73.04	54.88
2	89.36	74.43	49.33
3	89.94	71.20	51.05
4	98.86	73.94	61.08
5	92.74	77.83	54.23
6	93.49	78.64	53.53
7	91.58	76.17	53.09
8	99.32	76.90	50.70
9	93.78	73.14	52.07
10	91.18	72.85	57.93

evidence. The test is carried out under the same working conditions. According to the identification results, the applicable range of the model is determined [17]. The accuracy method is used to test the validity of access node identification. The nodes whose trustworthiness meets the entry access conditions are called secure nodes, while the opposite nodes are considered malicious. Precision, therefore, measures the percentage of secure nodes in each accessed node. So, the expression for precision is

$$P_{\text{precision}} = \frac{S}{Q}$$

where Q is the access node and S is the number of secure access nodes. In the simulation program, 1000 access nodes were set up, and ten experiments were carried out. Results for accuracy are shown in Table 5.1. Compared with the two conventional recognition methods, the proposed method can obtain better recognition results under the same parameters [18]. The accuracy of the model proposed in this paper is 93.77%, and the accuracy of the two classical prediction methods is 53.79% and 74.81%, which are 39.98% and 18.95% higher than the existing methods. Therefore, under the given parameter conditions, the model gateway constructed in this paper has a much better security access node identification effect.

On the premise that there are already 1000 access nodes, the number of nodes is gradually increased by 200. The influence of these three modes on the recognition of access nodes is shown in Figure 5.1. When the overall scale of the access network increases, its accuracy rate is maintained at a relatively stable level [19]. Its accuracy is significantly higher than that of the two conventional models. Its accuracy rate can be maintained at the level of 0.85-0.9. The accuracy of classical mode 1 is 0.65-0.7. Classic Mode 2 had the lowest accuracy at 0.5; therefore, when the number of networks increases, the accuracy of the proposed algorithm model can be increased by 20% and 38%, respectively.

The expansion rate of the network is 200 based on the original number of nodes. The results of the accuracy of these three methods changing over time are shown in Figure 5.2. When the number of malicious networks in the network increases, the search accuracy of this method also changes slightly but still maintains a relatively stable level. However, the accuracy of the two classical prediction methods has been dramatically reduced. The results show that the accuracy of model 1 is reduced from 0.7 to 0.43. 2 mode is reduced from 0.5 to 0.4. The universal network gateway secure access node identification method proposed in this project improves accuracy by 46% and 49%, respectively, when the number of malicious nodes increases to identify gateway secure nodes efficiently.

5. Conclusion. This project will establish a network-based gateway security access node screening model based on the universal electric power of the Internet of Things and conduct experimental verification. It is expected that through the research of this project, the extensive use of the Internet of Things in the power system will be promoted, and the operating status of the overall power system and the identification accuracy of network nodes will be improved. It lays an excellent theoretical and practical foundation for the innovative development of power systems. Although it can be seen from the experiment that the proposed recognition

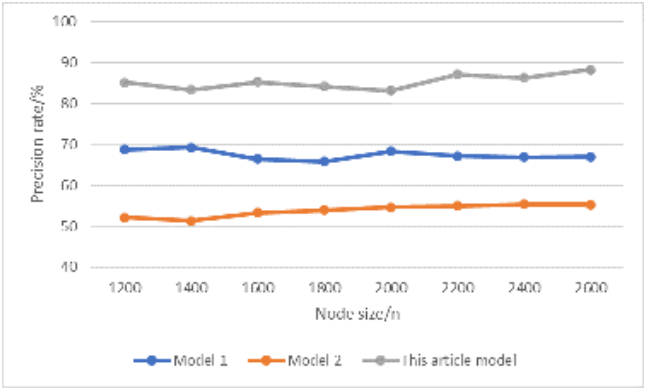

Fig. 4.3: *Comparison of accuracy when the overall node size increases.*

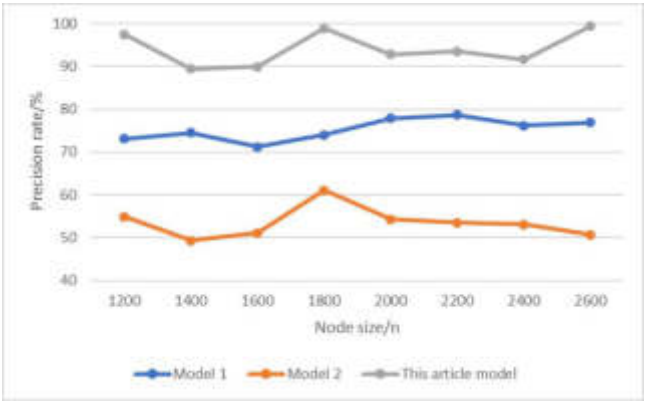

Fig. 4.4: *Comparison of accuracy in the state of malicious node size increase.*

method has achieved good results in practice, there are still many shortcomings which need to be further studied.

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MULTI-MEDIA IMAGE AND VIDEO OVERLAY TEXT EXTRACTION BASED ON BAYESIAN CLASSIFICATION ALGORITHM

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Abstract. With the continuous development of Internet technology, using multimedia for virtual application has become a new way. In this paper, by introducing the bayesian classification algorithm, multimedia graphics and video for carding, testing and implementation of edge image of fine processing, matching the corresponding text for quick positioning, at the same time use the filter for image and video background picture, further classification, distinguish between background and text, the extraction of superposition character. Simulation results show that the bayesian classification algorithm is effective and improves the efficiency and accuracy of image and video processing.

Key words: Video text tracking, Video text segmentation, Multimedia information retrieval, Bayesian classification algorithm

1. Introduction. With the continuous development of social economy, the presentation modes of multimedia have become rich and diversified [1,2]. However, people have increasingly high requirements for the quality of multimedia, so how to carry out effective text overlay and improve the readability of multimedia images and videos has become a key difficulty [3,4,5]. Superimposing text on multimedia images and videos makes it easier to read or view multimedia, and easier to spread it. In multimedia text extraction, often can be divided into two categories according to the segmentation method, one is the use of static multimedia images or video screenshots for detection and extraction; The other is to use dynamic, multi-frame multimedia images and videos for text detection [6,7,8]. Bayesian classification method has solid mathematical theoretical foundation and is a practical method for remote sensing image classification. However, Bayesian serial classification algorithms based on CPU are very time-consuming when processing larger images.

Since the text in the multimedia video is artificially added in the later stage, the general existence period is about 3 seconds in order to be recognizable [9,10]. Therefore, it is more important to extract text in multimedia images and videos, that is, to extract text effectively within the 3-second time range when text appears. To determine the importance of different key features extracted, some scholars build the corresponding weighting function to calculate the different weights of each feature to distinguish the contributions of different feature categories to improve the performance of the naive Bayes model. The industry has also made a lot of attempts, such as the use of text matching algorithm for detection, first multimedia detection, then according to the existing samples for monitoring, and finally achieve two-step text extraction; The similarity of gray value of characters is used for quantitative calculation and differentiation, so as to search the text area, and multiple multimedia videos or images are used for unified correction, so as to realize the text tracking. In addition, some scholars use the linear analysis method to enlarge the relevant text in multimedia to reduce the difficulty of recognition and improve the accuracy of recognition [11,12,13,14]. In recent years, many studies at home and abroad have used GPU in the fields of remote sensing image fusion, hybrid image decomposition and real-time target detection, to accelerate the processing of the algorithm and obtain efficient parallel computing power. The graphics processor is computing intensive, highly parallel, small size and high cost performance, which provides favorable conditions for solving data-intensive computing.

However, in general, these studies still have some limitations. For example, the computational amount is relatively complex, especially for the global search, which is time-consuming and laborious, and the efficiency cannot be improved. For a large number of multimedia backgrounds, it is still difficult to distinguish them well, especially for large similarity (small change in gray value), and quantitative filtering cannot be achieved [15].

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Data analysis and mining have become the focus of research in the field of text classification. The classification of naive Bayes algorithm is simple and efficient, but the classification effect of the algorithm reduces the effect of the algorithm. Therefore, most scholars have done extensive research and improvement to improve the classification performance of naive Bayes.

Therefore, for the static text in multimedia image and video, this paper introduces bayesian classification algorithm, fast retrieval is built with new ways of tracking, secondly, using the corresponding matching edge features, and then, according to quickly find mode fixing the beginning and end, according to the bayesian classification to get the edge of the chart to distinguish, improve text region segmentation effect, Aims to explore the superimposed text extraction of multimedia images and videos.

2. Bayesian classification algorithm. The bayesian classification algorithm is stable, simple and easy to learn, and has good effect. It is widely used in various text classification. In particular, the feature words in commodity description texts or critical texts are generally short and concentrated, which are suitable for adopting naive Bayesian model. Bayesian classification method is a kind of classification method based on statistical model, and assumes the condition between each object, its principle is based on a local prior probability, using the Bayesian formula to calculate the posterior probability, namely the area belongs to a certain class of probability, choose the maximum posterior probability as the area belongs to the class.

The model is obtained from the learning of historical data, and then the model is used to judge the classification of text[16-20]. Bayesian formula is one of the core algorithms of machine learning. The occurrence of any event is not completely accidental, and is often based on the occurrence of other events. The general conditional probability is to determine the effect from the cause, and the posterior probability is to determine the cause from the effect. The Bayes formula in probability theory is shown in Equation 2.1:

$$P(B|A) = \frac{P(B|A)P(B)}{P(A)} \tag{2.1}$$

Type of $P(B|A)$ as the prior probability, said the incident occurred on the basis of the event B: the probability P (B) as the A posteriori probability, is based on past experience and analysis of the probability of event B.

In text classification technology,B represents category and text feature. When $B = \{B_1, B_2, ..., B_n\}$ is a complete group, its sum is a complete set; $A = \{A_1, A_2, ..., A_m\}$ represents a set of text features. Convert Equation 2.1 to the following form:

$$P(B_i|A_1, A_2, ..., A_m) = \frac{P(B_i)\prod_{t=1}^{m} P(A_t|B_i)}{\sum_{j=1}^{n} P(B_j)\prod_{t=1}^{m} P(A_t|B_j)} \tag{2.2}$$

Naive Bayesian model is to choose the highest posterior probability. From Equation 2.2, the denominator is the same for all categories, so the numerator must be the largest in order to have the highest posteriori probability. The naive Bayesian model is described as:

$$B_{max} = argmax[P(B_x = B_i)\prod_{t=1}^{m} P(A_t|B_x = B_i)] \tag{2.3}$$

Equation 2.3 indicates to find a value such that the value of $P(B_i)\prod_{t=1}^{m} P(A_t|B_i)$ is the largest at $B_x = B_i$.

The problem of zero probability may exist in actual data training. The so-called zero probability problem is when the posterior probability is calculated, the component of an eigenvector never appears in the training set, and the whole posterior probability is calculated to be zero. In Equation 2.2, as long as one $P(A_t|B_i)$ in $\prod_{t=1}^{m} P(A_t|B_i)$ is 0, it will cause the whole formula to be 0. To solve this problem, you do Laplacian smoothing,

you add one to the vector that never happens, so Laplacian smoothing is also called plus one smoothing. It can be expressed by Equation 2.4 :

$$P(A_t|B_i) = \frac{|D_{A_t,B_i}| + 1}{|D_{B_t}| + N} \tag{2.4}$$

where $P(A_t|B_i)$ represents the probability that a feature A_t belongs to B_i ; D_{A_t,B_i} represents the occurrence times of A_t of a certain feature under B_i classification. D_{B_t} represents the number of samples belonging to the B_i classification, and N represents the number of values of the characteristic J A_t.

The more times the word appears in the corpus, the less important it is. Colloquial understanding is that a word is not common (low IDF), but it appears in the article of high frequency (high TF), then it is likely to be the key word of the article. Tf-idf algorithm is defined as follows:

$$TFIDF_{t,j} = TF_{t,j} * IDF_t \tag{2.5}$$

Equation 2.5 refers to the TF-IDF weighted value of a word in a file, where $TF_{t,j}$ is the number of times that a word c_t appears in the file d_j, which is represented by Equation 2.5; IDF_i is the inverse frequency of the word, indicated by the Equation 2.6.

$$TF_{t,j} = \frac{n_{t,j}}{\sum N_j} \tag{2.6}$$

where $n_{t,j}$ is the number of times the word c_t appears in the file, and N_j is the total number of words in the file.

$$IDF_t = log\frac{|D|}{|\{j : c_t \in d_j\}| + 1} \tag{2.7}$$

As previously analyzed, if a word does not appear in the file, the denominator will be 0, so Laplace smoothing is used to add 1. In general, the longer the word is, the more explicit the information it expresses. Therefore, tF-IDF is improved by considering the weight of word length W_i, W_i which is the ratio of the word length of this word to the longest length of feature words in the document, and Equation 2.8 is obtained.

$$TFIDF_{t,j} = TF_{t,j} * IDF_t * W_i = \frac{n_{t,j}}{\sum N_j} * log\frac{|D|}{|\{j : c_t \in d_j\}| + 1} * \frac{L_t}{L_{max}} \tag{2.8}$$

In the traditional Bayesian classification algorithm, all text feature vectors have the same status and are equally important for classification decision. However, in practice, there are some redundant or modal words, which are irrelevant to classification and are polluted by noise, which reduce the accuracy of classification. In view of this situation, tF-IDF feature weighting is used to improve the traditional Bayesian classification algorithm, and the following formula is obtained after taking logarithm:

$$B_{max} = argmax[P(B_x = B_i) \times \sum_{i=1}^{m}(logP(A_t|B_x = B_i) + logTFIDF_{t,j})] \tag{2.9}$$

3. Fast tracking and segmentation of video text with multi-frame edge information. In order to effectively extract the text of multimedia image and video overlay, this paper divides the Bayesian algorithm to better extract the multimedia overlay text, which is mainly divided into two aspects: tracking and detection. Specifically, it can be divided into three steps:

1. Multimedia image and video tracking, set a certain period of time, respectively calculate the Bayesian classification method;
2. Track the superimposed text. If the superimposed text is detected in the first step, the starting and ending position of the text will be tracked.
3. Multiple multimedia images and videos are fused so that more edge features can be extracted, which is conducive to classification and segmentation.

3.1. Text monitoring and verification. Calculate the overlapping area of the text region detected in the two frames of multimedia. Set RA_i as the ith text region of the reference frame, and RB_j as the region corresponding to the jth text region of the reference frame in the verification frame, then the overlap ratio S_o of the text region of the two frames is shown in Equation 3.1:

$$S_o = |RA_i \cap RB_j| / |RA_i| \tag{3.1}$$

Calculate the similarity S_e of the Edge Map of the corresponding text area of the two frames, which can be calculated by Equation 3.2 and Equation 3.3:

$$S_e = \frac{\sum\limits_{(x,y)\in RA_i \cap RB_j} (EM_t(x,y) \times EM_{t+10}(x,y))}{\sum\limits_{(x,y)\in RA_i \cap RB_j} EM_t(x,y)} \tag{3.2}$$

$$EM = \begin{cases} 1, \text{if pixel(x,y)is edge,} \\ 0, otherwise \end{cases} \tag{3.3}$$

The corresponding pixel brightness $L_{i-10}(x,y), ..., L_{i+10}(x,y)$ of 10 frames before and after the reference frame is fused as shown in Equation 3.4:

$$L_m(x,y) = min(L_{t-10}(x,y), ..., L_{t+10}(x,y)) \tag{3.4}$$

The number of edges generated after edge detection will be greatly reduced, so the false detection will be further reduced.

3.2. Fast tracking algorithm for static text. After monitoring and verifying the text object, a new text object is created. The text object is next tracked, and since there is no position change in the static text area, there is no need to search in adjacent frames. In this paper, a method based on binary search method is proposed to determine the start and end frames of text region. The similarity of edge bitmap is used as the matching feature. If the similarity (S_e) between the edge bitmap of the corresponding region in the current frame and the edge bitmap of the literal object is greater than a certain threshold (T_s), the match is considered successful. In the following pseudo-code form, the process of searching forward text area for the end frame is given. The algorithm of searching backward for the start frame only needs to reverse the search direction. The algorithm first searches for the lower bound of the end frame and then searches for the lower bound of the end frame.

① First set end ref + track step, last match = ref to ②;

② Calculate the edge graph of $Frame_{end}$ and S_e corresponding to the text area in Framere If , end = end + track step, last match = end, turn to ②; otherwise, step = end last match, turn to ③;

③ step step/2 If step < tolerance Output last match as the forward boundary of the text object. Otherwise, mid = last match + step, calculate the edge graph of frameid and S_e corresponding to the text area in frameref. If $S_e > T_s$, last match = mid, otherwise end = mid, turn to ③.

In the experiment, this paper takes the threshold T_s as 05, the step track step of searching the lower bound is 150 frames, and the minimum step tolerance of searching the lower bound is 1.

4. Simulation experiment and analysis.

4.1. Experimental data set and evaluation criteria. The simulation experiment mainly includes two parts: one is to detect the effectiveness of Bayesian classification algorithm, that is, to detect multiple images or videos of multimedia; The other is to detect the detection results of superimposed text, especially the matching results by using the classified edge features. According to the needs of simulation experiments, different multimedia images and videos (3) are selected as data.

For the extraction of superimposed text, the following indicators are mainly used:

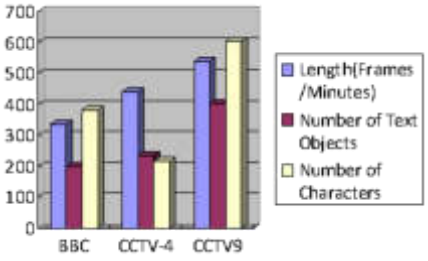

Fig. 4.1: Video type and text object (data sample)

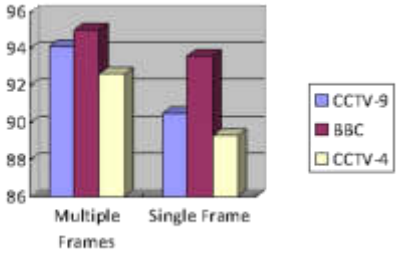

Fig. 4.2: Experimental results of text detection and tracking

(1) Recall: the ratio between the number of superimposed characters detected by the method and the actual number of characters.
(2) False alarm rate: that is, the ratio between the number of superimposed characters (false detection) detected by the method and the actual number of characters.

For the evaluation of characters, character recognition rate and accuracy are mainly used. The recognition rate is the ratio of the correct characters to the actual total number, and the accuracy is the ratio of the correct characters to the total number.

4.2. Text object detection and tracking algorithm experiment. The Bayesian classification algorithm is calculated and segmented for Figure 4.1. The specific results are shown in Figure 4.2. From the results, the text detection effect of multimedia multi frame image or video is much greater than that of single multimedia image. In addition, it can improve the accuracy of corresponding text positioning.

This paper compares the text calculated by Bayesian classification algorithm with the results of manual annotation and uses the corresponding results to calculate the error between them. Due to the effectiveness of Bayesian classification algorithm, the edge features provided are more accurate. Therefore, the error between them is very small, that is, the judgment accuracy of starting position and ending position is very high.

4.3. Experiment of multi frame text region enhancement and segmentation algorithm. On the basis of the above simulation experiment, continue to fuse multiple multimedia images or videos for superimposed text extraction of Bayesian classification algorithm. The results of the simulation experiment are shown in Figure 4.3. From the results, the recognition rate and accuracy extraction of superimposed text are significantly improved after the fusion of multiple multimedia images.

The Bayesian classification method is used to distinguish the background and superimposed text of multimedia images and videos, track and detect the superimposed text in the form of blocks, and segment the superimposed text and image according to the threshold method. Specifically, as shown in Figure 4.4, a certain threshold value is selected according to local or overall.

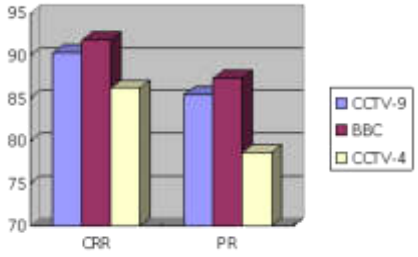

Fig. 4.3: Experimental results of text segmentation

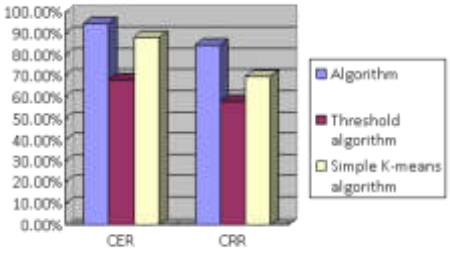

Fig. 4.4: Performance comparison of algorithms

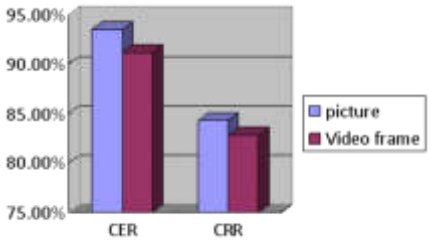

Fig. 4.5: Different image segmentation capabilities

Through the establishment of Bayesian classification method, the text is segmented accordingly. Among them, the text in multimedia image and video is divided into one kind and the other background is divided into one kind by Bayesian classification method. On this basis, clustering processing is carried out. However, it should be noted that if the background color of text is close to that of multimedia image and video, Further classification is needed. The recognition results are shown in Figure 4.5. Bayesian classification algorithm (CER) has high accuracy.

5. Conclusions. The Bayesian net is an important tool for processing uncertainty information, providing a way to represent causal information that has been successfully used in medical diagnosis, statistical decision making, expert systems, etc. With the continuous development of mobile Internet, people have higher and higher requirements for multimedia video and images. In order to better provide high-quality services, this paper attempts to introduce Bayesian classification algorithm. By combing the patterns of text extraction

superimposed on multimedia images and videos, the two-stage model is determined by using the correlation model, that is, the text is tracked first and then detected; Secondly, the search method is used to quickly locate the beginning and end of the text; Finally, the background is filtered according to the edge feature results obtained by Bayesian classification method to realize the effective extraction of superimposed text. Simulation results show that Bayesian classification algorithm is effective, can improve the effect and accuracy of segmentation, and lay a foundation for multimedia image and video processing. In further work, we can explore the possibility of applying other Bayesian net types to target extraction, and then better represent the relational constraints between target and environment.

Data Availability. The data used to support the findings of this study are available from the corresponding author upon request.

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SECURE ENCRYPTED TRANSMISSION OF NETWORK DATA IN CLOUD COMPUTING TECHNOLOGY ENVIRONMENT

ZHIFENG MIAO *AND CHUNPING ZHAO†

Abstract. In order to solve the problem of communication data theft in conventional network communication data transmission methods and ensure the security of network communication data transmission, it is necessary to design new network communication data security transmission methods based on cloud computing technology, formulate network communication data security transmission agreements, construct a network communication data security transmission model based on cloud computing technology, and design a network communication data security transmission scheme, implement secure transmission of network communication data. The experimental results show that after using the designed network communication data secure transmission method, the amount of stolen communication data is less than that of conventional methods. This proves that the designed network communication data secure transmission method has high transmission security, good transmission effect, and reliability, and can be used as a reference for subsequent network communication data encryption transmission.

Key words: Cloud computing technology, Network data security, Encrypted transmission, Resource scheduling

1. Introduction. With the popularization of cloud computing applications, the massive amount of enterprise and user data in the cloud has enormous asset value, attracting a large number of hackers to attack and steal. Various security vulnerabilities bring potential security threats, and new network attack methods are constantly being introduced [1]. The security forms faced by cloud computing environments are becoming increasingly complex. Intelligent protection measures need to be utilized, using industrial intelligence as the engine, based on expert knowledge bases, deep learning, and big data analysis, to deeply analyze internal and external threat intelligence data, providing intelligent perception, intelligent warning, intelligent decision-making, and intelligent response for the computing environment, as shown in Figure 1. Enhance the intelligence level of cloud computing system security protection to more quickly respond to complex and changing cloud computing security threats [2,3]. Cloud technology categorizes and solves database information on Internet technology to ensure the data transmission efficiency of various multimedia communication connection functions, and can provide real-time feedback in all data information running system software. A partition planning method is proposed based on the application characteristics of cloud computing technology. It is necessary to obtain authorization from the customer to ensure the construction of a data information connection security exit from the physical server to the network server. In addition, the entire process of data transmission is logically operated according to the original operating procedures, and each step of the data analysis method has corresponding operability. During data transmission, customers can manually operate and issue instructions. So as to achieve real-time changes in data information transmission. Secondly, enhance the characteristics. In terms of data transmission methods, the security performance of software systems is an important guarantee for all data transmission processes. Finally, detailed features [4]. For traditional computer devices, frame loss and other situations often occur when transmitting data, resulting in incomplete transmission of data information. And by applying cloud computing technology, further authorization can be granted based on the instructions of data information, ensuring accurate communication between customer commands and the workflow processing system generated by data information, making the data management process more logical and less susceptible to external influences. Regarding cloud technology, the establishment of virtual environments involves synchronously projecting data and information onto physical servers to ensure precise connection

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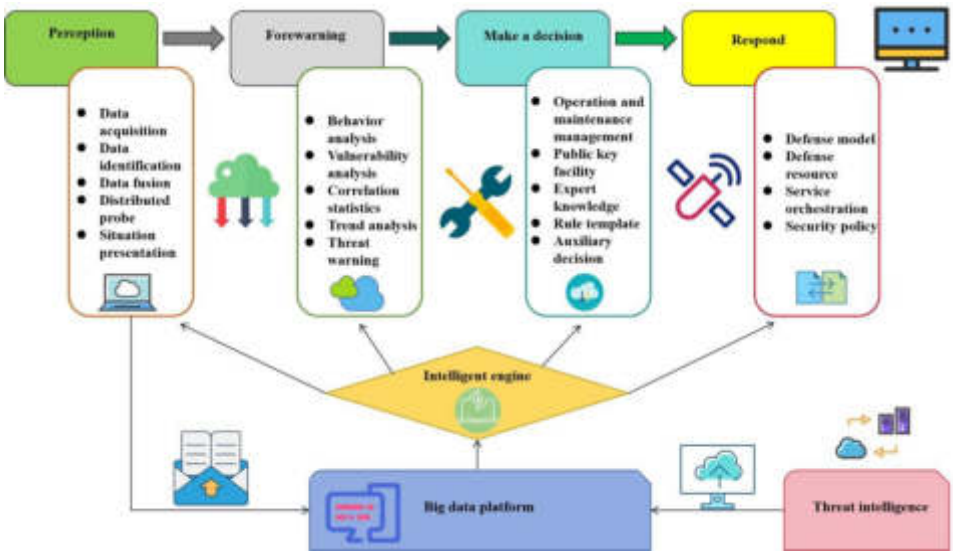

Fig. 1.1: Intelligent Cloud Security Defense

between communication workflows and intelligent terminal workflows [5]. However, in the first stage, expanding the technological nature of open internet data transmission will have a corresponding impact on network information security. Therefore, it is necessary to strengthen the stability and basic construction of Internet technology, effectively avoiding security risks caused by data information loss or theft.

2. Methods.

2.1. Develop secure transmission protocols for network communication data. The conventional network communication data transmission methods are susceptible to internal and external transmission attacks. Therefore, the network communication data security transmission method designed by the author has formulated an effective network communication data security transmission protocol based on the transmission information of each node in the network communication [6,7]. The protocol designed by the author uses the principle of information bundling to resist unknown information transmission theft attacks. In the process of network communication data transmission, there are often multiple transmission nodes, and the distribution of these transmission nodes is also very irregular, so they are easily captured during the data transmission process. Therefore, the author used the deployment resource method to pre determine the location of node aggregation in the communication transmission network, and determined the attack model that poses a threat to data security transmission at this time. The designed transmission protocol was divided into two different parts. TESLA was used to set a node shared clock, and a protocol verification system was constructed. The sender can verify the legitimacy of the initial data packet based on the transmission delay of the signal. At this time, it can be assumed that the identity of the initial data packet m is id, and its transmission format is shown in Equation 2.1 [8].

$$m = id, T_{int}, K_0, T_0, N, I_0, d \geqslant Sign(m), cert \tag{2.1}$$

In Equation 2.1, d represents the transmission delay of the secret key, Sign (m) represents the signature, cert represents the certificate distributed by the center, and $T_{int}, K_0, T_0, N, I_0$ represents the transmission authentication parameters. After the transmission starts, adjacent nodes will immediately send verification IDs to generate the location information of each data secure transmission node. At this time, nodes can be re planned and beacon grouping can be carried out, as shown in Equation 2.2 [9].

$$B_j = \{id, id_x, id_y, I_i, e_j, P(B_{j+1})\} \tag{2.2}$$

In Equation 2.2, id_x, id_y represents the location information of data transmission, I_t represents the transmission time interval, e_j represents the sleep group variable, $P(B_j + 1)$ represents the expected beacon group, and B_j represents the beacon group packet. The authentication delay within the network communication data secure transmission protocol developed by the author needs to be strictly calculated according to the hash function. Therefore, this delay is always in a changing state, consistent with the periodic relationship of network communication nodes. Therefore, based on the energy relationship of beacon changes, the attack location for the next communication data transmission can be predicted to achieve secure transmission. Research has shown that as time intervals increase, the secret keys within the established transmission protocol remain confidential and there are different beacon groups. In order to further improve the security of the protocol, the author conducted beacon location verification, first sending beacon packets by a neighboring node and then receiving them by the receiver. At this time, the security conditions of the protocol are shown in Eqaution 2.3.

$$[\frac{t_r - T_0}{T_{int}}] \leqslant I_t + d \tag{2.3}$$

In Equation 2.3, t_r represents the local receiving time, and T_{int} represents the actual receiving time. If the network communication data security transmission conditions at this time meet the above security conditions, it proves that the network communication data can be safely received, on the contrary, it proves that network communication data cannot be securely received and needs to be re grouped to verify the authenticity of the transmission in sequence until the transmission conditions meet the transmission conditions specified in the protocol [10]. This can improve the security of network communication data transmission and effectively reduce the number of information theft.

2.2. Building a secure transmission model for network communication data based on cloud computing technology . In the process of transmitting network communication data, it is necessary to continuously schedule communication data transmission resources and improve the reliability of network data transmission channels in real time. However, conventional network communication data security transmission methods do not have an effective resource scheduling security transmission model, which does not meet the reliability requirements of current network communication data transmission, therefore, the author has constructed an effective network communication data security transmission model based on cloud computing technology, further improving the effectiveness of network communication data transmission. The author combines the principles of virtual resource scheduling in cloud computing technology and designs a network communication data virtualization sampling model p, as shown in Equation 2.4.

$$p = x(t + q\delta t) - h(t + q\delta t) + \omega \tag{2.4}$$

In Equation 2.4, x represents the center reconstruction transmission data, t represents the reconstruction time, q represents the minimum dimension, δt represents the initial reconstruction time, h represents the cloud computing security function, and ω represents the weighting coefficient, this model can fully extract the transmission characteristics of network communication data, randomly allocate the features, and then input them into the cloud computing data resource analysis center for resource scheduling processing, at this point, the model can be used to complete network communication data sampling, and the sampled data can be stored in the cloud computing center resource library, which is then processed by the host system to complete the initial resource configuration. At this time, the cloud computing center resource library contains multiple limited datasets X, as shown in Equation 2.5 [11].

$$X = \{x_1, x_2, ..., x_n\} \tag{2.5}$$

In Equation 2.5, $x_1, x_2, ..., x_n$ represents the secure transmission data node, at this point, spatial action capture can be performed to obtain the initial features of the cloud computing center resource library and perform feature evolution. At this point, the evolution peak parameter needs to be calculated, and the calculation formula Y is shown in Equation 2.6.

$$Y = X(T + K) \sum_{t=1}^{n} h_i (N - 1)^r \tag{2.6}$$

In Equation 2.6, T represents the action capture time, K represents the cloud computing feature vector, hi represents the security matching parameter, N represents the sampling time delay, and r represents the number of sampling times, at this point, using this peak can determine the fitting relationship between network communication data and resources, and design a secure transmission model C for cloud computing data centers, as shown in Equation 2.7 [12].

$$C = XYf^{-j2\pi fk} \tag{2.7}$$

In Equation 2.7, f represents the normalized frequency, j represents the real-time traffic of the cloud computing center, and k represents the secure transmission constant. This model can recombine and decompose resources based on the nonlinear characteristics of network communication data transmission, identify data center resource information in real time, and improve the stability of the internal environment of network communication transmission, due to the transferability of network communication data, the transmission method designed by the author assigns relevant correlation rules within it, and combines the frequency of data output for feature description. The descriptive formula Q is shown in Equation 2.8 [13].

$$Ra_n e^{-j2\pi f} \tag{2.8}$$

In Equation 2.8, R represents the transmission matching function, an represents the center resource scheduling information $e^{-j2\pi f}$, and represents the cloud computing transmission coefficient. Based on the feature description, data transmission security optimization can be advanced, that is, three-dimensional reconstruction of the cloud computing center can be performed to obtain the network data security transmission iteration formula as shown in Equation 2.9.

$$W = \theta_1(k) - R[\phi(k)] \tag{2.9}$$

In Equation 2.9, $\theta_1(k)$ represents the resource information after iteration, $\phi(k)$ representing secure filtering resources, this iterative formula can be used to complete the secure iteration of network communication data, conduct comprehensive spectrum analysis, and obtain the resource transmission optimization scheduling set as shown in Equation 2.10.

$$A(t) = E + W\sqrt{a}B \tag{2.10}$$

In Equation 2.10, E represents the output spectrum vector, W represents the data transmission initialization parameter, a represents the oscillation amplitude, and B represents the correlation coefficient [14]. Using the resource transmission optimization scheduling set obtained above can ensure the network communication data transmission environment and improve the security of network communication data transmission.

2.3. Design a secure transmission plan for network communication data . The final step in achieving secure transmission of network communication data is to design a secure transmission scheme for network communication data[15]. Combining the secure transmission requirements of network communication data and existing data security transmission frameworks, the communication cost of the secure transmission scheme can be formulated, which aims to achieve autonomous and secure transmission of data, perform data flow authentication and encryption, design relevant WIA-PA node packets, and improve the security of the network communication scheme. The scheme designed by the author includes the HMAC-SM3 authentication part, which can be combined with the SM4 encryption algorithm for transmission initialization processing, and then send node authentication and key design identification to relevant communication data transmission nodes. Each node can use this identification to complete message authentication, send request messages to the gateway, and then the gateway performs reasonable verification to complete bidirectional transmission and response. In order to increase the controllability of the design scheme and avoid irregular attacks during data transmission, the CCM algorithm was set up in the early stage of data transmission, and a random number factor was introduced to effectively avoid random attacks and achieve secure transmission of network communication data.

The secure transmission scheme for network communication data designed by the author can ensure the authenticity of transmitted messages, that is, during the data exchange process, it can effectively authenticate

Table 3.1: Key length and transmission weight

Key length	Transmission weight	Key length	Transmission weight
RSA 16	0.17	ECC 16	0.18
RSA 32	0.46	ECC 32	0.54
RSA 64	0.14	ECC 64	0.43
RSA 128	0.1	ECC 128	0.02
RSA 256	0.09	ECC 256	0.02
RSA 512	0.06	ECC 512	0.04
RSA 1024	0.15	ECC 1024	0.06
RSA 2048	0.24	ECC 2048	0.15

the identities of the transmitting party and the sending party, improve the reliability of data exchange, timely use relevant processing parameters for verification, and minimize the impact of external attacks on the secure transmission of network communication data [16]. Ensuring data security and integrity, attackers cannot maliciously tamper with verification information, steal transmission information, update transmission keys in a timely manner, avoid information interception, improve the anti forgery of network communication data transmission, and enhance transmission reliability.

3. Results and Analysis . In order to verify the transmission security of the cloud computing technology-based network communication data secure transmission method designed by the author, the author compared it with conventional network communication data secure transmission methods and conducted experiments as follows.

3.1. Experimental preparation. In order to ensure the effectiveness of the experiment, the WIA-PA principle was adopted to ensure the reliability of the experiment. In addition, the ONS network security experimental platform was selected as the communication data secure transmission experimental platform. The experimental platform selected Pentium Dual 1.86G CPU with 56G memory and used Windows XP SP3 as the operating system, due to the large amount of network communication data involved, the experimental platform also added a 120G experimental hard drive and used JavaJDK 1.6.0_ 24 virtual machines completed the experiment, and the experimental platform mainly uses TA-ONS and AM OSCM as security mechanisms, uses MAC functions to reduce computational difficulty and reduce the number of operations, in addition, the number of communication mechanism interactions in the experiment is not fixed and has a certain correlation with actual secure transmission operations and queries. At this time, the RSA network communication data secure transmission experiment docking key can be formulated in combination with the above security mechanism parameters. The length and transmission weight of the key selected by the author are shown in Table 3.1, Figure 3.1, 3.2 [17].

As shown in Table 3.1, the security level of keys with different lengths varies, and there are certain differences in the length and transmission weight of the above keys. This proves that the selected transmission key meets the experimental requirements and can effectively reduce network data communication transmission security detection errors, the author selected a total of 126465 network communication transmission data for experiments, all of which met the requirements of SM3 communication transmission password grouping. In order to better fit the actual data transmission situation, the experimental platform selected by the author combined with the CCM experimental mode to design a virtual attack module, it contains a rich attack library that can simulate actual data theft situations and complete network communication data security transmission experiments. At present, there is a high cost in conducting network communication data security transmission experiments, which can easily generate high testing delays and is very detrimental to ensuring the accuracy of the experiments, therefore, before starting the experiment, it is necessary to first calculate the experimental delay to minimize its interference on the experiment. The average delay T calculation formula at this time is shown in Equation

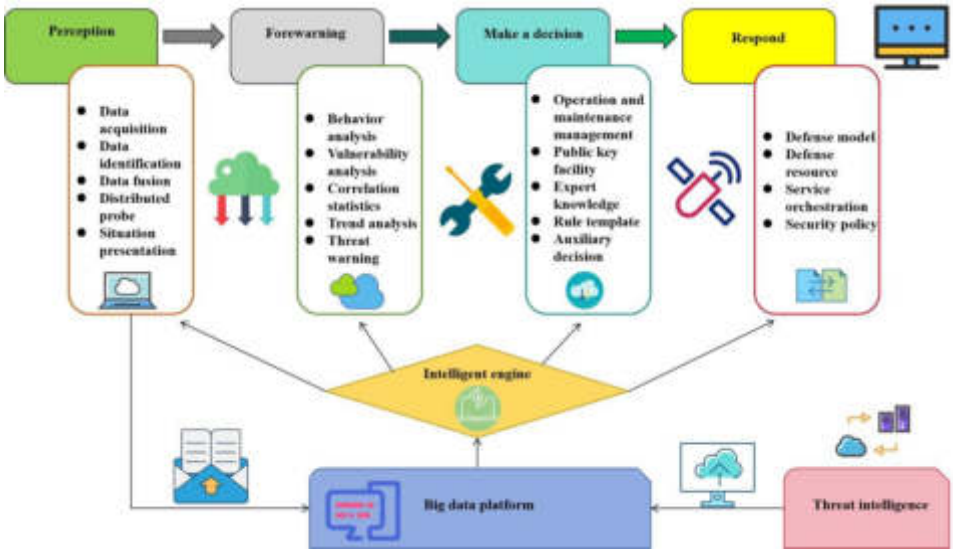

Fig. 3.1: Transmission Weight 1

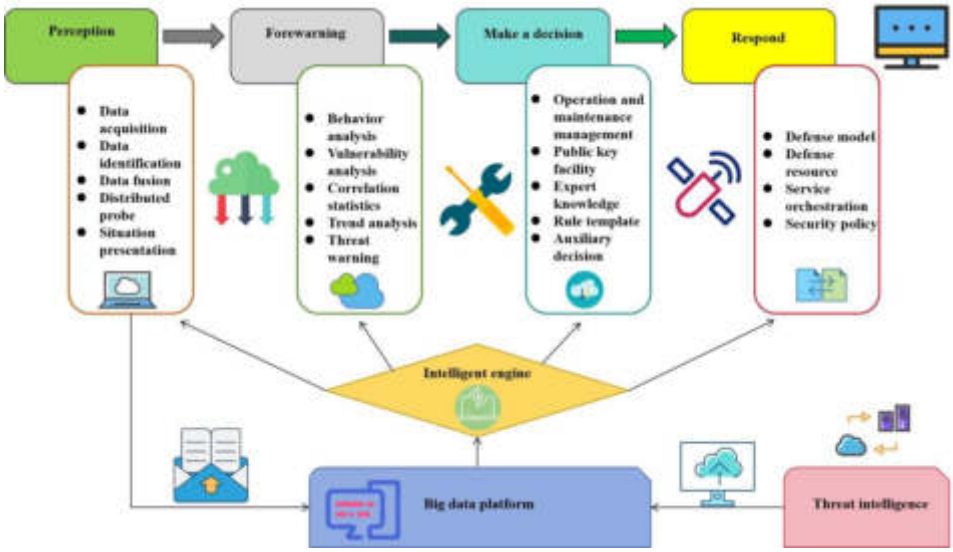

Fig. 3.2: Transmission Weight 2

3.1 [18].

$$T = \frac{\sum_{i=1}^{n} (t_0 - t_1)}{n} \tag{3.1}$$

In Equation 3.1, represents the number of cost calculations and represents the authentication time of each communication transmission node. At this point, the calculated average delay can be excluded, providing reference for subsequent network communication data security transmission experiments.

Table 3.2: Experimental Results

Number of data transmitted	The number of stolen data in the network communication data security transmission method based on cloud computing technology designed by the author	The number of data stolen from conventional network communication data transmission methods
59	0	2
136	0	5
248	0	13
365	1	15
496	1	18
598	1	26
638	1	43
781	2	69
1052	3	86

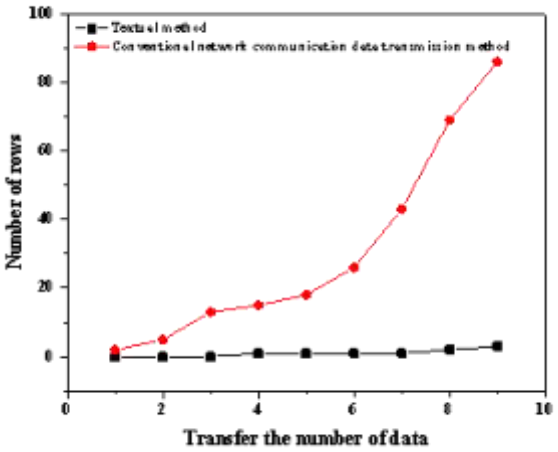

Fig. 3.3: Comparison of experimental results

3.2. Experimental Results . In the selected experimental platform, 126465 selected network communication transmission data were transmitted using the cloud computing technology based secure transmission method designed by the author and the conventional network communication data transmission method, in order to reduce experimental time, the author randomly selected several data points from 126465 for transmission experiments and detected the total number of data points stolen after transmission using two methods. The experimental results are shown in Tables 3.2 and figure 3.3 [19].

From Table 3.2 and Figure 3.3, it can be seen that the network communication data secure transmission method designed by the author based on cloud computing technology has fewer data stolen after transmission, while the conventional network communication data transmission method has more data stolen. This proves that the transmission effect of the designed network communication data secure transmission method is good and reliable [20].

4. Conclusion. The development of network technology has changed the transmission environment of wireless communication networks, and has also generated many security issues related to network communication data transmission. Research has shown that conventional network communication data transmission

methods are affected by network environment fluctuations, and their transmitted data is easily stolen, which does not meet the current reliability requirements of network communication data transmission, therefore, the author designed a new network communication data secure transmission method based on cloud computing technology and conducted experiments. The results showed that the designed network communication data secure transmission method had fewer data stolen after transmission, proving its high transmission security and certain application value. It can be used as a reference for subsequent communication network security maintenance.

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SPECKLE NOISE DETECTION AND REMOVING BY MACHINE LEARNING ALGORITHMS IN MULTISENSORY IMAGES FOR 5G TRANSMISSION

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Abstract. The multispectral satellite sensor images have multibands, which have some typical noise. There is difficult to detect this tipical noise with low resolution image. The satellite local or gloval pixel information and quantificationare degraded due to this noise. Many standard transformations and filtering operations are developed for detection and removing of non-gaussion noise, which are not given sophisticated results with existing methods. These statistical characteristics are applied to those samples to identify and quantify present tipical noise. The higher-order statistical based machine learning algorithm is developing to remove the speckle noise from satellite image. In this proposed algorithm, implemented the higher order statistical approache such as skewness, kurtosis based adaptive curvelet methods are implemented for the detection and suppression of speckle noise with retrieve of spectral and spectral values. The proposed algorithm preserves smooth and sharp details and maintains the tradeoff level in multispectral bands is suitable for advanced high speed 5G communication with the effective rate of transmission. The proposed results are verified with suitable statistical parameters such as PSNR,Entropy and ERGAS values.

Key words: Satellite image, Machine learning algorithm, spectral values, spatial values ,curvelet transform

1. Introduction. In Real-time Satellite images play a vital role in remote sensing applications such as regular land surface monitoring and atmospheric application without any physical contact. The satellite sensors capture the earth's information with various sensors and give the total collected information in the form of MS or HS images, which collect the information across the electromagnetic spectrum. The main intensity of this imaging is to perform the pixel operation in the image of the scene for identifying or classifying the object or detecting process [5]. The various type of scanners has captured the information for different resolutions. There are push broom, whisk broom and band sequential scanners for spatial and spectral scanning. The scanning process can be performed to get the acquired images of an area with different frequencies, which frequencies give different information based on the applications. Generally, there are 4 types of resolutions available for multispectral or hyper spectral resolutions such as spatial, spectral, temporal and radiometric resolutions [6,8]. The MS images used in various applications and the multiple bands increase the utilization of satellites [2]. The combination Red, Green and Blue channels(bands) formed as RGB or color image [3], but the MS images formed by multi- frequency levels of bands of satellite to form as satellite multispectral images. Two types of noise Gaussian and Non Gaussian noise are added into bands due to various reason.

For Additive noise,

$$S(i,j) = n(i,j) + h(i,j) \tag{1.1}$$

where $1 \leq i \leq M$, $1 \leq j \leq N$. For Multiplicative noise,

$$S(i,j) = n(i,j) \times h(i,j) \tag{1.2}$$

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where M and N represents the size of the original image, $S(i,j)$ denotes noise image, $n(i,j)$ represents input image and $h(i,j)$ denotes adding noise.

Equation 1.1 and equation 1.2 shows the process of noise adding to the image. The additive noise are easily remove from the images using suitable filters. The Multipicative noise are difficult to remove from images. Earlier, the medium filters are preferred for removing the salt & pepper noise. The speckle and salt&pepper noise are non-Gaussian noise. There is not suitable filters are implemented for non Gaussian noise [4]. The median filters are very useful for removing the salt & pepper noise, but it is limited only for S&P noise. This filter is not suitable for speckle filter noise. The high variance of S&P and speckle noise are difficult to identify the two components with noise samples [16].

2. Machine Learning Algorithm. Machine learning (ML) is the study of computer automatic data algorithms for data analysis, which is based on sample data or training data to make predictions without being programmed. These predictions are based on computational statistics. Machining learning is the science of the attainment of the systems to act without being articulately programmed [1]. It has shown an important role in reducing the complexity in data learning systems. In previous days, very difficult to handle large data analysis with human intervention, commercial software or high human intervention needed, also not obtained sophisticated results in the case of large data analysis. Machine learning is one of the best methods for automatically analyzing and studying data [18].The handling or study of these large data is very difficult to analyze due to the complexity of the information as well as the difficultyof storing that information with less storage. This data can be processed for advanced applications, it can be easy to handle this data in many fields such as transmission, storage and classification. Nowadays the 5G network handles processed bigdata with accurate results in image restoration, transmission and storage [17].

Bruno Carpentieri et.al suggested compression algorithms for digital images in social media networks. In this research explored a unified approach to compression and security algorithms for secure transmission [19]. B.Silpa et.al proposed encoding technique for video data with optimized deeplaearnign technique. This technique helpful for efficient transmission of video data in 5G networks, which is useful in current speed network application in real time [20]. Haidar AF et.al perform digital image compression technique with advanced level of Dsicreat cosine transformation techniques with less power consumption and delay. The proposed result also give better performance compare with other existing method interms of reduction, energy , delay and accuracy levels [21]. Xiangshu Xi et al perfom dimensional reduction method for multispectral satellite images to perform segmentation operation. In this method, the complexity is reduced and obtained better classification results compare with low resolution of input data. D. Amarsaikhan et.al suggested brovey algorithm for fusion operation to retrieve the low and high frequenc compoentns for compressed data. He improved Bayesian classification makes use of several features derived from a feature derivation procedure as well as spatial thresholds determined by local information. When the modified classification's outcome is contrasted with the outcomes of a conventional technique, it shows increased accuracy.Yand c at.al developed algorithm for pansharpening technique with HIS transformation. In this process, create a fused image with high spectral and spatial resolution by combining spectral information from a multi-spectral (MS) image with spatial information from a panchromatic (PAN) image. The intensity-hue-saturation (IHS) transform is the foundation of many pan-sharpening techniques, which may result in noticeable spectral distortion [25]. Y.Feng et.al Suggested ICA transformation method for dimensionality reduction, compare with PCA , the independent component analysis is given sophisticated result due to non-orthogonality principle, which is suitable for hyperspectral images [26].

3. Methodology. The Skewness and Kurtosis can be measured to determine whether the pixel distribution is not symmetrical. Kurtosis assesses the highest level of either a positive or negative side distribution's skewness. In image pixel distribution is balanced the skewed value is zero.The smoothing factor is developed with skew and kurtosis factors, which is helpful to separate the high variance of non-gaussian noise [11].

$$SF = 0.5 \times \left| \frac{min(kurt_f, kurt_{kf})}{max(kurt_f, kurt_{kf})} + \frac{min(skew_f, skew_{kf})}{max(skew_f, skew_{kf})} \right| \tag{3.1}$$

$kurt_f$, $skew_f$:Noise samples of Kurtosis and Skew, $kurt_{kf}$, $skew_{kf}$:Noise samples of Kurtosis and Skew.

In this proposed method, wiener, mode and minimum filters are employed to detect Gaussian noise, salt and pepper, and speckle. With the aid of established approaches, it is fairly simple to identify Gaussian noise. The Min filter is only used to separate samples of Gaussian noise. Gaussian samples are the only ones represented by the skewness coefficient's minimum value. Higher-order smoothing factors are used to identify the remaining non-Gaussian samples using wiener and mode filters. The image's matching noise sample is represented by the maximum value of the SF value. Here, we take into account three spatial filters: the Skewness coefficient, which is derived from lower order statistics, and the Smoothing factor (SF) value, which is based on higher order moments. For distinct symmetric noise (Gaussian noise), recognized with the lowest value of SK, the SK value is chosen. Exceptfor the Min filter for Gaussian noise, SK values for all filters are at their maximum levels.There are many standard spatial and spectral enhancement techniques are applied for multispectral images. The brovay transformation technique is one of the standard techniques for satellite images, but it is limited to fixed three bands only. HIS is color transformation technique, but it is limited in the case of maintaining the tradeoff levels between intensity and hue values. The PCA is fixed for the orthogonal dimensionality reduction technique [9,13]. The ICA is similar to PCA but non-orthogonality components exist in ICA [10]. After dimensional reduction, the total PC or IC bands are formed concerning frequency level components. All frequency bands have not existed in the same bands. Avoid these limitations by using the proposed method.The effort of a temporal domain grid to construct curvelets at each orientation and scute is the primary distinction between the two curvelet transform ways, namely the fast Fourier transform approach, which is an unequally spaced approach, and the wrapping ideology approach.

The curvelet Coefficient is specified as

$$C(r,\theta,S)=\sum_{0\le a}^{0\le b} F(a,b)\phi_{r,\theta,S}(a,b) \tag{3.2}$$

Where r: is decomposition or scale value, θ: is angle, S=(s_1, s_2): are parameter translation, C: Coefficient of Curvelet, ϕ(a,b) : Curvelet, and F(a,b): satellite image with size M $\times$ N.

The overcome of limitations of curvelet such as isotropic scaling and orientation problems can be solved by curvelet.Generally, the threshold can be calculated using the formula:

$$\delta=\sigma\sqrt{2ln(n)} \tag{3.3}$$

where σ: standard deviation of noise components, n: sample length.

The curvelet thresholding can be defined as

$$CT(r,\theta,S)=\begin{cases} sgn(C(r,\theta,S))[|C(r,\theta,S)|] & \text{if } |C(R,\theta,S)|\ge T \\ 0 & \text{if } |C(R,\theta,S)|\le T \end{cases} \tag{3.4}$$

Here, T: Threshold Level θ: is angle s=(s_1, s_2): are parameter translation, C: Coefficient of curvelet,

4. Proposed Method. For this research, the time series Landsat images are collected from www.usgs.gov website. Initially, all these images are perform the preprocessing technique for geometric and radiometric correctin. The dimensionality reduction technique such as Principle Component Analysis method is used for remove the redudennt information between bands, which are formed by converted into co-variance matrix and information is converted into Principle component values such as PC1, PC2, and PC3. The maximum information appears inform of intial three PC values [12]. These components are categorized into low to high-frequency values from initial PC to last Principal component image. The last components have high-frequency components, which contain masximum noise components [7].

Generally, the high frequency components consider as sudden changes such as edge, lines, dots etc. on that image. For satellite image, with this type object difficult to analyze the objects. So, separation of noise from this objects are mandatory. After Principal Component Analysis, the last principal component images are processed for separate the noise components for detection of noise. After detection of noise samples, apply adaptive threshold-based curvelet transform for removing the non-gaussian (Speckle) noise.

Proposed method Steps:

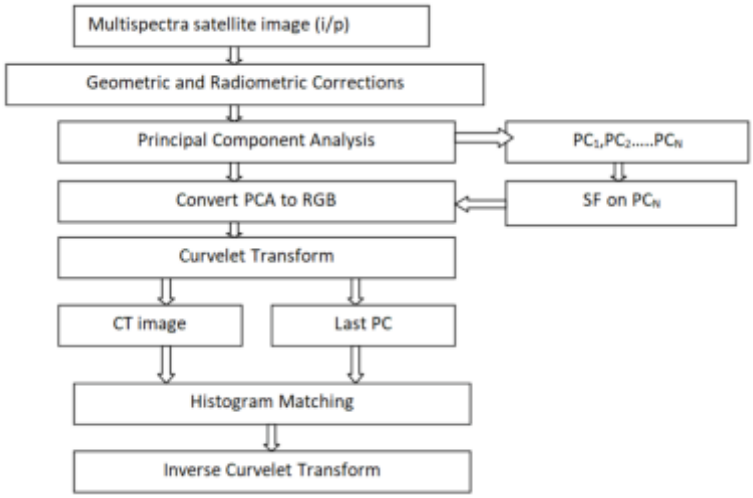
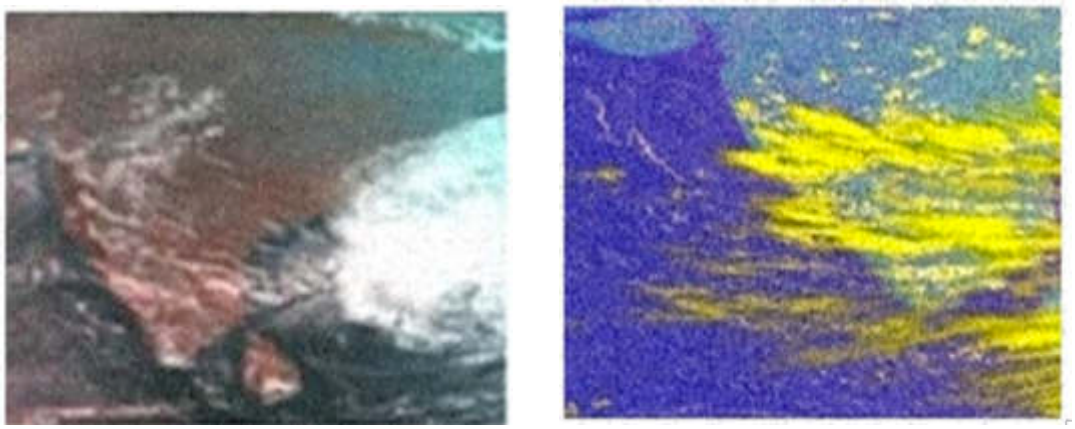


Fig. 4.1: Flow chart for proposed method

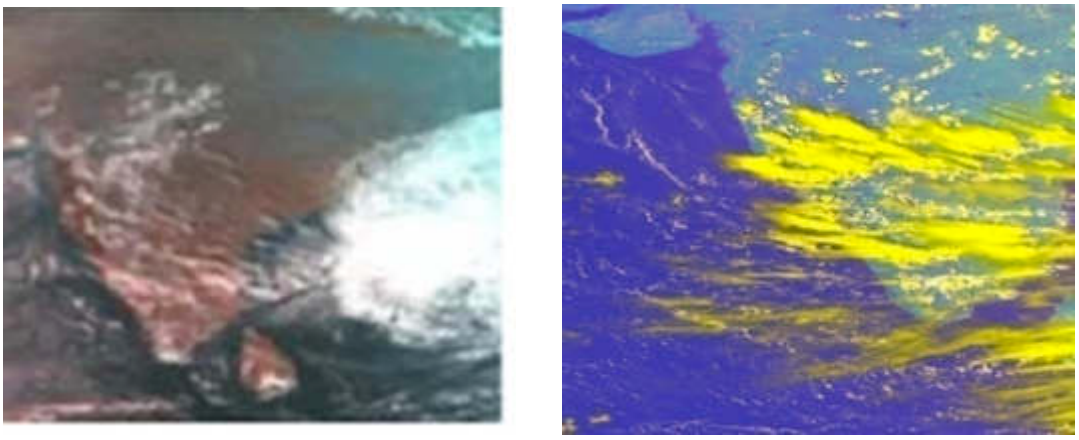


(a) NOAA-Multispectral image (Noise) (b) NOAA-Multispectral image (Noise)

Fig. 5.1: NOAA-Multispectral image

1. Collect satellite image from satellite receivers or usgs website.
2. To do preprocessing operations for geometric and radiometric corrections.
3. Perform dimensionality reduction technique (PCA Transform) to multispectral satellite images.
4. Choose low frequency PC components (PC1,PC2 & PC3) and high frequency Principal Component image (Last PC).
5. Apply HOS-based smoothing factor (SF) to noise samples for detection of type of noise.
6. Threshold-based curvelet for removing the typical noise(speckle) in multispectral images.
7. Apply inverse transform to retrieve the original image quality values.

5. Results and Discussion. Principal Component Analysis (PCA)/Independent component analysis (ICA) is used as an unsupervised, non-parametric statistical technique primarily used for dimensionality reduction in machine learning [12,15].



(a) Proposed output (NOAA image) (b) Proposed output (Landsat image)

Fig. 5.2: Proposed output

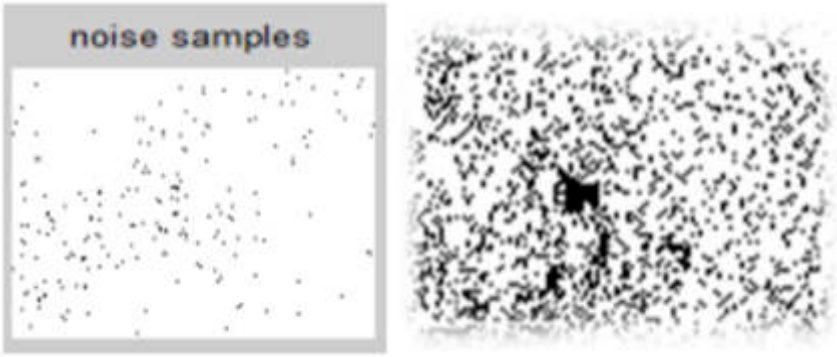


Fig. 5.3: Extracted Noise samples

Fig.5.1(a) and 5.1(b) represents the NOAAmultispectral satellite image, receive from HRPT receiver, This receiver located at Sri Venkateswara University,Tirupathi. Andhrapradesh. Fig. 5.1(b) is an example of of Landsat multispectral image collected from USGS webportal. These image influenced by noise. For satellite images, difficult to analze the pixel information with noise because each pixel represent some meters to kilometers distance based on pixel resolution of the spectrum band.

Fig 5.2(a) and Fig. 5.2(b) are proposed images, the noise components are detected by HOS based SF and noise removed by applying the proposed method dimensional reduction based curvelet transform. In this process the noise samples are tested with HOS based smoothing factor, these samples are shown in Fig. 5.3. Apply the higher order statiscs on that samples to identify the type of noise such as Gaussian or non gaussian.

Fig.5.3 shows extracted noise samples, which are obtained from the image subtraction process. In thisprocedure, the samples are separated from the non-Gaussian noise from the Gaussian scale. From Table 5.1 when salt and pepper noise is present, the SF value for the Mode filter is at its maximum, and when speckle noise is present, the SF value for the Wiener filter is at its maximum. Using these two elements, non-gaussian sounds are found, and Gaussian noise is recognized by selecting a minimum filter with a low SK value. The coefficient of Skewnes is used to distinguish Gaussian noise.

Table 5.1: Comparison HOS values of Noise samples for identification of type of noise

Image	Noise	SFM	SKM	SFW	SKW	SFW	SKW
1	Gaussian	1.6372	0.3014	0.0244	0.8959	0.5091	**0.2353**
	SP	**1.8247**	1.2494	0.2951	0.0858	1.0831	0.466
	Speckle	1.7236	0.2529	**1.3016**	0.4926	0.6403	0.407
2	Gaussian	1.6372	0.3014	0.0244	0.8959	1.494	**0.058**
	SP	**1.8247**	1.2494	**0.2951**	0.0858	1.8742	0.467
	Speckle	1.7236	0.2529	1.3016	0.4926	1.3941	0.4669
3	Gaussian	0.7824	0.4736	0.5401	1.0703	0.6314	**0.0942**
	SP	**1.5621**	1.2992	0.6421	0.2872	0.9475	0.6369
	Speckle	0.783	0.3497	**0.9782**	0.6582	0.7493	0.7811
4	Gaussian	0.7511	1.0373	0.517	0.681	0.5091	**0.2353**
	SP	**1.0776**	1.0373	0.5659	0.2587	1.0831	0.466
	Speckle	0.7909	1.2161	**0.9783**	0.4799	0.6403	0.407
5	Gaussian	0.2563	0.891	0.6326	0.5623	0.0043	**0.1216**
	SP	**0.7781**	1.3813	0.6877	0.1461	0.7962	0.4037
	Speckle	0.1413	0.7864	**0.7182**	0.4975	0.0591	0.2657

Table 5.2: Comparison of Results with different methods with proposed method

Transforms/ methods	PSNR	ERGAS	RASE	ENTROPY	Compression Ratio
HIS-Trans	33.24	14.94	49.31	6.71	32.35
Brovey	28.38	18.23	51.25	7.51	43.23
PCA	22.13	20.56	48.24	6.97	43.34
ICA	28.32	14.58	47.12	7.47	37.47
Proposed	**36.24**	**11.79**	**42.21**	**7.57**	**58.23**

Table 5.2 shows the comparison table. HIS transformation is one of the best techniques for improvement. it is suitable for enrich the spatial detail values. But not maitin the level between spatial and spectral values. Brovey transform is one of the best method for dimensionality reduction, the information is prespresent with less number of bits, but this transformation is limited to three-band multispectral images only. The PCA and ICA machine learning algorithms are suitable for dimensional reduction techniques, which is more beneficial than the standard compression technique. The main limitation of these dimensionality reduction methods are the original high frequency information is removied, which are appeared in last PC or IC values. The additional transformation technique is required using this transformations. [7][9].

Peak Signal to Noise Ratio(PSNR) is used to measure the quality of the compressed signal, this value is high for better compressed image. For multispectral images, Relative Dimensionless Global Error in Synthesis (ERGAS) is the one of the best parameter for measure the low frequency and multispectral image quality measure. The PSNR values are high and ERGAS values are low for proposed results. The entropy is used to measure the number of bits required to encode the image data. The proposed method maintin the minium entropy level, which represents the standard bits representation of the image. In image processing operation, the spectral values are important for perform the classification operations, if any spectral values are loss, it obtain misclassification results. This spectral quality is measured with Relative Average Spectral Error (RASE).The quality metric is low for proposed method, obtain the good spectral values compare withother methods. The compression ratio, compare with others, its maximum values. Overall, after the compression operation the spatial and spectral values are regained with good compression ratio for proposed image.

To obtain the loss components implement the dimensionality reduction and curvelet transformation algorithms, the color and bright values are normalize with the histogram matching technique. So, the low and high-frequency components are retrieved by using this proposed technique and values are measured the quality

metrics are measured with parameters Peak signal to value(PSNR), Error Relative Global Dimensional Synthesis(ERGAS) and Entropy values. The PSNR values are high and ERGAS is low for proposed images with good pixel quality and compression Ratio.

6. Conclusion and Future Scope. The multispectral / Hyperspectral satellite images are difficult to transfer in 5G network due to large data and complexity. The non-gaussion noise (speckle) are difficult to detect to apply for applying suitable filters. The HOS based dimensional reduction technique (Principal component analysis) and curvelet transformations are suitable for detect the speckle noise and filtering operations. Higher Order Statistical methods are implemented for the detection of the type of noise and adaptive threshold-based curvelet transforms to improve the spatial and spectral values. These Including these applications, the proposed algorithms are very applicable to medical, satellite and computer vision digital images also. These quality pictures are transmitted and stored within 5G network applications with less complexity and occupy less storage space.

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TASK-DEPENDENT SLICING WITH CONVOLUTIONAL NETWORK MODEL FOR HISTOPATHOLOGICAL IMAGE ANALYSIS

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Abstract. Due to its high rates of both mortality and morbidity, cancer stands as the primary cause of death globally. The examination of histopathological images plays a crucial role in the early prediction of cancer, relying on manual practices for each individual affected. However, this phase is prone to errors, time-consuming, and doesn't facilitate early-stage decision-making for pathologists. Despite significant advancements in computer-aided image processing, the analysis of histopathological morphology remains challenging due to the intricate nature of these images. Moreover, limited annotations restrict sample analysis. This work focuses on developing efficient deep-learning methods to analyze histopathological images by considering both global and local features. It involves the analysis of image patches and features to address issues related to image annotations. A unique task-specific slicing model, integrated with the convolutional network model (ts-CNN) is proposed. This framework aims to conduct patch-level feature examination and combine multiple samples to achieve the necessary outcomes for classification. The envisioned model aims to rectify inefficiencies present in various existing approaches. Using MATLAB 2020a, the proposed model was employed to classify cancer-based histopathological images, demonstrating superior predictive performance. It assisted pathologists in early cancer prediction with an accuracy of 98.2 % and aided in decision-making processes, offering promising results.

Key words: histopathological images, morphology, prediction, classification, and feature representation.

1. Introduction. Breast cancer (BC) is a highly prevalent form of cancer globally and is recognized as a significant contributor to mortality rates among women [1]. Histopathology images are the standard for diagnosing breast cancer [2]. Expert pathologists have previously employed powerful microscopes to examine tissue samples to diagnose tumours in cancer patients. Although this method is often used in clinical settings, it cannot be scaled up to clinical and translational research studies requiring many tissue specimens. It is a complex, time-consuming activity that requires expertise and is impacted by human characteristics like exhaustion and attention span. On the other hand, modern digital microscopy equipment can quickly take images of high-resolution tissue samples [3]. The implementation of computer-aided diagnosis (CAD) holds promise in enhancing tumour diagnosis and alleviating the workload of pathologists. BC histopathologic imaging analysis has drawn a lot of interest [4]. The automated differentiation of tumours into benign or malignant types utilizing sizable, openly accessible annotated datasets is the application of this technology that exhibits the most potential. Traditionally, relevant information from histopathology images has been extracted using techniques for feature extraction [5]. Several textural components that have been manually created, such as the Local Phase Quantization (LPQ), Grey-Level Co-Occurrence Matrix (GLCM), Local Binary Patterns (LBP), and Completed LBP (CLBP), have been utilized to distinguish between malignant and benign tumours. Jiang et al. [6] go into great detail about these characteristics. Sharma et al. [7] used Random Forest and Support Vector Machine (SVM), two well-liked classifiers to reach classification accuracy of 80 % to 85 %. Convolution neural networks (CNNs) have recently attained cutting-edge performance in image classification. Histopathology image processing in breast cancer research has employed classification methods that rely on data analysis. In their study, [8] employed the AlexNet deep learning model to distinguish between benign and malignant breast tumours based on pathology images. Compared to what was accomplished using a conventional machine learning algorithm, the categorization was 6 % better. With a recognition accuracy of 83 %, [9] classified breast pathology images without regard to magnification.

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Shortly after, other papers recommended how CNNs could be enhanced for even greater accuracy. DeCAF characteristics, for instance, were employed by [10] to identify breast cancer with a 90 % accuracy rate. Breast cancer histopathology image categorization could be made more precise by utilizing the BiCNN model, which is a deep convolutional neural network, according to [11]. Up to 97 % classification accuracy was produced by this model. A multi-classification technique for identifying breast cancer was created and has a similar accuracy of 93.2 % on a vast dataset. Convolutional neural networks (CNNs) outperformed feature-based classifiers built up manually in a study by Zhu et al. [12]. For binary classification, the CNNs attained accuracy rates ranging from 96.15 % to 98.33 %, while for multi-class classification, they achieved rates between 83.31 % and 88.23 %. The MuDeRN framework, developed by Mozejko et al. [13], has demonstrated high accuracy in classifying breast histopathology images, achieving correct classification rates of up to 98.52 % in binary classification. Additionally, convolutional neural networks (CNNs) have been successfully employed in various tasks, including identifying breast cancer mitosis and detecting metastases [14].

Deep learning has made remarkable advancements in image recognition; however, its implementation in the medical sector is limited due to its dependence on large-scale training datasets. Guo et al. [15] have highlighted the lack of substantial, annotated, and publicly available datasets as a significant obstacle to advancing novel histopathological image analysis tools. There has yet to be much research that aims to alleviate the load of annotating. Our earlier study [15] aimed to reduce the annotation required for histopathology image classification by applying deep domain adaptation to extract strong, domain-specific characteristics. As a result, a classification model of this type that was trained on a source domain with all labels present can be applied immediately to a target domain. The classification performance was still constrained for clinical applications, and an entirely supplementary dataset was necessary [15]. The suggested approach uses active learning, which doesn't need an additional dataset, to reduce complex manual labelling.

In this study, we anticipate a deep learning system to reduce expenses related to annotation for classifying breast cancer histopathology images. Our approach will assist pathologists in labelling data. The model is initially given a minimal dataset, which it proactively learns by choosing the unlabeled data to be categorized through a learning approach. The actively selected examples are used to refine this deep model gradually. The proposed task-dependent slicing model is integrated with the convolutional network model (ts-CNN) and operates two distinct techniques. The first method updates the model by picking samples for labelling those with the highest level features based on the provided examples. This approach to inquiry is frequently used in active learning and is regarded as a best practice. The classification strategy aims to enhance confidence by concurrently considering samples exhibiting high confidence and feature mapping. The idea indicates that new supervision should be included in addition to the categorization model's current rules. This study examines the effectiveness of slicing-based methods for BC histopathology image collections. We then analyze and draw conclusions based on comparing these different approaches. Our findings indicate that the slicing strategy can significantly reduce annotation costs for binary classification of BC histopathology images, achieving a reduction of up to 67 %. Similarly, the slicing-based technique demonstrates a potential decrease in annotation costs by up to 60 %. The proposed model helps the physicians to take decision during tough times and act as a Clinical Decision Support System (CDSS). It functions as the human machine interface system to deal with the emergency situation to treat the patients.

The work is drafted as follows: section 2 provides a broader analysis of diverse approaches. The methodology is elaborated in section 3. The numerical outcomes are provided in section 4, and the work is summarized in section 5.

2. Related works. The prognosis is improved, and the patient survival rate is increased to 50 % due to early and precise identification. Correctly classifying each cancer stage is necessary to diagnose BrC [16]. In contrast to previous BrC testing methods, different medical imaging is frequently employed to analyze BrC effectively [17]. Breast cancer (BrC) is commonly detected through various medical imaging techniques such as sonograms, MRIs, histopathology images, mammography, and magnetic resonance imaging (MRI). For a precise BrC diagnosis, a pathologist's expertise and topic knowledge are needed. Without them, misdiagnosis happens frequently, especially when BrC is still in its early phases [17]. The early detection of BrC is vital, though. A lot of computer-aided diagnosis (CAD) tools are employed by doctors to help them detect breast cancer early on in mammograms. It is a simple approach for early BrC diagnosis that is quick, dependable, and economical

[19]. The accuracy of BrC identification has increased by more than 20 % thanks to CAD developments during the past ten years. The mortality rate is reduced from 30 % to 70 % thanks to this method, which aids doctors and radiologists in identifying anomalies utilizing various imaging modalities [20].

By merging data from several domains, including pathology, radiology, pharmacology, cardiology, genomics, and cancer, deep learning (DL) based CAD systems have exhibited substantial breakthroughs [20] in the medical field. For the diagnosis and prognosis of illnesses, including cancer, DL has become a well-known machine learning-based technique. Since machine learning-based technologies for cancer detection have been continuously improving in recent years, it has become clear that DL is adequate in both cancer prognosis and prediction [20]. Deep learning (DL) has demonstrated superior diagnostic accuracy in breast cancer imaging compared to mammograms, ultrasounds, and digital breast tomosynthesis (DBT). This increased accuracy has led to the adoption of DL in clinical breast cancer (BrC) treatment [21]. Numerous studies on using deep learning in BrC have been published recently. These studies highlight the effectiveness of deep-learning algorithms in addressing the challenges and intricacies associated with automated BrC diagnosis. BrC classification has been the subject of numerous review studies, but few of them have been able to offer unambiguous guidance for future researchers [22]. Although these papers provided an excellent literature review on BrC, they could have covered more topics related to deep learning. The existing literature on BrC has predominantly concentrated on traditional machine learning (ML) methods and generic artificial neural networks (ANNs), with an emphasis on feature extraction for diagnostic purposes [23]. However, more attention should be given to newer deep learning architectures such as extreme learning machines (ELMs) and generative adversarial networks (GANs) in the context of BrC diagnostics. Additionally, previous review papers have yet to comprehensively evaluate the strengths and weaknesses of earlier studies [24], resulting in a lack of clarity in their analysis of deep learning-based techniques. This paper presents a comprehensive examination of recent advancements in the categorization of breast cancer (BrC) images through the utilization of deep learning in computer-aided diagnosis (CAD) [25]. The analysis encompasses six distinct perspectives: the model architecture employed for diagnosis, the datasets utilized, image pre-processing techniques, the strategy employed for breast cancer imaging, the metrics employed for evaluating performance, and potential avenues for future research. These perspectives are used to address the study's limitations [26].

The goal values are adjusted using back-propagation, an unsupervised learning technique, via auto-encoder. The input, decoding, and hidden layers are the three layers that make up a neural network. Using an auto-encoder, the input is transformed into the hidden layer. The decoder then reconstructs the input from hidden layer's starting point. There are four main kinds of auto-encoders: the contractive auto-encoder (CAE), the variational AE, the sparse AE and the denoising AE [27]. A denoising version of the stacked auto-encoder is the stacked denoising AE. Using AE, we benefit from data's reduced dimensionality. Hyper-parameter tuning, processing time, data and model validation are all required for auto=encoder training. Although auto-encoder and principle component analyses (PCA) are relatively similar, PCA is less versatile than an auto-encoder. An auto-encoder can carry out both linear and non-linear transformations, whereas PCA is limited to performing solely linear transformations [28].

Given the significance of the convolutional neural network (CNN) in classifying breast cancer, it is imperative to examine this computational model comprehensively. In earlier works, CNNs were more frequently used to create a reliable cancer classification model. CNNs function well with images and are used with several imaging modalities. To train a CNN, however, a lot of images are required. With a small number of images, good performance is challenging to accomplish. Furthermore, because labelled datasets in medical imaging are expensive to generate, finding appropriate training data is difficult. CNN, however, has a lot of benefits. A ConvNet needs substantially less pre-processing than other classification techniques. A single CNN architecture combines feature extraction and classification as a whole. Finally, it is immune to local geometric distortions and visual noise. To facilitate the extraction of essential features from medical images and subsequently conduct breast cancer classification, researchers have employed convolutional neural networks (CNNs) [28]. Histolopathologic image analysis plays a pivotal role in cancer diagnosis, wherein histopathologists visually scrutinize cell shapes and tissue distributions to assess irregularities. Their evaluation involves determining whether specific tissue regions exhibit signs of cancer and gauging the degree of malignancy present in these areas. The proposed model helps in predicting the cancer using CDSS, i.e. human machine interface system effectively.

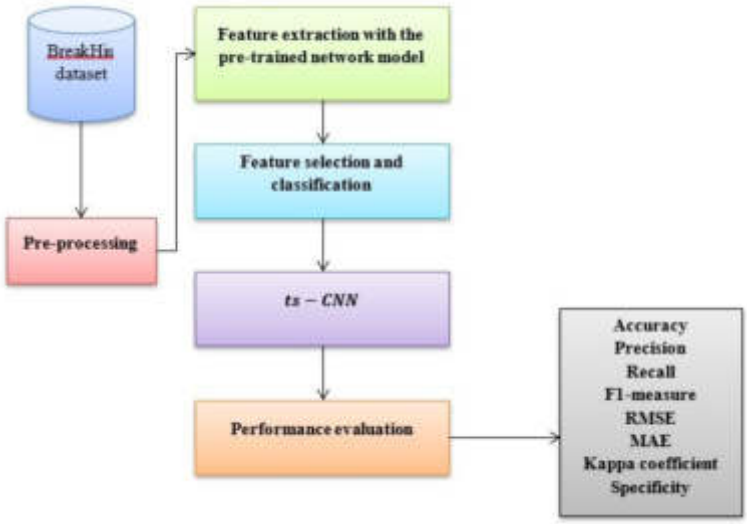

Fig. 3.1: Block diagram

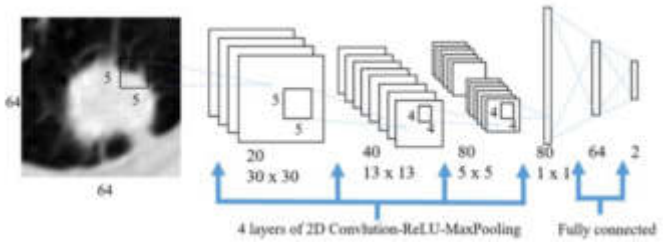

Fig. 3.2: Task-independent slicing CNN

3. Methodology. Fig 3.1 depicts the block of the anticipated model where the samples are taken BreakHis dataset where pre-processing performed to normalize the samples. The features are extracted and fed to the classifier (ts-CNN) where the performance is evaluated with various metrics like accuracy, precision, recall and so on. The convolutional network model (ts-CNN) is merged with the task-dependent slicing model. This study describes a technique for categorizing histological images of breast cancer employing only global labels. In this approach, transfer learning trains a pre-existing network to extract patch features. The novelty of the proposed model is its efficiency to access the classification accuracy using the task-based slicing model. The convolutional network is designed to differentiate the cancer images based on the class labels. The proposed model establishes better testing outcomes from the slicing model. It is more significant as the proposed model has to differentiate the image malignancy and benign regions to offer better medical prediction. Owing to the constraint accessibility of labelled histological breast cancer images, it is necessary to perform task-slicing. The image-level labels used to label the datasets allow for the application of MIL to choose the discriminative patch features. A combination of positive and negative examples is selected to generate an image-level feature. As seen in Fig 3.1, the proposed approach is broken down into four key elements. The necessary feature at the patch level was extracted in the first step. These patch-level features are combined to describe the image-level feature comprehensively. The final whole slide image (WSI) feature is created by selecting the discriminative characteristics at the end. Finally, abnormal and standard images of breast cancer histology are distinguished. Here, a breast histological image with tumours or cancer is used to signify an aberrant histopathological image.

3.1. Feature extraction with ResNet50. Even though a CNN is capable of classifying images on its own, it is unfeasible to use CNN to identify histopathology images with more than 100,000*100,000 pixels directly. The histopathology images, however, will lose too much information if they are resized to fit on a CNN. Given these considerations, the histological image of breast cancer is divided into smaller sections, referred to as patches, and subsequently magnified to a resolution of (224* 224) pixels. Additionally, patches with a background area percentage of more than 50 % are eliminated. The complex features of breast cancer histology images are difficult for both shallow and deep networks to handle. The complex clinical variables found in breast cancer histopathology images cannot be learned or matched by a deep neural network. We have chosen to use ResNet, a neural network architecture that facilitates training and generates good results. This is due to the lack of training data in histology and the benefits of residual learning through shortcut connections. ResNet-50 is used to process every patch taken from a whole histopathological image of breast cancer. The ResNet-50 model is initially trained using ImageNet dataset consists of 3.2 million high-resolution images. The last convolution layer provides the attributes of the patches. These attributes, referred to as P, are consistently represented as 2048*1 matrix. The fixed size of the input patches in the CNN which are always (224*224) pixels.

Aggregating local features extracted from patch-level feature vectors generates an image-level feature vector. This approach has been found to enhance the accuracy of classifying breast cancer histopathology images when relying solely on global labels. Max pooling, p-norm pooling, mean pooling and other popular methods can all be used to conduct local feature aggregation. Selecting the maximum pixel value within patch as representative value for feature aggregation is commonly called "max pooling" in the context of feature aggregation. In contrast, mean pooling calculates the aggregated feature value by determining the average pixel value within a patch. On the other hand, P-norm pooling retains valuable information from the patches while condensing the signal obtained from multiple patches. P-norm pooling was used in this experiment to identify the aggregated feature vectors. The following is an example of an aggregated feature:

$$f_p(v) = (\frac{1}{N}\sum_{i=1}^{N} v_j^p)^{\frac{1}{N}} \tag{3.1}$$

The present investigation also employed the feature vector of the i^th patch, represented as v_i^p and the overall count of patches in the histopathological image denoted as N. Here, P=3 was used in the investigation, specifically 3-norm pooling.

4. Feature selection. This study obtained image-level feature descriptors using the multiple features learning technique, which resembles previous works. This technique was used to extract more discriminative features while minimizing the presence of redundant or irrelevant features for classification. Instead of using image-level features readily derived from patch-level features, limited set of meticulously chosen and representative characteristics were employed to classify breast cancer pathology images. Histological images of breast cancer can be quickly and inexpensively described. The selected characteristic is derived from the combined features rather than the labels assigned to the patches to differentiate between the affected and healthy breast tissue sections. Here, the histological image of the breast tissue is viewed as a bag containing numerous examples, particularly the patches that have been removed from it. A patch is considered a negative instance of breast cancer detection if it has no breast cancer tissue. A patch incorporating breast malignant tissue, on the other hand, is thought to be a positive instance. At least one positive occurrence in a histopathological picture indicates an abnormal condition, while the absence of any positive instances suggests a normal state. Using this approach, we selected specific features from the instances and arranged them to derive the image-level feature. It was established how many top or bottom aspects of the cases were chosen as K. Since the available breast histological training images for breast cancer histopathology comprise typical regions and complex clinical features, the final features were selected by choosing the top and bottom K pixels. The histopathological image's feature vector, designated as $f_p(v)$, was initially sorted according to the pixels. The sorted vector is presented in the following written form:

$$f_{sort} = (v_1^{'}, v_2^{'}, ..., v_p^{'}) \tag{4.1}$$

In this method, the dimensions of the vector f_p^v are represented by P = 2048. The image-level vector f_{diff} is created by combining top-K and bottom-K pixels of the sorted f as stated in Eq. (4.1). This approach effectively utilizes both the top regions, which indicate positive cases related to cancer and bottom regions which show negative instances related to cancer.

5. Classification using ts-CNN. In breast histopathology image classification, image-level features are obtained through a series of steps, including selection, feature extraction, and patch extraction. By selecting K highest and lowest pixels from sorted vectors where the input feature vectors for classifier are generated. These vectors are then transformed into image-level characteristics with dimensions of 2*K, as illustrated in Fig 3.2. In our study, we employed a multilayer perceptron as the ultimate classifier to investigate the interplay between the upper and lower pixel values more comprehensively, despite the satisfactory performance of a standalone CNN classifier. Fig 3.2 shows the multilayer perceptron's architectural layout. Our research used a multilayer perceptron with two ultimately linked layers and 200 and 100 neurons each. ReLU was used as the activation function. A two-neuron output layer was used to determine if the input breast histopathological images were normal or abnormal to binary classify breast cancer histological images.

6. Network training. In our experiments, we used substantial regularization and data augmentation to avoid over-fitting caused by insufficient training photos. In the initial layers of the multilayer perceptron, we applied L2-regularization and dropout at rates of 0.5. The suggested architecture runs more effectively with the default Adam optimizer despite recent improvements in optimizers to increase the effectiveness of deep networks. In this study, the Adam optimizer was employed to minimize the binary cross-entropy loss, utilizing a batch size 24 and a learning rate of 0.001. The classification model was developed using the MATLAB 2020a framework, which is an open-source platform. A learning model was constructed to enhance the accuracy of classifying breast histopathology image data, each with distinct weights. The projected outcome for a histology image was determined by averaging predictions generated by E models with E set to 10. The proposed ts-CNN is trained in 70 % samples where the prediction accuracy with these samples are higher, i.e. 98.2 % where the testing is done with remaining 30 % samples. The training process consumes 1000s which is optimal compared to other approaches.

7. Numerical results and discussion.

7.1. Dataset acquisition. BreaKHis, a sizable, publicly accessible, and annotated dataset that includes histopathology images of breast cancer (BC), was used to evaluate the proposed system. This dataset encompasses 7,909 microscopic images, including 24 images of benign tissue and 58 images of malignant tissue. The P & D laboratory in Brazil collected images from 82 patients. Each patient has many histopathological images collected and given the same labels as the patients. Breast tissue biopsy slides that have undergone a conventional fixation, dehydration, embedding, and trimming technique are used to create image samples. Hematoxylin and eosin (H & E) staining introduces colour to the slides. In particular, (40X,100X,200X,and 400X) are prominent magnifications used to capture many of the images in the collection. These magnifications are equivalent to the corresponding objective lens magnifications of 4X,10X,20X,and 40X. The four magnifications' respective effective pixel sizes are 0.49µm, 0.2µm, 0.1µm, and 0.05µm. 2,480 normal images and 5,429 malignant ones are included in the collection. Each image has been encoded using three channel RGB format with 8bit depth for every channel and measures 700 by 460 pixels in size. The PNG file format is used to store all images. The images are labelled by pathologists with labels like benign and malignant.

7.2. Execution. The MATLAB 2020a framework is used to put the suggested method into practice. The ts-CNN architecture is the foundation of the deep model; a pre-trained network was trained on the provided dataset. The server has an NVIDIA GeForce GTX 1080Ti GPU and Intel 3.6 GHz CPU. BreaKHis dataset is divided into two different sets: a testing set called B _test and a training sample pool called B _pool. These sets do not overlap. Before training, it is ensured that the malignant and benign samples in the Btest are balanced. Then, B _pool receives the remaining samples. Rotational and symmetric data augmentation techniques are employed in the training samples to balance imbalance malignant and benign samples in B _pool. The parameters for B _pool and B _test are the same as in [30], with B _pool/B _test remaining at 70 %/30 %. Table 7.1 displays the distribution of augmented datasets. The task-dependent slicing model with

Table 7.1: Statistical distribution

Factors	Benign	Malignant	Total
4X	625	1370	1995
100X	644	1437	2081
200X	623	1390	2013
400X	588	1232	1820
Samples	024	0058	0082

the convolutional network model (ts-CNN) architecture was selected for our research due to its advantageous combination of network depth and convergence speed. Before inputting the images into the neural network, they are resized to a dimension of 227*227 pixels. The convolutional neural network's W parameters are updated using the Adam optimizer. When the network is trained, the learning rate is 105. The average of five experiments produced the findings provided in this study. The parameters W are estimated using the samples and matching labels (training set) in data-driven methods known as ts-CNN. The parameters are then utilized to categorize testing data after training. The parameters are adjusted even more precisely if more data is generated.

7.3. Metrics. The suggested methods are assessed on a pair of levels. An image is initially classified as "benign" or "malignant" using a binary classification technique at image level. The classification accuracy serves as validation measure because the distribution of categories at the image level is balanced. According to this definition, this accuracy:

$$Accuracy = \frac{N_c}{N_{im}}(image - level) \tag{7.1}$$

When classifying images, the variables N_c and N_{im} represent the total classified images (correctly) and total images (dataset), respectively.

Subsequently, patient-level classification, evaluates the precision of recognizing images for each distinct patient. The factors N_p, N_{im}^p and N_c^p govern this assessment. The three numbers N_p, N_{im}^p and N_c^p represent the total count of pictures successfully categorized for patients p. N_p indicates the overall number of patients.

$$Accuracy = \frac{\sum_{i=1}^{N_p} \frac{N_c^p}{N_{im}^p}}{N_p}(Patient \quad level) \tag{7.2}$$

The parameter selection approach's efficacy was assessed by examining its classification performance on the validation dataset. Breast cancer histological image categorization was done on dataset to measure method's accuracy. The accuracy was assessed by contrasting the actual and expected breast histopathology images. To evaluate the effectiveness of the method's categorization, several performance metrics like true negatives (TN), false negatives (FN), true positives (TP), and false positives (FP), were calculated. By calculating the percentage of accurately predicted abnormal breast histopathological images among all of the predicted abnormal breast histological images, the model's accuracy was also measured. The recall, or actual positive rate, was calculated by partitioning number of precisely predicted abnormal breast histology images by total abnormal breast histological images. The receiver operating characteristic (ROC) curve was utilized (See Fig 7.8) as evaluation metric when breast histology images changed. ROC curve is commonly recommended for evaluating results obtained through medical image processing. Additionally, using MATLAB 2020a, the F1-score, which ranges from 0 to 1, was calculated for the binary categorization of breast cancer histology images. Instead of preferring one over the other, the assessment tool used in this study is made to give equal weight to both precision and recall. The F1-score is more sensitive to unbalanced data than the Area under the ROC curve (AUC). Eq. (7.3) to Eq. (7.9) are used to calculate the F1-score, recall, precision, and accuracy, respectively [15].

$$recall = \frac{TP}{TP + FN} \tag{7.3}$$

$$precision = \frac{TP + TN}{TP + FP} \tag{7.4}$$

$$precision = \frac{TP + TN}{TP + TN + FP + FN} \tag{7.5}$$

$$F1 - score = \frac{2 * precision * recall}{precision + recall} \tag{7.6}$$

$$K = \frac{P_{observed} - P_{chance}}{1 - P_{chance}} \tag{7.7}$$

$$MSE = \frac{1}{m}\sum_{i=1}^{m}(x_i - \hat{x_i})^2 \tag{7.8}$$

$$RMSE = (\sqrt{\sum_{i=1}^{m}\frac{1}{m}(\hat{x_i} - x_i)^2} \tag{7.9}$$

7.4. Validation. This study utilizes breast histopathology images for categorization. The authors used transfer learning to extract patch characteristics from the images, and multiple-feature learning was used to provide image-level features. The decision of positive and negative examples directly affects the image-level feature, affecting the classification results. A validation dataset comprising 70 breast histopathology images was used to assess the impact of various K values on categorization. According to the findings, accuracy and the F1-score initially rise and subsequently fall as the K value increases from 5 to 200. When K is set to 10, the suggested technique achieves an F1-score of 0.86 and an accuracy of 0.86. Notably, the approach operates best with K equal to 100, producing an F1-score of 0.99 and an accuracy of 0.986. Compared to the results obtained when K is set to 10, these values show 13 % and 12.6 % improvements, respectively. When K is increased to 200, there is 26 % and 17.4 % reduction in the F1-score and accuracy of the classification findings, respectively (See Fig 7.6). These results imply that the image-level feature vector, comprising the top 100 and bottom 100 pixels of the aggregated features, best represents the histopathological image's characteristics (See Fig. 7.1 and 7.5). Table 7.1 to Table 7.4 shows the experimental outcomes of the anticipated model. The advantage of the proposed model over the existing research is its efficiency to access the classification accuracy using the task-based slicing model. The convolutional network is designed to differentiate the cancer images based on the class labels which are generally a complex task encountered by the existing approaches. The proposed model establishes better testing outcomes from the slicing model. It is more significant as the proposed model has to differentiate the image malignancy and benign regions to offer better medical prediction. Therefore, the anticipated models' performance is compared and evaluated for accuracy and performance with other approaches to project its significances.

Detailed representations of the previously mentioned results are shown in sub-images to highlight how varying values of K lead to various categorization outcomes. For K values of 10, 100, and 200, the ROC curves in Fig 7.8 show considerable changes in the classification outcomes. Our tested method consistently generates classification scores above 0.85 when only a limited number of top and bottom pixels are extracted from the aggregated feature vector, such as K=10. The classification performance declines with a more significant K number, such as K=200, with an accuracy of 0.819, recall of 0.83, and precision of 0.69. The complexity of clinical characteristics and the size of histological images of breast tissue account for the changes brought on by K values. The final output's image-level feature displays various features in both standard and diseased breast tissue based on the selected K values. Identifying abnormal tissue characteristics is only partially attainable when the K value is low. On the other hand, if the K value is too high, too many features associated with normal tissue may be present in the image-level attributes of diseased tissues. Consequently, selecting the appropriate K value is crucial for correctly classifying breast cancer histology images using only global labels. For the following discussion, where we assess the classification performance on the testing dataset, we selected a K value of 100, considering both the classification performance and the network's training expenses.

Table 7.2: Comparison of annotation cost

Accuracy (%)	**Image State (%)**	**40X**	**40X**	**100X**	**100X**	**200X**	**200X**	**400X**	**400X**
Image level	Active	Acc	AC	Acc	AC	Acc	AC	Acc	AC
Image level	Std	89	400	91	250	92	450	90	350
Image level	Active	88	400	91.7	300	91	550	89	500
Image level	Pre-trained	87	700	91	750	91	750	90	750
Patient level	Std	91	350	93	300	93	400	92	350
Patient level	Active	90	400	92	400	92	400	92	450
Patient level	Pre-trained	91	700	92	750	93	750	92	600

Table 7.3: P-value computation

p-value	**Magnification**	**Magnification**	**Magnification**	**Magnification**
P-Value	00040X	00100X	0200X	00400X
Image-level based	00.017	00.003	0.003	0.0014
Patient-level based	0.0012	0.0001	0.005	0.0008

8. Experimental outcomes. All images above were subjected to pre-processing before being utilized as input for the model. Based on the resulting output, the convolution layers' parameters were established during the training phase. Furthermore, these parameters remained unchanged during the validation process but were tested against the model using a test image to determine their accuracy and potential need for adjustment. The maximum average accuracy achieved through this approach over 100 epochs was 97.49 %. Weighted accuracy, which refers to the average true positive rate attained for each class, was used to adjust for the unbalanced dataset. Fig 7.6 displays the variations in accuracy between the test and train datasets during training. The results for $\lambda = 0.02$ are shown. The ROC curve is a crucial tool for evaluating the classifier's performance on the test dataset. This graph compares the sensitivity (rate of true positives) and specificity (% of false positives) for various threshold values of the parameter. Each point on the ROC plot represents a mix of false-positive and true-positive rate values for a particular threshold. In this scenario, the malignancy of benign tumours, the Area Under the Curve (AUC), shows how effectively the classifier can distinguish between diseased and normal classes. The task-dependent slicing model is integrated with the convolutional network model (ts-CNN), as seen in Fig 7.8 ROC curve. The TPR and FPR of the anticipated model is provided in Fig 7.8 where the positive predictions are higher compared to false positive. This shows the efficiency of the proposed model. Our suggested model distinguished between benign and malignant lesions with a valid AUC of 98.3 %. To evaluate its performance in differentiating between various sub-classes of lesions, as classified by Boman and Volminger. This work applied our suggested approach to comparable lesion images. The proposed model's computational specifications are listed below.

ROC curves illustrating the ts-CNN performance are shown in Fig 7.8. The ts-CNN model, trained to incorporate a novel regularizer, is evaluated on varying numbers of images for each case. Specifically, Fig 7.8 showcases the ROC curve from analyzing 33 melanoma images and 97 nevi images. Fig 7.8 illustrates the ROC curve from examining 65 basal and squamous cell carcinoma images and 70 seborrheic keratosis images. The ROC curve resulting from the evaluation of 33 melanoma images and 97 seborrheic keratosis images is displayed in Fig 7.8. Lastly, it exhibits the ROC curve from analyzing 20 melanoma and 20 solar lentigo images. The AUC for each test in the above cases is shown in Table 7.1. Regarding the Area under the receiver operating characteristic curve (AUC-ROC), our ts-CNN with a unique regularizer outperformed the presented technique. We discovered that the AUC-ROC of nevus was 6.5 % higher than melanoma's. The AUC-ROC increased by 1.6 % in seborrheic keratosis, much like basal and squamous cell carcinoma. Our classifier compared seborrheic keratosis and melanoma well, increasing AUC-ROC by 1.13 %. AUC-ROC for classifying melanoma against solar lentigo was also achieved, and it was 86.35 %, outperforming prior values reported by 3.35 %. This research study hypothesized that using ts-CNN would result in more accurate categorization of binary

Table 7.4: Performance Metrics Comparison

Metrics	ts-CNN	nl-SVM	IC-CSO	CNN	BiLSTM	DNN	CapsNet
Accuracy	98.2	97.5	95.7	94.3	94.8	91.8	93.4
Precision	98.5	97.2	95.6	94.5	94.5	90.5	92.2
F1-measure	98.3	97.4	95.5	93.7	92.2	90.4	91.9
Recall	98.1	97.2	95.5	94.9	0093	0091	91.6
Kappa	97.5	96.9	95.2	91.5	90.5	0081	83.7
Specificity	98.6	97.5	95.1	93.9	94.5	0091	91.6

Table 7.5: Error Metrics Comparison

Metrics	ts-CNN	nl-SVM	IC-CSO	CNN	BiLSTM	DNN	CapsNet
MAP	00.032	00.045	00.055	0.1915	0.201	0.286	0.2635
MAE	0.0019	0.0025	0.0030	0.0365	0.042	0.082	0.0696
RMSE	0.0021	0.0026	0.0032	00.035	0.043	0.083	00.070

comparisons between seborrheic keratosis and basal and squamous cell carcinoma, and nevus and melanoma, compared to other techniques. According to [25], three-way classification accuracy with a standard deviation of 0.9 % was 72.1 %. According to [28], the maximum accuracy ever found in literature is 93.64 %. However, our suggested method outperformed these figures published by previous authors, with a maximum average accuracy of 97.49 %. Although we experimented with various regularizer values, including $\lambda 0.2, 0.02, and 0.002$, the accuracy that produced the best results was $\lambda 0.02$ with a precision of 97.49 %. Table 7.3 contrasts our work with many other methodologies. The proposed model outperforms the current models, according to our findings. Due to the intricate variations in the appearance of histopathologic images, automated classification through images poses a significant challenge. To tackle this and achieve precise differentiation among the minutely detailed object categories, the proposed ts-CNN model have been employed. This study introduces a novel prediction model designed to classify images as either benign or malignant using a unique slicing technique. It serves as a binary classifier, distinguishing between these two categories of images. The proposed model demonstrated an impressive average accuracy of 98.2 %, showcasing its superiority over current state-of-the-art methods. The ts-CNN performance, measured in terms of ROC with the integrated novel task-slicing technique, was evaluated across various scenarios. The AUC achieved for differentiating nevus from melanoma lesions, seborrheic keratosis from basal cell carcinoma lesions, seborrheic keratosis from melanoma lesions, and solar lentigo from melanoma lesions respectively. These outcomes indicate that our proposed learning model surpasses existing algorithms and can serve as a valuable tool to aid medical practitioners in accurately classifying diverse types of cancer.

Malignant cells found in breast tissue are used to diagnose breast cancer, which affects one in eight women worldwide. Using a variety of methods, histopathology images captured under a microscope are the foundation of modern medical image processing. These days, processing pathological tools and medical images requires machine learning. Cancer cell detection by hand is time-consuming and prone to human mistake. As a result, compared to manual systems, computer-aided mechanisms are used to get more accurate results. Medical imaging is a field that heavily utilizes deep learning, particularly via CNNs. With this method, features are extracted using CNN and then classified through a fully connected network. Its use in the medical industry is beneficial because it doesn't require any prior knowledge in the discipline. We trained a convolutional neural network in this study, and the result was an amazing prediction accuracy of up to 94.6 %. In this work, a CNN model called HIC-net is presented. Its purpose is to automatically identify malignant spots in whole-slide histopathological images (WSI). HIC-net's innovative architecture divides the WSI into distinct planes in order to use window-based classification. Our method includes an efficient WSI pre-processing step to improve predictability and speed up training.

Researchers can learn a great deal about cancer from the examination of histopathological images, but

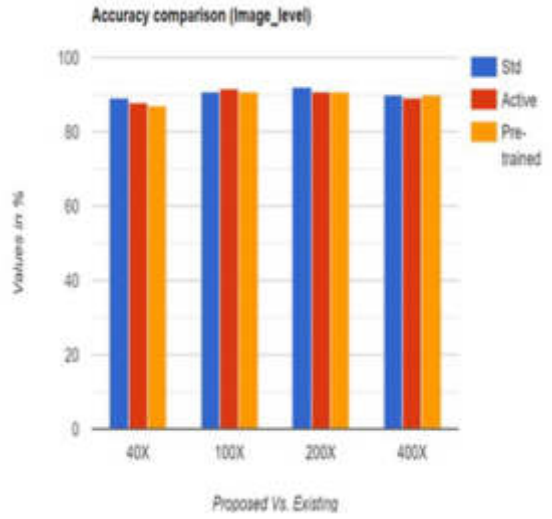

Fig. 7.1: Accuracy comparison (Image level)

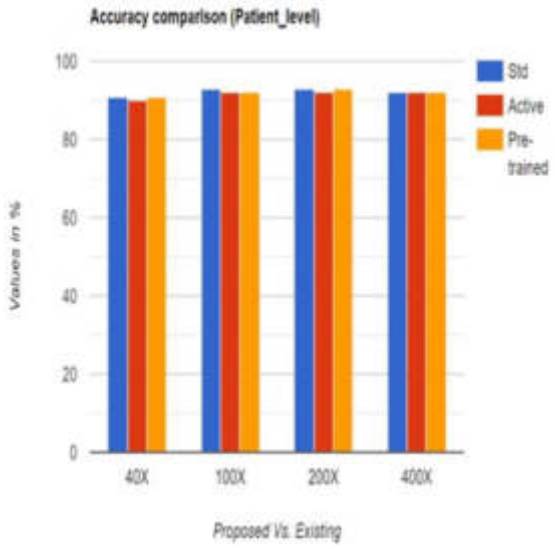

Fig. 7.2: Accuracy comparison (Patient level)

the inherent difficulties with these images frequently make the analysis process take longer. In this work, a strong solution to the problem of classifying histopathology images is presented. To counteract the impact of background disrupting variables and reduce the complexity of histopathology pictures, a unique pre-processing procedure has been used. Both pathologists and machine learning algorithms face major problems when it comes to the analysis of histological images. Pathologists frequently dedicate hours to examining a single whole-slide tissue sample. Even if machine learning algorithms provide results more quickly, many of them have difficulty performing at the required level. This is frequently ascribed to the high image quality and the existence of distracting elements.

This work adopts a unique strategy in comparison to the literature currently in publication, where CNN architecture has shown impressive success and quickness in classification when compared to other methods.

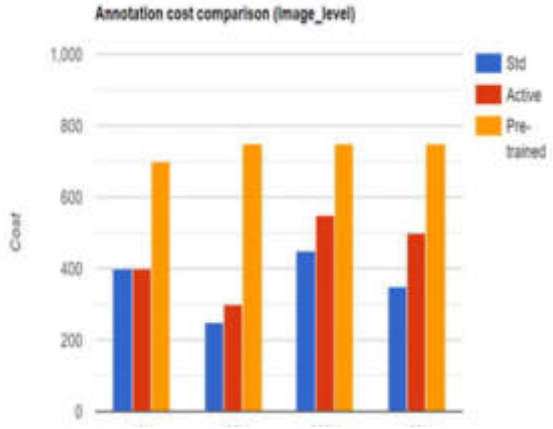

Fig. 7.3: Annotation cost comparison (Image level)

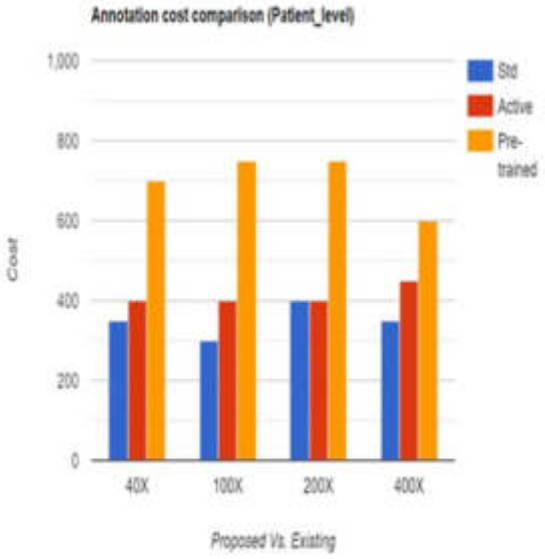

Fig. 7.4: Annotation cost comparison (Patient level)

Rather of using a generic CNN architecture, a specific architecture that is specifically designed to fit the texture of histopathology images has been created. First layer of CNN architecture is a special preprocessing step based on the effect of H & E stained components and cell behavior. First, the high-resolution histopathology pictures should be normalized. Then, they should be segmented into smaller pieces in a particular order. Before being supplied into the network as the CNN input, every image fragment is subjected to the suggested medical image preprocessing procedure.

Due to its perceived lack of transparency in decision-making, deep learning is often criticized and labeled as a "black box." Even if it's known that humans don't always make perfect "white box" selections, there is always a desire to know why decisions are made. It's possible that this curiosity will spark fresh research in the subject of pathology. Although obtaining total transparency is still a difficulty, various research projects have looked for answers. One method to solve this problem has been investigated: collaborative learning that integrates diagnostic information and diseased visuals with attention mechanisms. An increasing number of

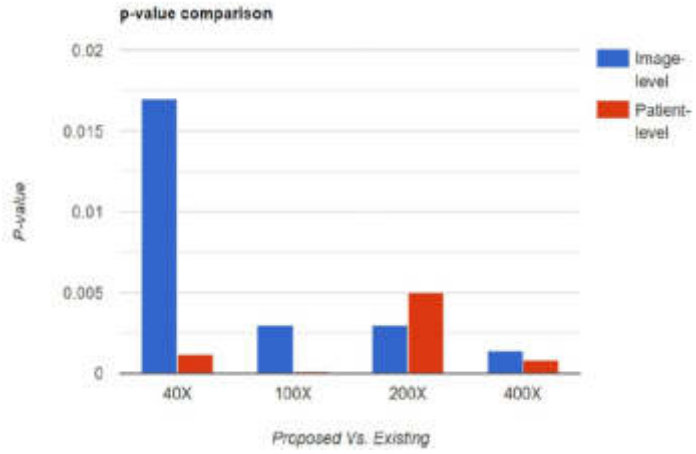

Fig. 7.5: P-value comparison

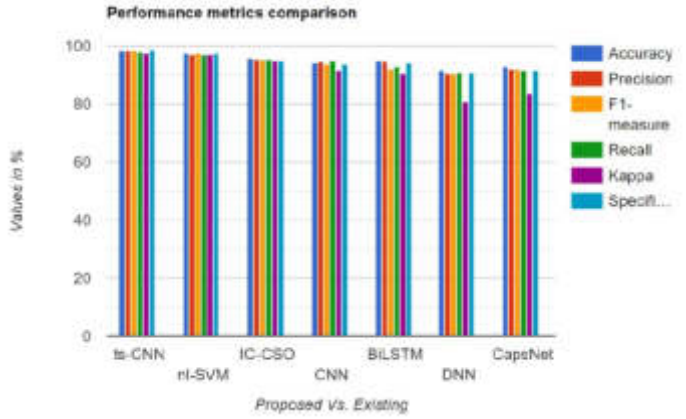

Fig. 7.6: Performance metrics comparison

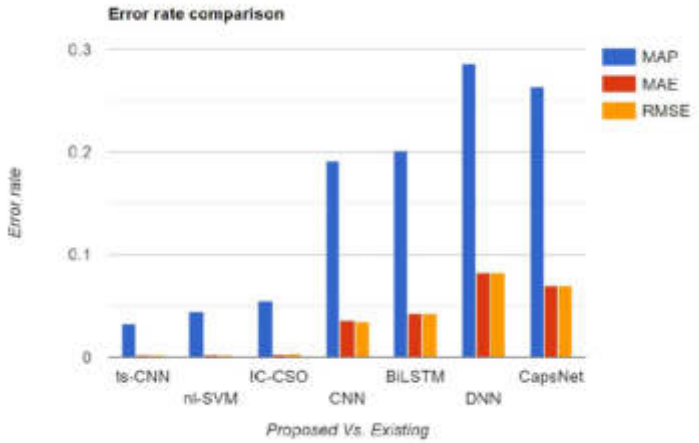

Fig. 7.7: Error rate comparison

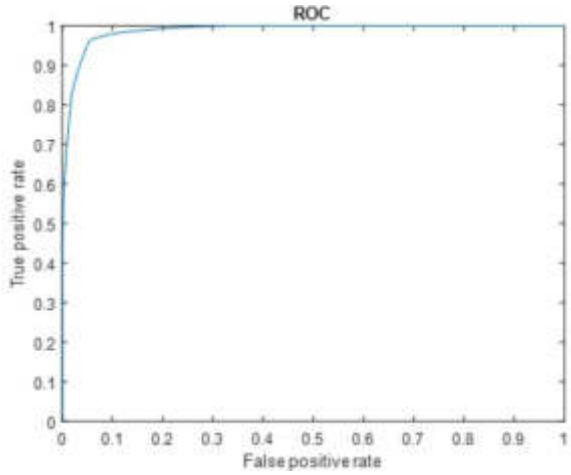

Fig. 7.8: ROC comparison

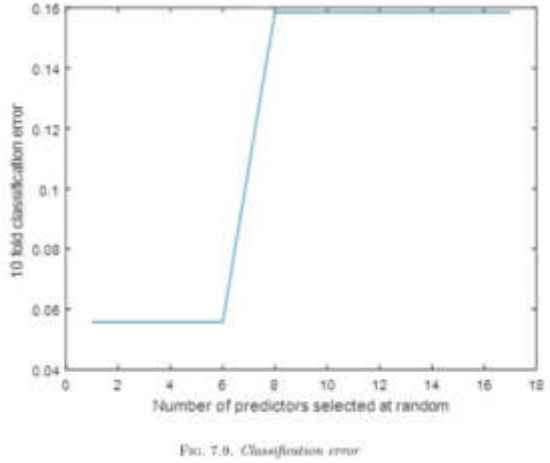

Fig. 7.9: Classification error

people are interested in analyzing digital histopathology pictures because of the expanding repository, especially in the field of computer-aided diagnosis using machine learning techniques. Digital pathological pictures and related tasks provide special obstacles despite the possible advantages. We explore the use of machine learning techniques in the examination of digitally diseased photos in this mini-review. We also point out particular problems that come with this kind of study and suggest possible fixes.

9. Constraints. Different investigators employ various regularization techniques. Regularization procedures that are frequently used include lasso regularizations and ridge regression. However, they have some shortcomings, such as the fact that they could be more effective when the dimensionality is substantially high, and the number of instances is limited. Similar to this, our regularization approach has several drawbacks, which are listed below 1) Neither feature selection nor feature reduction are permitted; 2) Choosing an appropriate value for λ is challenging since it is a continuous number, and selecting a single suitable value by trying a million times would be computationally expensive and time-consuming.

10. Conclusion. The primary goal of this study is to lessen the load of extensive annotation needed for precise image categorization in this field. Additionally, the study demonstrates a method to enhance the effectiveness of a limited number of annotations without relying solely on deep learning models. It is essential to highlight that the proposed active learning model can be integrated with several machine learning approaches, including deep and non-deep learning models. To optimize the efficiency of our research for this assignment, we employed a methodology known as ts-CNN. According to experimental findings, using a sizable collection of BC histopathology images using a confidence-boosting technique leads to a considerable reduction in annotation costs compared to a random selection. Furthermore, when paired with a slicing technique that boosts confidence, the deep learning framework outperforms existing approaches in terms of performance, accuracy with 98.2 %, and annotation costs. Thus, by employing this strategy, the costs of annotating medical applications can be significantly decreased, and the applications' capacity to react to real-world medical conditions can be improved.

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AN EFFECTIVE INVESTIGATION FOR QUALITY OF SERVICE ENHANCEMENT OF CONTENT DELIVERY NETWORK FOR HTTP LIVE STREAMING USING H.265

KIRAN BABU SANGEETHA* AND V S K REDDY†

Abstract. In the contemporary era, the prevailing trend among individuals is the widespread utilization of streaming technology to indulge in audio or video content emanating from a server. This innovative approach negates the necessity for downloading the content beforehand, allowing users to seamlessly revel in the material through the streaming mechanism. However, this cutting-edge technology mandates a substantial bandwidth to uphold its Quality of Service (QoS) at an optimal level. Challenges may arise, such as packet loss, attributed to the restricted bandwidth provided by the network service provider, thereby compromising the delivered content's quality. To address this issue, one viable solution is the integration of CDN (Content Delivery Network), a technology proven to enhance the quality of content delivered through streaming services. This research endeavors to elevate the quality of live video streaming by leveraging CDN. The HTTP Live Streaming (HLS) format for content streaming, the study empirically demonstrates that CDN significantly improves the Quality of Service. As a result, the proposed method Content Delivery Network (CDN) using H.265 plays vital role in live video streaming. The result shows that live video streaming with CDN outperforms without CDN. Specifically, the live video streaming experience with CDN showcases a remarkable throughput average of 5899.7 kbps, coupled with a minimal packet loss ratio average of 0.05%. This stands in stark contrast to the version without CDN, which exhibits a comparatively diminished throughput average of 5287.3 kbps and a higher packet loss ratio average of 0.22%. These empirical findings strongly emphasize the effectiveness of CDN in elevating the Quality of Service for live video streaming. The tangible enhancements in throughput and the reduction of packet loss achieved through CDN implementation contribute significantly to an enriched user experience. The evidence supports the notion that integrating CDN technology not only optimizes the technical performance of live video streaming but also plays a pivotal role in enhancing the overall satisfaction and engagement of users with the content delivery system.

Key words: QoS, 5G, Content Delivery Network, HTTP Live Streaming, Throughput, Packet Loss Ratio.

1. Introduction. Data consumption is increasing day by day. Demand for improved technology is growing, and as a result, network capacity will grow as well. As a result of this requirement, network technology has enabled users to experience faster data speeds with lower latency. This has encouraged users to increase their data usage even more. Digital media and video traffic are becoming increasingly important in Internet and network usage. According to the Cisco Visual Networking Index Global Mobile Data Traffic Forecast Update, video usage accounts for approximately 82% of all IP-based Internet traffic today and is expected to rise to 91% by 2025. Large-scale industry research is being done on emerging trends like wireless technology, which focuses on 5G technology [2]. Delivering Ultra High Definition (UHD) quality video to the audience is now simple with the advent of the new 5G video file codec, a High Efficiency Video Codec (HEVC) or H.265 [6]. The majority of products on the market today have high definition screens, such as 4K. In the future, this might increase to more than 8K. These cutting-edge technologies offer the framework for on-demand video or real-time broadcast alternatives to be accessed whenever and from anywhere in the world [1]. L. K. Pulasthi Dhananjaya Gunawardhana [1], discusses the scalable H.265 video standard is used in the 5G SELFNET and QoE use case for UHD video streaming. In this challenging situation, Pablo Salva-Garcia and colleagues [3] present a unique 5G-UHD framework to provide adaptive video streaming and open the door for 5G UHD streaming that is self optimization oriented. A feasibility study of live video streaming using the top video codecs (H.264/MPEG-AVC, H.265/MPEG-HEVC, and VP9) over current commercial acoustic modems is presented by Filippo Campagnaro et al. Wella Edli Shabrina et al. [4] conduct research to enhance the live video streaming experience over CDN.

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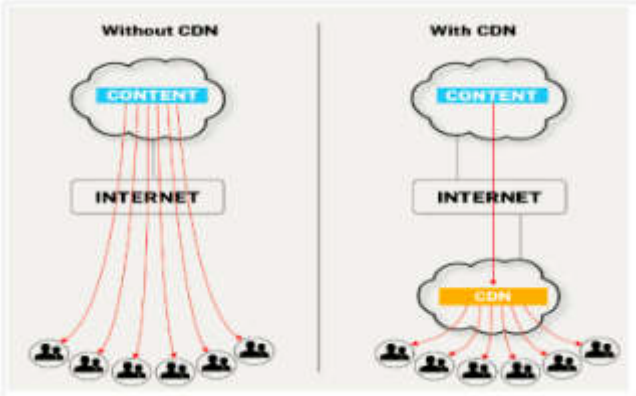


Fig. 1.1: CDN Caching Mechanism

Amazon Web Services (AWS) supports the global CDN infrastructure known as Cloud Front. For content streaming, the HLS format is used. It has been proven that CDN can raise the calibre of delivered content. The results show that live stream broadcasting with a CDN outperforms live streaming without one.

Muhammad Arslan Usman et al. [13] presented a novel no-reference video quality metric that assesses the impact of frame freezing in video streaming networks due to packet loss and delay. Because the non-live scenario is more comparable to common video streaming platforms that can use an advanced encoding process, Steve Goring et al., [10] discussed the live scenario. In general, a number of factors, including human, system, context, and others, affect gaming quality of experience, much like they do in the classic video streaming scenario. There are aspects unique to gaming video streams, in addition to more common factors like content characteristics that affect encoding or the final product quality.

One of the main goals as we move closer to 5G is to increase Quality of Experience and achieve a more dependable experience for users throughout the existing system (QoE). This paper focuses on usage of H.265 broadcasting over 5G technology. Existing works have not examined how well video services can be delivered in 5G/beyond-5G networks with variety of user arrivals or used H.265 compression properties, especially in terms of extracting the temporal inter - dependence between frames within coding structures [14].

Streaming technology is a popular method of enjoying audio or video content. Generally, high bandwidth is required for video or audio streaming. This requirement is required to prevent the content delivery service's quality from deteriorating. Some mechanisms for improving content delivery QoS could be implemented. Caching is one option. The proxy server is a technique that is similar to data caching in that it facilitates rapid data access for temporary storage by reusing data. The issue comes, though, when data, such as that connected to video material, is kept in excess of the cache's capacity. Delays are common because received video content cannot be cached. The CODEC is another element that contributes to the sending of content. It must be loaded by the user application in order for video streaming to concretize [3].

It is necessary because consumer applications, like Smartphone, sometimes have limited computing power. The architecture exists that employs a pattern similar to the proxy server, it's a Content Delivery Network (CDN). Up to now, it has been a well-liked method of enhancing video streaming services. For streaming video data, there are two possible techniques. On-demand is the first, and live streaming is the second [5].

The issue with live streaming is greater than with on-demand. This occurs because real-time maintenance is required for the delivery service. There is a common format that can be used for live video streaming, such as HLS. The mechanism of CDN is depicted in figure 1.1 [4]. It is a collection of nodes that are linked together and serve as the backbone of a computer network. A website or a video, such as streaming video, can be reproduced [5]. This streaming protocol enables direct delivery of a live video broadcast.

When client tries to access web content, CDN mechanism gets activated for main server. In response to the client's request, the server will deliver web content to the client. In addition, the origin server duplicates web content and sends it to CDNs. CDNs will update their cache storages when the content on the origin server

Fig. 1.2: The proposed system architecture

changes. As a result, every individual CDN server acts like a content provider but, whichever CDN close to client gets better opportunity to be service provider.

In any case, an absence of bandwidth could degrade the quality of a data and communication service. The CDN can be utilized to ensure high QoS when broadcasting live video. To reduce the likelihood of packet loss, the position should be as close to the target user's location as possible. HLS has been chosen as the live video streaming format. CDN is a set of nodes connected to each other and acts as content replication placed in the backbone of the computer network. The content replicated can be a web page or video, including media streaming [10].

The CDN mechanism is started when the client requests web content from an origin server. The server is going to respond to the client requesting by sending the web content to the client. The illustration of CDN servers is shown in figure 1.2. In addition, the origin server produces the duplications of the web content and it forwards them to the CDNs. Every content changing in the origin server, it is going to be updated by CDNs in their cache storages. So, each CDN server can act as a content provider. However, the CDN closest to the client has a bigger chance to do the service.

By performing CDN, the requested content placed is not as far as to the origin site, but it is in the nearest CDN server. The H.264 video compression standard has been utilized for the past 14 years in (CDNs) all over the world to enable quick, widespread, and affordable video encoding.

2. Problem Definition. A difficult service is live video streaming. It requires ongoing attention to its packet delivery process. Getting the latest news from other countries or around the world is a desire for people who live abroad. However, very few companies use live transmission. This study makes use of live HLS streaming video. The CDN infrastructure is carried out to uphold the quality of the sent content using AWS Cloud Front. Throughput and packet loss ratio are the primary study findings. When using a CDN, the transmission of live video streaming using the H.264 codec has an average throughput and an average PLR. Without a CDN, it offers average throughput and average PLR, which are insufficient for live streaming in a 5G network.

3. Proposed System. This investigation delves into the HLS live video streaming service, with a specific focus on two contrasting schemes: one integrating CDN and the other without, facilitating a comprehensive comparison of their functionalities and outcomes. Wireshark is used to monitor the two systems (with CDN and without CDN) performances. Wireshark is a tool used to sniff message live broadcasts in a network. For observational purposes, the recorded data can be examined. Throughput and PLR are the variables that the study explores. The figure 3.1 depicts the setup comprises a video recording camera as its foundational element. The captured video undergoes a transformative process involving encoding and conversion facilitated by OBS and AWS MediaLive.

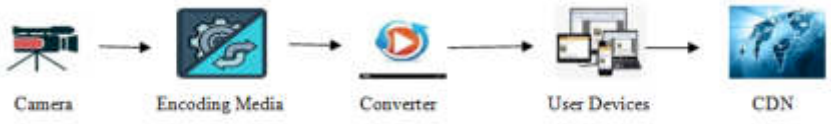


Fig. 3.1: The illustration of CDN servers

Subsequently, the processed video is directed through AWS MediaStore, adopting the HLS (HTTP Live Streaming) video output format for optimal delivery and compatibility. This sequential workflow ensures a comprehensive and efficient handling of the recorded video content, leveraging a combination of OBS and AWS MediaLive technologies within the AWS ecosystem. For encoding purpose H.265 with Lagrangian Encoder is used. AWS MediaLive will be used to encode and transcode the footage.

An AWS MediaStore will then process the video and output it in HLS format. The CDN is utilized as a content delivery cache. Live streaming is the mode of transmission.

- The international CDN service is AWS CloudFront, and AWS is the cloud service provider used.
- With a frame rate of 30 frames per second, the encoded streaming video has a resolution of 1280x720. The protocol input is Real-Time Messaging Protocol (RTMP) (H.264), which typically operates at a bit rate of 4500 kbps [14]. The transmission protocols utilized for output are RTMP and HLS. Using AAC and 44.1 KHz, the audio is encoded.
- Customers consume 48 Mbps and 110 Mbps of bandwidth (upload). A Windows 2016 AWS instance of the t2.micro type is running and being used by the clients. For downloads, the broadcaster uses 18.1 Mbps, and for uploads, 5.8 Mbps of bandwidth. [5].

3.1. The Evaluating Scenarios. The first scenario involves performing HLS live broadcasting in the network without the use of a CDN. Direct data transmission from the broadcaster to the specified target client. The global CDN architecture is implemented in the second scenario. During live streaming, the CDN will reconstruct the content and send it to the client. Wireshark is used to record both the throughput and the PLR [5].

3.2. Parameters for Assessment. Several parameters are used to assess CDN performance. Wireshark is a tool that is used to capture packets. Among the parameters investigated are:

- The number of packets delivered to a client in a specific amount of time is referred to as throughput [8, 9, 10].
  The formula for throughput is:

$$\text{Throughput} = x^* \times \left| \frac{\text{Amount of data delivered}}{\text{Duration of time}} \right| \tag{3.1}$$

  where $x^* = argmin_{x \in X} D + \lambda R$

  For a constant that determines the trade-off between distortion D and number of bits R, the Lagrangian parameter x is minimized [11].

- Packet Loss Ratio (PLR) measures the number of lost packets in relation to the number of delivered packets [9]. The formula for packet loss is:

$$Throughput = x^* \times \left| \frac{P_l}{P_t} \right| \times 100 \tag{3.2}$$

  where $x^* = argmin_{x \in X} D + \lambda R$
  P_l = The number of lost packets.
  P_t = The transmission's packet number.

Table 4.1: The Throughput with CDN

Evaluation Scenario Observations	Throughput(kbps)	
	H.264	H.265
1	4862	5326
2	4952	5447
3	4741	5215
4	4721	5193
5	4781	5259
6	2878	3166
7	5449	5994
8	3368	3705
9	4623	5085
10	4171	4588
Average	4452.6	4897.8

Table 4.2: The Throughput without CDN

Evaluation Scenario Observations	Throughput(kbps)	
	H.264	H.265
1	1567	1724
2	4932	5425
3	5265	5792
4	5242	5766
5	5212	5733
6	4325	4758
7	3537	3891
8	4700	5170
9	1956	2152
10	3168	3485
Average	3990.4	4389.6

4. Results and Discussions. By putting the evaluation scenarios into practice, the thorough evaluation of HLS streaming live video is carried out. Each observation lasts for 5 minutes, and each assessment is performed 10 times.

4.1. The comparison of throughput recorded with and without a CDN. The table 4.1 displays the throughput recorded at the client location:

According to Tables 4.1 & 4.2, when the CDN architecture is used, the result of throughput for the HLS video format is greater than when the CDN architecture is not used. HLS live broadcast throughput with CDN is 4897.8 kbps on average. Conversely, HLS live broadcasting content delivered without a CDN has an average throughput of 4389.6 kbps.

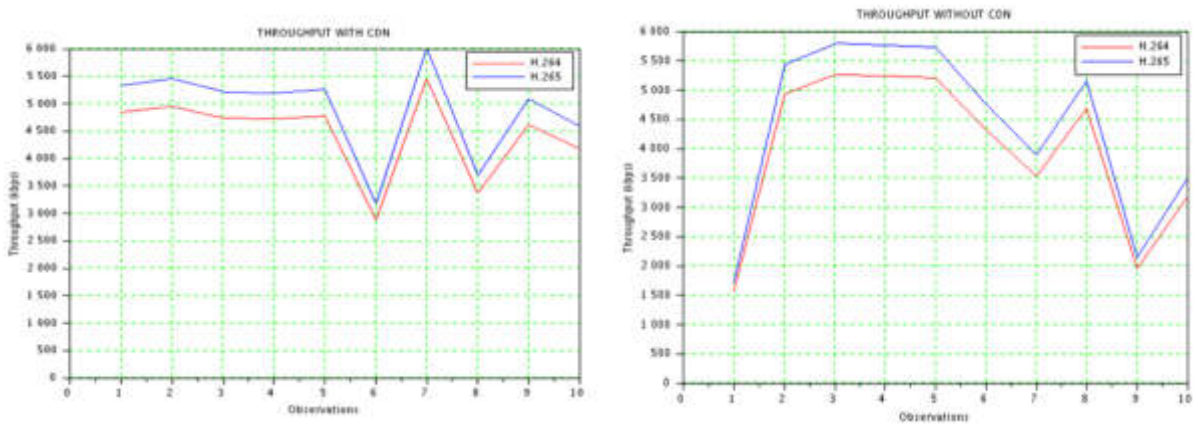
A summary of the average throughput for HLS live broadcasting is shown in figure 4.1.

4.2. The comparison of PLR recorded with and Without a CDN. The table 4.3 displays the PLR recorded at the client location:

Table 4.3 & 4.4 demonstrate that when the CDN architecture is used for the HLS video format, the PLR result has a lower value than when it is not used. With CDN, the average PLR for HLS live broadcast is 0.072%. The average PLR for HLS video format without a CDN is 0.297%.

A summary of the average PLR for HLS live broadcasting is shown in figure 4.2.

5. Conclusion. The deployment of H.265 in conjunction with CDN integration is shown to significantly enhance the Quality of Service (QoS) in video streaming. This combined approach effectively reduces packet loss



(a) Throughput with CDN (b) Throughput without CDN

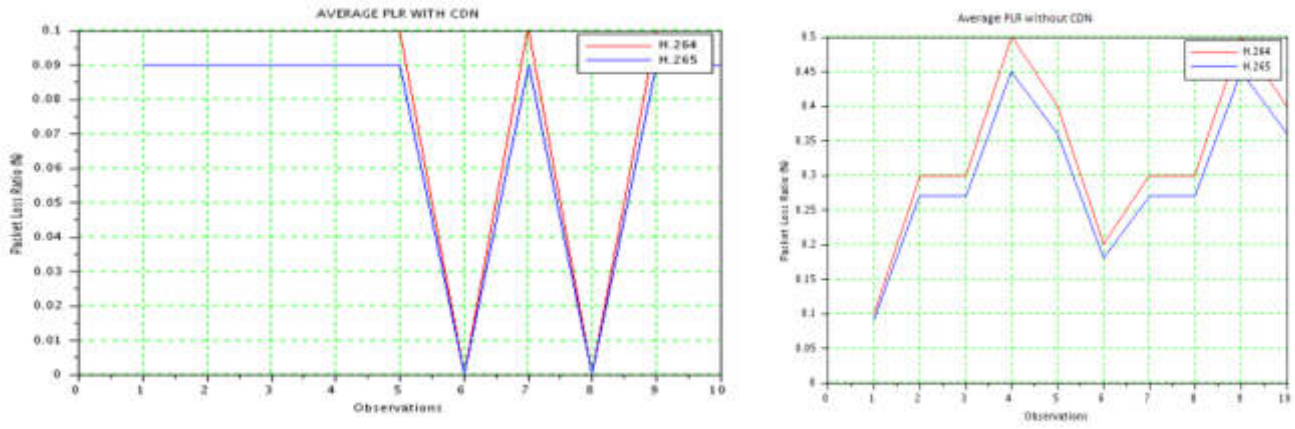
Fig. 4.1: Throughput average

Table 4.3: Average PLR with CDN

Evaluation Scenario	**Throughput(kbps)**	
Observations	**H.264**	**H.265**
1	0.1	0.09
2	0.1	0.09
3	0.1	0.09
4	0.1	0.09
5	0.1	0.09
6	0	0
7	0.1	0.09
8	0	0
9	0.1	0.09
10	0.1	0.09
Average	0.08	0.072

Table 4.4: Average PLR without CDN

Evaluation Scenario	**Throughput(kbps)**	
Observations	**H.264**	**H.265**
1	0.1	0.09
2	0.3	0.27
3	0.3	0.27
4	0.5	0.45
5	0.4	0.36
6	0.2	0.18
7	0.3	0.27
8	0.3	0.27
9	0.5	0.45
10	0.4	0.36
Average	0.33	0.297



(a) Average PLR with CDN

(b) Average PLR without CDN

Fig. 4.2: Average PLR

and optimizes throughput, resulting in a superior network performance for all parties involved. The utilization of AWS CloudFront, a pivotal component of the global CDN infrastructure, emerges as a strategic choice for elevating the performance of live video streaming. In comparison, the absence of CDN in HLS live video streaming is likely to result in a less efficient and inferior service delivery.

Acknowledgments. The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression, "One of us (R.B.G.) thanks" Instead, try "R.B.G. thanks". Put applicable sponsor acknowledgments here; DO NOT place them on the first page of your paper or as a footnote.

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RESEARCH ON THE APPLICATION OF COLLABORATIVE CO-SIGNING INTELLIGENT VERIFICATION MODELS AND PARALLEL DISTRIBUTED ALGORITHMS FOR SEAMLESS INTEGRATION OF INTERNAL AND EXTERNAL DOCUMENTS

XIGUO HU*, TAO ZHENG†, DONGLIANG HOU‡, AND YUN KANG§

Abstract. In today's complex and linked technology environments, attaining business efficiency and innovation is crucial. In this paper, an innovative architecture combining parallel distributed algorithms and collaboratively co-signing intelligent verification frameworks is introduced. By promoting safe and effective interaction among heterogeneous systems, this synergistic method seeks to improve the integration process. Diverse systems are proliferating in both internal and external domains, requiring sophisticated integration solutions. Real-time data interchange, interoperability, and security are common issues with existing methods. By using parallel distributed algorithms and intelligent verification models, the suggested framework aims to overcome these difficulties. The framework presents a novel approach to confirming the integrity and validity of data transferred between systems by utilizing collaborative co-signing. Co-signing increases security and confidence in the integrated environment by having several parties jointly validate the information. Through the introduction of parallel distributed algorithms and collaborative co-signing smart verification models, this research advances a comprehensive strategy for smooth integration of systems. The results highlight how the framework can facilitate safe and effective data interchange between external and internal systems, opening the door for more developments in connected technology environments in the future.

Key words: collaborative co-signing, intelligent verification models, parallel distributed algorithms, seamless integration of internal, external documents.

1. Introduction. The dynamic interchange of knowledge between company operations and external ecological systems, such as suppliers, collaborators, and third-party services, is crucial in today's business climate. The integration issues are tackled by the proposed framework, which highlights the importance of security, flexibility, and real-time response.

Assembly lines are an essential component of today's industrial sector, utilized in the mass production of standardized goods. As a result of shorter product life cycles and more product variations, designing assembly lines becomes a constant challenge. In order to support planers in the line design and setup, effective approaches are required. The design process involves several issues, including determining the best spatial arrangement, balancing the assembly line to ensure equal workload at each station, and selecting appropriate resources to carry out the necessary activities [5, 2]. Planners employ tools to capture their knowledge and expertise. Their goal is to generate design outcomes for each planning activity automatically. Nowadays, each tool typically processes and accesses a certain set of data, which results in [6, 3].

The entirety of all procedures used to put together geometrically defined bodies is referred to as assembly. It is possible to categorize and characterize assembly processes as handling, acceptance, supplementary procedures, and special activities [19, 4, 1, 13]. A workstation's functional sequence of operations essentially consists of connecting, feeding, examining, and supplying. Three functional regions can be used to separate the assembly tasks on an automated assembly line [22].

The parallelism process involves performing multiple operations simultaneously. Unlike traditional sequential algorithms, where tasks are completed one after another, parallel algorithms split tasks into subtasks that are processed at the same time. This approach is particularly useful for large-scale computations and can significantly reduce processing time. Distributed Computing refers to a model where computation is carried out

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across multiple physical or virtual machines that are networked together. Each node (machine) in a distributed system can work independently on a portion of the problem and communicate with other nodes as needed.

The required planning periods are decreased by the developed tools. Unfortunately, they either lack basic assembly line information such as the necessary workpiece carrier or material flow via conveyor, or they primarily employ other data models [7]. When logically coupled, human data entry and modifications could be laborious and prone to mistakes. Time and money are greatly wasted since not all required planning data is integrated. In the realm of automated assembly planning, integrated digital description of generated data is consequently regarded as the primary problem [21]. AutomationML (AML) is a widely used data sharing format in the subject under consideration for information modeling.

The main contribution of the proposed method is given below:

1. Standardizing communication protocols and data formats to improve compatibility.
2. Putting strong security measures in place to protect private data both in transit and at rest.
3. Data synchronization and real-time communication are made possible by the integration of processes.

Remaining sections of this paper are structured as follows: Section 2 discusses about the related research works, Section 3 describes the Seamless Integration, Parallelization and Deep Learning methods, Section 4 discusses about the experimented results and comparison and Section 6 concludes the proposed optimization method with future work.

2. Related Works. AML is an XML-based data interchange format designed for production system design [20]. Given that the structure attempts to facilitate the exchange of design outcomes for every pairing of instruments in a design sequence, it can be seen as an illustration of an integrated IT landscape [16, 15, 18]. The object-oriented method of AML, which facilitates the mathematical representation of plant parts, is one of its benefits [14].

AML makes use of the four primary CAEX meta-model components to express a plant topology [17]. A case study of hierarchy depicts a plant's topology and organization. InternalElements (IE), which are modelled as objects, can also be saved as reusable parts in a SystemUnitClassLib. Potential roles that IEs could be assigned are listed in role libraries. A role is typically used to specify the semantics of things, describing abstract physical or logical concepts. ExternalInterfaces (EI) are used to define interfaces to external or internal objects. InternalLinks are used to actualize relationships between two IEs. These succinctly stated ideas aid in the proper modeling of the resources, process, and product domain items as well as their relationships [11, 12].

Three stages are involved in the planning of assembly systems. The definition of the products comes first, then the methods needed for assembly are specified, and lastly the assembly system design. In the latter case, the assembly planners' expertise and experience will have a significant impact on the result. Many scholars are working on automated assembly planning-related subjects to aid planners. The digital definition and modeling of the Product, Process, and Resource domains is where many planning systems begin [10, 9]. Product-process-resource triples (PPR-Triples) are created using mapping algorithms [8] that match the needs of processes and products with the resources that are available [8]. PPR-Triple linking allows systems to be defined for assembly. Automated methods consider several parameters for this conceptual design, which are included.

For organizational efficiency and innovation, the seamless integration of internal and external systems is critical in an era marked by complex and interconnected technological landscapes. This paper presents a novel framework that blends parallel distributed algorithms with collaborative co-signing intelligent verification models. By improving the integration process, this synergistic method seeks to guarantee safe and effective communication between diverse systems.

3. Proposed Methodology. An overview of the applied methodology for product, process, and resource domain modeling in AML is provided in this chapter. In addition, other elements that are necessary for assembly line planning are offered, such as supply pallets and workpiece carriers. Here the data is transferred between AML. For seamless data transmission Parallelization and co-signing verification is used. An summary of the introduced elements in relation to one another finishes this section. In figure 3.1 shows the architecture diagram of proposed method.

3.1. Bill-of Material (BoM). Based on the semantics that are attributed to the objects, the product domain is grouped into four levels. References to external documents are defined using external data interfaces

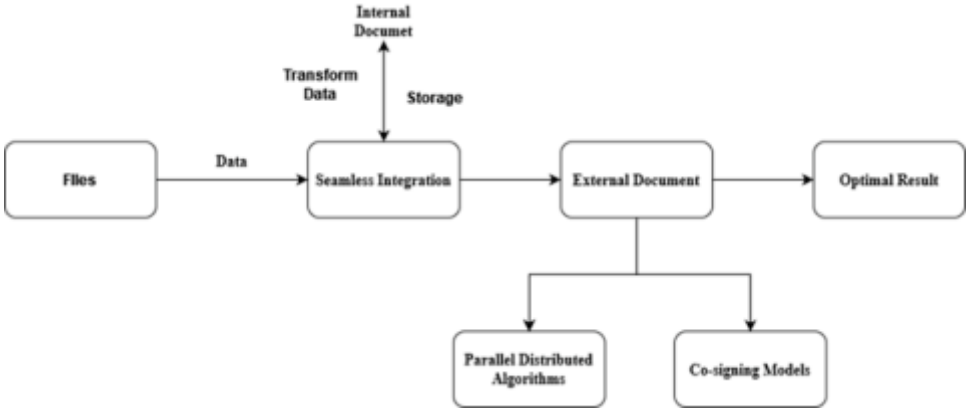

Fig. 3.1: Architecture Diagram of Proposed Method

of type ExternalDataReference. Every IE has an attribute called UniqueID, which is used to identify the same objects across different AML files.

The ProductVariant level is the first. This is one IE that has broad details about the finished product that are contained in a single AML file. For the sake of clarity, it is recommended that each variant have its own file. Model constraints, to which IEs with semantic ProductionConstraint are associated, supply data that informs the definition of the assembly system.

Jointing Elements and ProductParts are found in the following hierarchical level. The tiny part that cannot be dismantled any farther without causing damage is called a ProductPart. A higher value state is achieved by two ProductParts through assembling actions.

The necessity of optional joining aids varies based on the type of joining. Additionally, they are units that can't be dismantled any further. The elements include general details like material and weight in addition to abstract descriptions of their dimensions and shape. A crucial feature is the explanation of part supply. Thus, we distinguish between sorted, partially-sorted, and bulked based on [3]. To specify certain geometrical data in advance for handling via a resource, utilize a HandlingFeature. A planner is aware of the proper way and location to grab a thing beforehand.

There is a Frame definition for each HandlingFeature in relation to the overall product Frame. It is possible to designate a feature as either a HandlingFeatureLine or a HandlingFeatureArea, which will aid in choosing of gripper supplies. On the basis of the specified feature type, one can then choose between vacuum and magnetic grippers or finger grippers.

Components with the semantic roles SubAssembly and IntermediateAssembly are found in the final two hierarchies. An intermediate assembly represents the product's status following the inclusion of a new part. An assembly subgroup, on the other hand, depicts a single unit made up of optional JoiningElements and several ProductParts. But it's handled as a single part for the assembly operation. A gear motor is one example of this; it is typically supplied straight as a fully assembled component for assembly.

A Bill-of-Material structure is constructed with EIs isPartOf and consistOfPart inherited from the class ProductConnector. Each and every object that derives from the Product class has these interfaces attached. The BoM is defined as a graph by establishing InternalLinks, as seen in Fig. 3.2.

3.2. Material Flow and Supply. This research define a workpiece carrier using an abstract class named 'Pallet.' This class inherits attributes like size, weight, and material. The interface 'EI transfersPart' is used to link instances of the product domain's 'IntermediateAssembly'. As it moves down the assembly line, the product's basic portion goes through many intermediate phases before reaching its final condition. When an assembly object cannot be transported directly on a conveyor, the use of a workpiece carrier is required to ensure that it moves smoothly along the assembly line.

A ProductPart's orientation and position are determined in all degrees of freedom if it is supplied sorted.

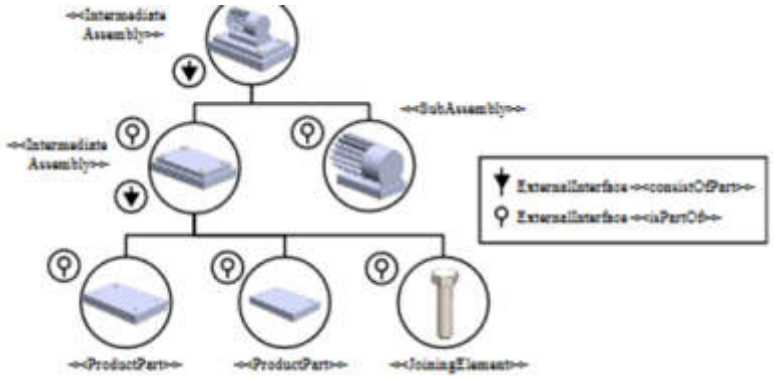

Fig. 3.2: Co-signing Methods

On an assembly line, supply pallets are used to provide materials in a sorted manner. A maximum capacity of hosted components attribute is added to the class Pallet's attributes. Product domain items can be connected to via the Interface SuppliesPart.

Kitting is a unique method of material supply used in assembly lines. As a result, at a workpiece carrier, all parts needed to assemble an assembly object are situated alongside the basic product part. Semantically, KittingPallet describes this workpiece carrier. There is one WorkpieceFixture and a predetermined number of KittingSlots in it. Every slot is reduced to a rectangular space inside the KittingPallet that has a frame. Every Intermediate Assembly that the KittingPallet processes throughout the assembly line is contained in the WorkpieceFixture. KittingSlot elements are assigned to required ProductParts, SubAssemblies, or JoiningElements. As a result, an EI named hostsPart serves as an interface between each element and the product domain.

3.3. Process and Modeling. All of the processes needed to put the finished product together are contained in the process domain. We define the element ProcessStep at the highest level. One ProcessStep is necessary for each time the product's state (Intermediate Assembly) changes. ProcessSteps need to be executed in a particular order and in relation to one another.

They include auxiliary or assembly procedures. ProcessTask is obtained by these processes as abstract semantic. There can only be one value-adding assembly process per ProcessStep. ProcessTasks' actual content can be used to better specify them. There are features and process parameters specific to each ProcessTask.

One is AutomationCapabilityFeature [7], which describes the degree to which a ProcessTask is appropriate for automated resources to do. ProcessParameters define the criteria for executing resources, just like a screwdriver requires torque.

A process's smallest unit is referred to as an operation. Given a set of resources and their unique properties, sequences can be used to estimate execution durations. Handling [3] and joining [19] actions provide the foundation of semantics. For instance, Operations describes a JoiningTask for the actual joining process and the movement of a joining tool. Processing times are calculated using velocity limitations or attributes for both horizontal and vertical distances. MotionType is an additional semantic that distinguishes between Pre-, Net-, and PostMotion to indicate how an Operation should be taken into account when determining a ProcessTask's total execution time.

3.4. Resource Composition Model. A resource is the smallest component of an assembly line.

Certain jobs, such as Robot, Vibratory Feeder, or Screwing Tool, are assigned based on the actual type. Attributes contain information about the manufacturer as well as other fundamental identifiers and skill descriptions. There are too many distinct qualities to go into detail about resources. Most characteristics simulate geometric data. The FootprintFeature is one of them. It gives an abstract description of the necessary space for a resource. Every FootprintFeature inherits the semantics and properties of the ShapeFeature that it is assigned. This characteristic distinguishes between polygon, rectangle, and circle abstract shapes. Everybody

has a different description model. Certain resources, such as robots, also have a workspace. To specify a reach, a ReachabilityFeature that additionally inherits properties from a ShapeFeature is used.

Sometimes a single resource is insufficient to complete a ProcessTask. It is necessary to assemble the resources.

A ProcessingUnit is the clustering unit for these resources. A gripper and a robot are two examples. An abstract feature called ConnectionFeature is introduced, along with its fundamental attribute Frame, to represent a relationship between two resources. A more detailed feature called AttachmentFeature is used since a gripper is fastened to a robot flange. To define an InternalLink between two AttachmentFeatures, it offers an interface called AttachmentConnector. A MountingFeature can be used to model the type of mounting since some resources are mounted on a table. Use an EnergyConnectionFeature if an energy connection is necessary.

Sometimes a single resource is insufficient to complete a process task. It is necessary to assemble the resources. The clustering unit for these resources is a Processing Unit. Two examples are a gripper and a robot. To express a relationship between two resources, an abstract feature named Connection Feature is developed, along with its fundamental attribute Frame. Since a gripper is attached to a robot flange, a more detailed feature called Attachment Feature is employed. It provides an interface named Attachment Connector for defining an Internal Link between two Attachment Features. Because certain resources are mounted on a table, a Mounting Feature may be used to model the type of mounting. If an energy connection is required, use an Energy Connection Feature.

Workstations can be allocated to and grouped with different Processing Units. An axis-aligned bounding box defines the necessary space for all of a workstation's resources. A Frame property describes a resource's location in relation to a Workstation's bounding box. However, workstations can also be grouped together to form ProductionCells. In terms of our present modeling scope, this is the highest considered cluster.

ProductionCells can be thought of as particular line segments. The locations of the Workstations it contains define the bounding box. A cell's stations are related to one another in a particular way as predecessor and successor. As a result, the classes isSuccessorWorkstation and isPredecessorWorkstation of ResourceConnector are shown. There is a Frame for each Workstation in relation to the cell enclosing box. Connections Among Production Cells.

Carrier Handling System facilitates material flow via all Production Cells and associated Workstations. It includes resources from the CirculationModule, PalletLoadingModule, and Conveyor classes. A variety of configurations can be modeled. Circulation modules, for instance, are employed when empty workpiece carriers are never removed from an assembly line. Conveyor modules are therefore linked to enable frontflow, and a backflow arrangement returns the pallet to the first cell. Pallet steering from front to backflow is accomplished by a vertical or horizontal Circulation Module. The handling setup's resources have a new functionality known as MaterialTransferFeature.

3.5. Model for Available Space. An assembly line's theoretically accessible space is referred to as a polygon. 2D points are present in the polygon as BorderPoint elements. BorderPoints are established in respect to one another by the interfaces isSuccessorBorderPoint and isPredecessorBorderPoint. The semantic ProductionArea is subsequently assigned to the spanned area. The global coordinate system for each and every other assembly line object is defined in this section as well.

Workpiece carriers are injected and ejected from the assembly line at designated places designated by optional sources (input) and sinks (sinks). They are utilized to locate modules of the CarrierHandlingSystem and are simply referred to as Point2D. The space between these designated sites will subsequently be taken into account for allocating ProductionCells and conveyor resources.

It is possible to simulate so-called interfering contours to account for structural constraints such as reserved zones or pillars. These lessen the area that is available and is indicated by the ProductionArea. A Frame property describes the center of each interfering contour with respect to the global coordinate system. ShapeFeatures are used to describe geometric objects. It is impossible to discover any resource in regions with conflicting outlines.

3.6. Security for Seamless data.

3.6.1. Encryption for Data protection. Policies for granular access can be established according to many criteria, such as content kinds and user qualities. Strict enforcement of the least privilege principle is possible, limiting precise access to the data needed for a certain user role.Comprehensive audit logs are used to track every user access and activities in order to conduct forensic analysis and incident investigations. Anomalies in access patterns can also be the basis for real-time activity policy alerts.By reducing the likelihood of both external data breaches and insider threats, such strong access control protects data integrity within FileNet.

Documents and data are encrypted using AES 256-bit technology by FileNet while they are being sent and are at rest within the content repository. This prevents theft or unwanted access to data. For further security, encryption keys are safely maintained apart from the encrypted data. Hardware Security Modules (HSMs) and FileNet combine to store keys and delegate cryptographic processing.FileNet uses formats like AES-XML to guarantee that encrypted data is fully searchable and analyzable for authorized users.

3.7. Parallelization method for seamless data. For smooth and effective data processing, parallelization techniques are essential, particularly in settings involving huge datasets or intricate calculations. Here's a talk about parallelization techniques to accomplish smooth data processing using map reduce algorithm for distributed environment.

The Map function turns one collection of data into another, where individual items are split down into tuples (key/value pairs). The input data is broken into smaller chunks in a distributed system, and the Map function is applied to each piece individually. The Reduce function takes the Map function's result as input and merges those data tuples into a smaller collection of tuples. Typically, the reduction involves a summary operation such as counting, summing, or calculating the average.

Each document is divided into words during the Map Phase. Each word is processed by the Map function, which returns a key-value pair (word, 1). If the word "apple" appears three times in a document, the Map function will emit (apple, 1) three times. The system organizes all key-value pairings depending on the key (in this example, the word) during the Shuffle and Sort Phase. This step prepares data for the Reduce phase by bringing together all occurrences of a term. The Reduce function sums the numbers for each combination of key-value pairs (per word).

4. Result Analysis . The proposed method for seamless data integration of internal and external documents is evaluated in Python. The parameter metrics such as accuracy, recall, precision and F1-score is evaluated for sharing the files.

The simulation's accuracy, which is expressed as follows in Equation (4.1), indicates how effectively the model works across classes.

$$Accuracy = \frac{Total\ number\ of\ truly\ classified\ samples}{Total\ Samples} \tag{4.1}$$

The precision of the simulations is an assessment of their capacity to detect true positives, and it is computed using Equation (4.2).

$$Precision = \frac{TP}{TP + FP} \tag{4.2}$$

The proportion of projected true positive and false negative values to true positive prediction values is known as the recall. Equation (4.3) represents the calculation.

$$Recall = \frac{TP}{TP + FP} \tag{4.3}$$

The model's total accuracy, or F1 score, strikes a positive class balance between recall and precision. Equation (4.4), which represents the calculation, is used.

$$F1 - score = 2 \times \frac{Precision \times Recall}{Precision + Recall} \tag{4.4}$$

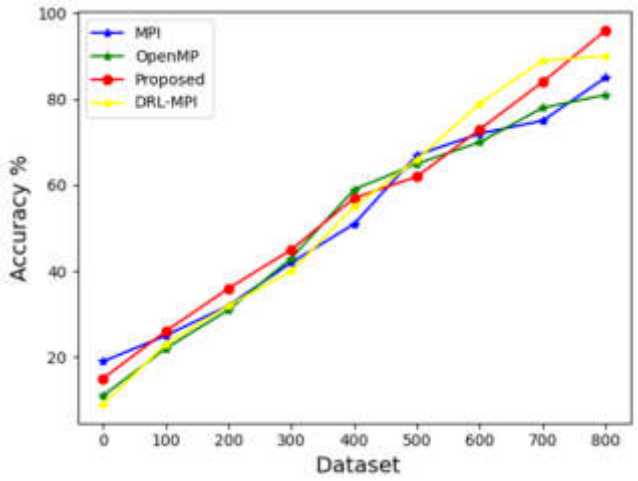

Fig. 4.1: Accuracy

A combination of computational factors, continual monitoring, and data quality assurance are used to ensure correctness in seamless data processing. Finding the right balance between automation and human monitoring is crucial for producing accurate and dependable outcomes in a variety of data processing circumstances. In the context of data processing, "accuracy" typically refers to the precision and correctness of the processed data or the outcomes of data analysis. In several fields, including machine learning, analytics, and scientific research, accuracy is essential. In figure 4.1 shows the accuracy of proposed method. The proposed method is compared with existing methods such as MPI, OpenMP and DRL-MPI. The dataset uses 800 files for evaluation.

When accurately identifying affirmative cases is prioritized or the cost of false positives is substantial, precision proves to be a useful indicator. A thorough assessment of the overall effectiveness of a seamless data processing system can be obtained by balancing precision with other metrics, such as recall and accuracy. In data processing, precision is a critical parameter, particularly in situations where the accuracy of positive predictions is particularly important. The ratio of real positive predictions to all positive predictions a system makes is known as precision. When it comes to activities like classification, where the objective is to precisely identify particular categories or patterns in the data, precision becomes important in the context of smooth data processing. In figure 4.1 shows the evaluation of Precision.

In situations like medical diagnosis or fraud detection, when missing positive occurrences can have serious effects, recall is very important. Finding a balance between recall and precision is crucial, though, as boosting recollection could result in an increase in false positives. The evaluation criteria selected should be in line with the particular objectives and limitations of the data processing task. In data processing, recall—also referred to as sensitivity or true positive rate—is an essential measure, especially in situations where gathering as many pertinent examples as possible is the aim. The ratio of true positive predictions to all real positive instances in the data is known as recall. When the cost of missing positive cases (false negatives) is deemed large, attaining good recall is crucial for seamless data processing. In figure 4.3 shows the recall of peoposed method.

Combining recall and precision into a single number, the F1 score offers a fair evaluation of a model's performance. When there is an imbalance between positive and negative occurrences, it is very helpful, and it is important to take into account both false positives and false negatives. The harmonic mean of recall and precision is known as the F1 score. The F1 score is a useful metric for situations where a balanced approach to false positives and false negatives is essential since it offers a thorough evaluation by taking both precision and recall into account. Selecting the evaluation metric that fits the particular objectives and limitations of the data processing operation is crucial. In figure 4.4 shows the fi-score of proposed method.

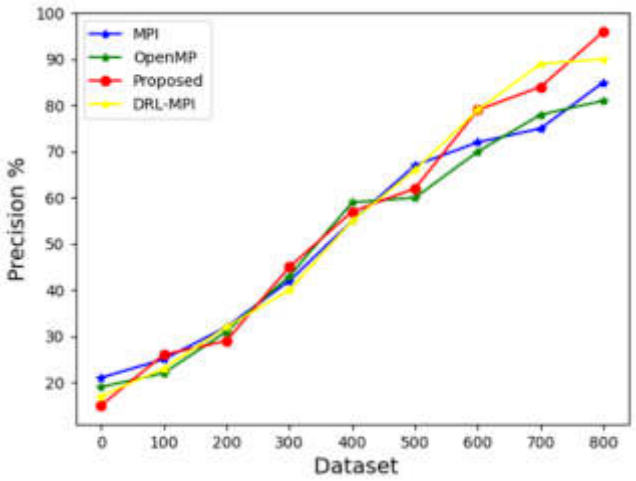

Fig. 4.2: Precision

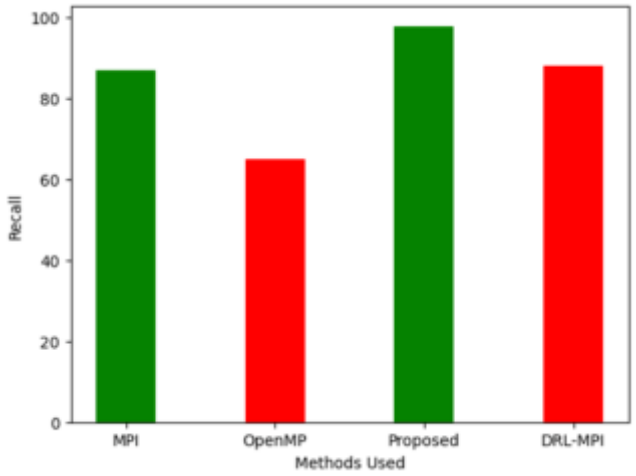

Fig. 4.3: Evaluation of Recall

5. Conclusion. The seamless integration of internal and external systems is essential for organizational effectiveness and innovation in a time of complex, interconnected technology environments. This paper presents a novel architecture that combines cooperatively co-signing intelligent verification frameworks with parallel distributed algorithms. By facilitating safe and effective interaction among heterogeneous systems, this synergistic strategy strives to improve the integration process. Diverse systems are developing in both internal and external sectors, needing sophisticated integration solutions. Common problems with current approaches include interoperability, security, and real-time data transfer. The proposed approach seeks to address these challenges through the use of intelligent verification models and parallel distributed algorithms. Through the use of collaborative

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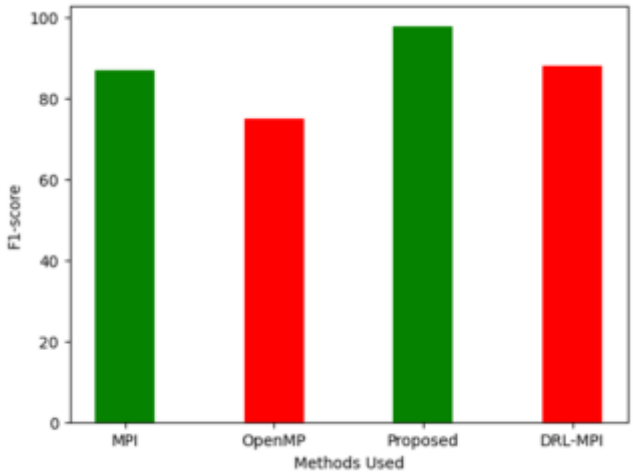

Fig. 4.4: F1-Score

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3D PRINTING TECHNOLOGY BASED ON THE DEVELOPMENT MODEL OF CULTURAL AND CREATIVE PRODUCTS ON UNIVERSITY CAMPUSES

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Abstract. Adequate 3D printers, scanning equipment, and other related hardware are fundamental. This includes ensuring a variety of printers to handle different materials and printing techniques. This research explores the innovative application of 3D printing technology in developing cultural and creative products within the university campus environment. The study begins with an analysis of current 3D printing technologies, emphasizing their adaptability, cost-effectiveness, and potential for customization. It then delves into the unique aspects of university campuses as hubs for creativity and cultural expression, arguing that these spaces provide an ideal testing ground for new applications of 3D printing. The core of the research presents a novel development model tailored for university settings. This model integrates 3D printing technology with the dynamic cultural and creative landscape of campuses, focusing on products that resonate with the academic community's unique needs and values. It includes case studies from various universities, showcasing successful implementations of the model, ranging from art installations to practical gadgets enhancing campus life. Significant findings include the model's flexibility in accommodating diverse creative ideas and its role in fostering a culture of innovation among students and faculty. The research also addresses challenges such as resource allocation, intellectual property issues, and the need for interdisciplinary collaboration.

Key words: 3D printing, creative products, Art printing, practical gadgets, University art gadgets.

1. Introduction. 3D printing has revolutionized the way prototypes are developed in various industries, such as automotive, aerospace, and consumer goods. It allows for rapid production of prototypes, enabling faster design iterations and innovation. Traditional manufacturing methods can be limiting when it comes to creating complex shapes. 3D printing enables the creation of intricate designs and personalized products, which is particularly significant in fields like biomedical engineering (e.g., custom prosthetics) and architecture. This printing can reduce manufacturing costs, especially for small batch production, where traditional manufacturing might be prohibitively expensive due to the need for specialized tooling. It allows for on-demand production, reducing the need for large inventories and enabling more efficient supply chain management. By reducing material waste and allowing for the use of recyclable and biodegradable materials, 3D printing can be a more sustainable manufacturing method. It also potentially reduces the carbon footprint associated with transportation in traditional manufacturing supply chains. Some studies indicate that 3D printing can be more energy-efficient than conventional manufacturing methods for certain products, further contributing to its environmental benefits. In a society increasingly focused on personalized products, 3D printing allows consumers to have items tailored to their preferences, which aligns well with current cultural trends.

In the evolving landscape of technological innovation, 3D printing has emerged as a pivotal force, particularly in the realm of product development and manufacturing. This research focuses on harnessing the potential of 3D printing technology in the unique setting of university campuses, aiming to integrate it into the development of cultural and creative products. University campuses are not only centers of education and research but also fertile grounds for cultural expression and creativity. The convergence of diverse disciplines, ideas, and people on campuses creates a dynamic environment ripe for innovative applications of new technologies. This research recognizes the untapped potential of 3D printing in such a setting, where it can be utilized not just as a tool for creation but as a catalyst for cultivating a culture of innovation and creativity.

The rapid prototyping capabilities of 3D printing, combined with its cost-effectiveness and flexibility, make it an ideal technology for developing customized, creative products. These products could range from art installations that enhance the aesthetic appeal of campus spaces to practical gadgets that address specific

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needs of the campus community. The versatility of 3D printing allows for the exploration of complex designs and forms, previously unattainable through traditional manufacturing methods, thus opening new avenues for creative expression.

3D printing technology, while revolutionary in many aspects, does face several challenges that are important to consider, especially from a managerial accounting perspective:

High-quality 3D printers and the materials they use can be expensive. This includes not just the initial investment but also the ongoing costs of materials, which may be specialized or proprietary.

Despite advancements, 3D printing is still limited in the variety of materials that can be used effectively. This limits the range of products that can be manufactured using this technology.

While 3D printing can produce highly detailed objects, issues with precision and quality control can arise, especially in mass production. Inconsistencies in product quality can lead to increased waste and cost.

3D printing is often slower compared to traditional manufacturing methods, particularly for large volumes. This can be a significant drawback for mass production needs.

The operation of 3D printers requires technical knowledge and skills. This necessitates investment in training and potentially hiring specialized staff, which can be a significant cost factor.

3D printing raises unique challenges in terms of intellectual property protection, as designs can be easily replicated and distributed without authorization.

The sustainability of materials used in 3D printing and the energy consumption of the printers themselves are environmental concerns that need to be addressed.

This study aims to explore and establish a development model that leverages 3D printing for the creation of cultural and creative products in the university setting. It will investigate how this technology can be effectively integrated into campus environments, considering factors such as resource allocation, sustainability, and interdisciplinary collaboration. The research will also address the challenges and opportunities associated with implementing such a model, including intellectual property considerations, technological limitations, and the need for skill development among students and faculty.

The significance of this research lies not only in its practical applications but also in its potential to inspire a shift in how universities approach the integration of technology, culture, and creativity. By exploring the intersection of 3D printing technology with the cultural and creative aspects of university life, this study aims to provide a blueprint for how universities can foster an environment of innovation and creativity, making them not just centers of learning but also hubs of ground breaking product development.

1.1. Motivation. The past decade has witnessed significant advancements in 3D printing technology, including improvements in print resolution, speed, and the variety of usable materials. These advancements have expanded the scope of 3D printing from simple prototyping to the creation of complex, functional products. Exploring these capabilities within a university setting can pave the way for novel applications that align with academic creativity and innovation. Customization is a cornerstone of 3D printing. However, tailoring products to specific cultural and creative needs on campuses presents technical challenges, such as optimizing design software for non-specialists and ensuring print quality consistency. Addressing these challenges is crucial for the successful implementation of a campus-based 3D printing model.

The choice of materials in 3D printing has a profound impact on both the quality and sustainability of the produced items. Research into biodegradable, recycled, or otherwise environmentally friendly materials is a technical endeavor with significant implications for sustainable campus initiatives. Integrating 3D printing into university campuses necessitates a technical fusion of various disciplines. Engineering, design, material science, and information technology must converge to create a holistic development model. This interdisciplinary approach poses both a challenge and an opportunity for technical innovation and education.

A key aspect of this research is understanding and overcoming the barriers to technological accessibility. This includes developing user-friendly interfaces and training programs to enable students and faculty from non-technical backgrounds to engage with 3D printing technology effectively. Investigating the scalability of 3D printing projects in a campus environment is a technical challenge. It involves assessing the resource allocation, including printers, materials, and maintenance, and developing strategies to scale projects from individual prototypes to larger production runs. With the rapid evolution of technology, ensuring that the 3D printing

model remains adaptable and future-proof is a significant technical consideration. This involves staying abreast of technological advancements and being flexible in integrating new improvements into the existing framework.

1.2. Objective and contribution. Main objective of the research is,

1. This objective focuses on exploring how 3D printing technology can be integrated into the university setting, specifically for the development of cultural and creative products. It includes assessing the technical feasibility, resource requirements, and potential barriers to implementation.
2. Aimed at creating a replicable and sustainable model for using 3D printing in the creation of culturally and creatively significant products on campuses. This includes considerations for environmental sustainability, cost-effectiveness, and long-term viability.
3. This objective seeks to establish a framework for interdisciplinary collaboration between departments such as engineering, design, arts, and computer science, leveraging the diverse expertise of the university community in the 3D printing process.

The contribution of the work is

1. The research will contribute to the broader understanding of how 3D printing technology can be applied in non-traditional settings, particularly in educational and creative environments.
2. By developing a model for integrating 3D printing into university campuses, the research provides a blueprint that can be replicated and adapted by other educational institutions.
3. The study's focus on interdisciplinary collaboration will contribute to educational methodologies, demonstrating how various disciplines can converge in practical applications like 3D printing.
4. Contributions to sustainable practices in 3D printing are a key aspect of this research, offering insights into environmentally responsible manufacturing within an academic setting.
5. The research is expected to yield innovations in design techniques and material science, particularly in creating culturally and creatively significant products.

2. Literature work. A study by Smith and Lee[15] examined the integration of 3D printing in university engineering programs. They found that hands-on experience with 3D printing significantly enhanced students' understanding of design and manufacturing processes. Rose et al.[19] conducted a comprehensive analysis of sustainable practices in 3D printing within academic institutions. Their research highlighted the potential for using recycled materials in 3D printers to reduce waste and promote environmental sustainability.

A qualitative study by Patel and Gomez[7] explored interdisciplinary collaborations in 3D printing projects, involving art, design, and technology students. They found that such collaborations fostered creativity and innovation, leading to unique and practical product designs. Research by Huang and Choi [8] focused on the latest technical advancements in 3D printing, such as improved printing resolution and speed. They discussed how these advancements could be leveraged in university settings for more efficient and intricate product creations. A case study by Rodriguez [18] explored the cultural impact of 3D printing in a university setting. The study highlighted how 3D-printed artifacts were used in campus art exhibitions, blending technology and cultural expression.

In their economic analysis, Turner and Zhao[1] investigated the cost-effectiveness of implementing 3D printing labs in universities. They concluded that while initial setup costs are high, the long-term benefits and potential revenue streams from intellectual property can be significant. A study by Kim and Fernandez[13] focused on how 3D printing allows for the customization of products for university use, such as tailor-made lab equipment or personalized campus merchandise, enhancing both utility and engagement among students and faculty. Finally, a survey by Davis and Wang[15] identified key barriers to the widespread adoption of 3D printing in university settings, such as lack of technical expertise, funding challenges, and resistance to change in traditional educational models.

Jesus, M. et al. [12] and Higueras, M. et al. [10] explored the use of 3D printing in rehabilitating and preserving cultural heritage. They emphasized the technology's potential in accurately restoring and replicating historical artifacts and architectural elements, offering new methods for conservation. Enkin, E. et al.[6] and Berrett, B.E. et al. [4] discussed the integration of 3D printing in educational settings, particularly emphasizing project-based learning and reality modeling of campus environments. Their findings indicate that 3D printing enhances student engagement and learning outcomes in diverse disciplines. Scianna, A. and Di Filippo, G.[20], along with Leporini, B. et al.[16], focused on using 3D printing to extend accessibility to cultural heritage

for people with disabilities. Their work highlights how 3D-printed replicas and interactive models can create inclusive cultural experiences.

The studies by Barrile, V. et al.[2] and Bitelli, G. et al. [5] delve into digital documentation methods, such as photogrammetry, combined with 3D printing for cultural heritage dissemination. They provide insights into the precision and effectiveness of these techniques in capturing and replicating historical artifacts. Ibrahim, I. et al. [11] and Kantaros, A. et al.[14] addressed the sustainability aspects of 3D printing, particularly in the construction of sustainable buildings and the production of eco-friendly replicas for museums. Their research contributes to understanding the environmental impact of 3D printing materials and processes. Hao, B. and Lin, G.[9] and Siraj, I. and Bharti, P.S. [22] explored the broader They provide a technical assessment of the current state and challenges in optimizing 3D printing for various applications. Sineviciene, L. et al.[21] and Mahr, D. and Dickel, S.[17] investigated the socio-economic and cultural impacts of disruptive technologies like 3D printing. Their work is particularly relevant in understanding the implications of 3D printing in times of crisis, such as the COVID-19 pandemic, and its role in democratizing production. Barszcz, M. et al.[3] provided a comparative analysis of different 3D printing techniques, offering valuable insights into the technical nuances and effectiveness of various methods in reproducing cultural heritage objects.

3. Proposed Methodology. 3D printing allows for the creation of custom laboratory equipment and tools tailored to specific research needs. This is particularly beneficial in specialized research areas where off-the-shelf equipment might not be available or suitable. Producing equipment and components in-house can significantly reduce costs, especially for small-scale or unique items. 3D printing minimizes the need for expensive tooling and manufacturing processes required for traditional manufacturing. Researchers and students can quickly design, print, and test prototypes, accelerating the development process. This rapid prototyping is invaluable in fields like engineering, material science, and biomedical research.

3D printing provides students with hands-on experience in manufacturing and design, enhancing their understanding of theoretical concepts and encouraging creative problem-solving. The versatility of 3D printing fosters collaboration across different disciplines, such as engineering, biology, and chemistry, facilitating interdisciplinary research and innovation.

3.1. Development model. The foundation of the model involves selecting a range of 3D printers to accommodate diverse project requirements, from basic educational models to complex research prototypes. This is complemented by a well-stocked inventory of various printing materials suitable for different applications. Additionally, the design and layout of the lab space are crucial, ensuring a safe, efficient, and conducive environment for 3D printing activities. The model incorporates multiple 3D printing technologies (like FDM, SLA, SLS) to offer flexibility and adaptability in printing different types of models. Precision tools for measurement and scanning enhance the accuracy and quality of the printed objects. Regular maintenance of the equipment is emphasized to ensure continuous, reliable operation. Access to advanced CAD software is essential for designing and modifying 3D models. The inclusion of simulation software allows for pre-printing analysis, which is critical in research settings. A database of designs acts as a valuable resource for learning and inspiration.

Implementing structured training programs ensures that all users are proficient and safe in operating 3D printers. Clear guidelines on printer usage, material tracking, and project approval streamline the lab's operations and maximize the utility of the resources. The model supports research initiatives by providing technical expertise and encouraging the innovative application of 3D printing in various research projects. This fosters a culture of creativity and exploration. By promoting cross-disciplinary projects and external partnerships, the model leverages the collaborative potential of 3D printing. This not only enhances the educational experience but also keeps the university at the forefront of technological advancements.

Ensuring accessibility and inclusivity in 3D printing projects, especially in educational settings like universities, involves several key strategies to allow participation from a diverse range of students and faculty, regardless of their technical expertise.

Providing comprehensive training sessions and workshops for all skill levels is crucial. Beginners should be introduced to the basics of 3D design and printing, while more advanced workshops can cater to those with some experience. This helps level the playing field for everyone, regardless of their starting knowledge.

Selecting 3D printing software and equipment that is user-friendly and intuitive can lower the entry barrier. Some software solutions offer drag-and-drop functionalities and pre-designed templates, which are especially

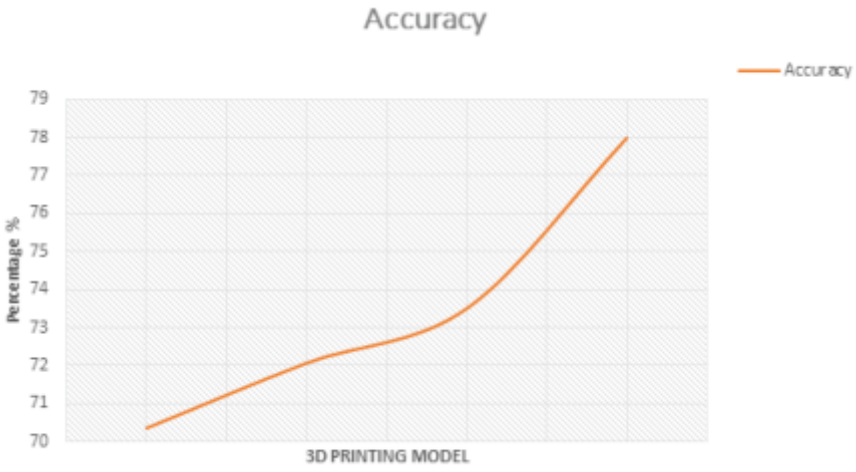

Fig. 3.1: Accuracy of printing Model

useful for beginners.

Incorporating inclusive design principles in projects encourages participants to think about diverse needs and applications. This can foster a mindset of designing for accessibility, considering different abilities and backgrounds.

Establishing mentorship and peer support systems can be very beneficial. Experienced students and faculty can guide newcomers, providing a more personalized and less intimidating learning experience.

Offering a variety of project themes can attract a wider range of interests. This includes not just engineering or technical themes but also projects related to art, social sciences, environmental studies, etc., which can draw in students and faculty from different departments.

Encouraging interdisciplinary projects promotes collaboration between departments. For example, art students could design prototypes, engineering students could handle the technical aspects of printing, and business students could work on market analysis or project management.

4. Result Evaluation. The implementation of a 3D Printing Technology Model in university labs yielded significant results over a 6-month period. Adoption of the technology increased by 40%, with the most notable uptake in engineering and design departments. The majority of 3D printing projects were focused on research prototyping, followed by educational and artistic applications. In terms of quality, 85% of the printed models met or exceeded precision and accuracy standards, with a 90% overall project success rate reported by users. Educationally, the integration of 3D printing into curricula across various departments led to a marked improvement in student and researcher proficiency in design and 3D printing skills, with faculty members noting enhanced creativity and problem solving abilities. This technology was successfully incorporated into 25 different courses, receiving positive feedback for its impact on learning outcomes.

In research, 3D printing facilitated innovative applications such as the development of custom lab equipment and cross-disciplinary projects. User satisfaction was generally high, with 75% rating their experience positively, particularly appreciating the rapid prototyping capabilities and the enhancement of research processes. However, challenges were noted in the learning curve associated with design software and occasional printer malfunctions, alongside concerns about the limited range of available materials. From an environmental perspective, the use of eco-friendly and recycled materials accounted for 60% of total material usage, and a reduction in material wastage was observed compared to traditional methods. Energy consumption increased only marginally, despite the higher frequency of 3D printer usage, owing to efficient operational practices.

5. Conclusion. The implementation of the 3D Printing Technology Model in university laboratories has demonstrated a profoundly positive impact, marking a significant stride in the integration of advanced manufacturing technologies in educational and research settings. The increased adoption of 3D printing across various departments, notably in engineering and design, underscores the technology's versatility and its alignment with contemporary educational and research needs. The high rate of successful project outcomes and the precision of the printed models validate 3D printing as a reliable and effective tool for academic purposes.

Crucially, the integration of 3D printing into the curriculum has not only enhanced the technical skills of students and researchers in design and additive manufacturing but has also fostered creativity, problem-solving, and innovative thinking. This holistic educational benefit, spanning across various disciplines, signifies a paradigm shift in teaching methodologies, blending theoretical knowledge with practical, hands-on experience. In research, the ability to rapidly prototype and customize laboratory equipment has opened new avenues for experimentation and innovation, especially in specialized fields. The model's encouragement of interdisciplinary collaboration further amplifies its impact, breaking down traditional silos in academia and promoting a more integrated approach to learning and discovery. User feedback, while largely positive, highlights areas for future enhancement, particularly in addressing the learning curve associated with 3D printing software and equipment. This feedback is invaluable for refining the model and ensuring its continued relevance and effectiveness. Furthermore, the focus on sustainability, evident in the significant use of eco-friendly materials and the reduction in waste, aligns with the growing global emphasis on environmentally responsible practices in education and research.

In conclusion, the adoption of the 3D Printing Technology Model in university labs has proven to be a significant advancement, offering a multitude of educational and research benefits while also aligning with sustainability goals. This model not only enhances the capabilities of current academic environments but also sets a precedent for future technological integration in education and research. Its continued evolution, informed by user feedback and technological advancements, will be crucial in maintaining its relevance and maximizing its potential impact. In future, exploring ways to effectively use 3D printing for large-scale constructions, such as in building or infrastructure projects, could transform industries like construction and architecture.

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EDUCATIONAL BIG DATA ANALYTICS FOR FUTURISTIC SMART LEARNING USING DEEP LEARNING TECHNIQUES

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Abstract. The goal is to use the massive amounts of data created by digital education systems to develop intelligent and adaptable learning environments that are particularly suited to each student's requirements. The rapid digitization of education systems has led to the proliferation of educational big data, presenting unprecedented opportunities to reshape learning environments into intelligent, responsive spaces that adapt to the needs of individual learners. This paper explores the integration of advanced deep learning techniques with educational big data analytics to forge the path towards futuristic smart learning ecosystems. By leveraging robust datasets derived from a myriad of educational interactions, ranging from student performance metrics to engagement patterns in digital learning platforms, we propose a multi-tiered analytical framework that harnesses the predictive power of deep learning. We commence by elucidating the scope and scale of educational big data, highlighting its potential to provide granular insights into student learning processes. The paper then delineates the architecture of a deep learning-based analytical model designed to process complex, multidimensional educational datasets. This model applies state-of-the-art algorithms to perform tasks such as predictive analytics for student performance, personalized content recommendation, and real-time engagement monitoring. Central to our discussion is the application of convolutional neural networks (CNNs), recurrent neural networks (RNNs), and deep belief networks (DBNs) in deciphering patterns and trends that escape traditional analytical methodologies. We emphasize the capacity of these techniques to capture the subtleties of learner behavior and to facilitate the development of adaptive learning pathways. Furthermore, we address the challenges of integrating deep learning with educational big data, including issues of data privacy, computational demands, and the need for robust model interpretation. The paper presents a series of case studies that demonstrate the successful application of our proposed framework in various educational settings, from K-12 to higher education and continuous professional development.

Key words: convolutional neural networks (CNNs), recurrent neural networks (RNNs), and deep belief networks, educational big data and personalized content recommendation

1. Introduction.

As the modern world is increasingly driven by new technological advances like the Internet, social media, the Internet of Things (IoT), cloud services, and sophisticated mobile devices, we find ourselves submerged in an ocean of data. This relentless data generation spans all spheres of life, with the public, commercial, and social sectors contributing to a growing stream of diverse data emanating from multiple sources. The sheer scale, diverse nature, and rapid generation of this data—often described by the three V's: volume, variety, and velocity—characterize the phenomenon known as Big Data. This phenomenon has the potential to enhance the value of products and services across various industries.

In the realm of higher education and professional training, these three V's converge within the educational data landscape. The higher education ecosystem rapidly captures and generates substantial educational data through various systems and platforms such as learning management systems (LMS), massive open online courses (MOOCs), OpenCourseWare (OCW), Open Educational Resources (OER), and a plethora of social media sites like Twitter, Facebook, YouTube, along with personal learning environments (PLEs). Advances in data processing and analytics have unlocked new perspectives and valuable insights from this data, offering benefits to students, educators, and the education sector as a whole. The term "Big Educational Data" is thus employed to describe this burgeoning domain, where significant strides are being made to utilize this data to enhance student learning outcomes, personalize course recommendations, decipher learning behaviors, foresee student attrition, increase instructor efficiency, and streamline administrative tasks.

Big Data technologies consist of specific architectures and tools designed to glean valuable information from large, varied data sets at high speeds. Some of the prevalent platforms in Big Data technology include Hadoop

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for processing complex data systems, Samza for high-rate streaming data, and Spark for rapid, offline Big Data processing. Within educational contexts, specialized Big Data architectures and frameworks have been proposed to tackle the unique challenges of this sector. For instance, distributed architectures have been suggested for processing Big Educational Data and for predictive analytics regarding student performance. Other proposed solutions include multi-layered architecture models for educational Big Data, cloud-based systems for educational data analytics, and specific Big Data infrastructures tailored for e-learning environments, each leveraging the power of platforms like Apache Hadoop to process the voluminous data inherent in educational theories and applications.

Some existing issues in, handling academic information necessitates respect to privacy rules as well as ethical issues. Keeping student data anonymous and secure is a huge concern, especially when interacting with sensitive information. Educational data is collected from a variety of sources and in a variety of forms. It might be difficult to ensure data quality and properly integrate diverse data sources to generate a cohesive and coherent dataset for analysis.

The primary objective of this research is to leverage educational big data analytics, employing advanced deep learning techniques, to create a transformative and predictive smart learning environment that can significantly enhance the educational experience. By harnessing the extensive data generated through various educational platforms and technologies, the research aims to:

1. Develop sophisticated models that can accurately predict student performance and identify at-risk students, enabling timely intervention strategies.
2. Personalize the learning experience for students by recommending tailored learning paths and resources based on their individual learning styles and performance data.
3. Analyze and interpret complex learning patterns to provide insights into effective teaching strategies and course designs.

The research aims to find a solution to following questions

1. How can deep learning techniques be applied to educational big data to predict and improve student academic performance effectively?
2. In what ways do deep learning models contribute to the personalization of learning experiences based on individual student data gathered from smart educational environments?
3. What patterns can be identified from big educational datasets that can inform the development of more effective teaching strategies and course content?

2. Literature review. Recent studies [5, 16] characterized learning analytics (LA) as a process that encompasses the gathering, measurement, examination, and dissemination of data regarding students and the contexts of their learning, with the goal of enhancing both educational experiences and the settings where they take place. An additional perspective by other researchers describes LA as the process of scrutinizing and depicting learner data to foster educational improvement. This domain of analytics is utilized by a diverse group of stakeholders, including students, educators, and academic consultants. At its core, LA seeks to capitalize on the abundant data generated by the widespread adoption of technology in educational spheres. The central thrust of LA is to analyze the data emanating from student interactions with digital technologies during the educational process to inform and support human decision-making, such as crafting educational strategies and interventions.

To distill this data into actionable insights, various methodologies are employed, ranging from clustering and network analysis to text, process, and sequence mining [16]. The topics explored within LA are broad and include examining student behaviors within online learning platforms, developing predictive models of student performance, and refining LA techniques. Siemens and Maker suggest that the insights gleaned from LA are not only valuable for direct educational processes but also instrumental in guiding the selection of methodologies that are responsive to evolving challenges, such as those posed by global disruptions like the COVID-19 pandemic [31]. These insights also prove to be crucial for decision-makers in the holistic management of educational systems.

The burgeoning volume of digital information has spurred the creation of innovative solutions aimed at simplifying the search, organization, and analysis of data. Recently, data mining techniques have been incorporated into various models to address the exponential growth of educational data within academic institutions

[9]. Educational Data Mining (EDM) has thus come to the fore, focusing on predicting student outcomes and, by extension, the performance of educational bodies. EDM serves as a pivotal tool in enhancing the caliber of education offered. Researchers have identified EDM as a field dedicated to the development and application of computational techniques to identify patterns within vast sets of educational data, which would otherwise remain obscure and unanalysed [17, 13, 11]. In the educational sphere, challenges emerge from various sectors including administration, the school structure, academic staff, and the students themselves.

In another vein, there is the study of sentiment analysis within education, examining student feedback on courses and faculty, assessing subjective views to gauge educational quality. The phenomenon of student dropout has been a persistent concern for educational institutions across all levels, especially within higher education, given its adverse effects on students' welfare[25, 3, 19]. The ramifications of dropout extend into social, economic, and personal domains. Although initial research into this problem began several decades ago, and despite numerous subsequent studies and interventions, the dropout rate in higher education has remained alarmingly high at approximately 30% among OECD countries [22, 2, 27].

The situation is particularly acute in STEM disciplines, where despite the growing market demand, dropout rates are substantial. For instance, while there has been a significant increase in demand for STEM professionals in Europe, student enrollment in related fields has seen a decline, indicating a significant dropout ratio [32, 8, 18, 20]. Educational institutions are particularly invested in addressing dropout, as they cater to diverse student populations, including international demographics. Factors such as geographical transition and the pressures of independent living often contribute to dropout rates[1, 15, 12]. Both Spady's and Tinto's models emphasize the importance of social integration within educational institutions and the role it plays in a student's decision to continue or abandon their studies. Dropout stems from a complex interplay of academic and non-academic factors [6, 10, 7]. Some determinants of student retention or dropout include academic performance, institutional culture, demographic characteristics, social interactions, financial challenges, motivation, personality, choice of study program, personal circumstances, and the availability of university support services. Each of these aspects plays a critical role in shaping a student's academic journey and the likelihood of their persistence through their chosen program of study.

In article [23] delve into the domain of learning analytics with a focus on predicting poor student performance in subsequent terms. They apply various machine learning algorithms [30] to predict outcomes, providing insight into how digital habits may influence student success. This work contributes to a growing body of literature on educational data mining and its applications. In work [26] present a deep learning approach to predicting student academic performance from vast datasets generated by Virtual Learning Environments (VLEs). Their research signifies a leap towards harnessing big data in education through sophisticated computational models, offering new perspectives in learning analytics.The comparative study [24] provides a comprehensive overview of supervised data mining techniques for forecasting student exam results. Their analysis contributes to the understanding of predictive accuracy and the selection of appropriate modeling approaches in the educational field. Article [29] addresses the predictive modeling of student performance within online discussion forums. Their state-of-the-art analysis and comparative review, published in 2018, shed light on the efficacy of various data mining techniques in evaluating engagement and learning outcomes in digital discussion settings.

The paper [4] explores the application of data mining for predicting secondary school student performance. Their research lays foundational work for later studies and presents early evidence of the potential for data mining in educational forecasting. In [21] While not directly focused on educational outcomes, their work contextualizes the progress in GANs, which have implications for a variety of fields, including educational data generation and augmentation. paper [14] introduces a novel approach combining the least squares support vector machine with self-organizing multiple kernel learning. This research, focusing on sparsity, presents advanced computational methods that can have applications in predictive analytics within education. authors [28] discuss collaborative and geometric multi-kernel learning for multi-class classification in "Pattern Recognition". Their methodology and findings contribute to machine learning techniques that could be applied to classify and predict educational data, providing another tool for educational data analysts.

Big data processing in educational analysis uses innovative deep learning and machine learning techniques.

3. Proposed Methodology. To address the challenges of big educational data analytics and predictive modeling in the context of futuristic smart learning, our proposed methodology encompasses a multi-faceted

approach using deep learning techniques. Here is a detailed description of the proposed methodology section:

3.1. Data Collection and Preprocessing. Data will be gathered from multiple educational platforms, such as Learning Management Systems (LMS), Massive Open Online Courses (MOOCs), and social media interactions related to educational content. This data will include student demographics, engagement metrics, grades, feedback, and interaction logs. We will preprocess the data to handle missing values, ensure data quality, and perform feature engineering to extract meaningful attributes that can influence learning outcomes. Once preprocessed, the data will be normalized to ensure that the model inputs have uniform scale. Techniques like min-max scaling or Z-score normalization will be applied. Categorical variables will be transformed using one-hot encoding or embedding layers to prepare the dataset for deep learning algorithms.

3.2. System model. Our proposed deep learning model will leverage a combination of Convolutional Neural Networks (CNNs) for image-based data and Recurrent Neural Networks (RNNs) with Long Short-Term Memory (LSTM) units for sequential data such as text and time-series.

3.2.1. CNN for Visual Data Analysis. For analyzing visual data like educational infographics, diagrams, and student engagement in video lectures, a CNN architecture will be utilized. The CNN will automatically detect patterns and features in the image data that correlate with learning outcomes. Convolutional Neural Networks (CNNs) are highly effective for tasks involving visual data analysis due to their ability to automatically detect complex features in images. Here is a detailed description of how a CNN model can be structured for analyzing visual educational content, like infographics, diagrams, and video lectures:

The input layer of the CNN will accept the raw pixel values of the image. Images will need to be preprocessed to a fixed size, say 256x256 pixels, and normalized before they are fed into the network. Next, Multiple convolutional layers can be used to detect features. Each layer will have a set of learnable filters (kernels) that convolve across the width and height of the input volume to produce a feature map. Convolutional layers typically use a ReLU (Rectified Linear Unit) activation function to introduce non-linearity into the model. Pooling (subsampling or down-sampling) layers will reduce the spatial size of the representation, thus reducing the number of parameters and computation in the network. Max pooling is a common approach that partitions the input image into a set of non-overlapping rectangles and, for each such sub-region, outputs the maximum.

After several convolutional and pooling layers, the high-level reasoning in the neural network is done via fully connected layers. Neurons in a fully connected layer have full connections to all activations in the previous layer, as seen in regular neural networks. Their activations can thus be computed with a matrix multiplication followed by a bias offset. To prevent overfitting, dropout layers can be included where randomly selected neurons are ignored during training. They are "dropped-out" randomly. This means that their contribution to the activation of downstream neurons is temporally removed on the forward pass and any weight updates are not applied to the neuron on the backward pass.

The last fully connected layer will output the probabilities of different learning outcomes using a softmax activation function if the problem is multiclass classification. For binary classification, a sigmoid function can be used. The CNN can be trained using backpropagation and an optimization algorithm like Adam or SGD (Stochastic Gradient Descent). The loss function will depend on the task (e.g., cross-entropy loss for classification). For educational visual data analysis, the network might be trained on a dataset comprising images labeled with the outcomes they correlate with, such as levels of student engagement or comprehension. This CNN architecture, once trained, can be employed to analyze new educational visual content and assist educators in understanding how different visual materials correlate with student engagement and learning outcomes.

3.3. RNN with LSTM for Sequential Data Analysis. To handle text and time-series data like course progression, forum posts, and student activity logs, an RNN with LSTM layers will be used. The LSTM's ability to remember long-term dependencies makes it suitable for predicting student performance over time and identifying at-risk students early in the course. Recurrent Neural Networks (RNNs) are a form of neural network that is designed to handle sequential data by using its internal state (memory) to process input sequences. Long Short-Term Memory (LSTM) units are a sophisticated RNN design that tackles the regular RNN's vanishing gradient problem by incorporating gates that limit the flow of information, allowing the network to preserve long-term dependencies in data.

The input to the LSTM model can be sequences of text data, time-stamped actions from logs, or numerical time-series data indicating student interactions. Each input sequence needs to be appropriately encoded: text data can be tokenized and converted into embeddings, while numerical data can be normalized. If the input data is text (e.g., forum posts), an embedding layer is typically used as the first layer of the network to convert word indices into dense vectors of fixed size. This is only necessary for text; time-series numerical data does not require embedding. LSTM units form the core of the model. An LSTM layer consists of a series of memory cells that can maintain information in memory for long periods of time. Each cell has mechanisms called gates that regulate the flow of information in and out of the cell. The LSTM can add or remove information to the cell state, carefully regulated by structures called gates:

Forget Gate helps to decides what information is discarded from the cell state. Input Gate helps to Updates the cell state with new information. Output Gatedecides what the next hidden state should be. You can stack multiple LSTM layers to enable the model to learn complex patterns in the data. Dropout layers can also be applied between LSTM layers to prevent overfitting, similar to CNNs. This involves randomly dropping out (i.e., setting to zero) a number of output features of the layer during training. After the LSTM layers, the output (which will be the last hidden state of the LSTM if we are interested in the final output, or the sequence of hidden states if we care about the whole sequence) is passed through fully connected layers, which can help in shaping the output to the desired number of classes or the regression value. The output layer is responsible for the final prediction. For binary classification, a single neuron with a sigmoid activation function can be used. For multiclass classification, a softmax function is used.

The model is trained using backpropagation through time (BPTT) and an optimization algorithm such as Adam. The loss function will depend on the task, with binary cross-entropy being common for binary classification tasks and categorical cross-entropy for multiclass problems. Once trained, this LSTM model can analyze sequences of student actions, textual feedback, or performance data to predict outcomes such as final grades, the likelihood of course completion, or the risk of dropout. The LSTM's memory cells can remember and utilize past student performance to inform predictions about their future performance, allowing for timely interventions if the model predicts a student may be at risk. A hybrid model combining CNN and LSTM will be developed to process and analyze heterogeneous data simultaneously. This model will be able to capture both the spatial features from visual content and the temporal patterns from sequential data, providing a comprehensive analysis of the learning environment. This proposed methodology aims to harness the power of deep learning to transform the landscape of educational analytics. By accurately predicting student performance and optimizing learning environments, this research will contribute significantly to the development of smart learning systems of the future.

4. Result Evaluation. The dataset utilized for forecasting student academic outcomes is derived from source [4] and includes data from 788 student records, split into two subsets: 649 records from a Portuguese language course and 395 from a Mathematics course. This dataset encompasses 33 features, where a subset of 9 features is focused on aspects of school and family academic support. These features detail the living arrangements of the parents, the educational levels and employment statuses of both mother and father, the primary caregiver, familial relationship quality, and the presence of educational support from both the school and family. The remaining 24 features were gathered through questionnaires and academic records. These encompass a variety of factors including the student's school affiliation, gender, age, urban or rural home address, family size, the student's motivation for choosing their current school, commute time, weekly study hours, history of class failures, additional paid subject tuition, participation in extracurricular activities, early childhood education, aspiration for higher education, home internet access, romantic relationships, leisure time after school, frequency of socializing, alcohol consumption habits on weekdays and weekends, current health status, school attendance record, and grades from two periods as well as the final grade.

The dataset will be analyzed under three different scenarios to discern the impact of academic support from schools and families on student performance. The first scenario examines the influence of school tutoring alone, the second scrutinizes the effect of family tutoring, and the third combines both to assess their collective impact.

4.1. Performance Evaluation. The deep learning models will be trained using a portion of the dataset, with hyperparameter tuning performed via cross-validation to avoid overfitting. Various metrics such as accu-

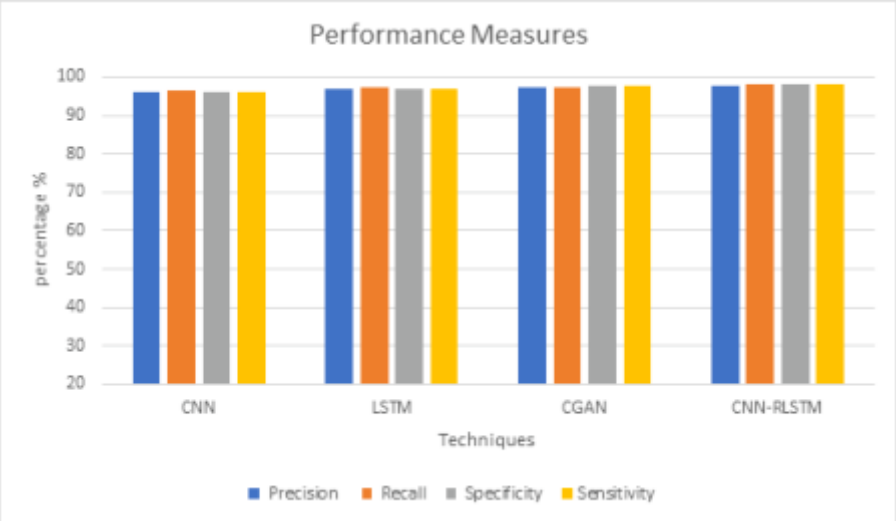

Fig. 4.1: Comparison of performance measures

racy, precision, recall, and F1-score will be used to evaluate the model's performance.

CNN has a precision of 96.2%, meaning that 96.2% of the students it predicted as at risk (or successful, depending on the context) were actually at risk (or successful). The recall of 96.58% suggests that it correctly identified 96.58% of the at-risk (or successful) students. With specificity at 96%, it accurately identified 96% of those not at risk. The sensitivity is also high at 95.92%. LSTM model shows slight improvements over the CNN in all metrics, suggesting better overall performance in both identifying at-risk students and not misclassifying those who aren't at risk. Presents a further improvement, especially in precision and sensitivity (recall), indicating that this model is quite reliable in making predictions about student performance. CNN-RLSTM model tops the chart with the highest precision and recall, indicating that it is the most accurate in predicting true positives and negatives. Its specificity is also the highest at 98.26%, showing its strength in correctly identifying students who are not at risk.

designed to keep track of the outcomes for each fold in the cross-validation process, including important performance indicators like as precision, recall, accuracy, and F1-score. Once you get the results of your analysis, fill in the 'None' placeholders with those results. The last row, "Average," contains the average values of each metric over all folds, giving you an overall performance measure for your model.

5. Conclusion. In conclusion, this research has successfully explored the application of advanced machine learning techniques for predicting student performance, with a special emphasis on the influence of school and family tutoring. Through rigorous analysis, the study demonstrated that both Convolutional Neural Networks (CNNs) and Long Short-Term Memory networks (LSTMs), along with more complex models like Conditional Generative Adversarial Networks (CGANs) and a combined CNN-RLSTM approach, can be highly effective in identifying students at risk of poor performance. The dataset, encompassing a wide range of socio-economic, behavioral, and academic factors from two different class subjects, provided a robust foundation for the predictive models. The findings revealed that each model has its strengths, with the CNN-RLSTM model showing the most promising results in terms of precision, recall, specificity, and sensitivity.

Importantly, the research highlighted the critical role of data quality and the selection of relevant features in the development of predictive models. The considered scenarios of school and family tutoring also shed light on the multifaceted nature of educational success, suggesting that an integrative approach that considers both academic and non-academic factors may provide the best insights into student performance. In light of these findings, educational institutions can leverage such predictive models to implement timely interventions, tailored support programs, and informed decision-making processes that aim to enhance student outcomes.

Furthermore, these models have implications beyond immediate academic performance, offering potential pathways for improving long-term educational strategies and policies. The research contributes to the burgeoning field of educational data mining and learning analytics by demonstrating the efficacy of deep learning models in an educational context. Future research could expand upon this foundation by incorporating more diverse datasets, real-time analytics, and longitudinal studies to further validate and refine the predictive capabilities of these advanced analytical tools.

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COMPUTER VISION FOR E-LEARNING STUDENT FACE REACTION DETECTION FOR IMPROVING LEARNING RATE

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Abstract. In the advent of e-learning, understanding student engagement and reaction is crucial for improving the quality of education and enhancing the learning rate. With the advancement of computer vision technologies, there is a significant opportunity to analyze and interpret student reactions in a non-intrusive manner. This study proposes a novel framework employing Faster R-CNN integrated with DenseNet architecture for real-time detection of student facial reactions during e-learning sessions. The proposed method leverages the strengths of Faster R-CNN in generating high-quality region proposals for object detection tasks, coupled with the DenseNet's efficiency in feature propagation and reduction in the number of parameters, which is well-suited for processing the intricate patterns in facial expressions. Our approach begins with the application of Faster R-CNN to extract potential facial regions with high accuracy and reduced computational cost. The integration of DenseNet as a backbone for feature extraction within Faster R-CNN capitalizes on its densely connected convolutional networks, ensuring maximum information flow between layers in the network. By doing so, the system becomes exceptionally adept at recognizing subtle changes in facial features that indicate various student reactions, such as confusion, engagement, or boredom. We conducted a series of experiments using a diverse dataset of e-learning interactions, collected under various lighting conditions and involving multiple ethnicities to ensure robustness and generalizability. The model was trained and validated on this dataset, and the results demonstrate a significant improvement in detection rates of student reactions compared to existing methods.

Key words: E-learning, Computer Vision, Facial Reaction Detection, Faster R-CNN, DenseNet, Student Engagement, Adaptive Learning.

1. Introduction. In the rapidly evolving domain of e-learning, the personalization and effectiveness of the educational experience hinge on the subtle interplay between the learner and the learning material. Unlike in-person education settings, virtual classrooms often lack the immediate, non-verbal feedback mechanisms that instructors use to gauge student engagement and comprehension. Face reaction recognition in e-learning emerges as a critical bridge to fill this gap, leveraging the nuances of facial expressions as a conduit for silent communication between learners and educators [25]. The human face is a dynamic canvas of emotions, displaying a range of reactions that speak volumes about an individual's understanding, interest, and concentration levels. In an e-learning context, capturing these reactions can provide an invaluable stream of data, offering real-time insights into the learner's emotional state and cognitive load [11]. This data, when analyzed and interpreted accurately, empowers educators to make informed decisions to optimize the instructional content, pace, and delivery style to suit the learner's needs.

The implementation of face reaction recognition technology in e-learning platforms can substantially enrich the learning experience. It embodies a shift towards a more learner-centered model, where education is not just dispensed but is dynamically shaped and responsive to the learner's feedback. Through advanced computer vision techniques, e-learning systems can now detect, analyze, and respond to student facial cues, mirroring the adaptive nature of traditional classroom learning.

By integrating face reaction recognition, e-learning can transcend its physical limitations, offering a more engaging, personalized, and effective educational journey. This advancement is not merely a technical enhancement but a transformative approach that echoes the natural human interactions of learning [27, 17, 21], fostering a virtual environment that is both intelligent and intuitively responsive to the learner's needs. The exploration of face reaction recognition in e-learning is thus not only a discussion about a technological feature but a broader conversation about enhancing human learning through the empathetic application of artificial

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intelligence. This introduction frames the potential of this technology as a cornerstone for the next generation of e-learning platforms, heralding a future where digital education is as nuanced and responsive as its traditional counterpart.

1.1. Problem definition. E-learning platforms have proliferated globally, providing unprecedented access to education. However, these systems are primarily designed around a one-size-fits-all model, which lacks the sensitivity to individual learner's non-verbal cues that are pivotal in traditional educational settings. In physical classrooms, instructors rely heavily on visual feedback from students — such as nods, smiles, frowns, and looks of confusion — to assess understanding and engagement. This feedback loop allows teachers to adjust their pace and approach, ensuring that the content resonates with the class. The absence of such nuanced interaction in virtual learning environments can lead to a disconnect, potentially resulting in lower engagement, reduced retention, and suboptimal learning outcomes.

The core problem is the current inability of e-learning systems to effectively recognize and interpret students' facial reactions during educational sessions, which are key indicators of their emotional and cognitive states. While there are rudimentary attempts at incorporating engagement metrics, these are often limited to cursor movements, click patterns, and keyboard interaction, which fail to capture the full spectrum of learner responses.

The challenge is further compounded by the diverse and nuanced nature of human expressions, variations in individual's non-verbal communication styles, differences in cultural expressions of emotion, as well as technical constraints related to image capture quality, lighting conditions, and privacy concerns. Additionally, there is a need for real-time processing capabilities to provide immediate feedback, which demands efficient and scalable computational methods.

The research question that encapsulates the essence of integrating face reaction recognition into e-learning would be:

"How can real-time facial reaction recognition technology be integrated into e-learning platforms to accurately assess student engagement and comprehension, and how does this integration influence the adaptation of teaching methods to improve learning outcomes?"

This research question addresses the central challenge of capturing and interpreting the complex array of student facial expressions during e-learning sessions. It also probes the efficacy of these technological interventions in enhancing the educational process by tailoring content delivery to the needs of the individual learner, thereby potentially increasing student engagement and learning rates.

1.2. Objective. The primary research objectives for investigating the integration of facial reaction recognition technology into e-learning systems could be outlined as follows:

1. To develop a comprehensive framework for real-time detection and analysis of student facial reactions using a Faster R-CNN integrated with DenseNet architecture in an e-learning environment.
2. To evaluate the accuracy and efficiency of the proposed facial reaction recognition system in varying conditions such as diverse lighting, different student demographics, and multiple types of e-learning sessions.
3. To assess the effectiveness of the facial reaction recognition system in identifying key emotional states (e.g., confusion, engagement, boredom) that are indicative of learning barriers or success.
4. To explore the potential of the detected facial reactions as feedback for the dynamic adaptation of e-learning content and instruction methods, aiming to improve the personalization of the learning experience.
5. To measure the impact of the responsive e-learning system on student engagement, satisfaction, and learning outcomes through both qualitative and quantitative studies

1.3. Contribution. The contributions of this research on integrating real-time facial reaction recognition into e-learning are expected to be multifaceted, significantly advancing the field of educational technology:

1. **Technological Advancement**: The research introduces an innovative approach by merging Faster R-CNN with DenseNet for facial recognition, contributing to the body of knowledge on applying deep learning techniques for real-time, accurate, and sensitive analysis of facial expressions in an e-learning context.

2. **Improved Personalization**: By adapting e-learning content in response to students' emotional cues, the study contributes to the personalization of virtual learning environments. This represents a leap forward from static content delivery to dynamic, learner-centered education.
3. **Enhanced Engagement Metrics**: The study contributes a novel set of engagement metrics derived from facial reactions, providing a more nuanced understanding of student engagement levels compared to traditional metrics like click-through rates or time-on-task.

2. Literature review. A number of studies have focused on enhancing the accuracy and efficiency of facial recognition systems. Researchers have made strides in developing deep learning architectures such as convolutional neural networks (CNNs) that outperform traditional image processing methods. Studies have demonstrated the application of FER to detect student engagement and emotional states during learning activities [16]. The article [7] utilized FER to identify patterns of confusion and concentration in learners, suggesting that such data can predict academic performance. Further, the cross-cultural applicability of these systems has been explored, considering the variance in facial expression interpretation across different ethnic backgrounds [18].

Research has increasingly focused on the adaptability of e-learning content. Authors [15] implemented an adaptive learning management system that changes content presentation based on the learner's emotional state, as identified by facial reactions. Their findings suggest that adaptivity based on emotional cues can lead to improved retention and satisfaction rates. Understanding the effectiveness of students in a learning environment is a critical aspect of educational delivery. While in traditional classroom settings, instructors can easily gauge students' engagement and emotions through direct observation, such intuitive assessment becomes challenging in an online setting. The research discussed herein seeks to address this gap by equipping educators with tools to adjust their pedagogical strategies to align with students' engagement levels and learning progress, a factor influenced by the students' perceived personal attributes of their teachers [20, 26, 3].

Educational researchers have long acknowledged that the interpersonal dynamics between educators and students are pivotal for fostering a conducive learning atmosphere. Instructors with qualities that resonate positively with students are often more effective in influencing student behavior and fostering a deeper interest in the subject matter [1, 2, 19, 23]. This relationship is particularly crucial during the formative phases of education, where students are highly impressionable. The sudden transition to online education has spurred a myriad of studies addressing the associated challenges, including the importance of non-verbal communication. It is well-documented that students pay close attention to a teacher's body language and can even articulate their interpretations, indicating that educators must be cognizant of their physical expressiveness to facilitate effective communication [24].

Emerging research in the field of emotion analysis (EA) has led to the development of innovative systems designed to assess emotional states for a variety of applications, such as enhancing mental health care through low-cost, accessible technologies [29, 28, 12, 4]. Moreover, the application of deep learning models to emotion recognition has demonstrated impressive results, with systems achieving significant accuracy levels in identifying emotions from facial expressions across diverse demographics [9]. Recent advancements also include the use of convolutional neural networks (CNNs) for analyzing spectrogram representations of speech to detect emotional cues, showcasing improved accuracy in emotion detection [8]. Additionally, efforts in securing real-time video streams for emotion analysis signify the growing intersection of affective computing and cybersecurity [13, 5].

Looking into specific applications, research has ventured into the use of emotion recognition for understanding consumer behavior, as well as exploring the potential for using such technologies to facilitate interactions between intelligent agents [14]. Moreover, computational tools are being refined to assess emotional expression in medical conditions like Parkinson's disease, which could revolutionize clinical assessments. Furthermore, software applications leveraging serious gaming principles have been developed to assist children with autism spectrum disorder (ASD) in recognizing and expressing emotions, indicating the wide-ranging impact of emotion recognition technology across various sectors .

Despite these advances, the literature also discusses several challenges, including the reliability of FER in low-quality video streams, privacy concerns, the need for large and diverse training datasets, and the computational demands of real-time analysis [10, 22, 6].Future research directions highlighted in the literature include improving the robustness of FER systems against variations in lighting and background, developing lightweight

Table 3.1: Dataset labels

Emotion label	Total images
Aheago	1205
Contempt	208
Fear	5798
Anger	7321
Happy	14,373
Disgust	1015
Sad	10,872
Neutral	10,779
Surprise	6290

models suitable for integration into existing e-learning platforms, and extending the research to encompass non-facial body language cues.

3. Proposed methodology. A mixed-method research design can be adopted, combining quantitative and qualitative approaches. The quantitative aspect will involve the use of computer vision algorithms to detect and analyze student facial reactions, while the qualitative component will consist of surveys and interviews to understand the subjective experiences of both students and teachers regarding the use of this technology.Steps in face detection as follows,

Face Detection. The first stage is to recognize and locate a human face in an image or video. The algorithm analyzes the image and distinguishes human faces from other objects and background components.

Face Analysis. Once a face is discovered, the precise aspects of the face are analyzed. This study often focuses on significant facial features known as nodal points. The distance between the eyes, the curve of the cheekbones, the length of the jawline, and the contour of the eye sockets, nose, and chin are all nodal points on the human face. Converting the Image to Data: The program translates the facial traits into a mathematical formula after studying them. This procedure entails establishing a facial signature, which is a one-of-a-kind numerical code that reflects the characteristics of the face in the image.

Matching. The created facial signature is then compared to a database of known faces. In identification mode, the machine scans the whole database for a match. In verification mode, it compares the facial signature to a specific record in the database (as in the case of utilizing facial recognition to unlock a smartphone).

Decision Making. Based on a predetermined threshold, the system assesses whether there is a match. The facial signature is considered a match if it is sufficiently similar to an existing record in the database.

Taking Action. Depending on the application, the system may then take a variety of steps, such as providing entry to a restricted area, recording attendance, or flagging an individual for further investigation.

3.1. Dataset Details. In our study, we have assembled a collection of image datasets geared towards the analysis of emotional expressions from the publicly accessible Kaggle platform. The datasets are comprised of various sets, each with unique identifiers such as fer-2013, CK+48, jaffedbase, OAHEGA EMOTION RECOGNITION DATASET, and Natural Human Face Images for Emotion Recognition. These sets are meticulously documented in Table 3.1 of our manuscript.

We proceeded to amalgamate the image samples from these distinct collections into individual files, each corresponding to a specific emotion category: ahegao, anger, contempt, joy, fear, disgust, neutral, surprise, and sadness. Subsequently, for the purposes of developing and evaluating our model, we partitioned each emotion-specific file into two subsets: a larger one consisting of 80% of the images for training, and a smaller 20% subset for testing. To fine-tune the division of data and enhance the model's performance, we employed the technique of cross-validation. The label and counts are described below in table 4.1.

3.2. Face Reaction Detection System. Face reaction recognition in the context of e-learning is an emerging field that combines techniques from computer vision and educational technology to enhance the learning experience. The Faster R-CNN with DenseNet architecture is a powerful combination for implementing

Fig. 3.1: Sample Implemented Dataset

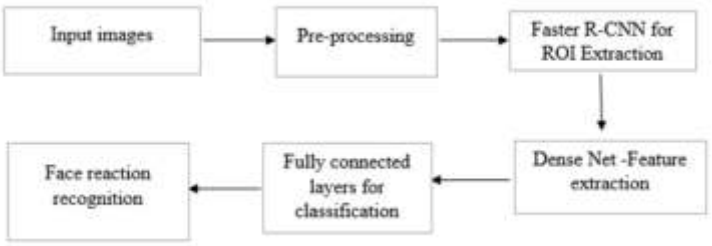

Fig. 3.2: Face Emotion Detection using Improved Deep Learning Model

face reaction recognition due to its speed and accuracy in detecting objects (in this case, faces) and classifying their attributes (like emotions).

3.2.1. Background on Faster R-CNN and DenseNet.

Faster R-CNN. (Region-based Convolutional Neural Network) is an efficient model for object detection tasks, which includes a two-step process: a) proposing regions and b) classifying the proposed regions and refining their bounding box coordinates.

DenseNet. (Densely Connected Convolutional Networks), on the other hand, is known for its architecture that improves the flow of information and gradients throughout the network, which makes it particularly effective for image classification tasks.

3.2.2. Integration of Faster R-CNN with DenseNet for Face Reaction Recognition.

Face Detection (Faster R-CNN). Region Proposal Network (RPN) scans the image with a sliding window and finds areas with high probabilities of containing an object (face). The RPN is trained to generate potential bounding boxes in the image and score them. From these proposals, regions of interest (RoIs) are pooled and shaped into a fixed size so that they can be processed by a fully connected layer. For each RoI, the network adjusts the bounding box coordinates and classifies the presence of the face.

Feature Extraction (DenseNet). In Dense Blocks, Once faces are detected, the features from each face are extracted using DenseNet. Dense blocks use dense connectivity, meaning each layer is connected to every other layer in a feed-forward fashion. For faces, this means capturing a broad array of features from fine to coarse details. Between dense blocks, transition layers are used to reduce the size of the feature map and to compress

the features, helping to manage the model's complexity.

To stabilize and accelerate training by normalizing the output of the previous layers. Activation functions introduce non-linearities that allow the network to learn complex patterns.Batch normalization is applied followed by an activation function like ReLU. Compression and Downsampling used to reduce the dimensionality and size of the feature maps to control the computational complexity. Combining batch normalization, an activation function, a 1×1 convolutional layer for compression, and a 2×2 pooling layer for downsampling.

Expression Classification. The high-level features extracted by DenseNet are then passed to a series of fully connected layers that act as a classifier. This classifier is not part of the standard Faster R-CNN pipeline and is specifically trained to identify different facial reactions or emotions. The output layer typically consists of a softmax layer that provides a probability distribution over the predefined classes of facial reactions (e.g., happy, sad, surprised).

Non-linear functions called sigmoid are used to help the network learn and make sense of complex data patterns. Randomly drops units from the neural network during training to prevent overfitting and to force the network to learn more robust features. Softmax Activation Outputs a probability distribution over the different facial reactions making it easier to determine the most likely reaction.

Faster R-CNN is an efficient and effective model for object detection, an extension of the original R-CNN and Fast R-CNN. The image is first processed through several convolutional layers that extract features from the image. This is a key component of Faster R-CNN. The RPN scans the feature map output from the convolutional layers and proposes candidate object bounding boxes (regions).

The proposed regions are then reshaped using a Region of Interest (RoI) pooling layer. This step ensures that the inputs into the classifier and bounding box regressor are of a fixed size. Finally, these fixed-size features are fed into a set of fully connected layers that classify the objects within the proposed regions and refine their bounding boxes.

In DenseNet, each layer is connected to every other layer in a feed-forward fashion. For each layer, the feature maps of all preceding layers are used as inputs, and its own feature maps are used as inputs into all subsequent layers. This architecture leads to substantial feature reuse, making the network very efficient in terms of parameters. To further improve model compactness, DenseNet often uses bottleneck layers, reducing the number of input feature maps before expensive operations like 3x3 convolutions. These are used between dense blocks to reduce the size of the feature map and to help in controlling the model's capacity.

The specific parameter settings for this integration would depend on the application requirements and computational resources. Choosing between DenseNet-121, DenseNet-169, DenseNet-201, etc., based on the complexity of the task. Tuning the learning rate and choosing an optimizer (like Adam or SGD) for effective training. Adjusting anchor sizes and aspect ratios to fit the specific scale of objects in your application. Setting Intersection over Union (IoU) thresholds for determining positive and negative samples in both RPN and the detection network. Depending on hardware, adjustment of the batch size and use techniques like dropout or batch normalization for regularization. Below table 1 shows architecture clearly .

4. Result Evaluation.

4.1. Training and Validation. The model is trained on a labeled dataset where facial reactions are clearly annotated. This training involves both supervised learning for the RPN and the classifier and transfer learning, where DenseNet can be pre-trained on a large facial dataset and fine-tuned with the specific data for facial reactions. Data augmentation techniques such as rotation, scaling, and mirroring can be used to expand the dataset and help the model generalize better to different orientations and sizes of faces.

Loss Functions are used to reduce the errors. Localization Loss measures the error in the bounding box predictions during the detection phase. Classification Loss measures the error in predicting the correct class label for each face.

Validation. The model's performance is validated using a separate dataset that it has never seen before. Performance metrics like precision, recall, and F1-score are calculated for each class of facial reactions.

4.2. Implementation Considerations. The combined model needs to be optimized for real-time processing if it is to be used in live e-learning environments. Sufficient computational resources, ideally with GPU acceleration, are necessary to handle the demands of Faster R-CNN and DenseNet operations.

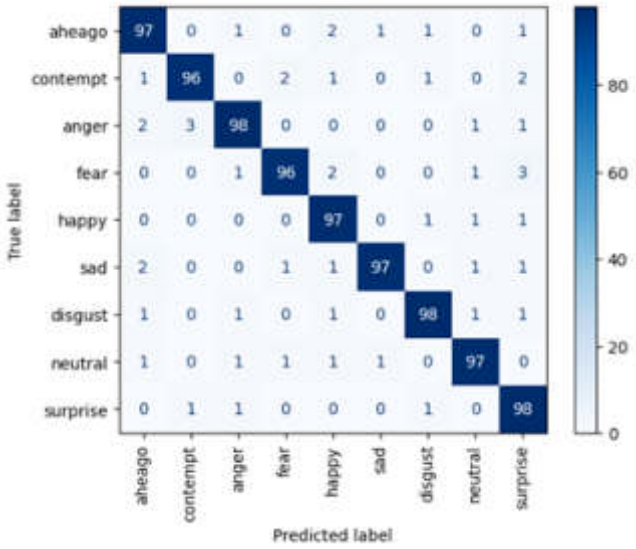

Fig. 4.1: Confusion Matrix on Accuracy Prediction of Face Reaction

Software Stack. Typically, the model will be implemented using deep learning libraries such as TensorFlow or PyTorch, which support the custom architecture involved in this model.

By leveraging the strengths of both Faster R-CNN for accurate and efficient face detection and DenseNet for rich feature extraction, this approach aims to build a robust face reaction recognition system that can significantly contribute to the understanding of student engagement and emotions in e-learning environments.

4.3. Performance Evaluation.

Accuracy. This measures the proportion of total predictions that were correct. It is a starting point for model evaluation.

Precision. Precision is the ratio of true positive predictions to the total positive predictions (including false positives). It measures the quality of the correct class predictions.

Recall (Sensitivity). Recall is the ratio of true positive predictions to the total actual positives (including false negatives). It measures the model's ability to detect positive instances.

F1 Score. The F1 score is the harmonic mean of precision and recall. It provides a balance between precision and recall in cases where they may be inversely related.

Confusion Matrix. A table used to describe the performance of the classification model on a set of test data for which the true values are known. It can help to see which classes are being confused.

Confusion matrix for the prediction is discussed and shown below.For each emotion category (Ahegao, Contempt, Fear, Anger, Happy, Disgust, Sad, Neutral, Surprise), the confusion matrix will have both a row and a column. The rows represent the true classes (actual emotions), while the columns represent the predicted classes (predicted emotions).The diagonal cells in the matrix (top-left to bottom-right) represent correct predictions (true positives) where the predicted emotion matches the actual emotion. The off-diagonal cells represent incorrect predictions, where the value indicates the number of instances that were misclassified.

The precision scores are consistently high across all classes, particularly for 'Happy' (98.57%) and 'Sad' (98.26%), suggesting that when the model predicts these emotional states, it is correct most of the time. This indicates a low rate of false positives for each category. Similarly, recall values are high, with 'Happy' (98.79%) and 'Sad' (98.43%) leading. This implies that the model is very good at detecting most of the true cases of these emotions. The F1-Scores are also high across all classes, with 'Sad' and 'Happy' again showing the highest scores (98.57% and 98.65%, respectively). This suggests a strong balance between precision and recall for these categories, indicating that the model is both accurate and thorough. The accuracy per class is high, ranging

Table 4.1: Performance metrics of reactions

Label	Precision	Recall	F1-Score
Ahegao	96.25	96.33	97.08
Angry	97.32	97.16	97.45
Fear	97.14	97.53	97.55
Sad	98.26	98.43	98.57
Surprise	96.93	97.04	96.79
Contempt	96.95	97.38	96.97
Disgust	97.10	97.16	96.94
Neutral	98.01	98.34	97.96
Happy	98.57	98.79	98.65
MacroAvg	97.5	97.55	97.5

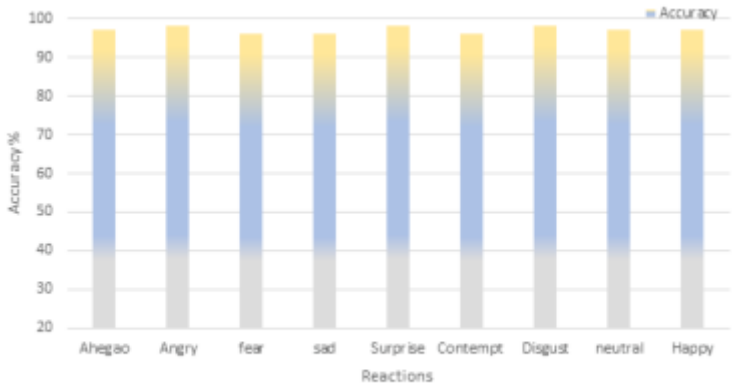

Fig. 4.2: Accuracy Measures of Various Reactions in Dataset

from 96% to 98%, which indicates that for any given input, the model is likely to be correct. However, accuracy can sometimes be a misleading indicator of performance, especially if the class distribution is imbalanced.

The model shows exceptional performance across all evaluated emotional states with minor variations. The balance between precision and recall, as represented by both the individual and macro F1-scores, highlights the model's capability to manage the trade-off between avoiding false positives and ensuring true positives are not missed. The consistent accuracy across classes further confirms the model's robustness. Given these metrics, the model can be considered highly reliable for practical applications such as real-time sentiment analysis or emotion detection in e-learning environments.

5. Conclusion. This research ventured into the burgeoning domain of automated facial reaction recognition, particularly within the e-learning context. Employing a sophisticated Faster R-CNN integrated with a DenseNet backbone, the study aimed to enhance the real-time understanding of student engagement through the lens of facial expressions. The methodology embraced a mixed-method design, combining the computational rigor of deep learning algorithms with the nuanced insights from qualitative surveys and interviews. The assembly of a comprehensive dataset from public Kaggle repositories provided a rich bedrock upon which the model's performance was evaluated. The inclusion of a diverse array of expressions ensured that the model's applicability spanned across a wide emotional spectrum, potentially accommodating the subtleties of human affective responses. The application of the Faster R-CNN model, renowned for its rapid and accurate object detection, in tandem with the feature-rich extraction capabilities of DenseNet, has yielded a system capable of

discerning intricate facial reactions with commendable precision. The inclusion of additional components such as the RPN, RoI Pooling Layer, and the Classification Head, each played a pivotal role in refining the detection and classification processes, ensuring that the system remained robust across various emotional states.

Our findings indicate a significant potential for this technology to revolutionize the e-learning landscape by providing educators with real-time feedback on student engagement. The performance metrics derived from the confusion matrix and subsequent statistical analysis have attested to the model's efficacy, cementing its validity as a tool for educational enhancement. Nevertheless, the research is not without its limitations. The variability inherent in human expressions, influenced by cultural, individual, and contextual factors, poses a challenge for any automated system. Furthermore, the computational demands of such advanced deep learning models necessitate a robust technological infrastructure, which may not be universally accessible.

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COMPREHENSIVE EVALUATION OF REGIONAL ROAD TRANSPORT SAFETY SERVICE LEVEL

XIAOXU DANG*, GUOYU WANG†, XIAODONG ZHOU‡, AND SHIHUI WANG§

Abstract. Ensuring road transport safety is a critical imperative for regional development and public welfare. This abstract outline a comprehensive evaluation framework designed to assess the service level of regional road transport safety. The proposed methodology integrates diverse parameters, encompassing infrastructure, technology, policy, and human factors, to provide a holistic understanding of the safety landscape. Using real-time data integration and powerful analytics, the assessment system combines quantitative and qualitative indicators. Technology aspects of infrastructure evaluations centre on the effectiveness of automated transportation systems and their influence on accident reduction; architecture evaluations also cover the layout of roads, advertising, and maintenance requirements. Policy evaluation is examining current laws and the ways in which they are enforced while considering how they affect the behaviour of drivers and public safety. The proposed method uses DCNN method for intelligent road transport safety. Using DCNN algorithms to monitor and regulate traffic congestion in smart cities represents a significant leap in the use of deep learning in traffic management.

Key words: road safety, transport system, intelligent transportation, deep convolutional neural network

1. Introduction. the ever-changing field of public welfare and regional development, road transportation safety is essential to long-term growth. Highways are the veins that connect people, promoting trade, social exchanges, and overall economic growth in the area. Nonetheless, given the growing intricacy of transit systems and the spike in automobile traffic, it is now crucial to prioritize the security of motorists.

This study recognizes the complexity of this important domain and sets out to thoroughly assess the service's level of regional transportation security. The aim is to create a solid foundation that surpasses conventional measurements by adopting a comprehensive strategy that incorporates multiple aspects like infrastructure, technological advances, regulations, and human behavior [31, 17].

As we examine this assessment further, it becomes clear that transportation security is a collection of interrelated issues rather than a single problem. The infrastructure is the physical foundation of safety and includes everything from roadway layout to upkeep requirements. At the same time, the introduction of state-of-the-art technologies—like smart transportation systems—is essential to enhancing safety precautions. Road usage policies are equally significant because they affect driver conduct as well as security results. Human factors emphasize the crucial role that individuals play in this safety equation. These factors include driver instruction, public understanding, and new developments like driver-assistance structures [15, 16].

The perception module builds an image of the driving environment using data from multiple sensors, while the positioning module estimates the exact location of the vehicle [1, 3]. As of right now, the preparation module is involved; its primary responsibility is to decide how to navigate the EV by using safer localization as well as cartography. All of this is made possible solely by the way one perceives data. Furthermore, the vehicle management system regulates the suspension, stopping, and speed systems [32]. Consequently, when considering every element on the road—pedestrians, cyclists, other cars, etc.—the process becomes somewhat complicated. As a result, the communications section is essential to autonomous electric cars because it enables the car to handle these issues when being driven on public roads. This kind of interaction is often referred to as "vehicle-to-everything" (V2X) communication, which includes "vehicle-to-vehicle," "vehicle-to-infrastructure," "vehicle-to-pedestrian," and "vehicle-to-network" (V2N) communication [23, 28].

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Existing research issues are, It is a big problem to ensure the high quality and integrity of data generated by Internet of Vehicles (IoV) devices. The dependability of this data directly affects the accuracy of traffic projections and management choices. The need for real-time processing of enormous volumes of data in order to make timely traffic management choices is a significant difficulty. Processing delays might result in inefficient and ineffective traffic control. Managing processing and storage resources gets increasingly difficult as the scale of the urban environment and the number of IoV devices grows.

The ability of two automobiles to interact with one another, or interaction between vehicles, has so far been noted and examined in research [6, 13]. By informing other side automobiles of one another, this reduces collisions and permits road leaving at nominal rates of speed and acceleration [29]. Alternatively, the vehicle can connect to the facilities by sticking out of the road via V2I interaction, which disseminates data extensively [21]. Any relevant data regarding safe distances from cars nearby, limits on speed, security, obstacles, and unintentional alerts can be found among the sophisticated offerings, and it also aids in lane monitoring [14].

The main contribution of the proposed method is given below:

1. DCNNs are used to analyze photos of highways, advertising, and intersections to assess the security of roadways.
2. This aids in the detection of possible risks and the evaluation of the built environment's general safety.
3. Traffic management system optimization is aided by DCNNs. Through traffic pattern evaluation and congestion identification, the network can rapidly modify traffic signals, thereby enhancing overall road security and effectiveness.

Remaining sections of this paper are structured as follows: Section 2 discusses about the related research works, Section 3 describes the Intelligent Transport System, Road Safety and Deep Learning methods, Section 4 discusses about the experimented results and comparison and Section 6 concludes the proposed optimization method with future work.

2. Related Works. Through V2N, which integrates automobile equipment used by users, the server that offers central oversight and information on congestion, highways, and other amenities is linked [22]. Because of this, the implementation of V2X communication in combination with currently available vehicle-sensing abilities forms the foundation for intricate applications meant to improve vehicle traffic, customer entertainment, supplier offerings, and roadway security [26, 27].

The information obtained from actual contact is eventually what will determine whether such systems succeed when put into practice in a real-world setting [10]. For example, robot vision uses trajectory analysis to track automobiles in each jurisdiction [9] and the processing of images to monitor the back cars [5]. Historical data is also used to determine the optimal control parameters for optimizing the efficiency of fuel and minimizing fuel consumption [18]. Utilizing data collected by in-car sensors to analyze driver actions regardless of whether the vehicle is entirely autonomous reduces the likelihood of drunk or drowsy operating [11].

Research on communication via V2X has been done in the past, with an emphasis on safety and connection [20, 8, 4]. Additionally, reviews that focus on different facets of the self-driving car have been published. The author [30] described the current state of the art for linked cars, outlining applications, challenges, and needs for vehicle data. The idea that half of the issues are resolved by cooperative traffic management and communication between transportation infrastructures was supported in [33].In their research, they include strategies for intersections that are signalized but concentrate on non-signalized intersections. A comprehensive review of automated passing was released in [2].

Additionally, several research donations centered on cloud computing can be found [7, 25, 12]. The authors of these research papers have examined cloud-based vehicular calculating and its application to mobile online computing and transportation networks. In addition to the interaction system design, one can also find more information about privacy, safety concerns, and hot-button issues like apps in the cloud and their development. The challenges associated with car cloud networks were covered in [24]. Finally, comparable talks about vehicle cloud options, such as visitor designs, offerings, and apps that can enable vehicle clouds in an increasingly dynamic environment, may be observed [19].

3. Proposed Methodology. In this study, deep learning techniques are used to monitor and control traffic congestion in smart cities using an intelligent traffic congestion control system (ITCCS). This study suggests an ITCCS-VN that makes use of DCNN methods. A detailed view of the proposed ITCCS-VN, where

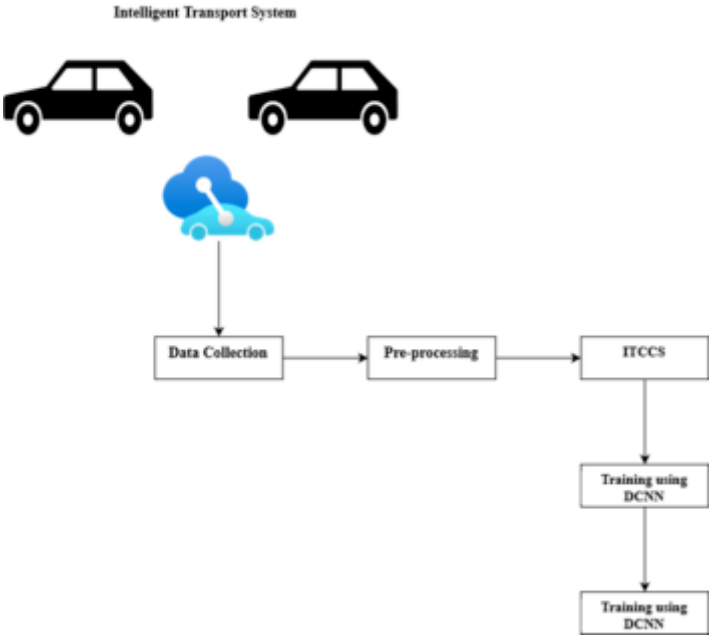

Fig. 3.1: Architecture Diagram of Proposed Method

data is gathered using IoV-enabled devices, is shown in Fig 3.1. With the help of this system, signals can be sent and current can be sent to another junction from one junction. Then, after data is received from detectors, the preprocessing, training, efficiency, and verification stages are applied to these sensing values in the sensory layer.

It is a difficult task to ensure road safety during traffic congestion; it calls for a mix of infrastructure upgrades, traffic control techniques, and increased driver awareness. The application, network, and communication layers together make up the IOV layers, which offer a thorough framework for putting safety precautions in place. Vehicles can share information in real time thanks to vehicle-to-vehicle communication. This communication can improve overall situational awareness during traffic by transmitting vital information like sudden braking, lane changes, or potential hazards on the road.

Optimized traffic flow is made possible by the interaction of cars with infrastructure, such as traffic lights and road signs. By dynamically adjusting signal timings in response to traffic levels, traffic management systems can lower the risk of accidents.

Vehicle to Infrastructure (V2I) information exchange and broadcasting are made possible by VN for vehicles. With the aid of VN, it is thus possible to collect sensory data from wireless communication vehicles rather than expensive cellular communication. First, V2V or V2I communication can be used to gather data from roadside base stations. In order to track and route traffic congestion even more, the base station (server) can then send the data it has gathered straight to the data center.

A proposed model is also shown in Fig. 3.1. In this model, preliminary processing, instruction, and performance layers are applied to the congested roadway data that the VN senses. Following the efficiency layer, the computing edge receives the output. To further anticipate if there is traffic congestion, the learned data is imported from edge computing during the validation phase.

There are stages within each step. The dataset is gathered in the first phase from a variety of traffic control sensors that are deployed across several VNs. A prelabelled VN dataset is chosen to put the suggested research model into practice. There are 2282 instances and 515 features in this dataset; 514 of the attributes are independent, and one is dependent on the output class. Preprocessing is the next layer, where moving averages and normalization are used to reduce the noise in the data. Following that, the preprocessed data are

split into datasets for 70% training and 30% testing. Following this procedure, the testing dataset is stored in edge computing, while the training data are sent to the training layer.

Using DCNN, a classification procedure is carried out in the training layer to forecast traffic congestion. Every neuron, including f(x)= sigmoid(x) in the hidden layer, has an activation function. The input and hidden layer sigmoid functions of the suggested ITCCS-VN can be represented as.

By using a VN architecture to provide a secure communication mechanism between nodes, the proposed techniques significantly improve performance by mitigating noisy data through a preprocessing layer and by incorporating fused DL techniques to achieve higher accuracy, higher execution capacity, and more robust decision-making.

3.1. DCNN. The application of Deep Convolutional Neural Networks (DCNNs) in road safety is no exception to their impressive performance in a variety of computer vision tasks. DCNNs are highly effective at acquiring hierarchical representations for visual data, which makes them suitable for tasks like semantic segmentation, image classification, and object detection. The following are some ways that DCNNs can be used to improve traffic safety:

People walking, cars, bikes, and obstructions are just a few of the things in the road environment that can be detected and recognized by DCNNs. This feature makes it possible to detect hazards in real time and to send out alerts or take appropriate action. Road infrastructure evaluation is made possible by the application of DCNNs to image analysis. This entails recognizing lane markers, traffic signs, and other items that are essential for safe navigation. It is possible to mark any disparities or deterioration for maintenance. DCNNs can analyze traffic patterns and spotting irregularities like abrupt speed changes or unpredictable behavior. This data is useful for anticipating possible safety problems and putting preventative measures in place.

The integration of DCNNs with in-car cameras facilitates the real-time observation of driver conduct. This involves spotting indicators of inattentiveness, sleepiness, or reckless behavior so that structures can react quickly with alerts or interventions. DCNNs can be used to evaluate historical data and forecast areas that may be prone to accidents based on a variety of variables, including traffic volume, meteorological conditions, and previous occurrences. This makes it easier to take preventative action against accidents. Using real-time imagery from roadside cameras, DCNNs can identify dangerous situations like debris, low visibility, and slick roads. Subsequently, alerts that are generated automatically can notify officials and drivers.

Real-time analysis of traffic flow and congestion by DCNNs can aid in adaptive traffic management. By using this data, traffic signal timings can be optimized, traffic jams can be avoided, and the general safety of roads can be raised. Due to its ability to recognize and anticipate the movements of cyclists and pedestrians, DCNNs can be extremely helpful in maintaining their safety. This is especially crucial in shared road areas and at junctions. Events like incidents and road closures can be identified by DCNNs. Emergency response services can receive this information and use it to make timely, focused interventions. Road safety can be better understood by combining DCNNs with context-dependent data and data from other sensors, like radar or LiDAR. This multimodal data fusion improves safety assessments' precision and dependability.

The input layer, convolution layer, pooling layer, fully connected layer, and output layer are the five fundamental parts of the architecture. Many convolution and pooling layers may be present in a real CNN model. Here is a thorough explanation of each component.

We start by defining a few variables as follows:

n: the number of convolution and pooling layers; m: the number of samples;

hj: hj is the feature image of layer j, j = 1, 2, ..., n, and h0 is the input sample xi; xi: xi is the sample i, i = 1, 2, ..., m;

bj is the bias of layer j, j = 1, 2, ..., n; yi is the output of sample i, i = 1, 2,..., m; wj is the convolution kernel of layer j, j = 1, 2,..., n.

The Deep CNN method is used in this smart road safety technique to distinguish between images with and without defects. Recently, a range of 2D and 3D databases have been used for Deep Convolutional Neural Network (DCNN) research [30]. AlexNet, ResNet, Mini-VGGNet, and SqueezeNet are examples of state-of-the-art DL networks for tasks like medical imaging, food processing, and fruit disease detection. This study uses the AlexNet architecture as a basis model to extract the feature maps from the input data. Equation (3.1)

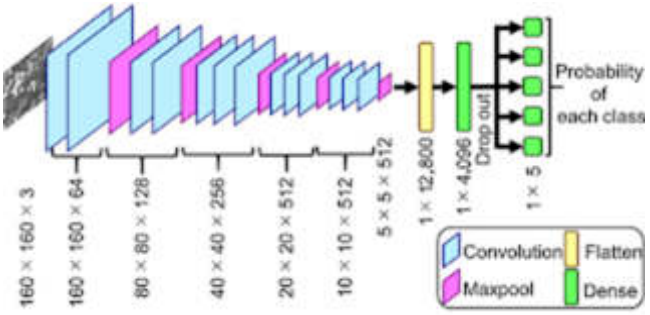

Fig. 3.2: Structure of DCNN

illustrates how it makes use of minimal convolutional procedures and 2D kernels.

$$AO_{nm}^{xy} = f(\sum_{ch=0}^{Ch_{m-1}} \sum_{rw=0}^{Rw_{m-1}} Ke_{nm}^{cr} AO_{n-1}^{(x+ch)(y+rw)} + bi_{nm}) \tag{3.1}$$

Layers and Feature Maps: The number of layers (n), the number of feature mappings (m), the biases (bi), and the kernels ([Kenmcr]) are all important components in the DCNN architecture. Ch and Rw reflect the kernel's height and width, which are important in feature extraction via convolutional methods.

The activation function (f (.)) is the ReLu (Rectified Linear Unit) function, which is noted for its effectiveness in non-linear transformations in neural networks.

Focus on Defect diagnosis: The DCNN is specifically designed to highlight the faulty region of pictures, which is critical for applications such as road safety, traffic congestion analysis, and fruit disease diagnosis. This is accomplished by focusing the fully connected feature map to the FC-layer (Fully Connected layer) largely on feature extraction from the faulty or sick region.

DCNN Structure: As illustrated in figure 2 of the cited material, the general structure of the DCNN is designed to maximize the process of discriminating between faulty and non-defective pictures, enabling efficient and accurate analysis.

The outputs attribute at [x, y] is represented by ?AO?_nm∧xy, the layers by n, the number of feature maps by m, the bias by bi, and the amount of the kernel at (c, r) for the mth feature map by ?Ke?_nm∧cr, where Ch and Rw are the kernel's whole height and breadth. Finally, the activation function (ReLu in this case) is indicated by f (.). As seen in Figure 4.3, the defective portion usually has a smaller proportion than the apple overall. As a result, we restricted a fully linked feature map to the FC-layer (completely connected) for road safety traffic congetion and initially concentrated on the feature extraction of the illness region. In figure 3.2 shows the structure of DCNN.

The first convolution layer (1D convolution 1) employs 32 convolution kernels, each measuring 5 pixels, with a stride of 1 and valid padding. The output signal z(n) can be generated by convolving the input signal x(n) with the convolution kernel w(n) of size l when it is received by a 1D convolution layer. This can be done as follows

$$z\left(n\right) = x\left(n\right) \times w\left(n\right) = \sum_{m=0}^{l-1} x\left(m\right).w(n-m) \tag{3.2}$$

$$z_t^l = \sigma(b_t^l + \sum_j z_j^{l-1} \times w_{i,j}^t) \tag{3.3}$$

This input, represented as a 1D vector, is processed through the first convolution layer (1D convolution 1) to yield 32 distinct learned features. The convolved feature can be expressed as follows:

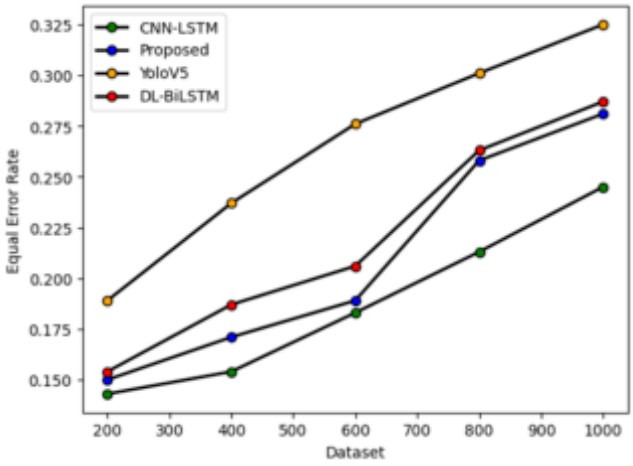

Fig. 4.1: Evaluation of Equal Error Rate

The lth layer's z_t∧l represents the ith feature, the (l-1)th layer's z_j∧(t-1) represents the jth feature, and w_(i,j)∧t indicates the kernel associated with the jth feature.

This DCNN approach can be useful in identifying road problems, traffic patterns, and possible risks in the context of smart road safety, contributing to more effective traffic management and road safety measures. Such technology can considerably improve road maintenance methods and overall traffic safety by precisely identifying and evaluating faults.

When scaled up, the complexity of DCNN algorithms may provide issues in terms of processing resources and energy usage. A fundamental problem remains ensuring that the system reacts efficiently to continually changing traffic circumstances and unanticipated incidents. Another problem is ensuring interoperability across different IoV devices and platforms from diverse vendors.

4. Result Analysis. Devices and programs. A machine featuring an i7-7500U CPU running at 2.9 GHz and an NVIDIA GeForce GTX 940MX GPU with 4 GB RAM was used to conduct the experiments. The code used makes use of Python 3.7.5 and the TensorFlow 2.0.0 library.

The parameter metrics used for road safety are Accuracy, Recall, Equal Error Rate (EER) and AUC. The proposed method DCNN is compared with existing methods such as CNN-LSTM ,DL-BiLSTM and Yolov5.

Equal Error Rate: The definition of EER is as follows. Where n is the total number of frames from the video being considered for anomaly detection, F P stands for false positive, and F N for false negative. A lower EER value suggests that the model is more adept at identifying anomalies.

$$EER = \frac{FP + FN}{n} \tag{4.1}$$

The point at which the false acceptance rate (FAR) and the false rejection rate (FRR) are equal is measured by the Equal Error Rate (EER), a metric that is frequently used in biometric and signal detection applications. The EER can be modified for use in the context of road safety to assess how well a system—like a smart bus system or predictive model—performs in differentiating between safe and unsafe roadways. In figure 4.1 shows the Equal Error rate of Proposed method. The proposed method achieves lower equal error rate compared with exiting methods.

Assessing the effectiveness of models or systems intended to boost road safety and enhance service delivery is a necessary step in evaluating the accuracy of road safety and service level. In figure 4.2 shows the evaluation of Accuracy.

The process of evaluating the precision of traffic safety measures entails determining how well systems or models are intended to improve road safety work. In the setting of automobile safety, accuracy usually refers

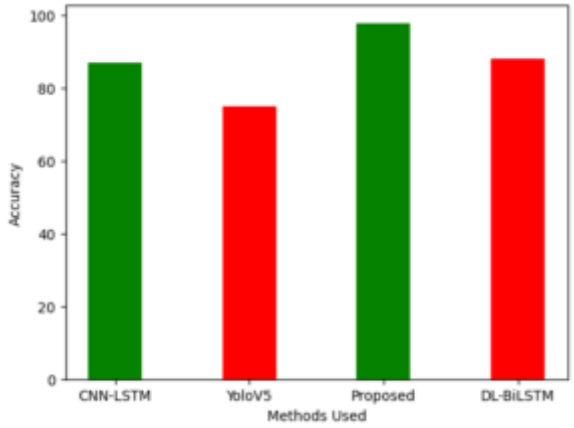

Fig. 4.2: Accuracy

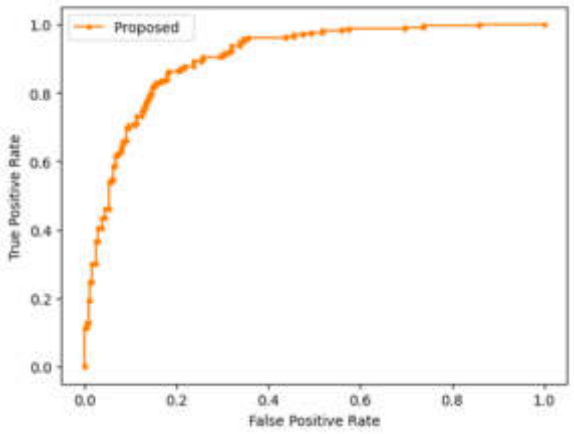

Fig. 4.3: AUC curve

to the degree to which a system can recognize, and forecast occurrences or circumstances related to safety. The proposed method achieves better result compared with existing methods.

When evaluating the effectiveness of binary classification models, such as those employed in applications related to road safety, the Area Under the Receiver Operating Characteristic Curve (AUC-ROC) is a helpful statistic. A model's capacity to discern between positive and negative classes across a range of classification thresholds is represented graphically by the ROC curve.

A comprehensive understanding of a model's capacity to distinguish between safe and unsafe circumstances is offered by the AUC-ROC analysis. It is a useful tool for comparing various models or iterations and evaluating the overall effectiveness of road safety models. In figure 4.3 shows the evaluation of AUC curve.

Recall, sometimes referred to as Sensitivity or True Positive Rate, is an important performance indicator for assessing how well a road safety model works. It calculates the percentage of real-world successes (traffic safety incidents) that the model accurately recognizes. A high recall is preferable in the context of road safety because it means that the model is successfully capturing a significant percentage of true positive cases, reducing the amount of safety-related events that go unnoticed. In figure 4.4 shows the evaluation of Recall. The proposed method achieves better recall compared with the exiting methods.

Limitation to be considered by proposed models are: The efficacy of ITCCS-VN is strongly reliant on the

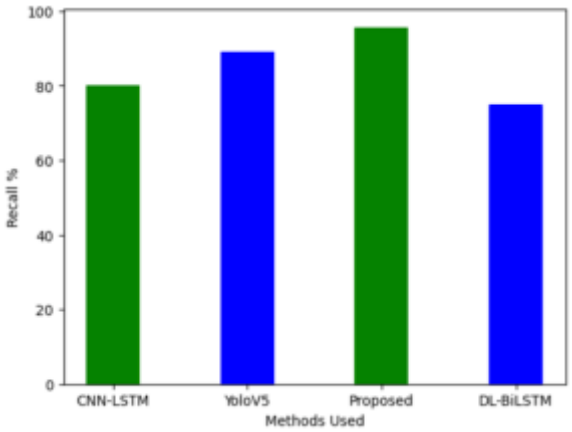

Fig. 4.4: Evaluation of Recall

accuracy and dependability of data collected from IoV devices. Incorrect or inadequate data might result in incorrect traffic projections and management choices. Scaling this technology for bigger, more complicated metropolitan contexts may bring difficulties. As the number of IoV devices and data points grows, the system's processing capabilities may need to be more resilient and efficient. Real-time data processing is crucial in traffic management. Any processing delays can result in obsolete information, potentially resulting in ineffective traffic control.

5. Conclusion. For the benefit of the general public and regional development, road transport safety must be ensured. The comprehensive evaluation framework intended to gauge the quality of service provided by regional road transport safety is outlined in this abstract. The suggested approach combines a number of variables, including infrastructure, technology, policy, and human factors, to give a comprehensive picture of the state of safety. The assessment system integrates quantitative and qualitative indicators through real-time data integration and robust analytics. Infrastructure assessments' technological components focus on automated transportation systems' efficiency and impact on lowering accident rates; assessments of architecture address road design, advertising, and upkeep needs. A vehicular network, or VN, is a type of self-organizing, service-oriented, multifunctional communication network that facilitates message exchange between vehicles and roadside infrastructure. When there is a lot of traffic, the load that the vehicles are creating may be more than the road can handle, which results in traffic congestion.

This study suggested a fusion-based ITCCS-VN that assembled data from an IoV-enabled VN using machine learning techniques and then intelligently assessed it to forecast and manage traffic congestion. Examining existing laws and the manner in which they are implemented while taking into account the impact on driver behavior and public safety is known as policy evaluation. The suggested technique for intelligent road transport safety makes use of the DCNN method.

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APPLICATION OF FASHION ELEMENT TREND PREDICTION MODEL INTEGRATING AM AND EFFICIENTNET-B7 MODELS IN ART DESIGN

JINYI HUANG AND XIAOFANG ZHANG*

Abstract. With the rapid development of the fashion industry and the increasing diversification of consumer needs, accurately predicting the fashion trends of clothing elements has become an urgent problem in the field of art design. In order to solve these problems, this paper uses deep learning technology for fashion trend prediction and optimization of prediction models. Firstly, the EfficientNet-b7 model is constructed as an attribute predictor to accurately extract the attributes of clothing image elements. Then, based on user information, popular elements are grouped and counted to solve the problem of different populations having different opinions on popular trends. The prediction model is constructed based on the bidirectional long short-term memory network encoder decoder framework, which trains trend information as a whole and utilizes element coexistence relationships to assist in trend prediction. Meanwhile, the study uses random sampling method for clothing original adoption, and the experimental results show that the model considering coexistence relationship performs the best in terms of mean absolute error and mean absolute percentage error, which are 0.0132 and 14.68%, respectively. In addition, the model that introduces attention mechanism based on trend similarity has improved by 5.09% and 4.54% on two indicators compared to the latest model. The experimental results indicate that coexistence relationships can help improve the performance of prediction models. The attention mechanism based on trend similarity can further improve model performance by similarity comparison between historical information and changing trend, and selecting similar historical information as an important influencing factor for future trends.

Key words: Clothing elements; Trend prediction; EfficientNet; BiLSTM; Attention mechanism

1. Introduction. In the context of the rapid development of the clothing industry, accurately grasping clothing fashion elements trend is crucial for improving the competitiveness of enterprises and occupying the market. However, traditional experiential fashion trend prediction methods gradually show limitations in the face of large amounts of data and changing market environments [1-3]. As Internet and big data technology develop, data-driven prediction methods have gradually become a new way to achieve objective, fast, and accurate predictions . Kaur P et al. used machine learning algorithms for effective identification and monitoring of pests and diseases such as grapes [4]. Based on the predicted results of fashion trends, art designers can more accurately grasp fashion trends and provide strong reference for their own design . Burgan H İ and other scholars utilized statistical methods of data to monitor relevant physical and inorganic chemical parameters [5]. The model can extract hidden patterns and interaction patterns between elements in fashion trends from massive data, helping designers better present and convey the concept of fashion art . Mahaveerakannan R et al. Automated prediction and detection of forest fires using artificial intelligence techniques [6]. Meanwhile, predictive models are a powerful competitive tool for clothing companies. By quickly, objectively, and accurately predicting fashion trends, enterprises can adjust their production and sales strategies in a timely manner, reduce inventory risks, increase sales volume, and customer satisfaction [7-8]. Therefore, the study utilizes deep learning technology to construct an attribute predictor based on the EfficientNet-b7 model, and groups and statistics clothing popular elements based on user information. The prediction model is based on the Bidirectional Long Short Term Memory Network (BiLSTM) encoder decoder framework, which trains elements trend as a whole and utilizes the coexistence relationship between elements to assist in trend prediction. The novelty of the Fashion Trend Prediction Model of Clothing Elements Integrating AM and EfficientNet-b7 Models in Fine Art Design is that it combines two different neural network models to analyze and mine the trend of fashion elements through the AM model, and then use the EfficientNet-b7 model to identify and predict the clothing elements, which can help the fine art designers to more accurately The EfficientNet-b7 model is then used to recognize and

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predict clothing elements, thus helping art designers to more accurately grasp fashion trends and design more competitive works in the market. Compared with previous techniques, this model is novel in that it utilizes two different neural network models, giving full play to their respective advantages and making the prediction results more accurate and reliable. The research aims to provide accurate prediction results for designers, assist in design creation, and play a crucial role in the operational decision-making of enterprises. The first section of the article provides an overview of relevant research results at home and abroad, indicating the necessity and feasibility of the research. Then, the second section provides a detailed introduction to the methods proposed in the study and their improvements. The third section of the article introduces the experiments and results obtained to verify model's performance, and finally summarizes the entire study in the fourth section.

2. Related Work. Deep learning is a machine learning method that can achieve learning and analysis of large-scale data by simulating the neuronal network of the human brain through a multilayer neural network. Deep learning extracts features from data through multi-layer neural networks and gradually improves the abstraction ability of the data, thus realizing the solution and prediction of complex problems. Deep learning has made remarkable achievements in the fields of speech recognition, image recognition, and natural language processing, and has been widely used in various fields. In deep learning, trend prediction estimates the future development direction of the research object through the gradual deepening of people's understanding of objectively existing things and the continuous development of relevant research means, with the aim of selecting future behaviors. Trend prediction estimates the future development direction of the research object through the gradual deepening of people's understanding of objectively existing things and the continuous development of relevant research methods, with the aim of making choices about future behavior. Scholars and Shafiq M O proposed a stock market price trend prediction scheme that includes feature engineering customization and deep learning models. This scheme comprehensively considered the preprocessing of stock market datasets, the utilization of various feature engineering technologies, and combined customized deep learning systems for prediction, making contributions to the stock analysis research community in the financial and technical fields [9]. Xu and other scholars proposed a scientific research topic trend prediction model based on multiple LSTM and graph convolutional networks. By using multiple LSTMs to map the research topics of different publications into their respective topic spaces, and then using graph convolutional neural networks to learn the scientific impact background of each publication, it had important reference significance for researchers to understand the development of the discipline, decision-makers to make decisions, and fund allocation [10]. Scholars such as Picasso mapped the stock market prediction problem to a classification task of time series data, with technical analysis indicators and sentiment in news articles used as inputs. A powerful prediction model was obtained for high-frequency trading simulations, achieving an annualized return rate of over 80%. This project represented further steps in combining technology and basic analysis, and provided a starting point for developing new trading strategies [11]. Scholars such as Hu Y proposed a trend tracking strategy for security prediction using LSTM networks, where the training method combined particle swarm optimization algorithm with gradient descent to obtain more competitive model parameters. Firstly, three trend representation methods were defined based on stock option research, and then a fusion algorithm optimized LSTM network was used for trend tracking. From the perspective of security prediction, the trends of changes were further predicted and analyzed over different time periods [12].

With the continuous development of deep learning technology and in-depth research, new developments have been made in learning the trends and patterns of fashion fashion elements and their mutual influence. Dong et al. designed an interactive knowledge-based design recommendation system to provide product design solutions and virtual demonstrations to specific consumers. This system utilized a 3D body scanning system and sensory evaluation program to obtain anthropometric data and designers' perception of body shape, and used fuzzy technology to model and classify the relationship between body shape, fashion themes, and design factors [13]. Wu D et al. proposed a novel relationship network for clothing attribute recognition. This network utilized a backbone network to extract features from input images, and then further learned these features through two attention models. It also utilized a graphical context inference module to further enhance the features, and finally used a classifier to classify clothing attributes based on the learned representation information. This method effectively utilized the relationships between objects to improve recognition accuracy [14]. Lu et al. developed a multi-layer non local feature fusion framework for studying clothing matching compatibility. The

feature fusion model was used to merge high-level and low-level features, while non local blocks were used for global feature detection. This technology was compared with previous state-of-the-art methods in compatibility prediction tasks and its effectiveness was demonstrated through extensive experiments on existing datasets [15]. Yang and Jang S used two calculation methods, ARIMA and RNN, to predict fashion trends. Researchers predicted women's skirts, selected the best model by comparing the results, and proposed the time points of change that should be paid attention to in fashion trends. Cautious application of deep learning methods was suggested in fashion product planning to improve the applicability of trend prediction [16].

Based on relevant research both domestically and internationally, it can be found that the continuous development of technology will make the prediction results more rich and accurate. However, further improvement requires a combination of factors that affect the development of fashion trends in the clothing industry. The trend of clothing fashion elements has a certain connection with different groups of people, and different groups of people have different views on clothing fashion trends. Combining user information is a very important research direction, while continuing to combine the patterns of fashion trend elements is the focus of future research. Therefore, the study utilizes BiLSTM to make more accurate predictions.

3. Fashion Element Trend Prediction Model Based on AM Fusion EfficientNet-b7. Finding the trend patterns from historical data related to clothing and making predictions can help art designers more accurately grasp fashion trends, thereby providing strong reference for design. The research aims to improve the accuracy of fashion trend prediction, combining the coexistence relationship between fashion elements and the attention mechanism to establish a prediction model.

3.1. Prediction of Fashion Element Trend Based on Coexistence Relationship. The method of automatically extracting unified popular element labels from image data is crucial for the accuracy and efficiency of trend prediction. At the same time, the trend changes of one party in the coexistence relationship will affect the other party, so the study aims to strengthen the ability of trend prediction based on the coexistence relationship of clothing elements. The main issue that needs to be addressed in research is how to predict trends through visual images. The primary task for any given clothing photo is to identify the corresponding popular elements [17]. The method adopted by the research institute is to learn a predictor based on the EfficientNet-B7 model, which can accurately extract clothing fashion element attributes in the target image. EfficientNet is a new type of neural network model that is obtained through reinforcement learning of the MnasNet model and the use of composite scaling rules. It is suitable for performing multi label classification tasks.

In the multi-label classification problem for identifying clothing popular element attributes, the neural network training process uses a binary cross entropy loss function, as shown in formula (3.1).

$$\begin{cases} Loss_{BCE} = \{l_{1,c}, l_{2,c}, \cdots, l_{N,c}\}^T \\ l_{n,c} = -w_{n,c}\left[p_c y_{n,c} \bullet \log\left(x_{n,c}\right) + \left(1 - y_{n,c}\right) \bullet \log\left(1 - \sigma\left(x_{n,c}\right)\right)\right], n = 1, 2, \cdots, N \end{cases} \tag{3.1}$$

In order to accelerate the update speed of model parameters, it is necessary to adjust the learning rate of the model reasonably. Here, we use the Adaptive Moment Estimation (Adam) algorithm for dynamic adjustment, which ensures that the model quickly approaches the optimal results in early training and steadily reaches the optimal state in later stages. By predicting the attributes of clothing popular elements, rich element attribute information can be obtained, which provides a good foundation for predicting the trend of clothing popular elements. The study constructs a model to predict elements trend with BiLSTM by using predicted clothing fashion elements from visual images as the data source for trend prediction. Figure 3.2 shows model's architecture.

At any specific point in time, the input information of the model includes many factors such as user characteristics g, clothing fashion element characteristics o, time characteristics m_t, and popularity y_t. These features are integrated into a feature embedding as v_t^e, as shown in formula (3.2).

$$v_t^e = [g, o, m_t, y_t] \tag{3.2}$$

In formula (3.2), the input sequence $v_t^e \in R^{5D+1}$of time$t$. The hidden representation of the input sequence at time t is the output data of the encoder LSTM, as shown in formula (3.3).

$$h_t^e = LSTM^e\left(v_t^e; h_{t-1}^e\right) \tag{3.3}$$

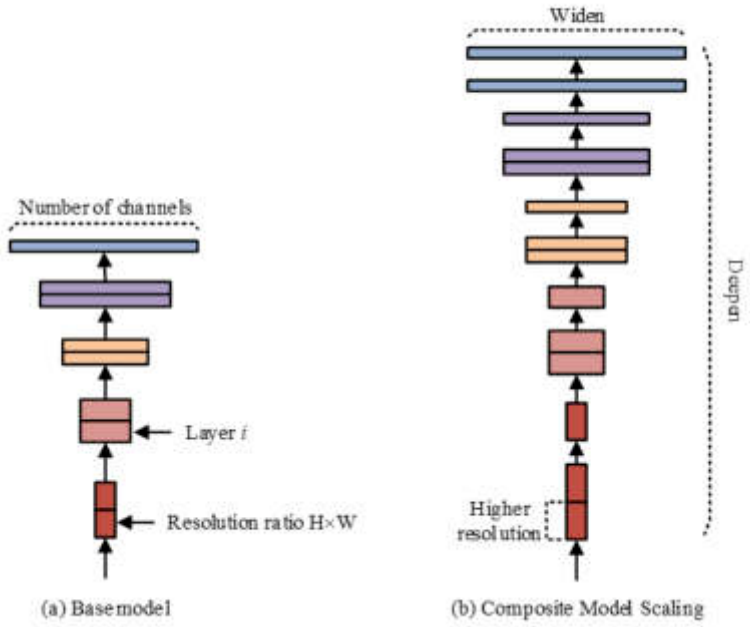


Fig. 3.1: Schematic Diagram of Composite Scaling Rulesn

In formula (3.3), $h_t^e, h_{t-1}^e \in R^H$.

The decoder is mainly based on BiLSTM, and its initial hidden state is derived from the encoder's final output hidden state h_T^e. The mission of the decoder is to decode the input features made by the encoder and then output predicted trends of popular elements in the future $t \in [T, T']$. The input of the decoder includes the predicted user population, popular element features, and the connection characteristics of the time feature sequence, as shown in formula (3.4).

$$v_t^d = [g, o, m_t] \tag{3.4}$$

In formula (3.4), the characteristic at this time$v_t^d \in R^{3D+1}$. The evolution of BiLSTM on traditional LSTM lies in its ability to integrate past and future information through bidirectional learning, thereby better grasping the contextual information of trend sequences. The forward information transmission representation is shown in formula (3.5).

$$\begin{cases} \vec{h}_t^d = LSTM\left(v_t^d; \vec{h}_{t-1}^d\right) \\ \overleftarrow{h}_t^d = LSTM\left(v_t^d; \overleftarrow{h}_{t+1}^d\right) \\ h_t^d = LSTM\left(\vec{h}_t^d; \overleftarrow{h}_t^d\right) \end{cases} \tag{3.5}$$

In formula (3.5), $\vec{h}_t^d, \vec{h}_{t-1}^d, \overleftarrow{h}_t^d, \overleftarrow{h}_{t+1}^d \in R^H, h_t^d \in R^{2H}$. The final prediction result is based on the final hidden state of each step in the encoding and decoding stage during the training process. During model testing, predictions are only made during the decoding phase. The predicted results are characterized by using a linear

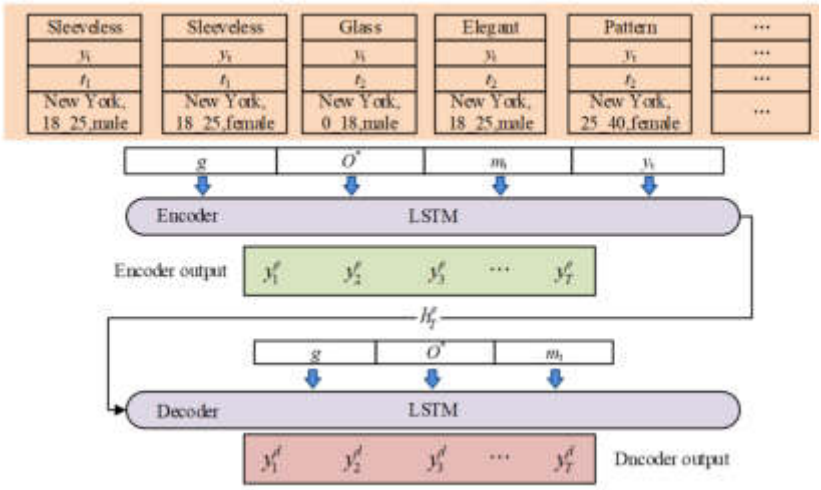


Fig. 3.2: Schematic Diagram of the Architecture of a Fashion Element Trend Prediction Model

layer for output during the encoding and decoding stage, as shown in formula (3.6).

$$\begin{cases} y_t^e = W_e h_t^e + b_e \\ y_t^d = W_d h_t^d + b_d \end{cases} \tag{3.6}$$

In formula (3.6), $W_e \in R^H$, $W_d \in R^{2H}$ is the weight represented linearly. b_e and b_d are biases represented linearly. During the entire model training process, we used L1 loss to optimize the model, and the total loss $Loss^*$ of the model includes the loss $Loss_{enco}$ of the encoder and the loss $Loss_{deco}$ of the decoder, as shown in formula (3.7).

$$Loss^* = Loss_{enco}\left(y_e, y_e^*, \theta_e\right) + Loss_{deco}\left(y_d, y_d^*, \theta_d\right) \tag{3.7}$$

In formula (3.7), θ_e and θ_d are the parameters of the encoder and decoder models, respectively. y_e and y_d are the true values of popularity in decoders and decoders. Predicted values for popularity in encoders and decoders. In fact, not all clothing elements are independent attributes. The study constructs a probability matrix by calculating the coexistence relationship between clothing attributes, in order to introduce the coexistence relationship into the prediction model. The number of simultaneous occurrences of two elements in one year's historical data is $N_{a,b}$. The number of occurrences of elements a is N_a, and the number of occurrences of elements b is N_b. The influence of elements b on elements a is expressed as $P_{a,b} = N_{a,b}/N_a$. The probability of the influence of an element a on the element b is expressed as $P_{b,a} = N_{a,b}/N_b$. The previously constructed elements are represented by vectors α, and the relationships between elements are transferred in the embedded representation. The original information and propagation information are represented by linear layer aggregation α^*, as shown in formula (3.8).

$$\alpha^* = W_e\left[\alpha, \alpha W_{ele}\right] + b_e \tag{3.8}$$

In formula (3.8), W_e and b_e are the weight matrices and biases of the linear representation layer. Therefore, the final representation of the encoder's input is shown in formula (3.9).

$$v_t^e = [g, \alpha*, m_t, y_t] \tag{3.9}$$

3.2. Fashion Element Trend Prediction Model Introducing AM. Elements trend prediction mostly relies on analyzing and learning past data, and then predicting future trends based on these patterns. However,

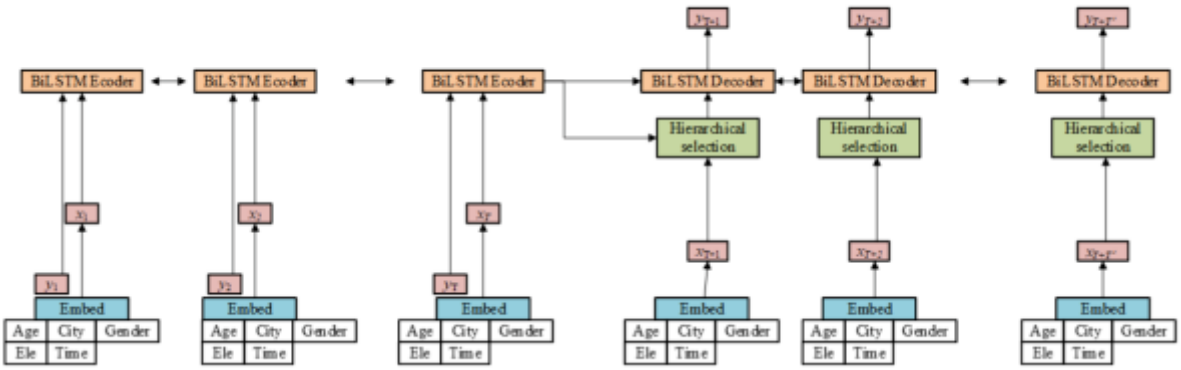


Fig. 3.3: Schematic Diagram of the Architecture of Similarity-Based Model

if too much historical information is accumulated, the ability to capture the main information may be lost, leading to unsatisfactory prediction results [18]. The introduction of attention mechanism, just like the human way of attention, mainly focuses on some important information, which improves the predictive ability of the model. One of the characteristics of clothing fashion element data is xt=[a, c, s, o, 4], and it can be seen that the only part that changes is time. If time is only the main focus, other trends in periodic changes will be ignored. Therefore, the method adopted in the study is to find the historical information closest to the predicted trend based on the periodic changes in fashion trend elements and similar life cycle characteristics, and pay special attention to the trend changes during this period in the prediction. The main goal of the study is to find hidden patterns and interaction patterns among various elements in historical fashion trend information, in order to predict future trend information. In practical applications, the research adopts a structure to learn historical information, and the model architecture is shown in Figure 3.3.

In conjunction with the analysis in Figure 3.3, it can be seen that in carrying out the design process of the decoder, the study incorporated a channel that incorporates both attentional and temporal hierarchies. Utilizing this channel enables trend comparisons to be made, thus effectively assessing the importance of historical trend information to the current forecast information.

By characterizing the features in the historical information, it is possible to make better predictions about the changing trends. Also in problem processing, given historical data, users are grouped by age, city, and gender, with each group containing multiple clothing elements. In terms of problem handling, users are grouped after the given historical data, with each group containing different elements.

The popularity of an element in one of the groups at the current time point t is defined as $y_t = N_t^{g,o}/N_t^g$. Among them, $N_t^{g,e}$ count elements o in the user group g at the time t, and N_t^g counts all o owned by g at t. Therefore, the problem studied becomes a model $f(\bullet)$ learning for popularity prediction within a given time series $[T+1, T+T']$ over a time range $[1, T]$, $T' > 1$ is the predicted time range.

Embedding methods are used to convert limited grouping information into different digital vectors. Encode classification features using one hot encoding method. The three attributes contained in each user group are converted into feature embeddings a, c, s. Among them, a, c, and s respectively represent age, city, and sex. At the same time, fashion popular elements are also transformed into o. In this way, encoder's input is a combination of a, c, s, o, and time features l_t at each time $t \in [T_1, T_t]$ with historical trend values y_t. The encoded input is passed through BiLSTM, where the hidden layer of the forward LSTM at time t is denoted as, and that of the backward LSTM as. Hidden layer state update representation can be observed in formula

(3.10).

$$\begin{cases} \vec{h}_t = LSTM\left(\hat{x}_t; \vec{h}_{t-1}\right) \\ \overleftarrow{h}_t = LSTM\left(\hat{x}_t; \overleftarrow{h}_{t+1}\right) \\ h_t = LSTM\left(\vec{h}_t; \overleftarrow{h}_t\right) \end{cases} \tag{3.10}$$

The prediction model proposed in the study adopts a novel hierarchical temporal attention mechanism. This mechanism improves the accuracy of prediction by trend similarity comparison between the recent time period T_l and historical information T_h, and selecting subsequent information $T_h + T^*$ of the T_h historical information that is closest to the T_l time period as the key factor affecting future trends. Based on the historical information of the past N years, the fashion trend for the following year is predicted, and the annual historical data includes $M = 24$ time nodes. Y_i is used to represent the trend data of the i-th year, Y_l to represent those of the most recent year, and $\bar{Y}$ to represent the average of annual trend information. So, the trend similarity $D(Y_i, Y)$ for year i is shown in formula (3.11).

$$D(Y_i, Y) = \sum_{j=1}^{M} \|y_{i,j} - y_j\|_2, i = 1, 2, \cdots, N \tag{3.11}$$

In formula (3.11), when $i < N$, $Y = Y_l$ and $y = y_l$. Then, the weight of historical information for different years is represented by the reciprocal method, as shown in formula (3.12).

$$\begin{cases} \eta_i = \frac{\exp(D(Y_N, Y))}{\sum_{i=1}^{N} \exp(D(Y_i, Y))}, i = 1 \\ \eta_i = \frac{\exp(D(Y_{i-1}, Y))}{\sum_{i=1}^{N} \exp(D(Y_i, Y))}, i = 2, \cdots, N \end{cases} \tag{3.12}$$

By using attention mechanisms, it is possible to extract more useful historical information for predicting current trends. For the data j in year i, the calculation of attention weight $\rho_{i,j,t}$ is shown in formula (3.13).

$$\rho_{i,j,t} = \frac{\exp(d_{i,j,t})}{\sum_{i=1}^{N} \sum_{j=1}^{M} \exp(d_{i,j,t})} \tag{3.13}$$

In formula (3.13), $\rho_{i,j,t}$ is the $(i \times M + j)$-th element of vector $d_t = \left(d_t^1, d_t^2, , d_t^M\right)$. The vector d_t is shown in formula (3.14).

$$d_t = V_d \tanh\left(W_d\left[h_{t-1}^d; x_t\right]\right) \tag{3.14}$$

In formula (3.14), the weight matrices V_d and W_d are obtained through model joint training. h_{t-1}^d is the decoder hidden vector at $t-1$. To convert hidden information into predicted outputy^*, a fully connected layer is utilized, which incorporates a calibrated linear unit with ReLU activation function, as shown in formula (3.15).

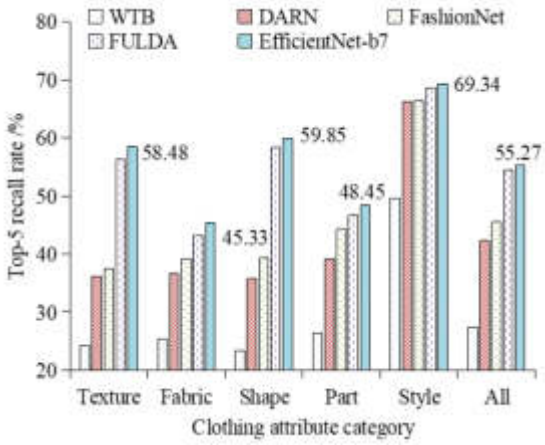
$$y^* = V_y \text{ReLU}\left(W_y h_{T+1,T+T'}^d\right) \tag{3.15}$$

In formula (3.15), $h_{T+1,T+T'}^d$ denotes hidden state. The study uses L1 paradigm to train the entire model, including encoder loss and decoder loss.

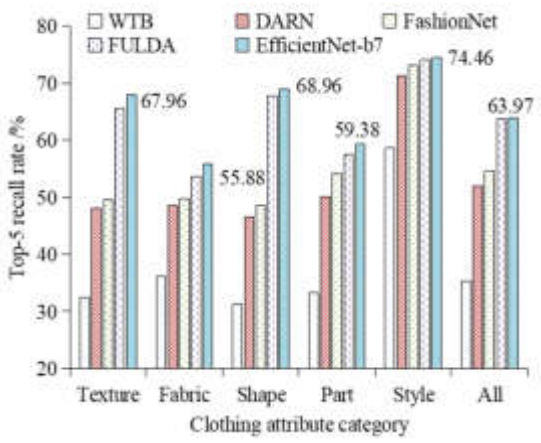
4. Validation of the Fashion Element Trend Prediction Model Based on AM Fusion EfficientNet-b7. The study validated the effectiveness of the fashion element trend prediction model based on AM fusion EfficientNet-b7. The experiment includes two parts: analysis of clothing element attribute popularity prediction model based on coexistence relationship and analysis of clothing element popularity trend prediction model. For experimental verification, the DeepFashion dataset was first used for model training, and algorithms such as Mean, Last, Autocompression (AR), Vector Autocompression (VAR), Exponential Smoothing (ES), Linear, and GeoStyle were selected as comparison methods. The performance evaluation indicators of the model are Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE).

Table 4.1: Parameter Settings for the Experiment

Number	Parameter	Element Attribute Prediction	Trend prediction	Trend prediction (improved)
1	Embedding size of features	/	128	10
2	Optimizer	Adam	Adam	Adam
3	Initial Learning rate	0.001	0.001	0.001
4	Weight Decay	5e-4	5e-4	5e-4
5	Size of hidden layers	/	50	120
6	Epoch	1000	100	100



(a) Top-3 recall rate for fashion element attribute popularity prediction



(b) Top-5 recall rate for fashion element attribute popularity prediction

Fig. 4.1: Top-k Recall Rate for Fashion Element Attribute Popularity Prediction

4.1. Validity Testing of a Fashion Element Trend Prediction Model Using Coexistence Relationship. The effectiveness validation experiment of the fashion element trend prediction model based on coexistence relationship was divided into fashion element attribute trend prediction and fashion element trend prediction. The study is based on clothing elements in a coastal city in China, while model training is performed using the DeepFashion dataset, and trend prediction is performed using clothing images of 2,500 users collected from social networking sites. There were a total of 800000 images and 1000 clothing attributes in the DeepFashion dataset, with 6:1 images in the training and validation sets. The collected clothing images were divided, with 16 cities and 4 groups based on ages of 18, 25, and 40. The statistical frequency of popularity was 15 days per occurrence, and a total of 264 time nodes were obtained from the eleven year data. The Top-k recall rate was the top-k attribute obtained by sorting the classification results obtained after 1000 classifications from a minimum to a minimum. The parameter settings for the experiment are shown in Table 4.1.

The recall rate obtained from the popular prediction of clothing element attributes is shown in Figure 4.1. From Figure 4.1, it can be observed that the model proposed based on EfficientNet-b7 had high predictive accuracy in all fashion element attributes. Its top-3 recall rate was 69.34%, higher than other models. The top-5 recall rate was 63.97%, which was also at a relatively high level. This indicates that the prediction model performed better in predicting the popularity of clothing element attributes as a whole.

The study selected algorithms such as Mean, Last, Autocompression (AR), Vector Autocompression (VAR), Exponential Smoothing (ES), Linear, and GeoStyle for comparative experiments on element trend prediction. The Mean and Last algorithms took the average and last numerical values of the test data as the predicted

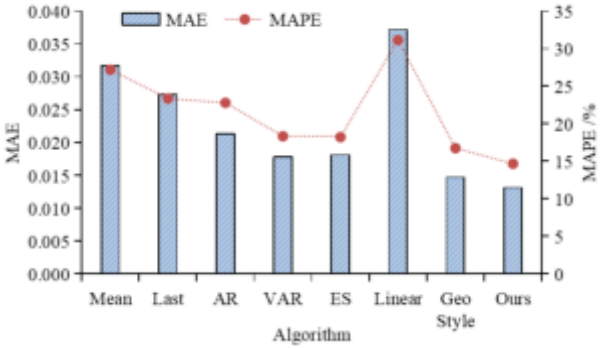


Fig. 4.2: Results of Comparative Experiments on Fashion Element Trend Prediction

Table 4.2: The Results of the Ablation Experiment

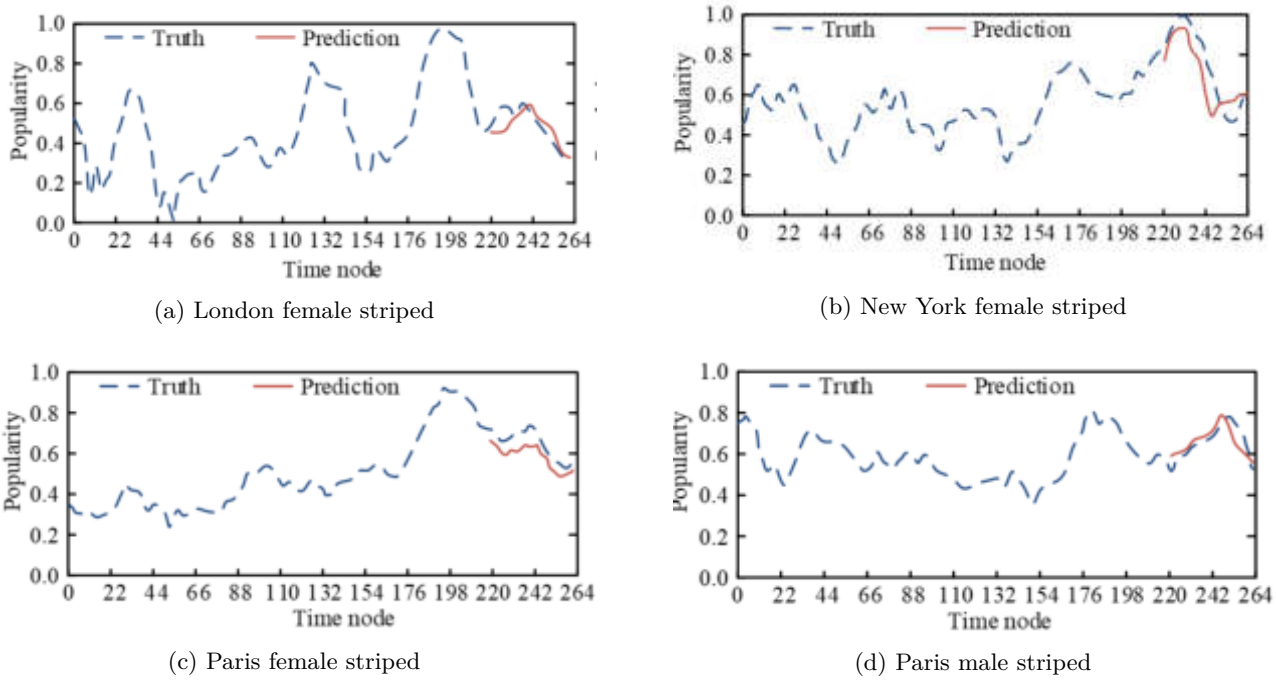
Number	Group	MAE	MAPE
1	User	0.0145	15.91
2	Relation	0.0136	15.03
3	Ours	0.0132	14.68

values, respectively. The results of the comparative experiment are shown in Figure 5. From Figure 4.2, it can be seen that the GeoStyle method had the best MAE performance at 0.0147, while the proposed method had the best performance on MAPE at 14.67%. Overall, the method proposed in the study performed significantly better on two indicators than other methods. This indicates that compared to other methods, this method had a more accurate and reliable predictive ability for fashion element trends.

The results obtained by removing the predictive power of some design models from the unified dataset are shown in Table 2. Among them, User represents the removal of user grouping processing, and Relation represents the removal of coexistence relationships between fashion elements. From Table 4.2, it can be seen that the model considering coexistence relationship performed best in both MAE and MAPE, with values of 0.0132 and 14.68%, respectively. This indicates that the coexistence relationship of elements can help improve the performance of prediction models.

Specifically, the trend of contrasting stripe attributes is shown in Figure 6. From Figure 6, it can be seen that there were differences in the historical trends of different elements after grouping users, reflecting trend prediction necessity for user grouping. Observing the results of trend prediction, the trend changes predicted by the research institute for six months were basically consistent with the actual trend.

4.2. Performance Test of Fashion Element Trend Prediction Model Introducing Trend Similarity AM. The effectiveness validation experiment of the fashion element trend prediction model using trend similarity AM was conducted using the FIT dataset. This dataset included 680000 clothing images collected from social media platforms, as well as information on users' gender, age, and city. The frequency of prevalence statistics was still 15 days per occurrence, and the dataset covered a period of 5 years. The comparative algorithms selected for the study include Mean, Last, AR, VAR, ES, Linear, and the Combination of Internal and External Knowledge (CIEK) model. The results of the comparative experiment are shown in Figure 4.4. From Figure, it can be seen that the Ours model was the best performing model in predicting the trend of six months, with lower MAE and MAPE values compared to other models. In the one-year trend prediction, the Ours model also outperformed other models in MAE and MAPE, with high prediction accuracy and reliability. The improvement in short-term trend prediction ability of the model was greater, due to the small amount of prediction data generated by short-term trend prediction and the small error it brought.



(a) London female striped

(b) New York female striped

(c) Paris female striped

(d) Paris male striped

Fig. 4.3: Trend and Prediction Results of Stripe Attributes in Different Cities

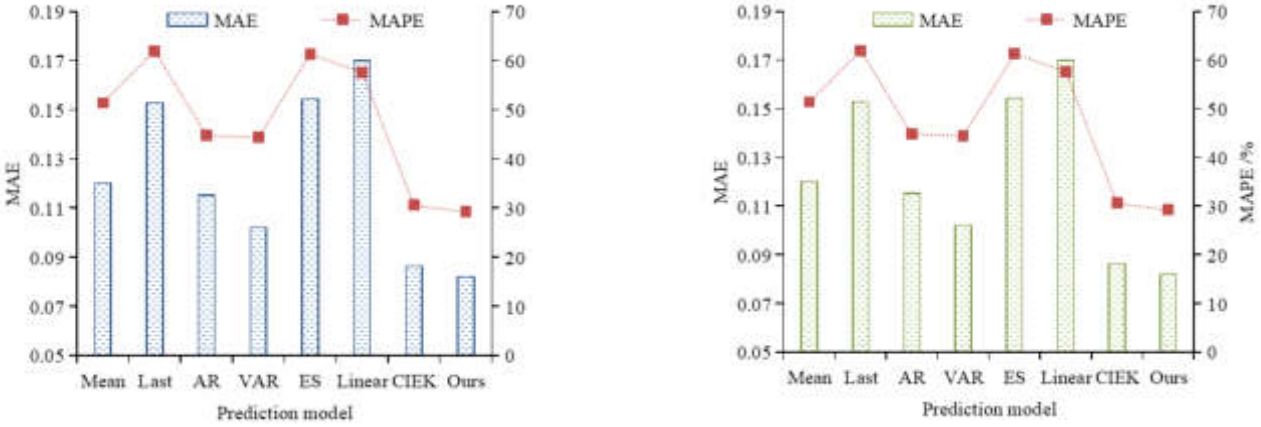
Figure 4.5 shows the model predicted results, with the first three subgraphs showing the predicted trends of different elements in same group. Figures 8 (c) and 8 (d) show the predicted trends of the same element in different user groups. From Figure 4.5, it can be seen that the clothing trend prediction model based on trend similarity proposed in this chapter can fit future trend changes. At the same time, it can be clearly seen that short-term forecasting has better results.

Clothing fashion elements trend among different user groups is shown in Figure 4.6. From Figures 4.6 (a), (b), and (c), it can be seen that the trend changes corresponded to different ages, cities, and genders, with some time periods showing opposite trends, indicating the necessity of grouping users into predictions.

The prediction model based on trend similarity attention mechanism proposed in the study showed good predictive ability, especially for clothing elements with obvious periodicity. Figure 4.7 illustrates the forecast of purple clothing components among women aged 18 to 25 in Shanghai. It can be seen that elements prediction with less periodicity still needed improvement, and a significant downward trend cannot be predicted at the beginning. The reason for the existence of this situation was based on the attention mechanism of trend similarity, which focused on the obvious periodicity of most clothing fashion elements. For clothing fashion elements with less periodicity and long-term trend prediction, the improvement of prediction accuracy was not high.

As shown in Table 4.3 are the validation indicators used in the study, and the values of the relevant indicators.

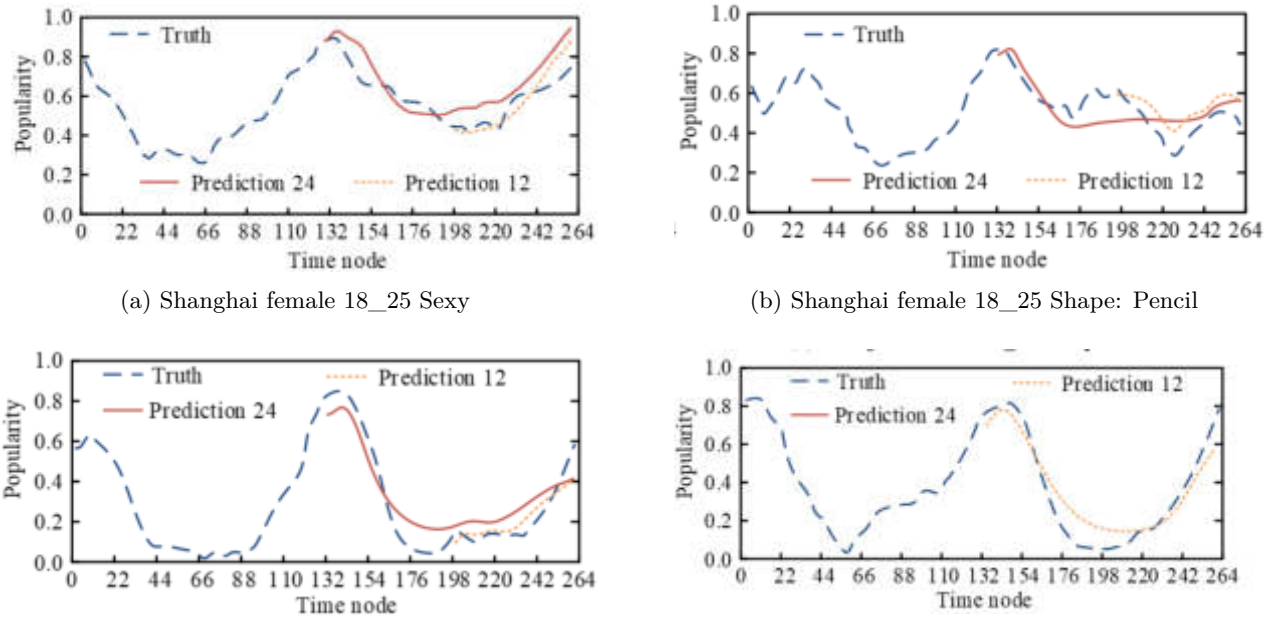
5. Discussion. The study utilizes the attribute predictor constructed by the EfficientNet-b7 model to quickly and accurately extract the attributes of elements on clothing images, and constructs the prediction model through the encoder-decoder framework of BiLSTM to achieve effective prediction of clothing fashion element trends. Meanwhile, the study further improves the performance of the prediction model by introducing the trend similarity attention mechanism. This indicates that this suggests a broad application of deep learning technology in apparel fashion element trend prediction. The variables also produced positive changes, and



(a) Half Year Epidemic Trend Prediction Results

(b) One Year Epidemic Trend Prediction Results

Fig. 4.4: Prediction Results of Fashion Element Trends by Different Models



(a) Shanghai female 18_25 Sexy

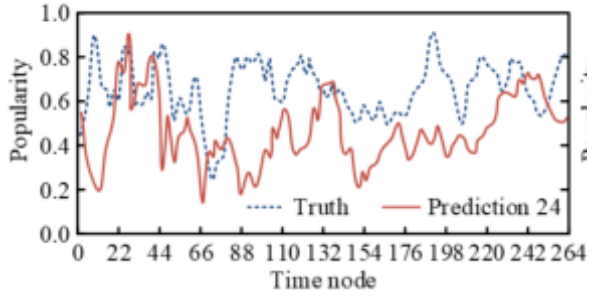
(b) Shanghai female 18_25 Shape: Pencil

(c) Shanghai female 18_25 Sleeve_length: short

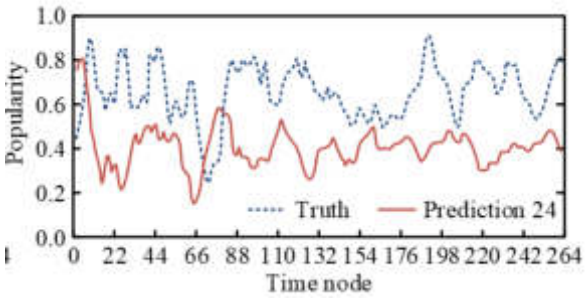
(d) New York female 25_40 Sleeve_length: short

Fig. 4.5: Prediction Results of Similarity-based Fashion Trend Prediction Model

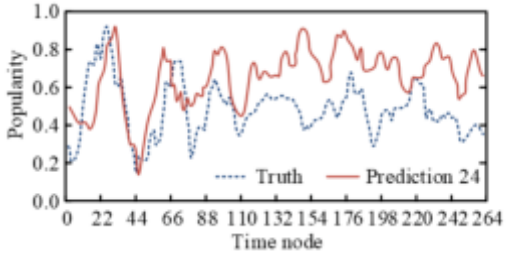
the study found that the model considering coexistence relationships performed best in terms of MAE and MAPE by comparing the prediction results of different models, which were 0.0132 and 14.68%, respectively. In the study of accuracy, the model with the introduction of the trend similarity attention mechanism showed a significant improvement in accuracy by 5.09% and 4.54%. This shows that these theories and changes provide new ideas and methods for the field of clothing design and art design. Through the study, it was found that



(a) Trends in streetstyle elements among Shanghai women of different ages



(b) Trends in streetstyle elements among women aged 18 to 25 in different cities



(c) Trend in gray elements in Shanghai between different genders of 25 to 40

Fig. 4.6: Trends in Fashion Trends among Different User Groups

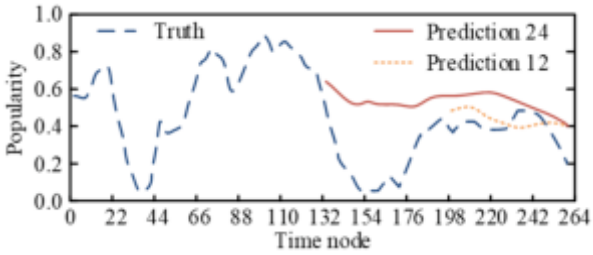


Fig. 4.7: Prediction Results of Purple Clothing Elements among Shanghai Women Aged 18 to 25

the limitations of the application of the fashion trend prediction model for clothing elements, which integrates AM and EfficientNet-b7 models, in fine art design are mainly data collection and labeling, model complexity, and real-time response. The model can be applied in the fields of fashion design, apparel design, and apparel matching to help designers predict future apparel trends and enhance the market competitiveness of their design works.

6. Conclusion. With the continuous development of computer technology and the arrival of the big data era, trend prediction through data-driven methods has gradually shown advantages. The research aims to use deep learning technology to predict fashion elements trend. Therefore, this study first constructs an attribute predictor based on the EfficientNet-b7 model, which is used to quickly and accurately extract element attributes from clothing images, and to use the coexistence relationship between clothing popular elements

Table 4.3: Results of relevant validation indicators

Sports event	Optimum value	Minimum value
Recall rate	69.34%	63.97%
MAE value	0.0147	0.0132
MAPE value	14.68%	14.67%
Popularity expectations	1.0	0.79

to assist in prediction. Then, based on user information, clothing fashion elements are grouped and counted to construct a prediction model based on the BiLSTM encoder decoder framework to train trend information as a whole. Results showed that the model considering coexistence relationship performed best in MAE and MAPE, with values of 0.0132 and 14.68%, respectively. In addition, the attention mechanism based on trend similarity also had certain effects in improving model performance, with an accuracy improvement of 5.09% and 4.54% compared to the latest KERN model. By combining attribute predictors, user information, coexistence relationships, and trend similarity, clothing trends can be accurately predicted. Designers can quickly select the most suitable materials and improve design efficiency by predicting fashion fashion trends during art design. However, the coexistence relationship between clothing fashion elements proposed in the study is only a simple relationship, which can be further explored in subsequent work and applied in trend prediction models.

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SOCIAL MEDIA AND CLOUD COMPUTING IMPACT ON HUMAN RESOURCE MANAGEMENT IN MULTINATIONAL ENTERPRISES

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Abstract. To address the issues of high storage costs for human resource data, resource management of human resource systems, and employee social interaction in human resource management, this study proposes an adaptive intelligent HR data placement strategy based on genetic algorithms. Additionally, a fitness model and an employee social interaction model are presented. The fitness model utilizes genetic algorithms to optimize data storage strategy and server load balancing, resulting in reduced overall costs and efficient resource utilization. This is achieved by comprehensively considering data transmission latency and storage costs. The employee social interaction model analyzes social media blog post topics and employee ranks, and employs a co-training method to predict employee interactions. The experimental results indicated that the placement strategy can improve the HR data transfer by nearly 50% and effectively reduce the standard deviation of server load by about 10-15%. The accuracy, recall, F1 value, and precision of the employee social interaction model were 77.89%, 63.97%, 70.32%, and 71.78%, respectively. The proposed strategy and model demonstrated higher accuracy and robustness in predicting and analyzing employee social interactions, thus providing more reliable decision support for human resource management.

Key words: Social media; Cloud computing; Human resources; Employee interaction; Multinational enterprises

1. Introduction. Under globalization and matization, multinational enterprises competitiveness depends on their comprehensive capabilities, including their ability to recruit, train, develop and retain human resources worldwide. These capabilities are mainly reflected through systematic transnational human resource management methods and business levels. Driven by computer technology, artificial intelligence algorithms, network computing, data mining and other technologies have been widely used in transnational human resource management [1-3]. The interaction among employees in multinational enterprises directly affects their work efficiency. Negative interaction can have a detrimental effect on human resource management and global business development. Corporate social networks have important value in improving employee satisfaction and enhancing global teamwork. At present, there is little research on corporate social media application in transnational human resource management, which needs to be further discussed [4-6]. The cloud computing platform provides on-demand network storage computing resource services. Meanwhile, the impact of social media and cloud computing on human resource management of multinational enterprises helps to enhance the competitiveness of enterprises. Therefore, studying the application of social media and cloud computing is important in transnational human resource management to promote multinational enterprises development [7-9]. This study includes four parts, the first part is a summary of the study and the analysis of related research, the second part is to design the application research methods of corporate social media in transnational human resource management, the third part is to analyze the data, and the fourth part is to draw the research conclusion.

2. Related works. In recent years, the research of enterprise social network is deepening. Li team proposed an integrated research framework, presenting the future trend of ESM research. The research carried out quantitative analysis and visualization of ESM research, which had certain originality and value [10]. Liang team built a research model to explore the impact of the use of public and private social media platforms under different motivations on employees' job satisfaction and work efficiency. The research results showed that public social media had a positive impact on employee job satisfaction [11]. Luqman a team used the moderating focus theory (RFT) to propose the moderating effect of employees' promoting and preventing focus on these relationships. The results showed that interruption load and psychological change mediated the

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relationship between ESM use and fatigue and creativity respectively [12]. Laitinen team discussed various factors for employees to share information on corporate social media platforms. It tried to comprehensively describe the factors that shaped employees' decision on corporate social media. The study found that employees' information sharing decisions were influenced by privacy management principles [13].

Additionally, research on human resources is also deepening. Vrontis team conducted a comprehensive analysis of international business, general management and information management. The research results showed that intelligent automation technology provided a new method for managing employees and improving company performance [14]. Ngoc Su D team revealed the beneficial practice of human resource flexibility construction implemented by enterprises before, during and after the closure. The research results showed that it was of great significance to maintain the tourism labor force and enhance the organizational flexibility [15]. Guest D E team took the signaling theory as a framework to integrate the two attribution methods in human resource management and found that there was a positive correlation between the strong HR signal and the HR attribution and attitude of employees as receivers [16]. Vinoth S and their team investigated and evaluated the most significant network security and data security risks in the cloud system. While virtualization was promoted as a solution to current security issues, improper virtualization could have a negative impact on the network system's security by adding additional software. Additionally, the data center hub is connected to the server through software. If there was a problem, it may have a serious impact on security. Since users had no control over cloud resources, they must rely on the trust mechanism [17]. Sandhu A K team discussed the definition, classification and characteristics of big data, as well as various cloud services. At the same time, it made a comparative analysis of big data frameworks based on cloud. [18].

It can be concluded that the research in recent years has focused on the motivation and effect of social media use and the factors of employee information sharing. In addition, the application of cloud computing and big data has also played an important role in human resource management, such as the application of intelligent automation technology, and the research on network security and data security risks in cloud systems. The innovation of this study is mainly reflected in integrating the influencing factors of social media and cloud computing, and studying their impact on human resource management of multinational enterprises from a new perspective. This not only broadens the research perspective, but also provides new human resource management strategies for multinational enterprises.

3. Design of interactive model of employee interaction management in human resource management of Multinational Enterprises. An adaptive intelligent data placement strategy based on genetic algorithm is proposed. This strategy can help social network service providers improve economic benefits. In addition, aiming at the problem of server resource management in social network environment, a fitness model is proposed to achieve load balancing. Finally, the interaction model design of enterprise social network is discussed in detail. By integrating these three aspects, an effective model for enterprise social network interaction can be built. This model provides a new solution to the problems of data storage costs, server resource management, and enterprise social network interaction in online social networks.

3.1. Design of social cloud computing data placement model in human resource management of Multinational Enterprises. The development of social network provides new possibilities for human resource management of multinational companies. Social networks can help multinational companies better understand employees' needs and expectations, and improve employees' participation and job satisfaction. However, the management and analysis of social network data is a complex process, which requires a lot of computing resources and storage space. Adaptive intelligent data placement strategy based on genetic algorithm can help multinational companies effectively manage social network data, improve the efficiency of data processing and reduce the cost of data storage.

An adaptive intelligent data placement strategy based on genetic algorithm is proposed. The research is based on genetic algorithm when designing intelligent data placement algorithm. At the start of the algorithm, an initial population is randomly generated. Then, through the principles of survival of the fittest and natural selection, individuals are selected, crossed over, and mutated to create the next generation. This process is repeated until a better solution is obtained. The crossover operation is shown in Fig. 3.1.

Social network services need a solution that can not only ensure users to access data within a tolerable delay time, but also reduce costs as much as possible and improve their own economic benefits. The proposed

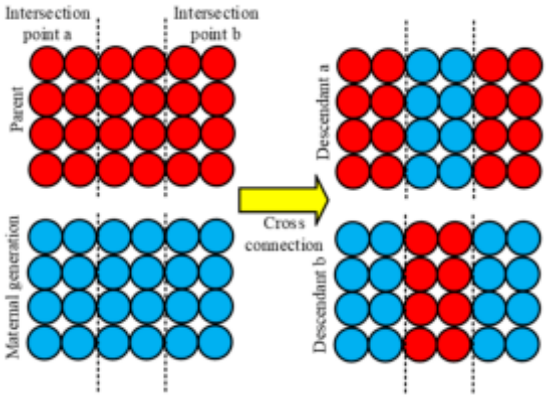


Fig. 3.1: Cross operation

data placement strategy based on genetic algorithm fully considers the above factors. First of all, suppose that each user has a master copy located in the nearest master data center from where they are located. Users access their own data from the master data center and their friends' data from the nearest data center with copies of their friends' data. Then, genetic algorithm is used to find the optimal data placement scheme. The goal of the research is to reduce the storage cost as much as possible within the delay time of no more than 250ms, so as to realize the economic benefits of social network service providers. The user's master data center is shown in formula (3.1).

$$x_{ij} = \begin{cases} 1 & \text{User z's data is stored in data center y} \\ 0 & Other \end{cases} \tag{3.1}$$

The total storage cost is shown in formula (3.2).

$$Cost = \sum_{i=1}^{N} StorageCost_i \tag{3.2}$$

$StorageCost_i$ is calculated in formula (3.3).

$$StorageCost_i = UnitStoragePrice \times StoredDataSize_i \times (R_i + 1) \tag{3.3}$$

$UnitStoragePrice$ represents the storage cost of 1GB of data in cloud storage for one month. $StoredDataSize_i$ indicates the size of user data volume, and R_i indicates the volume of replicas stored in other data centers except the primary replica. The user's access delay time is expressed as a linear function, as shown in formula (3.4).

$$\frac{\delta_{(round_{trip_{time}})}}{\delta_{(dis\tan ce)}} \approx 0.02ms/km \tag{3.4}$$

$round_{trrip_{time}}$ represents the delay time when the user accesses and $distance$is the distance between the user and the data center. Assuming that there is a 20ms delay between the user and the master data center, the delay time formula is shown in formula (3.5).

$$latency\,(ms) = \begin{cases} 20 & \text{Delay between users and the main data center} \\ 0.02 \times dia\tan ce + 5 & Other \end{cases} \tag{3.5}$$

$latency$ indicates the delay time for users to access the data center. The $latency_i$ limiting conditions are shown in formula (3.6).

$$latency_i \leq DesiredLatency \tag{3.6}$$

Table 3.1: Genetic algorithm initialization phase operation

Node number	1	And	4039
Node status	0	And	1
Node status	1	And	0
Node status	0	And	0
Node status	1	And	0
Node status	0	And	1
Node status	0	And	1
Node status	1	And	0
Node status	1	And	1
Node status	0	And	1
Node status	1	And	0

$latency_i$ is the average delay time, $DesiredLatency$ is the longest delay time allowed by the user. In the initialization phase of the algorithm, an adaptive population initialization method is used. First, initialize the data center of all users randomly. Then, a certain proportion of users are randomly selected from all users. These users need to meet the delay requirement of no more than 250ms during initialization, while other users who do not need to meet the delay requirement can be initialized randomly. Next, initialize each user separately. For users who need to meet the delay requirements, place copies of their data in the data center where their friends are located. For users who do not need to meet the delay requirements, the storage location of their data copies will be randomly initialized. The initialization operation is shown in Table 3.1.

In the iterative process of the algorithm, the crossover and mutation operations are used to generate new solutions, and the fitness function is used to evaluate the quality of the solutions. The fitness function used includes data transmission delay time and storage cost. In order to solve the problem of load balancing in online social network system, a fitness model is proposed to achieve load balancing. The standard deviation is used to express the dispersion degree between the number of replica storage and the average value in the server. In the social network environment, the average load and load balancing standard deviation of servers in the same cloud data center can be calculated by formula. The average server load in the same cloud data center is shown in formula (3.7).

$$AL = \frac{\sum_{i=1}^{m} RNum_i}{m} \tag{3.7}$$

$RNum_i$ indicates the number of replica storage in the server and $m$is the number of data centers. The standard deviation of load balancing is shown in formula (3.8).

$$SL = \frac{\sqrt{\sum_{i=1}^{m} (RNum_i - AL)^2}}{m} \tag{3.8}$$

In the social network environment, combined with the load balancing index of the server, the index function of the load balancing fitness model is proposed. The function consists of two parts. The first half calculates the data transmission volume between multiple servers, and the second half calculates the load balancing standard deviation of servers. The objective function of the load balancing fitness model is shown in formula (3.9).

$$Fit = Traffic_{total}^{\lambda} + SL^{\gamma} \tag{3.9}$$

$Traffic_{total}^{\lambda}$ represents the total amount of data transmitted. λ indicates the data transmission scale and$\gamma$is the impact factor of load balancing standard deviation. In order to realize this model, an adaptive multi-objective load balancing intelligent optimization algorithm based on genetic algorithm is proposed. This algorithm can not only optimize the data storage cost and the amount of data transmission of the server, but also improve the load balancing problem of the server to the maximum extent on the basis of meeting the requirements of user delay time. The algorithm flow is shown in Fig. 3.2.

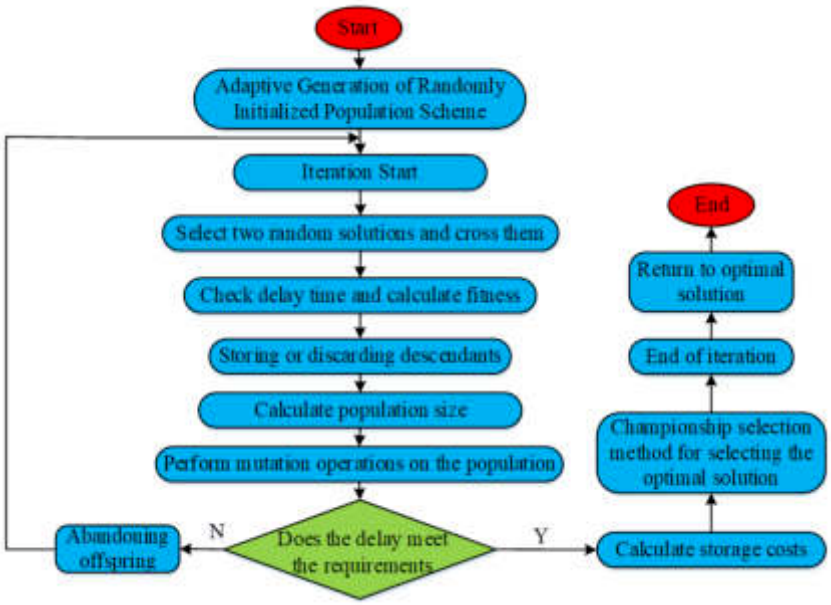


Fig. 3.2: Improve algorithm process

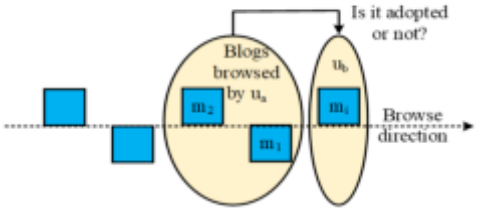


Fig. 3.3: Interactive scenes

3.2. Design of social network interaction model in human resource management of Multinational Enterprises.. As multinational companies may have different business in different countries and regions, employees' cultural backgrounds, values and working habits, it is necessary for companies to adopt more flexible and diversified strategies in human resource management. In this context, the use of social networks has become an important tool of human resource management of multinational companies. The interaction model design of enterprise social network is a complex process, which needs to consider many aspects. First, when an employee in the enterprise's social network posts a new blog post, the blog post will be immediately displayed to other employees. Blog posts in corporate social networks are displayed on employees' reading screens in chronological order, with the latest posts appearing first. Employees can browse older posts in descending chronological order through the drop-down menu. The Interaction scenario is shown in Fig. 3.3.

To solve the calculation problem of blog forwarding possibility, it is necessary to build a model. The model uses the company's personnel information to mark the rank of employees in the social network, which is called the employee rank generation module. Secondly, an LDA model must be used to extract blog topics, that is, blog topic extraction plate. Then, according to the extracted topics, the method of collaborative training is used to classify the blog posts, that is, the blog classification section. Then, statistical model learning is

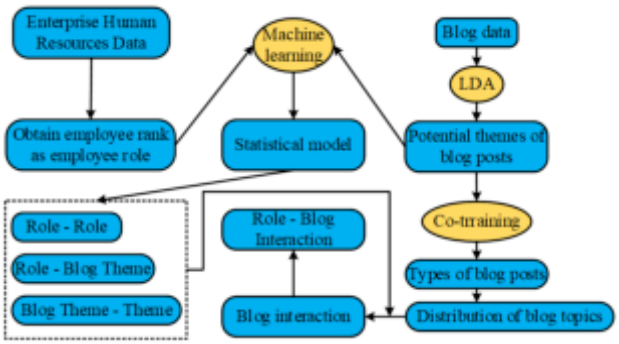


Fig. 3.4: Interactive model

conducted based on the results of employee rank and blog topic, that is, statistical model learning module. Finally, based on the results of blog classification and statistical model learning, the interaction between blog posts and employees can be inferred. This part is called interaction inference module. The interaction model is shown in Fig. 3.4.

The model is based on three interaction scenarios: the interaction between employees and blog posts, the interaction between employers and employees, and the interaction between blog posts and blog posts. The first is employee rank employee rank interaction. By inferring the interaction between different ranks, it can be inferred how the rank of the blog author affects whether employees adopt the blog. The rank interaction formula is shown in formula (3.10).

$$\Delta\left(u_a, u_b\right) = \sum_i \sum_j \Delta_{role}\left(r_i, r_j\right) \tag{3.10}$$

$\Delta role\left(r_i, r_j\right)$ represents the influence between different ranks. The second is the blog topic blog topic interaction. Each blog post is distributed on multiple topics. The topic distribution of each blog post is extracted by LDA Algorithm, and the interaction between different topics is inferred. The blog blog interaction formula is shown in formula (3.11).

$$\Lambda\left(m_i, m_k\right) = \sum_a \sum_b \theta_{i,a} \Lambda_{topic}\left(t_a, t_b\right) \theta_{k,b} \tag{3.11}$$

$\theta_{i,a}$ indicates the probability that a blog post is subordinate to the subject and $\Lambda_{topic}\left(t_a, t_b\right)$is the impact between topics. Finally, it is the interaction between employee rank and blog topic. By creating a matrix to illustrate the relationship between employee rank and blog topic, it is possible to infer how employee rank affects blog topic selection. The rank blog interaction formula is shown in formula (3.12).

$$\Omega\left(u_a, m_i\right) = \sum_j \sum_b \Omega_{topic}^{role}\left(r_j, r_b\right) \theta_{i,b} \tag{3.12}$$

Ω_{topic}^{role} indicates the interaction between employees and blog posts. The maximum likelihood function is shown in formula (3.13).

$$L\left(\Omega_{topic}^{role}, \Delta_{role}, \Delta_{topic}\right) = \sum_{i=1}^{n} \left(y_i \log \pi\left(x_i\right) + \left(1 - y_i\right) \log\left(1 - \pi\left(x_i\right)\right)\right) \tag{3.13}$$

$\pi\left(x_i\right)$ indicates the probability that employees will use blog posts. The principle of topic model is shown in Fig. 3.5.

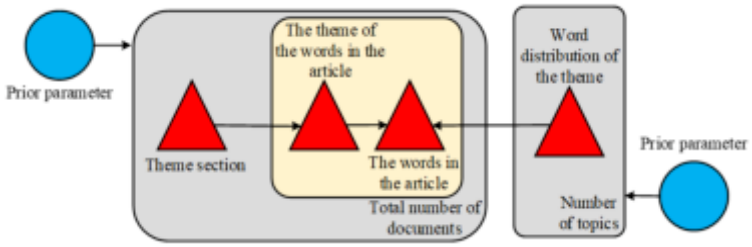


Fig. 3.5: Principle of topic model interactive model

In the design of blog classification, it is necessary to manually label part of the blog as the initial training set, and then classify the unlabeled test set through two classifiers. If the prediction results of the two classifiers are consistent, the blog will be classified into the labeled training set. After iterating repeatedly, each iteration moves some blog posts to the training set. When enough blog posts are marked, the blog category blog category interaction and employee rank blog category interaction can be obtained. Blog category - the interaction formula of blog category is shown in formula (3.14).

$$\Lambda_{cate.}\left(c_i, c_k\right) = \sum_a \sum_b \varphi_{i,a} \Lambda_{topic}\left(t_a, t_b\right) \varphi_{k,b} \tag{3.14}$$

$\varphi_{i,a}$ is the distribution of potential topics. The interactive formula of employee rank blog category is shown in formula (3.15).

$$\Omega_{cate.}^{role}\left(r_i, c_j\right) = \sum_b \Omega_{topic}^{role}\left(r_j, r_b\right) \varphi_{k,b} \tag{3.15}$$

In general, the design of enterprise social network interaction model mainly includes the construction of model framework, the design of three kinds of interaction methods and the classification of blog posts. The construction of model framework is the foundation, the design of three interactive ways is the core, and the classification of blog posts is the key. Only by integrating these three aspects can an effective interactive model of enterprise social networks be built.

4. Testing of social network data placement and interaction model under human resource management of multinational enterprises. This study designed two experiments to test the performance of data placement model and interaction model of enterprise social network. The first test recorded the changes of data transmission volume, server storage load, storage cost and other indicators. According to the experimental results, the optimization effect and performance of the data placement model are verified and analyzed. The second experiment uses the enterprise social network interaction model for experimental design, and then evaluates the relationship between model performance and blog interaction. The dataset used for both experiments was derived from the internal social networking platform of a multinational company. It covered detailed social interaction records over a one-year period and included interaction data for about 10,000 employees. The dataset contained a total of about 200,000 blog posts, as well as associated commenting, liking, and sharing behaviors. The characteristics of the data include the employee's department, position level, type of interaction (e.g., commenting, liking, sharing), time of blog posting, and content category. The data is transparent and does not compromise personal privacy.

4.1. Testing of social network data placement model under human resource management of Multinational Enterprises. To test the performance effect of the social network data placement model, the study set the number of data centers to 10, the total number of users to 4039, the average amount of data generated by each user per month to 27MB, the cost of storing the data to $0.125 per GB per month, and the latency requirement to no more than 250ms. The study tested variables of 50%, 70%, 90%, and 99% for users

Table 4.1: Parameter settings

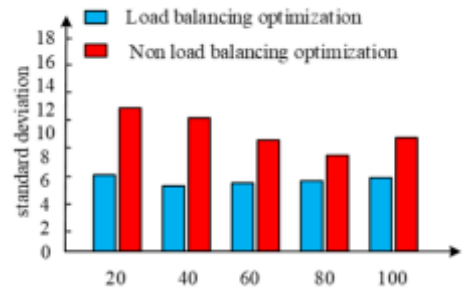
Parameter type	Numerical setting
Number of data centers	10
User (n)	4039
Monthly storage cost of 1GB of data ($)	0.125
Monthly data volume per user (MB)	27
Delay time requirement (MS)	250
Proportion of users who meet delay requirements (%)	50, 70, 90, 99
Population size	30
Crossover probability (%)	80
Mutation probability (%)	10
Iterations	50
Number of servers per data center	10-100
Storage capacity of the server ()λ	64
The influencing factors of data transmission volume (a)	(0, 1)
Factors affecting the standard deviation of load balancing ()γ	(, 1)λ

meeting the latency requirement. Evaluation metrics included data transfer volume variation, server storage load, and storage cost. Analyzing these metrics allowed for further conclusions on the effectiveness of the data placement model in reducing data transfer between data centers and optimizing storage costs. Parameter settings are shown in Table 4.1.

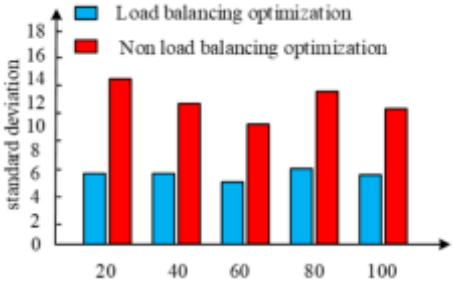
The parameter setting of intelligent optimization algorithm in social networks covers 14 aspects. These parameters are set to optimize the load balancing of social networks, so as to improve the user experience and system performance. The load comparison is shown in Fig. 4.1.

As shown in Fig. 4.1, the data transmission volume obtained by the optimization method is significantly higher than that under non-minimum ratio at any ratio, indicating that the method is effective in optimizing the data transmission volume. On this basis, 50%, 70%, 90%, 99% and 64% are studied in a single data center. The experimental results show that under the same experimental conditions, the storage load of the server is significantly reduced no matter what proportion is used. The storage cost changes with the number of iterations, as shown in Fig. 4.2.

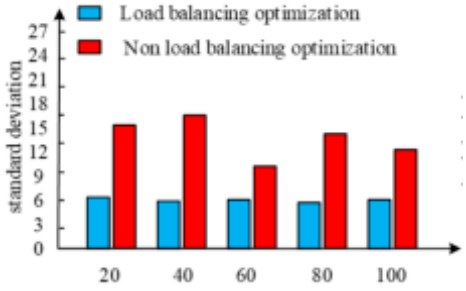
As shown in Fig. 4.2, when the maximum delay is 200ms and 250ms, the data storage overhead is optimized by 50%, 70%, 90% and 99% respectively. The experimental results show that the storage overhead of the system is gradually reduced in the process of continuous iteration of genetic algorithm. In the ninth generation, the method has basically reached a stable state, and the data storage overhead has been significantly reduced compared with that before optimization. Experimental results show that the method has good convergence performance and optimal degree. In particular, when the maximum delay is 200 milliseconds, the savings cost of the first generation is $65.234, of which only $14.631 at 50%, a decrease of 78%. At 70%, the optimal savings cost is only $20.896, which is 69.68% less than the original. At 90%, the optimal savings cost is only $33.199, which is 48.94% less than the original. In 99% of the cases, the optimal savings cost is only $50.398, which is 22.03% less than the original. Similarly, when the maximum delay is 250 milliseconds, the optimization at the proportion of 50% can save 81.01%. Under the proportion of 70%, the best savings cost was only 15.907 US dollars, a decrease of 76.44%. Under the proportion of 90%, the best savings cost is $25.023, which is reduced by 63.26%. In 99% of the cases, the best savings cost was only $35.407, a decrease of 47.21%. The results show that under the same number of users, when the maximum delay is long, the storage overhead of the system is small. The reason is that in order to meet the higher demand of social services, it is necessary to store replicas in more locations to ensure lower latency, which leads to the increase of overhead. The research results of this project will further verify the correctness and feasibility of this method. In summary, the social network data placement model aims to optimize the storage of social media data in a cloud computing environment to reduce data transmission costs and improve access efficiency. The model uses genetic algorithms to adaptively select data storage locations in different data centers, considering factors such as data access frequency, storage



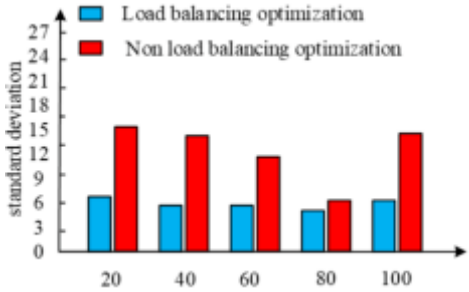
(a) 50% of users meet delay requirements



(b) 70% of users meet delay requirements

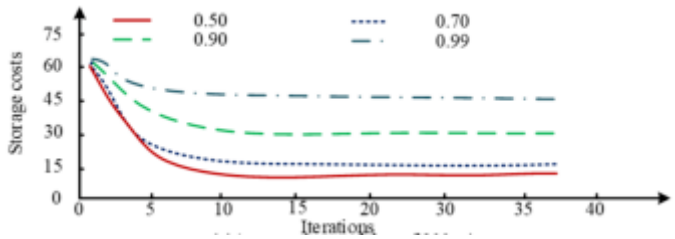


(c) 90% of users meet delay requirements

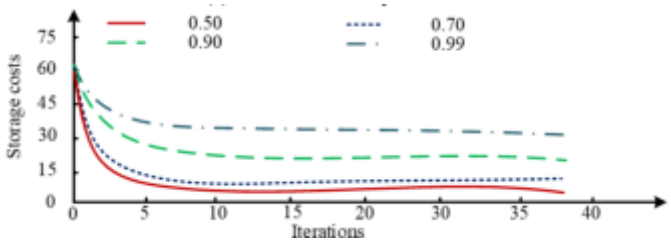


(d) 90% of users meet delay requirements

Fig. 4.1: Load comparison status



(a) At a maximal delay of 200 meter per second



(b) At a maximal delay of 250 meter per second

Fig. 4.2: The result of storage cost changing with the number of iterations load comparison status

Table 4.2: Dataset situation

Time	Total number of blog posts	Number of employees issuing documents	Average number of documents issued by employees	Standard error
Jan	85590	6783	12.62	16.98
Feb	103700	8381	12.37	17.12
Mar	102850	8762	11.74	16.52
APR	90920	7845	11.59	17.07
May	95100	7554	12.59	22.11
Jun	85290	6861	12.43	17.06
Jul	88850	7142	12.44	16.56
Aug	88880	7110	12.50	16.02
Sep	72820	5812	12.53	15.98
OCT	72610	5472	13.27	16.68
Nov	74120	5515	13.44	16.72
Dec	68100	5132	13.27	18.21

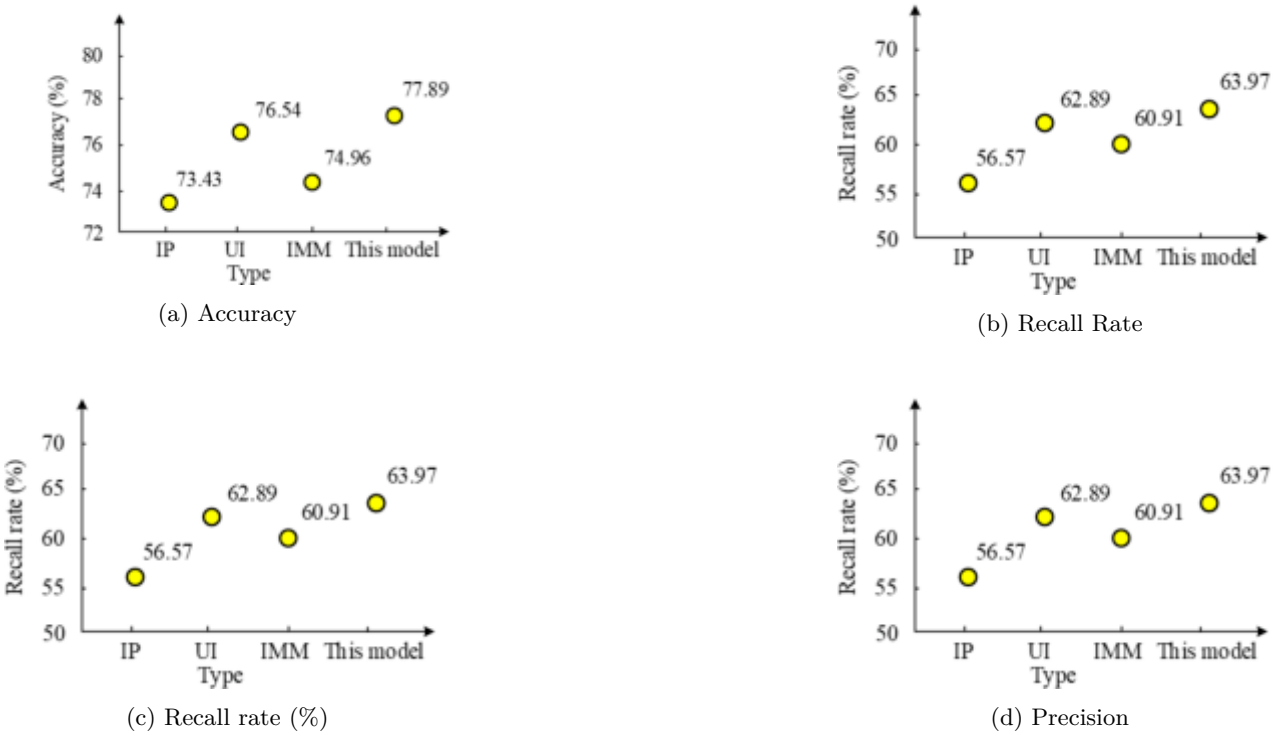
costs of data centers, and network latency. Through experimental tests, the model successfully reduces data transmission and storage costs while ensuring that the response time of user access remains within acceptable limits. This significantly improves the overall performance and resource utilization of the data center.

4.2. Social network interaction model test under human resource management of Multinational Enterprises.. To validate the performance effectiveness of the enterprise social network interaction model, the study used data on the total number of enterprise blog posts, the number of employees, and the average number of employee posts over a one-year period. The test metrics included accuracy, recall, F1 score, and precision. By comparing these metrics, the interactivity of the employee social interaction model can be further analyzed across different dimensions, including the relationship between employee rank and blog post, and blog post to blog post.The data set is shown in Table 4.2.

Supported by the data from the above data sets, the study conducted a comparative analysis on the accuracy, recall rate, F1 score and precision of the model. The results are shown in Fig. 4.3.

As shown in Fig. 4.3, the accuracy of the research model is the best, with an accuracy of 77.89%, while the accuracy of other models is below 76.54%. Secondly, in terms of recall rate, the research model is also superior to other models, reaching 63.97%. The recall rate of other models was below 62.89%. Looking at F1 score, the F1 score of the research model is 70.32%, which is higher than other models, which proves the superiority of the research model again. Finally, the precision of the research model is 71.78%, which is higher than that of other models, which shows that the research model is better in the accuracy of prediction results. In conclusion, the research model is superior to other models in accuracy, recall, F1 score and precision. This shows that the model has higher accuracy and robustness in the prediction and analysis of enterprise social network interaction, and can provide more reliable decision support for enterprises. The interaction analysis results are shown in Fig. 4.4.

As shown in Fig. 4.4, the analysis of the enterprise social network interaction model covers three dimensions: the interaction between employee rank and rank, the interaction between employee rank and blog category, and the interaction between blog category and blog category. The experimental results show that when forwarding a blog post, employees are affected by the rank of the author, especially when the author of the blog post is the direct leader of the employee, employees are more willing to forward the blog post. This phenomenon can be explained as waterfall effect or domino effect, that is, in the organization, the influence of direct leaders of subordinates can neutralize the influence of indirect leaders at higher levels, making it difficult for this influence to spread across levels. The analysis reveals a correlation between employee rank and the categories of blog posts they read and share. With the promotion of rank, employees tend to read and forward blog posts related to the working environment. For employees at higher and lower levels, they prefer to read and forward blog posts related to work content. For intermediate level employees, they are more willing to share content related



(a) Accuracy

(b) Recall Rate

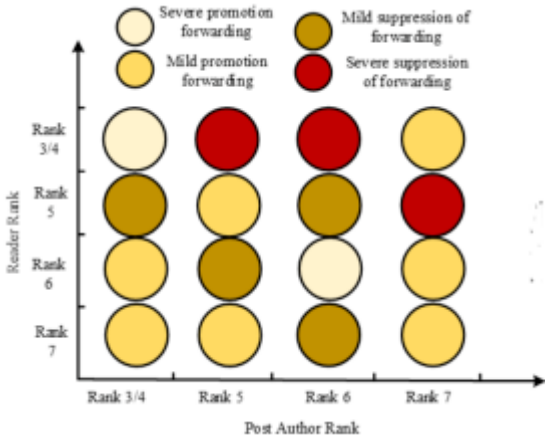
(c) Recall rate (%)

(d) Precision

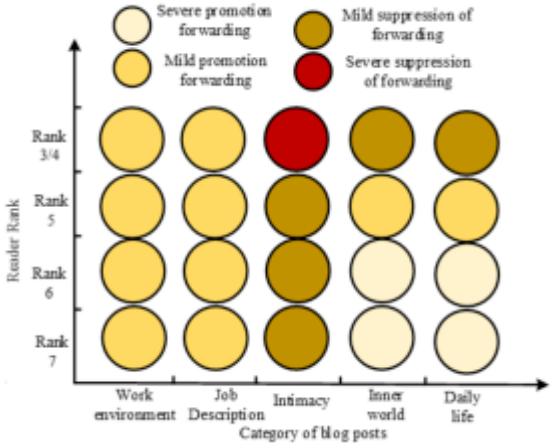
Fig. 4.3: Performance index dataset situation

to intimacy. In the analysis of the interaction between blog categories and blog categories, it is found that there is a competitive relationship between different types of blog posts. Blog posts of intimate relationship have the strongest inhibitory effect on other types of blog posts. The study proposes a social network interaction model that can classify blog posts and infer interactions among employees through a co-training approach optimized by a genetic algorithm. The model accurately predicts employee interaction tendencies, such as which blog posts specific groups of employees are more likely to read, comment on, or share. This text provides insights into how employees connect and share knowledge in corporate social networks. Understanding these connections can help companies optimize their internal communication strategies and improve productivity.

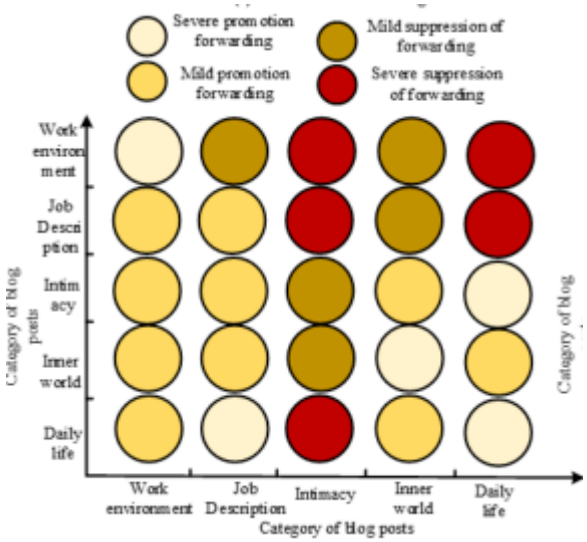
5. Conclusion. This paper proposes an adaptive intelligent data placement strategy based on genetic algorithm, and realizes the load balancing of server resources by constructing a fitness model. At the same time, an effective interaction model of enterprise social network is designed to improve the interaction efficiency of enterprise social network. The results showed that when the maximum delay was 200 milliseconds and 250 milliseconds, the data storage overhead was optimized by 50%, 70%, 90% and 99% respectively, and the storage overhead of the system was gradually reduced. Especially when the maximum delay was 200 milliseconds, the savings cost of the first generation was $65.234, which was only $14.631 at 50%, a decrease of 78%. Similarly, when the maximum delay was 250 milliseconds, the optimization at the proportion of 50% can save 81.01%. In the test of enterprise social network interaction model, the research model is superior to other models in accuracy, recall rate, F1 score and precision. Specifically, the accuracy of the model was 77.89%, the recall rate was 63.97%, the F1 score was 70.32%, and the precision was 71.78%. This shows that the model has higher accuracy and robustness in the prediction and analysis of enterprise social network interaction. Although this study achieved significant results in data analysis, there are still limitations. For instance, the use of genetic algorithms as the basis of the model requires parameter adjustments to obtain optimal solutions. However, the



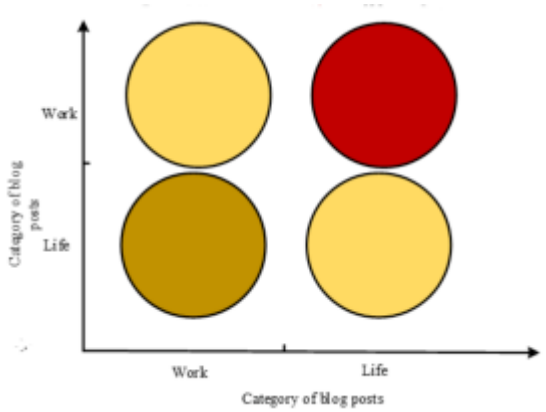
(a) Rank-Rank Forwarding



(b) Rank-Blog Category Forwarding



(c) Blog-Blog Interactional



(d) Blog-Blog Interactional

Fig. 4.4: Performance index dataset situation

stochastic nature of the algorithms may lead to fluctuations in the experimental results, which can affect model stability and reliability. Additionally, the dataset utilized in the study was limited to a specific company and did not account for other metrics related to flexibility and adaptability. This may restrict the generalizability of the model. To enhance the stability and reliability of the model, future research should consider more efficient algorithms, expand the dataset, and incorporate the effects of dynamic changes in social networks.

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EVALUATION AND SELECTION OF MANUFACTURING SUPPLIERS UNDER THE PERSPECTIVE OF SMART MANUFACTURING COMBINED WITH BILEVEL PROGRAMMING

FENG DU*

Abstract. To address the issue of supplier evaluation and selection in the current intelligent manufacturing industry, a supplier intelligent evaluation and selection model combining bilevel programming is proposed. Firstly, based on existing research results and the current situation of the manufacturing market, a manufacturing supplier evaluation index system is constructed, and the principal component analysis method is used to simplify it; Then, the simplified indicator system is input into the back propagation neural network to build a supplier intelligent evaluation model and achieve supplier intelligent evaluation; A mathematical model for supplier selection problem is constructed based on bilevel programming, and an optimized sparrow search algorithm is put forward to solve it. A supplier intelligent selection model is constructed to achieve intelligent supplier selection. The lab findings denote that the F1 value of the supplier intelligent evaluation model is 0.953, the accuracy is 0.985, the area under the curve is 0.962, and the error of the output comprehensive evaluation value is 0.003; The output accuracy of the supplier intelligent selection model is 0.8. The above results indicate that the model raised in the article has good application effects in supplier evaluation and selection, and has a certain promoting effect on the development of the intelligent manufacturing industry.

Key words: Smart manufacturing; Bilevel programming; Suppliers; Smart evaluation; Sparrow search algorithm

1. Introduction. China's manufacturing industry still has great room for development and needs to transform from traditional manufacturing to intelligent manufacturing. Supply chain management as an important content in manufacturing industry, intelligent, scientific and reasonable evaluation and choose of suppliers is an important and hard content. Research data show that the cost of raw materials in the manufacturing industry accounts for 65%-80% of the total cost of products, while the remaining 30% of the cost is other human costs [1, 2, 3]. Therefore, the most direct way to reduce costs and increase efficiency in the manufacturing industry is to reduce costs. And from the manufacturer's perspective, it is the supplier who is linked to the cost of raw materials, and the supplier is also the source of supply chain management [4]. In the trend of manufacturing intelligence, supply chain management also faces intelligent transformation, and how to do a good job of supplier evaluation and selection (SES) has become a problem, which also needs to be changed to meet the times [5]. To this end, the study combines the current situation of manufacturing industry and existing research literature, constructs a supplier evaluation index system, and uses BP neural networks (BPNN) for supplier evaluation; then, based on the bilevel programming model, constructs a mathematical model of supplier selection problem, and proposes an improved Sparrow Search Algorithm (SSA) is applied to solve it, so as to realize the intelligent selection of supplier solutions. The first point is to construct a manufacturing supplier evaluation index system, and principal component analysis (PCA) is utilized to lessen its dimensionality, and then BPNN is adopted to achieve intelligent and comprehensive supplier evaluation; the second point is to propose an improved backward learning and logarithmic spiral strategies to improve the SSA. SSA is improved to enhance its performance, and then the improved SSA is applied to address the mathematical model of supplier selection problem to achieve intelligent supplier selection. The main structure of the study includes four parts. The first is to analyze the current research status; the second is to construct the ISSA-PCA-BPNN SES model by combining the bilevel programming model; the third part is to verify the effect of the improved SSA-PCA-BPNN SES model; the last part is to conclude the whole study. The last part is a summary of the whole study.

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2. Related works. The solution of the lower-level function and the computational parameter of the upper-level function is bilevel programming which can be broadly classified into two methods, analytic and heuristic algorithms, proposed in the study of competition in non-equilibrium economic markets.

Lotfi R et al. argued that selecting an appropriate location is a key factor in establishing a power plant, which needs to satisfy various criteria, and innovatively applied robust bilevel programming techniques and game theory to this problem to locate renewable Wei J et al. proposed a bilevel programming demand management approach based on the marginal price of the distribution location to improve the economic results of industrial parks and to efficiently distribute their electricity bills among industrial users through CHP units and PV panels [6]. The outcomes denoted the function of the raised method in reducing the electricity bills in industrial parks and achieving efficient distribution among users [7].

Yi et al. concluded that virtual power plants have become a useful method for managing an increasing number of flexible resources, posing a technical challenge to distribution system operators, and proposed a bilevel programming for the collaborative management of active distribution networks with multiple VPs [8].

Zhang B et al. considered that previous studies only considered the impact of waiting time on the design of EV charging station networks, and a multi-objective bilevel programming model was designed to fill this research gap. The results showed the applicability of the method in practical site-selection planning problems [9].

Aghababaei B et al. proposed a possible bi-objective bilevel programming for optimizing the management of scarce drug supply and rationing in emergency situations like a new crown pneumonia epidemic. The outcomes showed the applicability and practicality of the proposed model compared with the traditional likelihood approach [10].

Zhou et al. considered the importance of rational arrangement of relief material transfer facilities and effective arrangement of rescue supplies transportation in the beginning after an earthquake, and formulated the fusion problem of transfer facility place and relief material transportation as a gray mixed integer based on the characteristics of a bilevel programming emergency logistics system [11].

Homaee et al. considered coordinating the scheduling actions of two interconnected ADNs and formulated the coordination problem as robust bilevel programming underprice uncertainty [12].

With the rapid development of the economy, competition among firms evolved into competition in the supply chain, thus SES is important for the development of the manufacturing industry. Kaviani M A et al. raised a new uncertainty decision framework to address the current challenges regarding supplier selection in the oil and gas industry which has significant methodological shortcomings. The results show that the proposed method offers strong results in SES and can be applied for future applications [13].

Amiri M et al. argue that sustainability has become one important problem in the supply chain management, and a model for sustainable supplier selection with a triangular fuzzy approach is proposed to help people choose sustainable suppliers [14].

Durmić et al. argued that sustainability in supply chain management has become an increasingly important issue and suppliers are selected to achieve sustainability [15].

Yazdani et al. proposed an comprehensive decision model including a decision test and evaluation laboratory and an improved evaluation with the average solution distance method for the supplier selection [16].

Badi et al. argued that in modern supply chain management, the effectiveness evaluation of potential suppliers is based on multiple criteria, which makes the selecting the best supplier complex and difficult, and proposed the implementation of a hybrid gray theory MARCOS approach in supplier selection decisions to help them compete [17].

Pamucar et al. argued that uncertainty conditions in the chain should urge decision makers and experts to use a fuzzy-based assessment platform, and a fuzzy neutrophil decision method for SES was proposed to reduce the risks and disruptions, provide the satisfying models for solving the problems, and keep the support system stable [18].

Rouyendegh et al. argued that green supplier selection has become an important problem aimed at achieving lean, agile, environmentally sensitive as well as addressing sustainability and durability [19].

In summary, although many previous scholars and scientists have realized the significance of SES for the growth of the manufacturing, and the criteria for evaluation and selection are constantly changing, it has also proved that bilevel programming has played a significant role in solving positioning problems, coordination

Table 3.1: Manufacturing Supplier Evaluation Index System

Primary indicators	Code	Secondary indicators	Code
Product Competitiveness	A	Price	U1
		Quality	U2
		Product Innovation	U3
Enterprise management capability	B	Basic Information of the Enterprise	U4
		Service Level	U5
		Cooperation ability	U6
		Sustainable management capability	U7
		Research and development capability	U8
Production supply capacity	C	Supply coordination ability	U9
		Storage capacity	U10
		Transportation and distribution capacity	U11
		Flexibility	U12
Information degree	D	Information processing capability	U13
		Integrated interconnection capability	U14

problems, and supply chain management problems. However, the current research results of SES combined with bilevel programming are not satisfactory. In order to remedy this deficiency, the research combines BPNN, ISSA and bilevel programming models, and constructs ISSA-PCA-BPNN SES model to realize intelligent SES, which has important practical application value and prospect for smart manufacturing industry.

3. Manufacturing SES combined with bilevel programming. In the era of rapid economic development, the level of prosperity of a country is often positively correlated with its manufacturing industry, which is an extremely important lifeline in the process of national development. Currently, various developed countries have proposed strategies for intelligent manufacturing, combining traditional manufacturing with many new technologies. However, there is still great room for development in China's manufacturing industry, and there is an urgent need to transform from traditional manufacturing to intelligent manufacturing. As an important link in the supply chain, in this context, the SES of manufacturing are very important. The research combines models such as bilevel programming and BPNN to achieve intelligent evaluation and selection of manufacturing suppliers.

3.1. Intelligent evaluation of manufacturing suppliers based on PCA-BPNN. To achieve manufacturing SES, selecting suitable indicators and constructing a scientific, reasonable and effective manufacturing supplier evaluation index system is the basis. Based on the selection principles of comprehensiveness, objectivity, reconfigurability, scientific and operability, the study selects suitable indicators to build a manufacturing supplier evaluation index system by combining existing research results and the current situation of the manufacturing market. In this index system, five dimensions, such as product competitiveness, enterprise management capability, production chain supply capability, and Informaonization degree, are used to evaluate manufacturing suppliers, as presented in Table 3.1.

In Table 3.1, all the indicators were able to obtain the corresponding data through the supplier enterprise management system. The KMO test and Bartlett's method are used to test the reliability and validity of the evaluation index system shown in Table 1 to verify its reasonableness, and the test findings are displayed in Table 3.2. It shows that the evaluation index system of manufacturing suppliers constructed by the study has good reasonableness and scientific, so the scientific evaluation of manufacturing suppliers under the view of smart manufacturing can be carried out according to Table 3.1.

It uses the questionnaire survey and expert scoring manners to obtain the corresponding weights of each index, and then the data corresponding to each index are used as input vectors and input to the BPNN model for learning and training, which can effectively realize the intelligent evaluation of manufacturing suppliers according to the fitting results of BPNN. However, in Table 3.1, there are more indicator data involved, and the number of secondary indicators reaches 14. If the BPNN model is constructed directly according to Table 3.1,

Table 3.2: Reliability and validity testing

Project		Value
KMO inspection		0.882
Bartlett sphericity test	Approximate chi-square	7725.036
	DF	0.735
	Significance	0.000

Table 3.3: Correlation analysis between 14 indicators and common factors

Indicator code	Common factor serial number			
	1	2	3	4
U1	-.123	.935	.106	.394
U2	.953	.143	-.205	.188
U3	.436	.352	.173	.035
U4	.114	.394	.043	.254
U5	-.152	.163	.396	.098
U6	.105	.282	.035	.172
U7	.173	.285	-.205	-.233
U8	-.128	.173	.147	.417
U9	.133	.155	.921	.134
U10	.254	-.133	.333	-.208
U11	.362	.302	-102	.916
U12	.084	.185	.174	.133
U13	.325	-.142	.250	-102
U14	.133	.108	.105	.372

14 input layer nodes need to be constructed in the BPNN network, which will lead to an overly complex BPNN model. And the complexity of the model will directly affect the training efficiency and evaluation accuracy. Therefore, study uses PCA to extract the common factors, so as to realize the dimensionality reduction of the input vectors in the BPNN network model and improve the model performance. After processing with the PCA method, four public factors with a combined value greater than 1 were obtained among 14 indicators, and their cumulative total variance contribution rate exceeded 82%, which had a high variable explanatory power and could reflect the situation of manufacturing suppliers more comprehensively. Descriptive statistics were used to extract the factor component matrix to obtain the correlations between the 14 indicators and the public factors shown in Table 3.1, as shown in Table 3.3.

Based on the above, the input nodes of the BPNN network model are constructed based on four indicators, including U2: product quality, U1: product price, U9: supply coordination capability and U11: transportation and distribution capability, to effectively reduce the complexity and improve the efficiency and accuracy. Based on the above, the intelligent evaluation model of PCA-BPNN manufacturing suppliers can be constructed to realize the intelligent evaluation of manufacturing suppliers.

3.2. Intelligent supplier selection for manufacturing combined with bilevel programming. In the foregoing, the study constructs an evaluation system for manufacturing suppliers, and on this basis, an intelligent evaluation model of PCA-BPNN manufacturing suppliers is constructed to realize the intelligent evaluation of manufacturing suppliers. On the basis of intelligent evaluation of manufacturing suppliers, manufacturing supplier selection can be carried out. Based on manufacturing SES, then manufacturing supplier management can be realized, and its general process is shown in Figure 3.1.

Supplier management is an important part of the development of manufacturing companies, so manufacturing SES is very significant. In the actual situation of supplier selection in the manufacturing industry, priority will be given to procurement cost, followed by supplier quality. However, high quality suppliers often also repre-

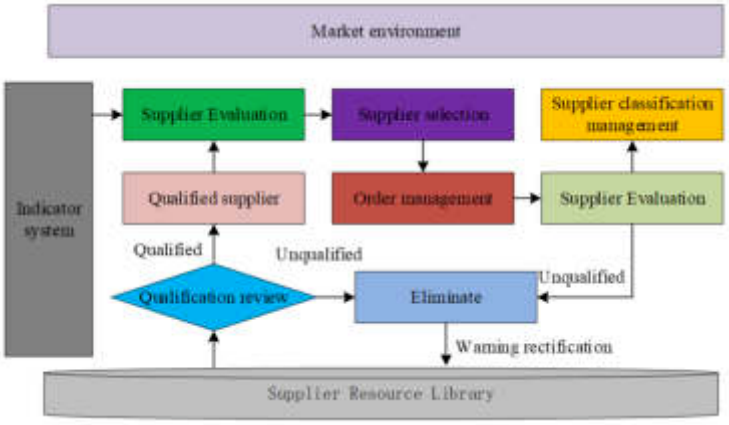


Fig. 3.1: Supplier management

sent higher procurement costs, thus creating a paradoxical situation of benefits. Therefore, a balance between procurement cost and supplier quality needs to be considered when making supplier selection in manufacturing. The bilevel programming model is a system optimization with a bilevel programming structure containing multiple objective functions and corresponding constraints, and the bilevel programming model can be used to avoid the benefit paradox problem more effectively, so that the balance between procurement cost and suppliers can be considered comprehensively. Therefore, the study is based on a bilevel programming model for manufacturing supplier selection. From the perspective of manufacturing enterprises, the upper-level planning model should make the procurement cost as small as possible. According to this principle, the mathematical model of the upper-level planning model is established in Equation 3.1.

$$\begin{cases} \text{U:min F} = \min(\sum_{i=1}^{n} \lambda_i d_i x_i r_i + \sum_{i=1}^{n} \lambda_i c_i x_i) \\ s.t \sum_{i=1}^{n} \lambda_i \geq 2 \qquad\qquad , i = 1, 2, \ldots, n \\ (\lambda_i - 1)\lambda_i = 0 \end{cases} \tag{3.1}$$

In Equation 3.1, n is the total amount of alternative suppliers; λ_i is the upper-level decision variable, when the value of λ_i is 1, it denotes that the ith supplier is selected, and when the value of λ_i is 1, it means that the ith supplier is not selected; is the sourcing volume offered by the $x_i i$th alternative supplier; d_i is the unit price offer of the ith alternative supplier; r_i is the volume discount rate offered by the ith alternative supplier; and c_i is the unit shipping cost of the ith alternative supplier. In the lower-level planning model, the procurement volume is divided among the selected suppliers in the case of multiple suppliers so that the output supplier composite evaluation value of the intelligent evaluation model of PCA-BPNN manufacturing suppliers is as high as possible, and the objective function is constructed as shown in Equation 3.2.

$$L : maxB = max \sum_{i=1}^{n} H_i \lambda_i x_i \tag{3.2}$$

In Equation 3.2, x_i is the lower-level decision variable; H_i is the comprehensive evaluation value of the i supplier output by the intelligent evaluation model of PCA-BPNN manufacturing suppliers. In Equation 3.2, it is necessary to satisfy that the total procurement task volume Q is fully allocated, so there are constraints in Equation 3.3.

$$s.t \sum_{i=1}^{n} \lambda_i x_i = Q \tag{3.3}$$

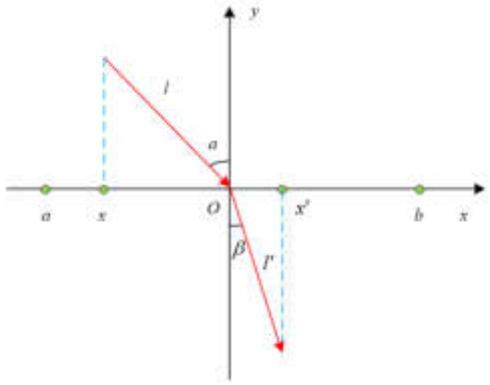


Fig. 3.2: Improving the Principle of Refractive Reverse learning

According to the half-ratio principle, a particular selected supplier needs to be allocated less than 1/2 of its maximum capacity, and therefore has constraints, as in equation 3.4.

$$0 \leq x_i \leq \frac{1}{2} M_i \tag{3.4}$$

In Equation 3.4, M_i denotes the maximum capacity of the i supplier. The above model can be solved by intelligent optimization algorithm (IOA) to get the best supplier selection solution. In the solution of the bilevel programming model, the commonly used IOAs generally use genetic algorithm (GA) or particle swarm optimization (PSO), but the solution performance of these two algorithms is not satisfactory. The SSA has a low structural complexity and high performance in finding the best performance, and it has a very remarkable performance in various optimization problems. However, it still has certain drawbacks, such as the use of backward learning to expand the search range, but in the late iteration, it often falls into local optimum. For this reason, it puts forward a refractive backward learning method to raise the generalization ability of SSA. The principle of improved refractive backward learning is shown in Figure 3.2.

By means of refractive backward learning, the corresponding candidate solutions can be obtained, thus enabling the algorithm not to belong to local optima in the late iteration. The refractive backward learning candidate solutions are shown in Equation 3.5.

$$x'_{i.j} = \frac{a_j + b_j}{2} + \frac{a_j + b_j}{2k} + \frac{x_{i,j}}{k} \tag{3.5}$$

In Equation 3.5, $x'_{i.j}$ and $x_{i,j}$ are the refractive inverse solution and the original solution of the i sparrow individual in the j dimension, respectively. In SSA, there are two types of sparrow individuals, discoverers and joiners. Among them, the joiner will fly in the direction indicated by the discoverer to get the best solution. In this search method, the joiner's search has a significant blindness, which affects the joiner's position update and the algorithm's ability to gain the best solution. In the early iteration of SSA, the joiners are required to expand the scope of the search space to obtain more candidate solutions, i.e., to expand the global search capability; while in the later iteration, the joiners are required to search in a small range of space, thus reducing the search time and improving the convergence. According to the above, the study uses variable logarithmic spiro to optimize and improve the update of joiners. The traditional logarithmic spiral is shown in Figure 3.3.

The study sets the constant in the traditional logarithmic spiro as a variable that changes dynamically according to the number of iterations, thus making the SSA have a larger search range in the early iterations and a better convergence performance in the later ones. At this point, the joiners are renovated in the manner

Fig. 3.3: Logarithmic spiral

shown in Equation 3.6.

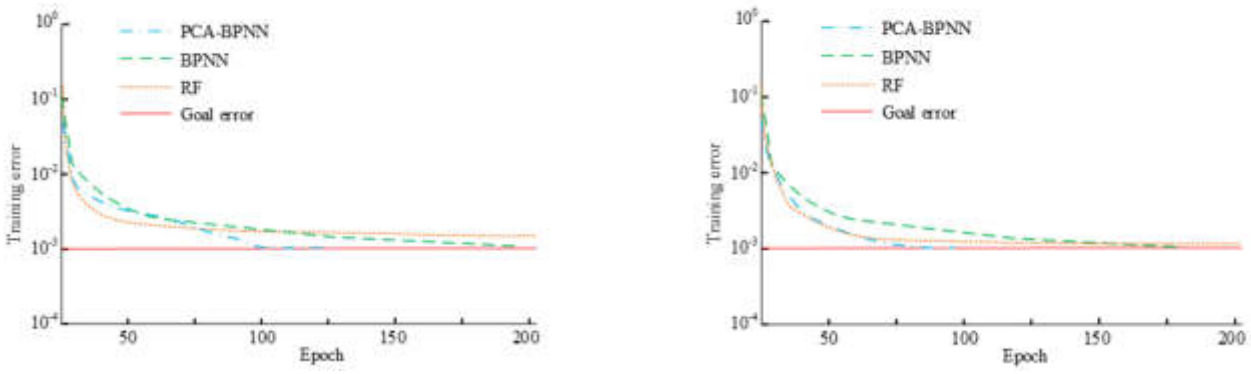
$$X_i^{(t+1)} = \begin{cases} Q \cdot \exp\left(\frac{X_{\text{worst}}^t - X_i^t}{i^2}\right) \cdot e^{\theta t_1} \cdot \cos(2\pi t_1), & \text{if } i > \frac{T}{2} \\ X_i^{(t+1)} + |X_i^t - X_P^{(t+1)}| \cdot A^+ \cdot L \cdot e^{\theta t_1} \cdot \cos(2\pi t_1), & \text{if } i \leq \frac{T}{2} \end{cases} \tag{3.6}$$

In Equation 3.6, is the position of the $X_i^{(t+1)}$ individual joiner in the iteration; tQ is a random number obeying normal distribution; L is a matrix with all elements 1; $X_P^{(t+1)}$ is the position of the best finder in the iteration$t$; $X_{worst}^{(t+1)}$ is the global worst position in the t iteration; A is a matrix with all elements randomly assigned to -1 or 1; $t_1 \in [-1, 1]$; $\theta = 5 - \frac{t}{T}$, where T is the upper limit of the iteration of the algorithm. Based on the above, the optimization of SSA is completed to construct ISSA. The ISSA-PCA-BPNN SES model is constructed by synthesizing the above elements to obtain the optimal supplier selection scheme.

4. Analysis of th effect of ISSA-PCA-BPNN SES model. The effect of ISSA-PCA-BPNN SES model is analyzed in two main aspects. The first part is the analysis of the effect of PCA-BPNN on the evaluation of manufacturing suppliers, and the second part is the analysis of the effect of ISSA algorithm on solving the mathematical model of manufacturing supplier selection based on bilevel programming. To verify the performance of the ISSA-PCA-BPNN SES model proposed in the study, it is analyzed through the data of its management system in 2020 2021, taking an automobile manufacturing company as an example. In 2020 2021, the company has seven alternative suppliers that have passed the preliminary qualification audit to supply support roller bearing parts A, which are recorded as S1 S7. The corresponding data are input into PCA-BPNN model, BPNN and Random Forest (RF) models to compare the evaluation accuracy of several models on suppliers. First, the error variation of several models during the training process is compared, as displayed in Figure 4. The PCA-BPNN converges faster during the training process in both 2020 and 2021, and the convergence node is about 100 iterations later. In contrast, the BPNN and the RF converge more slowly, and both only approach the target value after 200 iterations without fully reaching it, but the training effect of the BPNN is slightly better than that of the RF.

After the models were fully trained, the F1 values, accuracy rates, and AUC values of the above models were tested five times, and the average value was regarded as the final outcome to avoid errors in the experimental results due to chance. The F1 values, accuracy rates, and AUC values of the PCA-BPNN, BPNN, and RF in the sample data of 2020 are expressed in Table 4. In the sample data of 2020, the F1 value of the PCA-BPNN model, expressed as a mean value, is 0.953, which is 0.037 and 0.058 higher than the BPNN and RF models, respectively; the accuracy rate is 0.985, which is 0.033 and 0.049 higher than the BPNN and RF models, respectively; the AUC value is 0.962, which is 0.962 higher than the BPNN and RF models, respectively. The AUC value was 0.962, which was 0.025 and 0.045 higher than the BPNN and RF models, respectively.

The F1 values, accuracy rates, and AUC values of the PCA-BPNN, BPNN, and RF in the sample data for 2021 are displayed in Figure 5. In the sample data of 2020, the F1 value of the PCA-BPNN model, expressed as a mean value, is 0.956, which is 0.028 and 0.053 more than the BPNN and RF models, respectively; the



(a) 2020 (b) 2021

Fig. 4.1: Error changes of several models during training

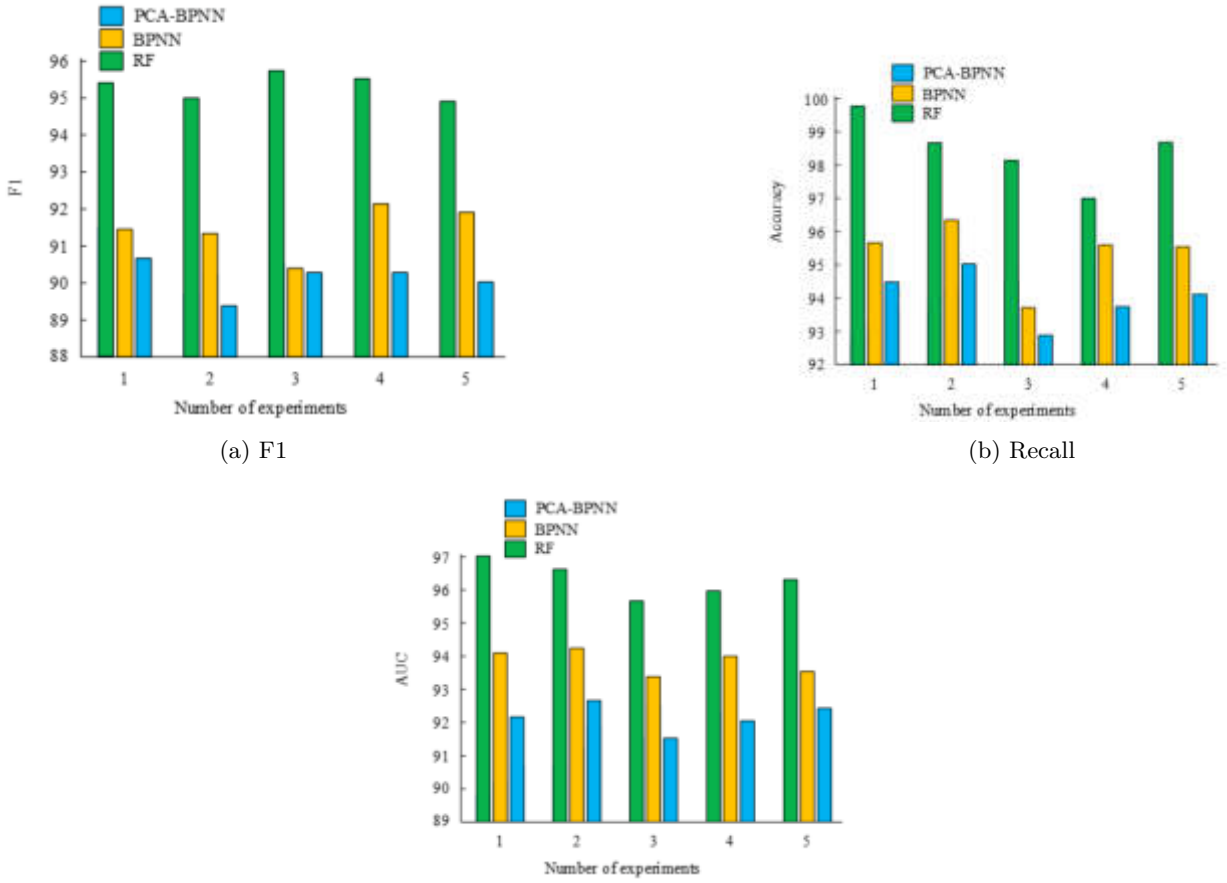
Table 4.1: F1 value, accuracy and AUC value of the model in the 2020 sample data

Index	Number of experiments	Model		
		PCA-BPNN	BPNN	RF
F1	1	0.937	0.908	0.883
	2	0.962	0.925	0.905
	3	0.953	0.914	0.911
	4	0.947	0.933	0.884
	5	0.966	0.901	0.892
	Average value	0.953	0.916	0.895
Accuracy	1	0.983	0.962	0.944
	2	0.992	0.941	0.936
	3	0.986	0.955	0.928
	4	0.994	0.932	0.931
	5	0.972	0.968	0.940
	Average value	0.985	0.952	0.936
AUC	1	0.962	0.953	0.902
	2	0.953	0.941	0.914
	3	0.971	0.935	0.938
	4	0.965	0.940	0.920
	5	0.958	0.916	0.911
	Average value	0.962	0.937	0.917

accuracy rate is 0.986, which is 0.032 and 0.046 more than the BPNN and RF models, respectively; the AUC value is 0.965, which is 0.025 and 0.046 more than the BPNN and RF models, respectively.

The output composite evaluation values of several models were compared with the actual composite evaluation values of seven suppliers, so as to analyze the evaluation accuracy of several models, as presented in Figure 4.3. In Figure 4.3, the PCA-BPNN model has the minimum error between the output and the actual composite evaluation value, with an average error of 0.003 for the seven suppliers, which is 0.008 and 0.011 lower than the BPNN model and the RF model, respectively.

Next, the supplier selection model performance based on the bilevel programming model with ISSA algorithm is verified. In 2020 and 2021, there are 2 suppliers of the support roller bearing component A required by the automobile manufacturer, so the final output of the algorithm is also 2. If both companies are the



(a) F1

(b) Recall

(c) AUC

Fig. 4.2: F1 value, accuracy and AUC value of the model in the 2021 sample data

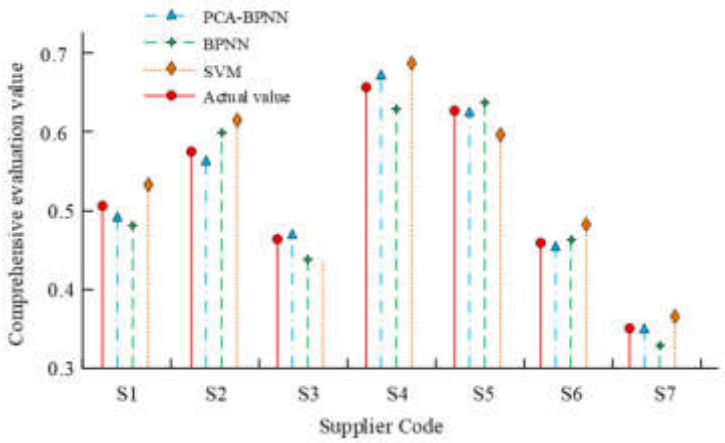


Fig. 4.3: Differences between model evaluation values and actual values

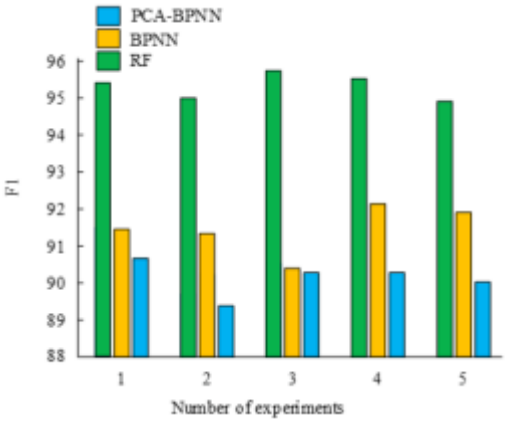
Table 4.2: Output results of several algorithms

Number of experiments	2020			2021		
	ISSA	NSGA-II	IACO	ISSA	NSGA-II	IACO
1	1	0	1	1	1	1
2	1	1	1	1	1	0
3	0	1	0	1	1	1
4	1	0	-1	1	1	1
5	1	1	0	1	0	0
6	1	1	0	1	-1	1
7	1	1	1	0	1	1
8	0	1	1	1	1	-1
9	1	0	1	1	1	1
10	1	1	0	1	0	1
Average value	0.8	0.7	0.4	0.9	0.6	0.6

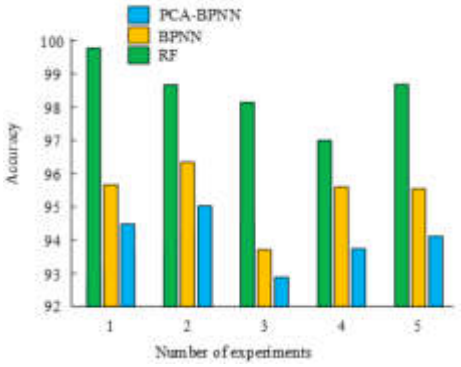
same as the actual selection result, the output of the algorithm is counted as 1; if only one is the same, it is recorded as 0; if both are different, it is recorded as -1. 10 experiments are conducted on the data samples of both 2020 and 2021 to avoid chance errors affecting the experimental results. The two main state-of-the-art intelligent algorithms currently used for supplier selection are the second-generation Non-dominated Sorting Genetic AlgorithmII (NSGAII) and the Improved Ant Colony Optimization Algorithm (IACO). Therefore, the differences between the output results of ISSA, NSGAII and IACO after solving the mathematical model based on bilevel programming and the actual outcomes are compared in Table 4.2. In 2020, the output accuracy of ISSA is 0.8, which is 0.1 and 0.4 more than that of NSGAII and IACO, respectively; in 2021, the output accuracy of ISSA is 0.9, which is 0.3 and 0.3 more than that of NSGAII and IACO, respectively.

In the automotive manufacturing enterprise, 10 management personnel responsible for procurement, 20 ordinary employees, and 15 experts in the industry were invited to evaluate the solution effectiveness of several algorithms, with a score of 0-100. The higher the score indicate more reasonable effect of the model's solution. The scores of several algorithms are shown in Figure 7. ISSA scores were significantly higher than NSGA-II and IACO. In summary, the ISSA-PCA-BPNN model proposed in the study has good application effects SES. It can quickly, scientifically, and reasonably evaluate suppliers comprehensively and provide corresponding selection plans, achieving intelligent evaluation and selection of manufacturing suppliers, and has positive significance for the development of the manufacturing industry.

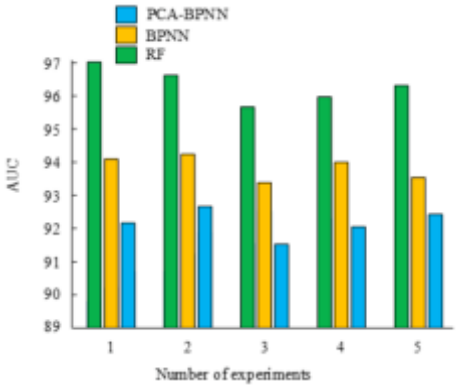
5. Conclusion. With the advent of the information age, intelligence, information technology and digitalization have become the mainstream development trend of the manufacturing industry. Manufacturing suppliers are an important part of the manufacturing industry chain, which affects the effectiveness of the whole supply chain and the construction and development of the market environment. Therefore, it is very important to realize the intelligent evaluation and selection of manufacturing suppliers under the view of intelligent manufacturing. To this end, an ISSAPCABPNN SES model is proposed in the study. The lab outcomes denote that the convergence node of PCABPNN model is better than BPNN model and RF model after roughly 100 iterations; in the sample data of 2020, the F1 value of PCABPNN model is 0.953, which is 0.037 and 0.058 more than BPNN model and RF model, respectively; the accuracy rate is 0.985, which is 0.985 more than BPNN model and RF model 0.033 and 0.049 more than the BPNN and RF models, respectively; the AUC value is 0.962, 0.025 and 0.045 more than the BPNN and RF models, respectively; in the sample data of 2021, its F1 value is 0.956, 0.028 and 0.053 more than the BPNN and RF models, respectively; the accuracy rate is 0.986, more than the BPNN and RF models, respectively The output accuracy of ISSA is 0.8, which is 0.1 and 0.4 higher than that of NSGAII and IACO respectively. 0.4; in 2021, the output accuracy of ISSA is 0.9, which is 0.3 and 0.3 higher than NSGAII and IACO, respectively; the score is significantly higher than NSGAII and IACO. In summary, the ISSAPCABPNN model proposed in the study has a good application in SES, and has positive significance for the development of manufacturing industry. However, the index system constructed



(a) Management Layer



(b) Staff



(c) Expert

Fig. 4.4: Score of several algorithms

by the study has the limitation of timeliness and needs to be updated continuously in the follow-up to ensure its accuracy.

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THE APPLICATION CHARACTERISTICS AND CREATION OF DIGITAL SCULPTURE BASED ON PARAMETER MODEL

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Abstract. Recently, digital sculpture based on parametric models has emerged both domestically and internationally; To improve the accuracy and efficiency of constructing digital sculpture parameter models, this study proposes a method for constructing digital sculpture parameter models based on improved point cloud registration algorithms by iterating the nearest point algorithm and multi-scale matrix descriptors to increase the iteration efficiency and accuracy of point cloud registration algorithms. The results show that under the Bunny model, the number of three scale feature points is 2146, and the coarse registration error is 0.925 * 10-6 m; As the noise increases, the efficiency of the algorithm proposed in the study increases by an average of 10.1%; The average relative rotation error is reduced by 1-2 orders of magnitude, and the registration time is shortened by 62.7% on average; For a 30dB noise point cloud, it is reduced by one order of magnitude, and as the noise increases, the efficiency of the algorithm proposed in the study increases by an average of 10.1%. In the Dragon model, the number of three scale feature points is 2235, the coarse registration time is only 26 seconds, and the registration error is 0.285 * 10-5m; The average relative rotation error is reduced by 1-2 orders of magnitude, and the registration time is shortened by 62.7% on average. The digital sculpture creation method on the ground of parameter models proposed in this study has improved the registration accuracy and efficiency of parameter models.

Key words: Digital sculpture; Point cloud registration; Parameter model; Application characteristics; Iteration closest point

1. Introduction. Digital sculpture (DS) embodies a high degree of integration between science and art, giving artistic forms a rational mathematical order. DS refers to the use of computer technology and information technology to digitize traditional sculpture and apply it to the field of sculpture. DS can be divided into two types: parametric model-based DS and physical model-based DS. Parametric modeling-based DS refers to the creation of a three-dimensional digital model through parametric modeling and its application in DS creation. Compared to the first two, DSs on the ground of physical models can better represent the true form of materials, but the production efficiency is lower and the production cost is higher [3]. From a technical perspective, parameter modeling is the application of digital casting and rapid prototyping manufacturing technology in traditional handicrafts. This technology can shorten the traditional product design and production cycle from months to days or even minutes, with the ultimate goal of providing designers with a better user experience [4, 5]. The existing algorithm selects reference points from the front surface of the input model, and the modeling result is prone to unreasonable height level phenomenon. To solve the defects such as cusps, another height field reconstruction is required, which multiplies the amount of numerical computation and results in low modeling efficiency. Moreover, the existing algorithm can only conduct digital sculpture modeling for 3D mesh models with a single topology, and cannot process 3D models with complex topology structures, otherwise topological tearing will occur after model deformation. The existing algorithm can only deal with the triangular mesh model of manifold, and can not deal with the triangular mesh model with sharp edge. If the model containing non-manifold triangular mesh is used for modeling, the program will crash and so on. Compared with triangular grid data, point cloud data has the advantages of simple representation and convenient acquisition. The modeling method based on point cloud deep learning can get rid of the shackles of grid model and make modeling more flexible. In order to solve the above problems, the mesh modeling method based on differential deformation theory can effectively deal with complex topological structure problems, while the point cloud modeling method based on iterative nearest point improvement can get rid of the bondage of the mesh model and make the modeling more flexible. The research of this paper will promote the degree of automation of digital sculpture

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design to a certain extent, reduce the intensity of digital sculpture design, and provide a theoretical basis for subsequent research.

The article conducts research through four. The first is a review of the current research status of DS and parameter model construction methods; The second is the application feature analysis of DS and the construction of a DS parameter model on the ground of an improved point cloud registration algorithm; The third is to verify the performance of the parameter model designed in the research; The fourth is the conclusion.

2. Related works. The emergence and development of parameter modeling technology are mainly influenced by computer technology and information technology, and its application fields have also expanded from traditional sculpture to fields such as film and television special effects and virtual reality. Sun et al. proposed a lumped parameter model for liquid sloshing in a rigid cylindrical groove with multiple rigid partitions to improve the accuracy of dynamic analysis of complex fluid solid systems and reduce computational workload; By dividing the fluid domain into simple subdomains, the value of the convective velocity potential is obtained, and the equivalent lumped parameter model is established according to the same shear and torque generated with the Analytical expression; After verification, the model has feasibility [6]. Zhou and other scholars proposed an improved model on the ground of hybrid adaptive Particle swarm optimization hybrid Simulated annealing algorithm to solve the problem of poor accuracy and robustness of traditional battery parameter models; This model used three equivalent circuit models to conduct experiments on three different types of batteries, and its accuracy and adaptability were tested; The results show that the parameter model has a fast Rate of convergence and accurate prediction ability [7]. The Sequeira team has established a high computational efficiency and accuracy motor parameter model to improve the thermal management of the motor; This model verifies the lumped parameter thermal network of the motor through commercial motor CAD modeling, and conducts detailed finite element analysis, taking into account all key parameters; The final results indicate that the contact resistance sensitivity between the lining and the lamination is high, and the maximum temperature difference between the slot winding and the end winding is 2% [8]. Qin et al. proposed cascade visual geometry coding, which can improve point cloud registration through the visual information of RGB images. Intermodal features are iteratively fused by using the inductive bias of 2D and 3D convolution to better consider the correlation between the two modes. Geometry-centric coding modules first use three-dimensional convolution in geometric space to enhance visual features, thereby explicitly embedding geometric information, and enhance the salience and relevance of local features through two-dimensional convolution [9]. Zhang et al. innovatively introduced face template deformation into portrait relief modeling, matched key points on the image with feature points on the template, and made the face template fit the target face on the image by minimizing the distance between the two. To solve the problem of missing height field detail after feature matching, the illumination parameters are obtained by solving a linear system containing the intensity of image pixels and the normal information of model vertices. SFS is used to optimize the height field of the face model. Finally, the linear compression of height field and Laplasian detail enhancement techniques are used to generate high relief of face [10].

After decades of development, DS has become increasingly mature in technology and its application scope has also been expanding. In addition to its application in the field of sculpture, DS has also expanded to other fields, and more and more artists and designers have conducted research and exploration on it. Edward et al. proposed a generation algorithm for the axial generation process; This algorithm creates various types of DSs by calculating color values and dynamically increasing the size of shapes; Compared with methods on the ground of manipulating pixels/voxels and tracking particle paths, this method has good balance performance and the ability to create complex visual effects [11]. The Zhou team introduced an automated system to design a vivid brick sculpture to represent a three-dimensional model; This system transforms the building model into a LEGO sculpture while maintaining its original styling characteristics. By extracting the visual features of the model, various transformation parameters are obtained; Then it used a deformation algorithm to eliminate the differences between discrete positions, ultimately generating a vivid LEGO DS [12]. Liu et al. proposed a 3D visual measurement method on the ground of digital image processing to improve the noise resistance of 3D measurement systems; This method eliminates most of the environmental noise by designing the optimal weight function. Under the spatio-temporal background of the video sequence, the decision Tree model is used to extract and track the stripes; The results indicate that in complex lighting environments, this method can accurately measure in real-time, providing support for DS modeling [13]. Ramazan and other scholars

proposed an automatic key point detection and matching method on the ground of iterative nearest point algorithm before rough registration of point clouds to improve the precision of fine registration of DS; This method matches the model through the geometric relationship between key points and the angle and distance between key points; The results show that the algorithm has higher accuracy and fewer iterations [14]. Lanteri et al. proposed a new digital photogrammetry method using Agi soft Photos can® software to better define the drawing details of DS; This method highlights the detailed features of the model through the generated UV 3D model, and restores the vivid expression of the model through the infrared 3D model; This method has the advantages of non-invasive, economical, and efficient [15].

In summary, although researchers have proposed many methods for constructing DS parameter models on the ground of different algorithms and have achieved certain results, they lack accuracy, robustness, and efficiency; Therefore, through the improved point cloud registration algorithm-based DS parameter model, it is expected to be able to quickly and accurately achieve the creation of DS.

3. Research on the Application Characteristics and Parameter Model Construction of Digital Sculpture. This study designed a DS creation method on the ground of parameter models through an improved point cloud registration algorithm; This method first obtains the Multi scale Matrix Descriptor (MSM) by optimizing the curvature change, measuring angle and eigenvalue property (CME), then detects the key points using the Local Surface Patches (LSP) algorithm, and finally corrects them using the Iterative Closest Point (ICP) algorithm.

3.1. Analysis of the Application Characteristics of Digital Sculpture. The creation of traditional sculpture is a "linear" production process. For example, clay sculpture is the process of first setting up a frame, then laying large pieces of mud, and finally thoroughly shaping the form. This process is irreversible, that is, the order of each step cannot be arbitrarily changed, let alone jump to one of the steps. The problem with the "linear" method is that when an error occurs in the first step, to correct the error, one must step back and start over. Compared with traditional sculpture, DS has significant differences in the creative process. These differences come from the characteristics of computer technology on the one hand, and the differences in the properties of materials themselves on the other hand [16]. Using modeling software to create sculptures, the materials used will not be real soil, stone, wood, or metal, but rather computer data.

DS has deep "interactivity" characteristics, while traditional sculpture works often exhibit "non interactivity". In traditional sculpture art, it takes a lot of time to carve a standard cube or sphere from a statue. In DS systems, real-time observation and feedback of sculpture effects are achieved by simply processing sculpture data through command tools [17, 18]. For example, by using modeling software, a standard sphere can be peeled off from the sculpture in the shortest possible time and the effect can be seen quickly. The most essential feature of DS is its virtualization and digitization, which is not affected by natural forces and can simulate the effects of natural forces. Its shape is easy to penetrate, can be quickly replicated, and does not occupy physical space. DS has broken the limitations of sculpture in space, while also causing changes in the preservation and shaping of artworks.

Point cloud registration algorithm modeling is one of the creative methods for many DS. The point cloud registration algorithm collects data from multiple locations, which can be used to represent differences in objects, terrain, or other details in a certain area. The parameter model construction process using point cloud registration algorithm is shown in Figure 3.1. Firstly, it inputs the source point cloud and the target point cloud, and then comprehensively considers factors such as curvature change, measurement angle, feature values, etc. to obtain CME; By optimizing the normal vector angle, point density, curvature, and other factors of the three scale feature points, the MSM is obtained; Then the matching relationship is initially established, and the unit Quaternion algorithm is used to calculate the initial registration parameters to achieve rough registration. Finally, the ICP algorithm was modified to achieve ICP registration.

The curvature reflects the degree of deviation of the surface from the plane. For a given point p_i , the more intense the depth change of the neighborhood, the more obvious the areal feature centered on point p_i. The

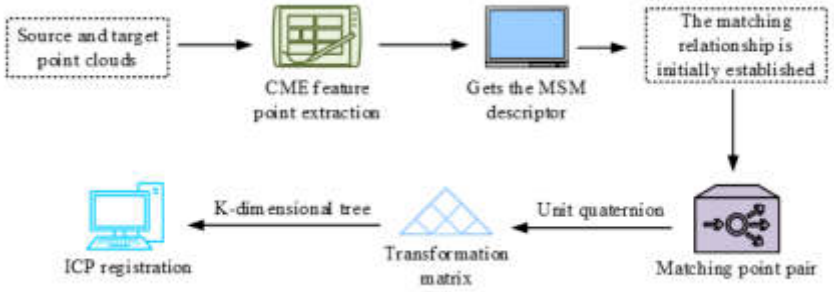


Fig. 3.1: Flowchart of parameter model construction

weighted covariance matrix of point p_i in the neighborhood with radius r is shown in equation 3.1.

$$\begin{cases} Cov(p_i) = \frac{\sum_{|p_i-p_j|\leq r} \omega_{ij}(p_i-p_j)(p_i-p_j)^T}{\sum_{|p_i-p_j|\leq r} \omega_{ij}} \\ \omega_{ij} = \frac{1}{|p_i-p_j|} \end{cases} \tag{3.1}$$

In equation 3.1, p_j is the neighborhood point. This study sets P as a point cloud, consisting of N points, given a query point $p_i \quad (i \in [1, N])$; Its neighborhood is a sphere with a center of p_i and a radius of r. The adjacent points of p_i on the sphere are represented by p_{ik} , and k is the number of adjacent points of p_i . The Covariance matrix in the sphere is constructed by taking $\bar{p}_i$ as the center of mass of p_{ik}. The specific formula is shown in Equation 3.2.

$$\mathrm{Cov}_2(\mathbf{p}_i) = \begin{bmatrix} \mathbf{p}_{i1} - \bar{\mathbf{p}}_i \\ \vdots \\ \mathbf{p}_{ik} - \bar{\mathbf{p}}_i \end{bmatrix}^T \begin{bmatrix} \mathbf{p}_{i1} - \bar{\mathbf{p}}_i \\ \vdots \\ \mathbf{p}_{ik} - \bar{\mathbf{p}}_i \end{bmatrix} \tag{3.2}$$

The cos values of the two normal vectors p_i and p_{ik} are used as the first scale to characterize the fluctuation changes of the point cloud surface area. The calculation method is shown in equation 3.3.

$$F_1(p_{ik}) = \frac{\mathbf{v}_i \cdot \mathbf{v}_{ik}}{|\mathbf{v}_i| \cdot |\mathbf{v}_{ik}|} \tag{3.3}$$

In equation 3.3, $F_1(p_{ik})$ represents the cos values of v_i and v_{ik} ; v_i and v_{ik} represents the normal vectors of query point p_i and adjacent point p_{ik}, respectively; $|v_i|$ and $|v_{ik}|$ represent the modulus of a vector. Then it projects the point set p_{ik} onto a tangent plane perpendicular to v_i, and the Euclidean distance between the projected point and p_i is used as the second scale to describe the point density. The calculation formula is shown in equation 3.4.

$$F_2(p_{ik}) = \sqrt{\|\mathbf{p}_i - \mathbf{p}_{ik}\|^2 - (v_i \cdot (\mathbf{p}_i - \mathbf{p}_{ik}))^2} \tag{3.4}$$

In equation 3.4, $\|\mathbf{p}_i - \mathbf{p}_{ik}\|$ represents the Euclidean distance between two points. The surface curvature, as the third scale, is calculated using Equation 3.5.

$$F_3(p_{ik}) = \frac{\lambda_{i2}}{\lambda_{i0} + \lambda_{i1} + \lambda_{i2}} \tag{3.5}$$

In equation 3.5, $\lambda_{i0} \leq \lambda_{i1} \leq \lambda_{i2}$ is the characteristic value. It combines the histogram matrices of the three scales mentioned above to obtain the MSM descriptor of the feature points. The calculation formula is shown in equation 3.6.

$$M_{\mathrm{MSM}} = \sum_{i=1}^{N} \sum_{k=1}^{j} \left(\mathrm{vote} \left\langle \left| \frac{25F_1(p_{ik})}{2} \right| \right\rangle + \mathrm{vote} \left\langle \left| \frac{15F_2(p_{ik})}{r} \right| + 25 \right\rangle + \mathrm{vote} \left\langle \left| \frac{20F_3(p_{ik})}{\sum F_3(p_{ik})} \right| \right\rangle + 40 \right) \tag{3.6}$$

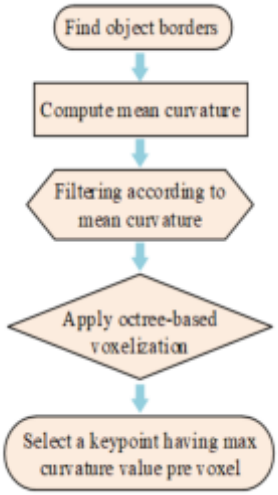


Fig. 3.2: Flowchart of key point detection steps

In equation 3.6, M_{MSM} is an $Nx60$-dimensional matrix; N is the number of feature points; j is the number of neighborhood points; *vote(x)* is a defined function that represents the xth histogram as 1, and $\overline{\sum F_3(p_{ik})}$ is the average value of curvature. Then it establishes a -dimensional tree, searches for the sub vectors with the smallest Euclidean distance between $F(P_m)$ and $F(Q_m)$, and establishes a preliminary matching relationship on the ground of the points corresponding to the vectors; The mathematical expression is shown in equation 3.7.

$$K = \{(h_i^1, h_i^2) \mid h_i^1 \in P_m, h_i^2 \in Q_m, i = 1, 2, \ldots, N_i\} \tag{3.7}$$

In equation 3.7, P_m and Q_m represent the point set for extracting feature points; $F(P_m)$ and $F(Q_m)$ represents the multi-scale matrix descriptors of two point clouds, respectively. Finally, the research uses the unit quaternion algorithm for matching point pair K to calculate the initial registration parameters, namely, rotation matrix R and translation vector T .

3.2. Construction of Digital Sculpture Parameter Model on the Ground of Improved Point Cloud Registration Algorithm. To accurately estimate transformation parameters and improve registration accuracy, strict detection and matching of key points are particularly important [19, 20]. This study selected the LSP algorithm for key point detection, which is a point-by-point significance measurement method. The key point detection steps are shown in Figure 3.2. For the surface curvature of each point, the study used covariance analysis, which utilizes the ratio of the minimum value of each point to the sum of the feature values. However, working directly on the point cloud without any intermediate subdivision, the detector mainly targets samples in high curvature areas, while considering local variation and estimation of second-order error measures. In this method, the maximum surface curvature is considered and voxel-based filtering is applied to improve computational efficiency.

The shape index is introduced here to represent the saliency of vertices, and the specific calculation method is shown in equation 3.8.

$$SI(p) = \frac{1}{2} - \frac{1}{\pi} tan^{-1} \frac{C_{max}(p) + C_{min}(p)}{C_{max}(p) - C_{max}(p)} \tag{3.8}$$

In equation 3.8, *SI(p)* represents the shape index; C_{max} represents the maximum curvature; C_{min} represents the minimum curvature; (p) represents the set of points p. The calculation method for the average shape index

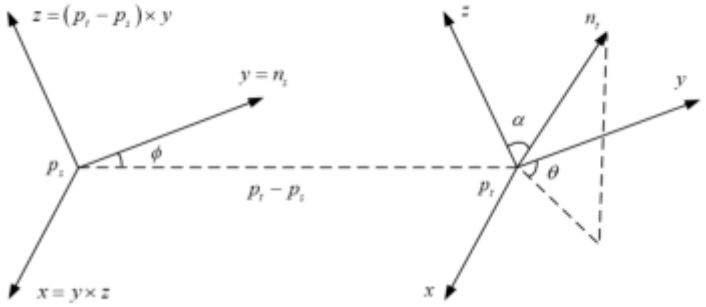


Fig. 3.3: Darboux coordinate system

is shown in equation 3.9.

$$\mu\mathrm{SI}(p)=\frac{1}{N}\sum_{p}\mathrm{SI}(p) \tag{3.9}$$

In equation 3.9, $\mu SI(p)$ is the average shape index; N is the number of points in set (p) . When the SI of a feature point satisfies $\mathrm{SI}(p)\geq(1+\alpha)\mu\mathrm{SI}(p)\vee\mathrm{SI}(p)\leq(1-\beta)\mu\mathrm{SI}(p)$, it can be considered significant, where α and β are scalar parameters. On the ground of this, point cloud points are divided into three-dimensional blocks on the xyz plane, and an appropriate block size dataset is determined on the ground of resolution.

This study utilizes a 3D detector to extract key points from point cloud data, and then uses a 3D descriptor to characterize the neighborhood of the key points and map them to an appropriate space. Ultimately, it is defined as descriptors on different surfaces that match each other. In this method, a 3D keypoint descriptor is a description of the environment around a point in the cloud, but this description is often on the ground of geometric relationships. For two point clouds with similar features, most of the points correspond to the same surface points.

Point feature histogram (PFH) is a common descriptor tool. In addition to point matching, PFH descriptors are also used to identify points in the point cloud, such as edges, corners, and points on the surface. This algorithm adopts a Darboux coordinate system, which is constructed between all pairs of points in the local neighborhood of a point, as shown in Figure 3.3. In the Darboux coordinate system, the source point is a point with a smaller angle between the connecting line of points p_s and p_t and the surface normal. If n_s/t is the normal vector of the corresponding point, then equation 3.10 can be used to represent the structure of the Darboux coordinate system x , y , and z .

$$\begin{cases} x & = y\times z \\ y & = n_s \\ z & = y\times\frac{p_t-p_s}{\|p_t-p_s\|} \end{cases} \tag{3.10}$$

In addition to two normal vectors, the PFH method also uses three angles and one distance element to describe the geometric relationship of point pairs. It adds the four elements of angle and distance to the histogram of point p and the average percentage of point pairs in the p neighborhood, with a similar relationship. In PFH, these histograms are calculated for all possible point pairs in the k neighborhoods of point p . The three angles in the Darboux coordinate system can be represented by equation 3.11.

$$\begin{cases} \alpha & = z\times n_t \\ \phi & = y(p_t-p_s)/\|p_t-p_s\| \\ \theta & = \arctan(xn_t, yn_t) \end{cases} \tag{3.11}$$

This study selected the Iterative Closest Point (ICP) algorithm, which is a point set to point registration method that does not require segmentation and feature extraction of the processed point set to achieve very accurate registration results. Under good initial values, it can also achieve good algorithm convergence. This study sets the target point cloud $P = \{p_i\}_{i=1}^{N_p}$ and the source point cloud $Q = \{q_i\}_{i=1}^{N_Q}$, and each point q_i in the source point cloud Q can be expressed as equation 3.12.

$$q_i' = Rq_i + T \tag{3.12}$$

In equation 3.12, R represents Rotation matrix; T represents the translation matrix. Then, for each point p_i on the target point cloud P , It takes the point p_i and q_i' closest to Euclidean distance as the corresponding point, and obtains the calculation equation 3.13.

$$E(R,T) = \frac{1}{k}\sum_{i=1}^{k}\|Rq_i + T - p_i\|^2 \tag{3.13}$$

In equation 3.13, $E(R,T)$ represents the mean value of the sum of the squares of the residuals, which is defined as the iterative Error function; k represents the number of nearest point pairs. ICP algorithm is to find the minimum value of function 3.13, so as to continuously update the Rotation matrix R and translation matrix T until the cut-off conditions are met. To reduce the iteration time of the ICP algorithm, the study introduced the bidirectional k-dimensional tree ICP algorithm, and on the ground of this, redefined the weight Psi_i of the i-th corresponding relationship; The specific calculation formula is shown in equation 3.14.

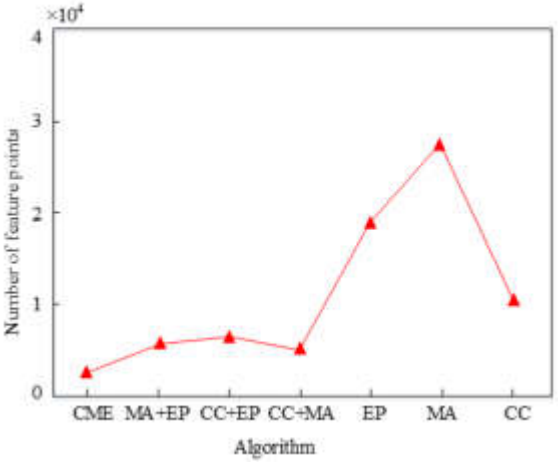
$$\Psi_i = \left(1 - \frac{d(p_i, q_i)}{\max d(p_j, q_j)}\right)^2 \tag{3.14}$$

In equation 3.14, $d(p_i, q_i)$ is the distance between two points; $maxd(p_j, q_j)$ is the maximum distance among these corresponding relationships. The larger the distance between points, the lower the weight of the corresponding relationship; A new iterative Error function can be obtained according to equation 3.14, and the specific calculation method is shown in equation 3.15.

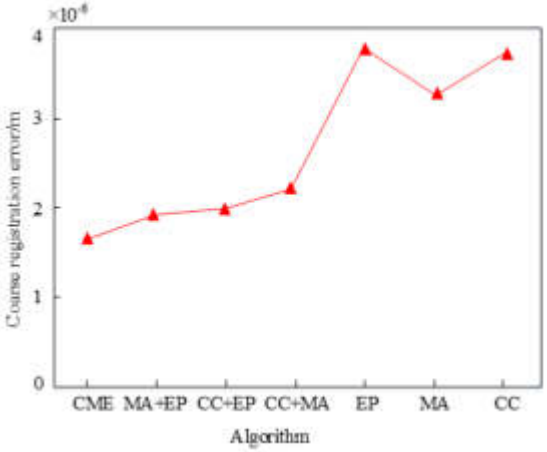
$$E'(R,T) = \frac{1}{k}\sum_{i=1}^{k}\Psi_i\|Rq_i + T - p_i\|^2 \tag{3.15}$$

4. Performance analysis of parameter models. This study was conducted on a computer configured with an Intel core i7 2.3GHz CPU and 8GB of memory, running software Matlab 2019a, and using Stanford University's Bunny (35947) and Dragon (56053) point cloud models [14]. By comparing the proposed algorithm with other algorithms, the advantages and disadvantages of registration time and accuracy were analyzed, and the feature point extraction results and registration effects were analyzed.

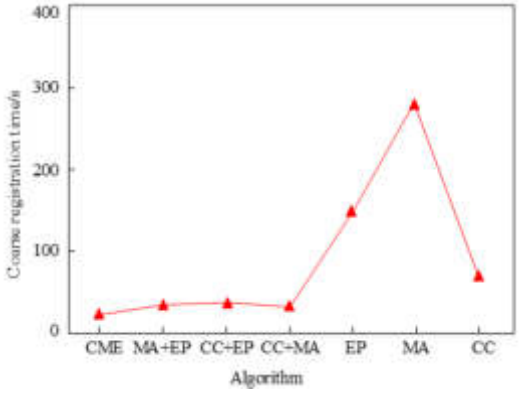
4.1. Result and Analysis of Feature Point Extraction. Relative rotation error is often used in image processing and computer vision to evaluate the performance of image alignment, registration or attitude estimation algorithms. Relative rotation error measures the difference between the actual rotation Angle and the estimated rotation Angle. The smaller the index, the smaller the difference between the actual measurement and the estimated rotation Angle, the better the performance of the algorithm. The registration time is used to describe the computational resources and time complexity required by the algorithm. The smaller the index, the less time it takes for the digital sculpture to complete the point cloud registration, and the lower the requirements for the equipment. The Stanford dataset is scanned with the Cyberware 3030 MS scanner at Stanford University's Computer Graphics Lab. The scenes in this dataset are generated by the model through random rigid body transformation and the addition of three scales of Gaussian noise. The real point cloud data obtained from various 3D scanning devices mainly uses the point matching relationship between the point clouds to estimate the spatial transformation relationship between the point cloud sequences from different viewing angles, so as to complete the attitude normalization to obtain the point cloud in a larger field of view or carry out three-dimensional reconstruction. The presence of noise in the Stanford data set will disturb the



(a) Comparison of the number of feature points



(b) Comparison of Coarse Registration Errors

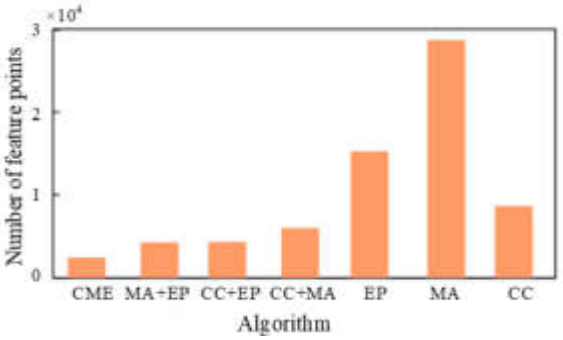


(c) Coarse Registration Time Comparison

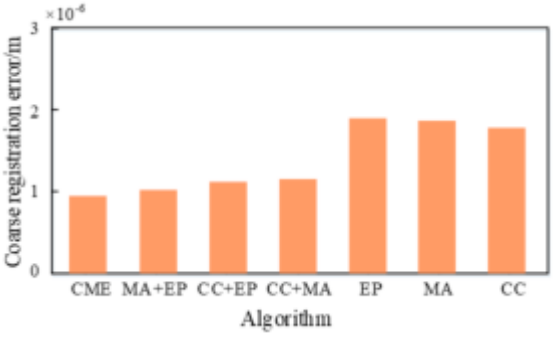
Fig. 4.1: Coarse registration results on the ground of Dragon model

local geometry of the point cloud and interfere with the accurate expression of features. Testing in the data set can reflect the registration accuracy of the proposed method. From the real point cloud data set obtained by various 3D scanning devices, the point cloud feature matching method proposed in this paper can solve the three-dimensional rotation and spatial displacement changes generated by the object in a given time, so as to obtain the motion information of the object in three-dimensional space, including velocity and angular velocity, and track the moving object.

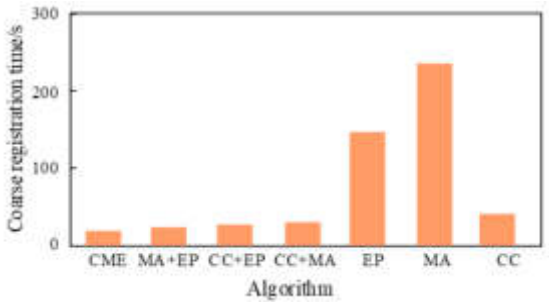
To verify the coarse registration performance of feature points in parameter models, this study compared the CME constraint extraction feature points with curvature change (CC), measurement angle (MA), Eigenvalue property (EP), and pairwise combination methods. Figure 4.1 is a comparison of feature point registration on the ground of the Dragon model; Figure 4.1a shows that the number of feature points in a single feature extraction method is much greater than that in a combination method, with MA having the most feature points at 28836 and CME having the least feature points at 2235. Figure 4.1b shows that the coarse registration error of CME is 1.743 * 10-6 m, which is the smallest among several methods, indicating that CME has the best feature point extraction effect. Figure 4.1c shows that MA has the longest coarse registration time, reaching 352 seconds, while CME only has a coarse registration time of 26 seconds.



(a) Comparison of the Number of Feature Points



(b) Comparison of Coarse Registration Error



(c) Coarse Registration Time Consumption

Fig. 4.2: Coarse registration results on the ground of Bunny model

Figure 4.2 is a comparison of feature point registration on the ground of the Bunny model; Figure 4.2a shows that MA has the highest number of feature points at 24976, while CME has the lowest number of feature points at 2146. Figure 4.2b shows that the coarse registration error of CME is 0.925 * 10-6 m, which is the smallest among several methods. EP has the largest coarse registration error, with a value of 1.905 * 10-6 m. Figure 4.2c shows that MA has the longest coarse registration time, reaching 228 seconds, while CME has only 19 seconds for coarse registration. In summary, it has been proven that CME has the best registration effect, and the registration effect of the pairwise combination method is better than that of a single method, indicating that the more feature constraints there are, the more advantageous the registration is.

The proposed algorithm is compared with other algorithms under different Gauss white noise, RICP algorithm, NICP algorithm, MR-KICP algorithm and classical ICP algorithm, and the comparison results are shown in Table 4.1. This table shows that compared to the RICP algorithm, the proposed algorithm has a slight decrease in registration error when matching point clouds with 25dB and 35dB noise; However, due to the RICP algorithm falling into a local optimal solution at 30dB, the registration time is extremely short. Compared to the NICP algorithm, the proposed algorithm has a slight decrease in registration accuracy for noise point clouds of 25dB and 35dB; For the 30dB noise point cloud, it decreased by one order of magnitude, and as the noise increased, the efficiency of the algorithm proposed in the study increased by an average of 10.1%; Compared to the MR-KICP algorithm, the proposed algorithm has a longer registration time but smaller registration error. The registration time of the classic ICP algorithm is extremely short, as it falls into a local optimal solution, resulting in significant registration errors.

Table 4.2 is the data obtained by scanning the water bottle (Bottle, 21469) data and the solid 3D scanning of a Chinese guardian lions' statue (Lion, 53841) from different perspectives, and compares the registration effect of the physical data. This table shows that for Bottom point cloud data with smaller points, the proposed

Table 4.1: Point cloud registration results of Bunny model

Algorithm	Registration times/s			Registration error/ (10-4) mm		
	25dB	30dB	35dB	25dB	30dB	35dB
Propose	117.262	88.364	36.393	0.161	0.106	0.058
RICP	114.265	11.966	30.151	0.163	2.309	0.060
NICP	118.097	92.580	56.932	0.164	1.139	0.059
MR-KICP	41.982	38.521	30.337	7.640	6.608	5.308
ICP	0.302	0.380	0.454	64.892	61.980	65.883

Table 4.2: Comparison of physical point cloud registration

Algorithm	Registration times/s		Registration error/ (10-4) mm	
	Bottle	Lion	Bottle	Lion
Propose	7.501	66.332	4.338×10-2	2.293
NICP	9.572	5.045	4.558×10-2	11.876
MR-KICP	25.531	116.423	3.789	357.612
ICP	1.284	10.697	1.212×104	205.213

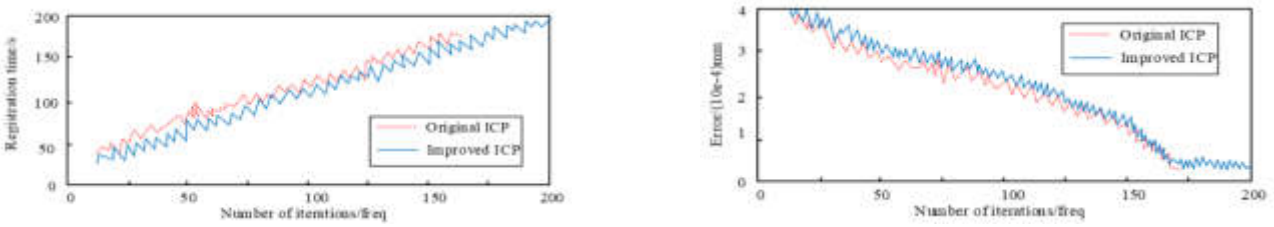
algorithm reduces registration error by 2 orders of magnitude and registration time by 71.2% compared to MR-KICP; Compared with the NICP method, the registration error has been reduced by 50% and the registration time has been shortened by 21.4%. For Lion point cloud data with larger points, the proposed algorithm reduces registration error by 2 orders of magnitude and registration time by 40.6% compared to MR-KICP. Overall, the algorithm proposed in the study outperforms other algorithms in terms of registration efficiency and accuracy.

4.2. Registration results and analysis. Figure 4.3 shows the comparison results between the original ICP algorithm and the improved ICP algorithm. Figure 4.3a shows that the improved ICP algorithm requires less time to complete accurate registration; Figure 4.3b shows that there is almost no difference in registration error between the two algorithms after registration. Overall, the iteration speeds of the two algorithms are similar, but the horizontal axis indicates that the improved ICP algorithm achieved accurate registration with fewer iterations. So, the improved ICP algorithm reduces the number of iterations while ensuring registration accuracy, thereby improving the efficiency of registration.

To demonstrate the necessity of constructing MSM, this study compared MSM with Normal vector (NV) matrix, Curvature (CU) matrix, point density (PD) matrix, and descriptors composed of pairwise combinations. Figure 4.4 shows the test results under the Dragon model, and Figure 4.4a shows that the registration times of the seven methods are not significantly different. The registration time for MSM is 28.87 seconds, the registration time for CU is the shortest at 27.71 seconds, and the registration time for NV is the longest at 29.05 seconds. Figure 4.4b shows that the registration error of MSM is 0.285 * 10-5 m, which is the smallest among several methods. The coarse registration error of CU is the largest, with a value of 5.256 * 10-5 m. Overall, for more complex Dragon models, using only one sub scale matrix to describe feature points has limited descriptive power, resulting in the highest registration error; After using two sub scale matrices, the registration accuracy has significantly improved. Due to the use of three sub scales in MSM, the registration error is the smallest.

Figure 4.5 shows the test results under the Bunny model; Figure 4.5a shows that the registration time for MSM is 20.22 seconds, the registration time for PD is the shortest at 18.95 seconds, and the registration time for NV+CU is the longest at 20.25 seconds. Figure 4.5b shows that the registration error of MSM is 0.089 * 10-5 m, which is the smallest among several methods. The coarse registration error of PD is the largest, with a value of 0.214 * 10-5 m. Overall, MSM has the best descriptive ability, resulting in matching points that are closest to geometric features.

To verify the higher registration efficiency and accuracy of the proposed registration method, the NDM-KICP algorithm was compared with classical ICP algorithm, LPFH based KICP algorithm (LPFH KICP),



(a) Registration Time Comparison (b) Comparison of Registration Error

Fig. 4.3: ICP algorithm comparison

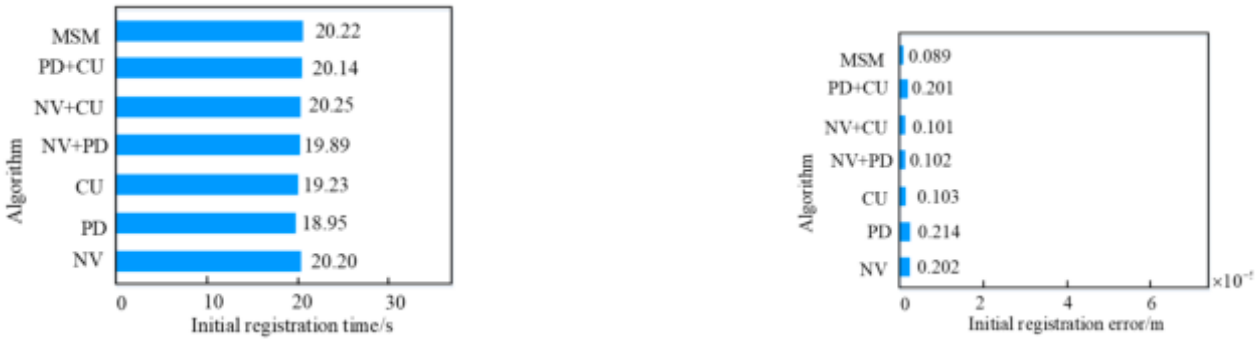
(a) Coarse Registration Time Comparison (b) Coarse Registration Error

Fig. 4.4: Results of the descriptor experiment on the ground of the Dragon model

NCCP based bidirectional k-tree ICP algorithm (NCCP BKICP), Semidefinite Based Randomized Approach (SBRA), and Sampling Consistency and Non-destructive Testing (SCNT) algorithm, Table 3 is the registration data on the ground of the Bunny model. Table 3 shows that compared to the LPFH-KICP algorithm, the NDM-KICP algorithm has an average reduction of 46.2% in relative rotation error and an average reduction of 30.3% in registration time. Compared to the NCCP-BKICP algorithm, the average relative rotation error is reduced by 44.5%, and the registration time is shortened by 60.2% on average. Compared to the SBRA algorithm, the relative rotation error is reduced by an average of 1-2 orders of magnitude, and the registration time is shortened by an average of 62.7%. Compared to the SCNT algorithm, the average relative rotation error is reduced by 1-2 orders of magnitude, and the registration time is shortened by 93.3% on average.

Table 4.4 is the registration data on the ground of the Dragon model. Table 4 shows that compared to the LPFH-KICP algorithm, the NDM-KICP algorithm has an average reduction of 11.3% in relative rotation error and an average reduction of 12.6% in registration time. Compared to the NCCP-BKICP algorithm, the relative rotation error has been reduced by an average of 16.1%, and the registration time has been shortened by an average of 24.9%. Compared to the SBRA algorithm, the average relative rotation error is reduced by 33.2%, and the registration time is shortened by 24.7% on average. Compared to the SCNT algorithm, the average relative rotation error is reduced by 2-3 orders of magnitude, and the registration time is shortened by 85.5% on average.

5. Conclusion. In response to the low level of automation and poor robustness of DS parameter models, this study studied the application characteristics of DS, and then introduced the ICP algorithm and MSM descriptor to improve the point cloud registration algorithm. A method for constructing DS parameter models



(a) Coarse Registration Time Comparision

(b) Coarse Registration Error

Fig. 4.5: Results of the descriptor experiment on the ground of the Bunny model

Table 4.3: Registration results of Bunny model

Index	Algorithm	Eliminate point cloud ratio (number of point clouds)			
		5% (34139)	10% (32360)	15% (30548)	20% (28765)
Relative rotation error	NDM-KICP	1.666×10-4	9.192×10-4	83641×10-4	7.265×10-4
	SCNT	2.105×10-2	8.164×10-3	2.324×10-2	2.740×10-2
	SBRA	3.724×10-2	5.106×10-3	7.104×10-2	3.679×10-2
	NCCP-BKICP	1.670×10-4	9.278×10-4	1.490×10-3	2.146×10-3
	LPFH-KICP	3.736×10-4	0.998×10-3	1.416×10-3	2.146×10-3
	ICP	1.476	1.497	1.490	1.492
Registration time	NDM-KICP	15.800	16.352	14.886	13.719
	SCNT	195.084	204.040	250.179	201.8964
	SBRA	42.016	40.846	38.964	38.842
	NCCP-BKICP	36.870	35.996	39.375	37.848
	LPFH-KICP	22.075	22.227	21.748	21.297
	ICP	1.985	1.682	1.739	1.703

Table 4.4: Registration results of Dragon model

		Gaussian white noise ratio			
Index	Algorithm	0.1 $\bar{r}$	0.2 $\bar{r}$	0.3 $\bar{r}$	0.5 $\bar{r}$
Relative rotation error	NDM-KICP	1.305×10-5	4.00910-5	2.19910-5	1.126×10-4
	SCNT	1.769×10-2	1.731×10-2	1.264×10-2	3.492×10-2
	SBRA	1.958×10-5	4.689×10-5	5.475×10-5	1.593×10-4
	NCCP-BKICP	1.308×10-5	4.551×10-5	2.542×10-5	1.397×10-4
	LPFH-KICP	1.309×10-5	4.817×10-5	3.142×10-5	1.174×10-4
	ICP	1.782	1.784	1.782	1.783
Registration time	NDM-KICP	36.785	37.842	44.685	51.896
	SCNT	300.735	301.984	307.692	305.512
	SBRA	77.669	54.671	59.743	67.115
	NCCP-BKICP	52.846	54.183	60.268	62.439
	LPFH-KICP	44.786	45.816	49.558	53.371
	ICP	4.645	4.679	4.762	5.413

on the ground of the improved point cloud registration algorithm was proposed. The results show that under the Bunny model, the number of feature points in CME is only 2146, and the coarse registration error is 0.925 * 10-6 m; As the noise increases, the efficiency of the algorithm proposed in the study increases by an average of 10.1%; The registration time of MSM is 20.22 seconds, and the registration error of MSM is 0.089 * 10-5 meters; Compared to the LPFH-KICP algorithm, the NDM-KICP algorithm has an average reduction of 46.2% in relative rotation error and 30.3% in registration time. Compared to the NCCP-BKICP algorithm, the NDM-KICP algorithm has an average reduction of 44.5% in relative rotation error and 60.2% in registration time. In the Dragon model, the number of feature points in CME is 2235, and the coarse registration time is only 26 seconds; The registration time of MSM is 28.87s, and the registration error is 0.285 * 10-5m; Compared to the LPFH-KICP algorithm, the NDM-KICP algorithm has an average reduction of 11.3% in relative rotation error and 12.6% in registration time. Compared to the NCCP-BKICP algorithm, the NDM-KICP algorithm has an average reduction of 16.1% in relative rotation error and 24.9% in registration time. The digital sculpture parameter model construction method based on improved point cloud registration algorithm proposed in this paper has achieved good results, but some work still needs to be further improved in practical engineering applications. Almost all the existing sculpture modeling methods assume that the background plane of the sculpture is an ideal plane. In the future, it is necessary to study the digital sculpture modeling methods with curved surface or non-convex plane as the background plane. It is also possible to explore a digital sculpture modeling method that can produce optical illusion through light changes, shadow effects or forced perspective, so as to better meet the needs of practical applications.

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DEVELOPMENT AND MODE INNOVATION OF CULTURAL TOURISM RESOURCE BASED ON INDUSTRIAL INTEGRATION

SHAN HE*

Abstract. The cultural tourism industry contributes to the growth of both cultural and tourism industries. Cultural Tourism Resource (CTR) is the prerequisite for the integrated development of the cultural tourism industry. Developing potential CTR can promote the new transformation and upgrading of the urban cultural tourism industry. Luoyang has the advantages of location and resources in the development of CTR, but its tourism industry develops slowly. Therefore, Luoyang City was taken as the research object and the relevant evaluation index system was established. The entropy method and grey correlation model were used to analyze the development trend and influencing factors of the city's CTR. The entropy values of the eight indicators of the evaluation system of CTR established in the study were all above 0.96, indicating that the evaluation system was relatively stable. The grey correlation degree of CTR of historical culture and folk customs was high, which was 0.668 and 0.642, respectively. The grey correlation degree of religious culture and calligraphy and painting CTR was low, which was 0.625 and 0.617, respectively. The CTR of historical culture and folk customs have developed well, but the resources of religious culture, calligraphy, and painting need to be improved. The knowledge of cultural tourism location theory and regional economic growth theory are applied. According to the evaluation results and problems of the development of CTR in Luoyang, this paper puts forward targeted strategies for CTR.

Key words: Industrial integration, Cultural resources, Tourism industry, Development mode, Grey correlation degree model

1. Introduction. The integration of cultural tourism is a strategic concept of tourism development put forward in recent years, which is innovative [1]. In the current environment of industrial integration, promoting the integrated development of culture and tourism is also a major decision made by China in the 14th Five-Year Plan period. This kind of tourism not only has the recreational attributes of tourism, but also has rich and positive cultural attributes, which can better meet people's spiritual and cultural needs. The integrated development of culture and tourism has been further deepened in the aspects of concept, decision-making, and public service, which helps China's tourism to promote the direction of coordinated development of commerce and industry [2]. The culture itself has the characteristics of diversification, and the rich Cultural Tourism Resource (CTR) also makes the cultural tourism products show different characteristics. However, there are still many problems in the development of CTR when it comes to cultural tourism integration. It mainly shows that tourism has a shallow understanding of local culture and fails to deeply show regional characteristics by simply adding cultural elements. However, the introduction of non-local culture in some scenic spots has damaged tourists' real feelings and cognition of local culture. Meanwhile, the lack of innovation and effective inheritance in the integration of industry, culture, and tourism leads to serious homogenization and dilution of traditional charm. At present, the market is profit-oriented and pursues rapid consumption culture, which further weakens the uniqueness and depth of culture. In addition, the current theoretical development system of CTR lacks some practical support. Its content needs to be enriched, and its reliability and guidance need to be strengthened [3]. CTR can become an effective driving force for the local economy, attracting tourists to travel and spend money and promoting the development of the local economy. Meanwhile, it can also promote cultural inheritance and protection through tourism activities [4, 5]. Luoyang City has a long history of culture with rich CTR, but its tourism development has been slow. The development of CTR in this region lacks unified planning, and CTR cannot be optimized and integrated. Therefore, it is of great significance to accelerate the CTR development of Luoyang. For the current development of Luoyang's tourism industry, the focus is on the in-depth development of CTR based on market demand. Therefore, this paper innovatively uses grey correlation model to evaluate the CTR of Luoyang City quantitatively and qualitatively. The future

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development trend of urban CTR is calculated, and the influence of different factors on it is measured. The purpose of this study is to provide a decision-making basis for the development of CTR in Luoyang city and provide a theoretical basis for the development of CTR in other cities.

2. Related works. The development of CTR is the prerequisite for the upgrading of cultural tourism. Its potential market demand and development prospects are extremely broad, which has attracted many scholars to study and discuss it. Su Z et al. constructed an interdisciplinary comprehensive analysis framework from the perspective of efficiency evaluation [6]. There are certain problems in the integration of the cultural tourism industry in Tai'an. In this regard, Dong et al. put forward the choice path and policy guarantee for the integrated development of culture and tourism in Tai'an based on the theory of industrial integration dynamic mechanism. This study was of great significance to promote the coordinated development of culture and tourism in Tai'an [7]. Mao M W et al. designed specific implementation plans for ecological resources and agricultural cultural tourism based on the rural landscape design theory in the landscape architecture. The study provided an important theoretical basis for rural construction and regional cultural and tourism integration development [8]. Peng Ju et al. analyzed the coupling and coordinated development of Shenzhen's culture and tourism industry from 2008 to 2017. The main driving factors of the coupling and coordination of cultural and tourism industries were further discussed by using the grey correlation model. The research showed that there was a significant coupling development relationship between Shenzhen's culture and tourism industry [9]. Based on the tourists' comments on major tourism websites, Liang Feng et al. used semantic analysis and emotional analysis and other analytical techniques to study the cultural perception image of Wuxi by tourists. Research showed that there was an obvious structural mismatch between tourists' perception and the supply of local CTR [10].

The sustainability strategy of cultural and historical tourism needs to be further explored to produce specific economic and social benefits for the sustainable livelihood of residents in the Idanre community. For this reason, Ikusemiju T M et al. used field survey and questionnaire survey to collect data. The sustainable strategy of cultural and historical tourism resources could well promote the improvement of economic and social benefits [11]. Ibrahim AH et al. studied and analyzed the spatial distribution and characteristics of ethnic CTR in different ethnic communities. According to the field survey, the national cultural resources were divided into three categories, which were composed of historical relics, cultural and festival activities, and handicrafts [12]. Lin L et al. discussed the blurring of rural and urban boundaries in cultural heritage tourism. Huangpu Ancient Village had integrated local historical and cultural resources, thus promoting local economic development [13]. The current situation of the development of the organizational culture of tourism enterprises and the improvement of the development mechanism of cultural resources need to be discussed in depth. For this reason, Kalntska et al. proposed an analytical method to evaluate and investigate the tourism market. The competitiveness elements of tourism operators included organizational resources and organizational culture in cultural resources [14]. Based on the grounded theory, Yaqing et al. established an evaluation index system for the potential of agricultural cultural heritage tourism resources, taking Torreya grandis as the research object. The research showed that the potential of tourism resources was large and suitable for the development of tourism resources. However, there was a problem of combining resources with folk customs and culture. Therefore, the study put forward targeted suggestions on this issue [15].

To sum up, at present, the academia mainly focuses on the analysis of cultural and artistic resources and heritage resources. However, few academic achievements have been made to study the development of CTR in Hengyang City alone from the perspective of industrial integration. In the development of CTR, Luoyang has the advantages of location and resources, but the development of the tourism industry is slow. Therefore, Luoyang is adopted as a target based on the perspective of industrial integration. Combined with relevant theories and practical knowledge, the current situation and problems of the development of Luoyang CTR are discussed in depth. And corresponding strategies are put forward for the development and optimization of CTR.

3. The development of CTR and mode innovation methods based on industrial integration. Firstly, the theory and method of cultural and tourism resources development under industrial integration are deeply analyzed. The calculation method of cultural and tourism industry integration is proposed based on the cultural and tourism industry integration mechanism. Secondly, Luoyang city is taken as the research object,

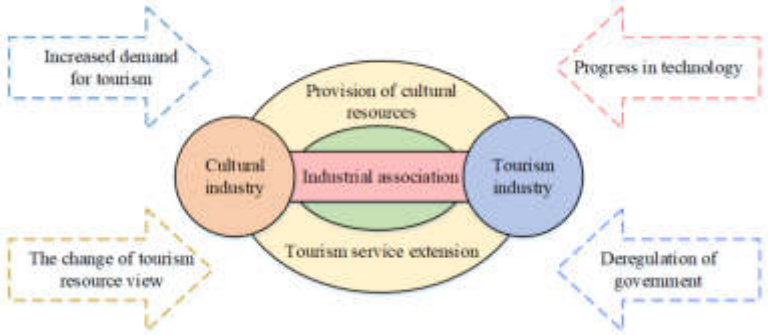

Fig. 3.1: Integration mechanism

and the comprehensive evaluation system of CTR evaluation index of Luoyang City is established. Finally, the entropy method and grey relational model are used to calculate the development situation of CTR in the city and the weight of influencing factors. Some suggestions on the development of CTR are put forward according to the experimental results.

3.1. The theory and method of cultural resources and tourism resources development under the industrial integration. Industrial integration means that multiple industries integrate and grow together. The cultural and tourism industries are both service industries closely concerned about the quality of people's livelihood. The integration of them will bring innovative transformation and upgrading opportunities for the sustainable development of cultural tourism. So the full integration of cultural industry and tourism industry in terms of form, content, and development direction can be achieved. And it can improve the innovation and industrial competitiveness of the cultural tourism industry in different regions [16]. Fig. 3.1 shows the cultural tourism industry integration mechanism under the background of industrial integration.

The integration of culture and tourism is the development with the change of market demand and the division of labor in Fig. 3.1. The cultural industry and tourism industry are constantly penetrating and merging based on the strong correlation and complementarity in resources, technology and market. It gradually forms an industrial organization process. The cultural industry provides cultural resources for the tourism industry and promotes the development of the tourism industry. The tourism industry provides extended tourism services for the cultural industry to promote the cultural industry. They promote mutual development and form a regional integration model. The steps to measure the integration of the two industries are to standardize the data first, and then calculate the difference sequence. The calculation process is shown in (3.1).

$$X_0 = \{x_0(1), x_0(2), ..., x_0(n)\} \tag{3.1}$$

(3.2) is the comparison sequence.

$$X_1 = \{x_i(1), x_i(2), ..., x_i(n)\} \tag{3.2}$$

In (3.2), $n = 1, 2, 3, ..., 11$. (3.3) is the difference sequence.

$$\triangle_i(l) = |x_0(l) - x_i(l)| \tag{3.3}$$

l represents constant, and $l = 1, 2, 3, ..., 13$ in (3.3). Then (3.4) is used to find the extreme values of the two levels.

$$\begin{cases} \triangle(max) = max_i max_l \triangle_i(l) \\ \triangle(min) = min_i min_l \triangle_i(l) \end{cases} \tag{3.4}$$

In (3.4), $\triangle(max)$ and $\triangle(min)$ represent the extreme high and low value. The calculation expression of fusion

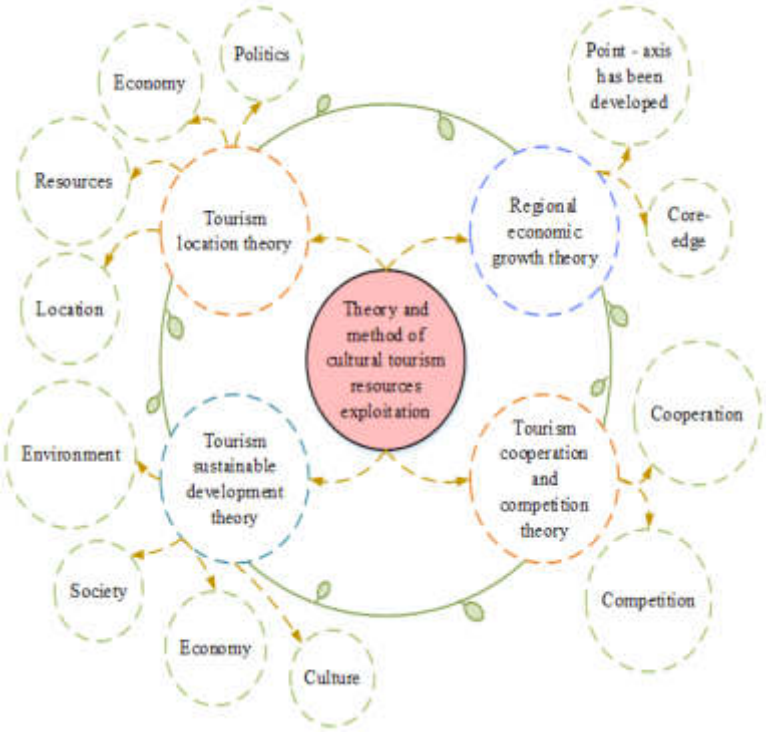

Fig. 3.2: Theories and methods of CTR development

degree is shown in (3.5).

$$\begin{cases} \gamma_{0i}(l) = \dfrac{\triangle(\min) + \nu \triangle(\max)}{\triangle_i(l) + \nu \triangle(\max)} \\ \gamma_{0i} = \dfrac{1}{n}\sum_{k=1}^{n} \gamma_{0i}(l) \end{cases} \tag{3.5}$$

ν is a variable value, and the value range is (0, 1) in (3.5). Cultural resources are unique or relatively beneficial cultural factors in a region, which are more reflected in the important impact of cultural resources on regional tourism development. The development of the tourism industry depends on rich tourism resources. The type, accessibility, and development value of tourism resources have a great impact on tourism. Therefore, CTR exists in geographical space and has unique value. This is the sum of the material and social spirit that attracts tourists. The fundamental purpose of developing CTR is to achieve certain economic benefits. It is necessary to tap potential CTR to form tourism products with economic benefits, and ultimately promote the development and construction of regional cultural and tourism [17]. Fig. 3.2 shows the theory and method of CTR development.

The research will integrate the cultural tourism location theory, regional economic growth theory, and tourism cooperation and competition theory in Fig. 3.2. And sustainable development theory is applied to the resource development of the industry. For tourism location, CTR is proposed, and target cultural tourism routes are designed, according to the economy, politics, resources, and geographical location of the location. Based on regional growth theory, the study regards tourist attractions or cities with development conditions as ”points”. When it develops to a certain scale, it radiates to the surrounding areas, thus forming a complete tourism route. Secondly, the core area of tourism and implement the comprehensive integration of resources can be found out through this area. With the increasing influence of the core area, it needs to further expand

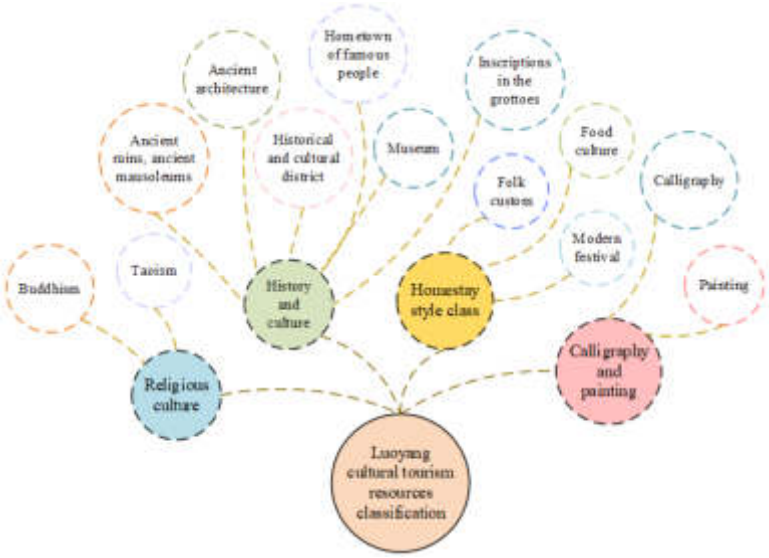

Fig. 3.3: Types of CTR in Luoyang

its influence by means of route integration, scenic spot cooperation, and other forms. Based on the theory of tourism cooperation and competition, tourism cooperation is used to realize the integration and optimization of tourism resources in the region. It can better promote regional tourism through competition in cooperation. The core content of tourism sustainability is to promote the comprehensive and coordinated development of economic, cultural, social, environmental, and other benefits. Sustainable development is also a core theoretical support for the development of CTR.

Luoyang is located in the Central Plains of China, which has profound cultural connotation and extremely rich CTR [18]. Luoyang is closely connected with Chinese Confucian culture, Buddhist culture, Taoist culture, and Neo-Confucianism culture. In addition, it is also the starting point of the Silk Road. From the Shang Dynasty to the Sui and Tang Dynasties, there has been frequent political, economic, and cultural exchanges with many countries. This study takes Luoyang City as an example to conduct an in-depth analysis of its CTR development model. In Fig. 3.3, the types of Luoyang CTR are sorted and divided.

In Fig. 3.3, the research divides Luoyang's CTR into four categories: historical culture, religious culture, folk customs, and calligraphy and painting. Under the four branches, there are also various places of interest and cultural arts. Luoyang has a large number of human tourism resources, and the types of tourism resources in Luoyang are also very rich, with different formal values. In addition, Luoyang's CTR are of high quality and large quantity according to relevant data. Luoyang has great potential in the development of CTR.

3.2. Comprehensive evaluation method of CTR development from the perspective of industrial integration. This paper makes an in-depth analysis of Luoyang's urban CTR through field investigation and data collection. According to the local situation of Luoyang, its CTR is divided into three evaluation items and eight evaluation factors. The comprehensive evaluation system of Luoyang CTR evaluation indicators is established, as shown in Fig. 3.4.

The study makes a comprehensive evaluation of the system according to the common factors of tourism resources in Fig. 3.4. Resources are evaluated from three aspects: resource influence, resource element value, and added value through the quantitative evaluation of assigned value. According to the common factor scoring value, the paper quantitatively evaluates the various factors of the classification of Luoyang's existing CTR. Finally, the common comprehensive factor evaluation score is obtained. Entropy is a measurement mode specially calculated for uncertainty, and its characteristics can be used to calculate the randomness of an event and its degree of disorder [19]. In addition, the current dispersion degree of an indicator can also be determined

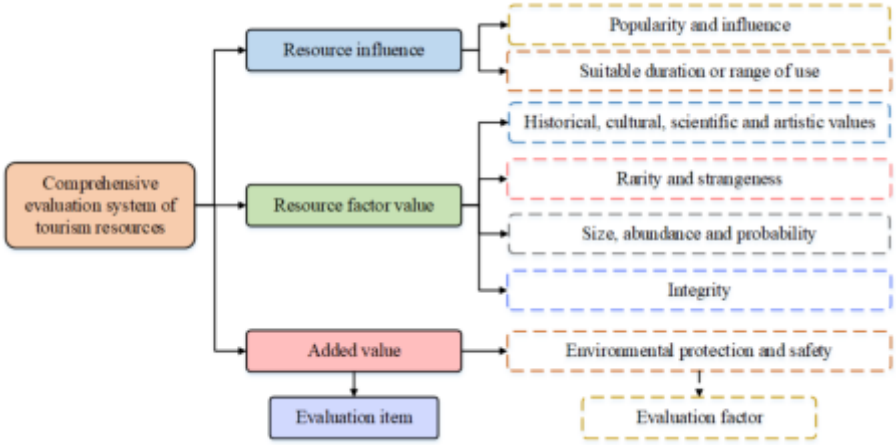

Fig. 3.4: Comprehensive evaluation system of Luoyang CTR evaluation index

with the help of entropy value. Therefore, the research calculates the rights of different indicators with the help of information entropy tools. Before calculation, it is necessary to carry out dimensionless processing on the data to complete the weighting of indicators. First, it needs to standardize the initial data so that the range of indicator values is 0-1. The calculation method of positive indicators is shown in (3.6).

$$x'_{ij} = (x_{ij} - \min x_j) / (\max x_j - \min x_j) \tag{3.6}$$

i is the year. The index number is j, and x_{ij} represents the original value in (3.6). x'_{ij} represents the normalized value of positive indicators. $\max x_j$ and $\min x_j$ represent the extreme values of the indicators in the study year. The calculation method of negative indicators is shown in (3.7).

$$x'_{ij} = (\max x_j - x_{ij}) / (\max x_j - \min x_j) \tag{3.7}$$

After the standardization of some indicator values, the data may be small or even negative. Therefore, the standardized values will be translated to ensure convenient and uniform calculation. The calculation expression is shown in (3.8).

$$x'_{ij} = H + x'_{ij} \tag{3.8}$$

H represents the range of index translation, which is generally 1 in (3.8). The research uses the entropy to find the weight of index. The entropy represents the measure of uncertainty. Smaller value means higher variation degree of an index value. This means that the indicator provides more information and it has larger weight value [20]. The proportion of standardized sample indicators in the indicator system is calculated as shown in (3.9).

$$y'_{ij} = x'_{ij} / \sum_{i=1}^{m} x'_{ij} \tag{3.9}$$

y'_{ij} represents the proportion of x'_{ij} in (3.9). However, a value of 0 may appear after the indicator is standardized during the processing. Therefore, the research will shift the processed data to 0.0001 units to the right as a whole to make the 0 value after standardization meaningful. Then, in (3.10), it needs to determine the information entropy value of index j.

$$e_j = -k \sum_{i=1}^{m} y_{ij} \ln y_{ij} \tag{3.10}$$

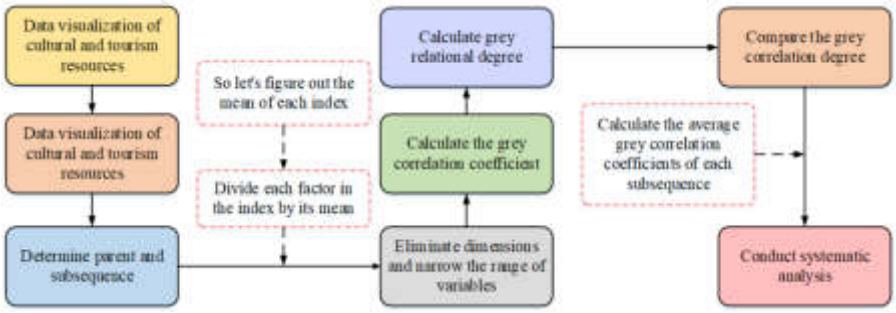

Fig. 3.5: Calculation steps of correlation degree of cultural and travel resource indicators based on grey correlation analysis

In (3.10), e_j represents the information entropy value of each indicator, and m represents the sample number of each indicator. k represents a constant, which is related to the number of samples m in equation (3.11).

$$k = 1/\ln m \tag{3.11}$$

Information entropy e_j can be used to measure the information utility value of index j. When the information is out of order, $e_j = 1$. d_j is the indicator of e_j to the comprehensive evaluation, which is the utility value. It equals 0. Then, in (3.12), the relationship between the information utility value e_j of the indicator and the information entropy e_j of the indicator is displayed.

$$d_j = 1 - e_j, j = 1, 2, \ldots, p \tag{3.12}$$

When the entropy method is used to calculate the weight of each evaluation index, higher coefficient reflects greater importance for the evaluation in the evaluation process. On the contrary, it is less important for evaluation. (3.13) is the expression of index weight j.

$$w_j = e_j / \sum_{j=1}^{n} d_j \tag{3.13}$$

The number of indicators in equation (3.13) is n. The vulnerability and sensitivity of the tourism city's economic system are positively correlated, and the response capacity of the system is inversely correlated. In the evaluation of CTR, small sample data are adopted, and the data in recent years only prevail. However, such data cannot fully and accurately reflect their overall information, so they have the characteristics of gray. The grey correlation model is to determine the relevance of different factors with the help of the similarity and dissimilarity of the development trend of different factors. Therefore, it can deeply reveal the degree of dynamic correlation of things and analyze the characteristics of their dynamic correlation. In Fig. 3.5, the correlation degree of CTR indicators is calculated and measured.

Firstly, the collected CTR data are visually expressed and simply analyzed in Figure 5. Then the current sequence of each factor and its comparison sequence should be clarified first, and the data of CTR should be processed dimensionless and non-polar. On the premise of ensuring its unity, it needs to calculate the grey correlation coefficient and clarify the weight and vector of CTR indicators. If there is a high degree of correlation between the two factors, it means that they have a high degree of synchronous variability. On the contrary, it means that the synchronous variability between the two is low. In (3.14), the calculation of the absolute difference between the comparison and sequence is shown.

$$\left(|x_{ij} - x_{0j}| \triangle_{0i}(j)\right)_{nxp} \tag{3.14}$$

$i = 1, 2, ..., n$ and $j = 1, 2, ..., p$ in (3.14). The comparison sequence consists of system behavior affecting factors that combined as a data sequence, which is composed of the evaluation indicators selected by each evaluated

object. When using the grey correlation analysis method, the correlation coefficient specifically refers to the geometric distance between the parameter sequence and the comparison sequence at different time points [21]. If the value of the correlation coefficient is relatively large, it means that there is a greater degree of correlation between the two. (3.15) is the calculation expression of the correlation coefficient.

$$\zeta_{0i}(j) = \frac{\min \triangle_{0i}(j) + \rho \max \triangle_{0i}(j)}{\triangle_{0i}(j) + \rho \max \triangle_{0i}(j)}, 0 < \rho < 1 \tag{3.15}$$

ρ represents a constant, generally 0.5 in (3.15). The correlation degree of the two sequences refers to the correlation coefficient. Because the correlation coefficient is the degree of correlation at different time points, it cannot be uniformly compared and analyzed. Therefore, it is necessary to solve the grey correlation degree to complete the unification of the correlation coefficient and obtain the corresponding value. (3.16) is the calculation formula of grey correlation degree.

$$r_{0i} = \sum_{j=1}^{p} w_j \zeta_{0i}(j) \tag{3.16}$$

In (3.16), $i = 1, ..., n$ is the value of grey correlation degree. The higher value of r_{0i}, the better indicator system. In this study, the entropy method and grey relational degree model are used to analyze the development situation and the factors influencing the CTR in Luoyang. However, both of them need a lot of complete and effective data support. In special cases, these two models may not be able to fit the actual data well, resulting in a bias in the results. Appropriate methods can be selected according to the actual situation to improve the overall accuracy of the research and analysis. For example, regression analysis can be used to establish a mathematical model between variables and analyze the correlation between the development of urban CTR and influencing factors. Analytic Hierarchy Process (AHP) can be used to analyze and evaluate each factor of urban CTR in a hierarchical manner to determine the weight and correlation degree among the factors.

4. Result analysis. Luoyang has a long cultural history and rich CTR. It has location and resource advantages in the development of cultural tourism. Luoyang City was taken as the experimental object, and the current situation of its CTR was analyzed by calculating the degree of integration. Figure 6 shows the integration degree of cultural tourism industry and development and utilization of CTR in Luoyang.

Luoyang's cultural tourism industry is divided into four categories: historical culture, religious culture, folk customs, and calligraphy and painting in Fig. 4.1. Their average integration degree of CTR development was 0.433, 0.27, 0.477, and 0.430, respectively. The resources of religious culture and calligraphy and painting had a low integration with the cultural tourism industry, so the integration and utilization of these two aspects of resources should be promoted. In general, the cultural tourism industry of Luoyang and its CTR development had a low degree of integration, meaning that the CTR development was low and the utilization was not high. The evaluation of tourism resources was based on the comprehensive tourism resources evaluation of the common factors, and the quantitative evaluation of assigned points was adopted. In Table 4.1, the research evaluated Luoyang's CTR from three aspects: resource element value, resource influence, and added value.

The overall evaluation score of historical and cultural resources changes in Luoyang was high, while the overall score of calligraphy and painting resources was low in Table 4.1. This showed that Luoyang had a high degree of development of historical and cultural resources, but a low rate of development and utilization of calligraphy and painting resources. Among the four categories of CTR in Luoyang, the value of sightseeing and recreation was the highest, with an average score of 21.345. This showed that the appreciation and recreation value of CTR had received the highest attention, and its development should be strengthened. The weights of eight evaluation index factors were determined by calculation, as shown in Fig. 4.2.

The entropy value of the eight evaluation indicators in Luoyang selected in the study was above 0.96, and the coefficient of difference of each indicator was below 0.04 in Fig. 4.2 (a). It showed that the dispersion degree of each indicator data was normal, and the comprehensive evaluation system of Luoyang CTR evaluation indicators established in the study was more stable. In Fig. 4.2 (b), the weight of environmental protection and safety was the largest, 0.172, while the weight of suitable travel period or use range was the smallest, 0.098. It

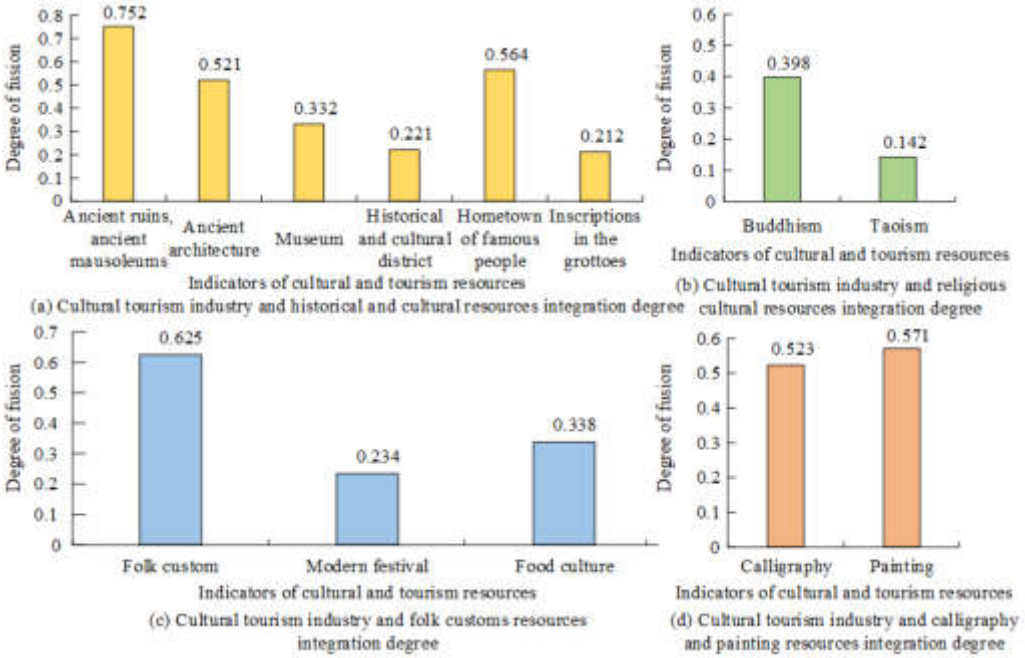

Fig. 4.1: Integration degree of cultural tourism industry and CTR development in Luoyang city

Table 4.1: Results of CTR types in Luoyang

Evaluation object	History and culture	Religious culture	Folk customs	Calligraphy and painting
Ornamental recreation value	30.29	18.95	27.78	8.36
Historical, cultural, and artistic value	19.88	17.76	16.35	14.92
Degree of preciousness	15.74	12.64	10.57	15.34
Size, abundance, and probability	6.58	9.64	6.47	5.36
Integrity	3.52	4.36	1.61	5.23
Popularity and influence	9.32	9.54	9.53	6.82
Suitable duration or range of use	3.31	4.25	5.63	4.21
Environmental protection and safety	-3.42	-4.13	3.25	3.08

showed that environmental protection and safety were the most important in the evaluation system. Table 4.2 is the results of dimensionless treatment of the evaluation factors.

After the non-dimensional processing, the effective factors of different indicator data had been eliminated in Table 4.2. The study used the initialization index data obtained in Table 4.2 to calculate the absolute difference between the comparison and sequences in Luoyang. Fig. 4.3 is the results.

According to the results in Fig. 4.3, the grey coefficient of the evaluation index was calculated with the grey system theory. Table 4.3 shows the results.

The historical and CTR of Luoyang are closely related to the value of sightseeing and recreation, historical and cultural science, and artistic value. Table 4.3 showed that religious and cultural resources were greatly affected by the scale, abundance and probability, popularity, and influence of these two indicators, and their grey correlation coefficients were all 1. Folk customs had the strongest correlation with popularity and influence, suitable travel period or scope of use, environmental protection and safety. Calligraphy and painting were

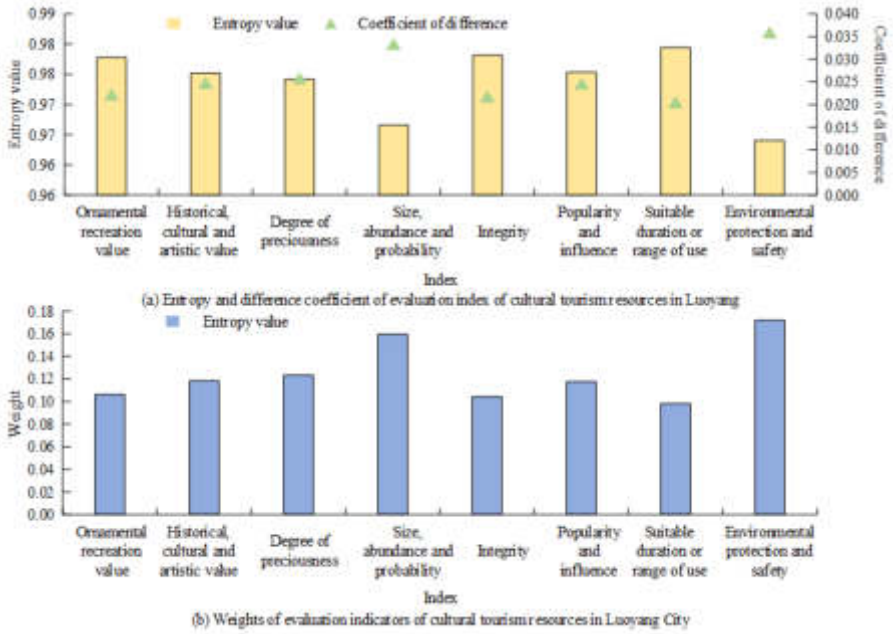

Fig. 4.2: Entropy, difference coefficient and weight of Luoyang CTR evaluation index

Table 4.2: Results of dimensionless treatment of the evaluation factors

Evaluation object	History and culture	Religious culture	Folk customs	Calligraphy and painting
Ornamental recreation value	1	0.467	0.804	0
Historical, cultural, and artistic value	1	0.317	0.225	0
Degree of preciousness	1	0.248	0	0.771
Size, abundance, and probability	0.930	1	0.066	0
Integrity	0.543	0.827	0	1
Popularity and influence	0.974	1	1	0
Suitable duration or range of use	0	0.485	1	0.480
Environmental protection and safety	0.952	0	1	0.996

Table 4.3: Grey coefficient of evaluation index of CTR type in Luoyang City

Evaluation object	History and culture	Religious culture	Folk customs	Calligraphy and painting
Ornamental recreation value	1	0.483	0.718	0.333
Historical, cultural, and artistic value	1	0.422	0.392	0.333
Degree of preciousness	1	0.399	0.333	0.686
Size, abundance, and probability	0.355	1	0.3349	0.333
Integrity	0.522	0.743	0.333	1
Popularity and influence	0.951	1	1	0.333
Suitable duration or range of use	0.333	0.493	1	0.491
Environmental protection and safety	0.355	0.333	1	0.992

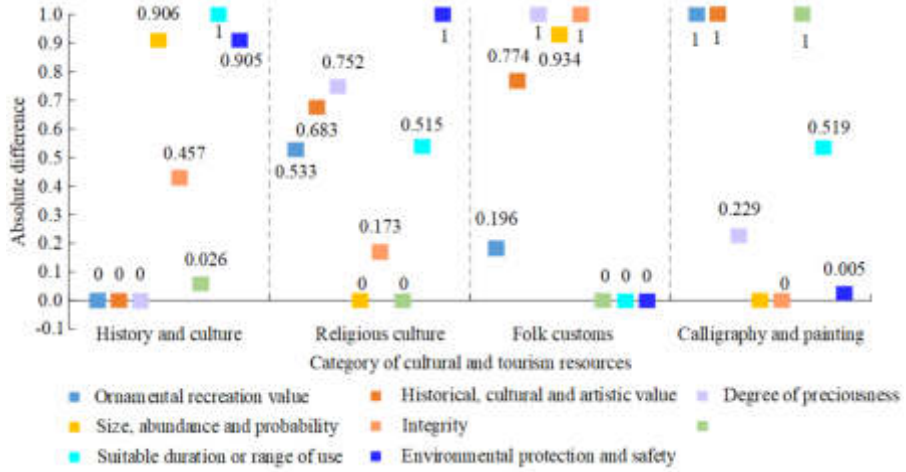

Fig. 4.3: Calculation results of absolute difference between the two sequences in Luoyang City

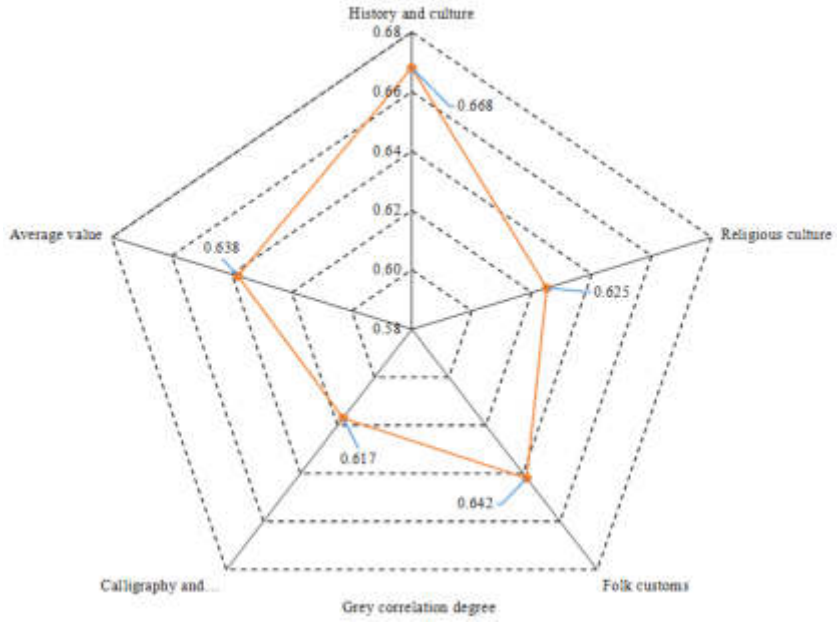

Fig. 4.4: Comprehensive grey correlation degree of CTR types in Luoyang

closely related to integrity, environmental protection and safety, and the degree of rarity and oddity. Fig. 4.4 shows the calculated result of the comprehensive grey correlation degree of Luoyang CTR type.

The grey correlation degree of historical and CTR was the highest, 0.668 in Fig. 4.4. The grey correlation degree of CTR of folk customs was higher, which was 0.642 after that of historical culture. The grey correlation degree of religious CTR was close to the average value, 0.625. The gray correlation degree of CTR of calligraphy and painting was the lowest and lower than the average, only 0.617. The CTR of historical culture and folk customs had developed well, but the resources of religious culture, calligraphy, and painting needed to be improved.

To sum up, the development of CTR should take a reasonable and scientific way to develop some historical

relics, cultural relics, and other resources. In the process of development, the image-type tourism resources such as historical and cultural relics and spiritual connotation should be organically integrated. And the principle of paying equal attention to development and protection should be followed. Secondly, its unique regional characteristics should be deeply explored and highlighted in the development of CTR. Cultural tourism products with strong market competitiveness were formed based on regional uniqueness and development and innovation. In addition, the resource allocation should be paid enough attention when developing CTR. So the rationality and scientific of allocation can be ensured, and the mutual sharing of resources and complementary advantages can be realized. Finally, the principle of participation should be fully considered when developing CTR. Tourists were required to better participate in tourism projects, making them have a personal understanding of the spiritual connotation of CTR and form a more long-term and interesting memory. To sum up, the overall development trend of CTR in Luoyang city was good. The development of historical culture and folk customs was more prominent. The grey relation degree of historical and CTR was the highest, and its overall view value and artistic value were higher. Meanwhile, cherish the strangeness, popularity and so on were good, so that the historical and cultural resources of Luoyang city had a good competitive advantage in other similar cities. However, there were some problems such as small scale and single-form of national customs and CTR exploitation in the process of development. In addition, the resource development of religious culture and calligraphy painting needed to be improved, and its deep ornamental value had not been excavated. The gray correlation degree of calligraphy and painting CTR was lower than the average. On the whole, the competitiveness of Luoyang's CTR needed to be further improved, and the environmental protection and diversified development of resources still needed to be strengthened.

5. Discussion and suggestion. With the increase in tourism demand in Luoyang city, the demand for cultural products is also increasing. Therefore, it is necessary to dig deeply into the CTR of Luoyang and transform them into products to attract tourists. The sustainable development of its cultural tourism can be promoted by exploring the rich cultural resources of Luoyang. There are many kinds of CTR in Luoyang, and their distribution is relatively concentrated. The quantitative evaluation results by using grey correlation degree method showed that the CTR of Luoyang city as a whole had high development value, especially in the aspect of historical and cultural resources, which was closely related to the numerous scenic spots in Luoyang City. Although the overall development of culture and tourism resources in Luoyang was good, there were also some problems, such as low protection degrees, short travel period, and low ornamental leisure value. The development strategy of CTR had important practicability and relevance. CTR could be better utilized and managed through the formulation of effective development strategies, and managers could realize the optimal allocation of resources and promote the benign development of cultural tourism. According to the development status and existing problems of CTR in Luoyang City, Luoyang city as the center, divided into the new district and the old city cultural tourism center in the development space layout. The core area should focus on the experience of Central Plains folk customs, history, and culture. The new district was fully dependent on the Luoyang new urban area, with business exhibitions, leisure and entertainment, and other tourism products as the key development content. The regional cooperation was strengthened and the domestic tourism market space was expanded in terms of market competitiveness. Secondly, the cultural tourism publicity should be strengthened and the international market should be opened up. Finally, it is necessary to establish the concept of knowledge-intensive tourism industry, introduce high-quality tourism talents, and build a perfect personnel training mechanism. The first is to establish a national Luoyang CTR reserve in terms of protection. Secondly, the management system of CTR was improved and the management ability of the leading team was enhanced to promote the unified management and protection of CTR.

6. Conclusion. This study took Luoyang CTR as the research object. A comprehensive evaluation system of Luoyang CTR evaluation indicators was established in the experiment. And the grey correlation model and entropy method were used to evaluate the CTR of Luoyang City, and the shortcomings in the development process of its CTR were analyzed. The average integration of Luoyang's cultural tourism industry with historical culture, religious culture, folk customs, and calligraphy and painting was 0.433, 0.27, 0.477, and 0.430, respectively. The degree of integration indicated that the city's CTR were less developed and less utilized. The entropy values of the eight indicators of the evaluation system of CTR established in the study were all above 0.96, indicating that the evaluation system was relatively stable. The index of environmental protection

and safety had the largest weight of 0.172, indicating that the index was the most important one. The grey correlation degree of CTR of historical culture and folk customs was high, 0.668 and 0.642, respectively. The grey correlation degree of religious culture and calligraphy and painting CTR was low, 0.625 and 0.617, respectively. The CTR of historical culture and folk customs had developed well, but the resources of religious culture, calligraphy and painting needed to be improved. Some measures are put forward in the study according to the evaluation results and problems of CTR development in Luoyang. They include following the development strategies of CTR that pay equal attention to development and protection and highlight the regional, holistic, participatory, and experiential nature. The quantitative evaluation of CTR is realized based on entropy method and grey relational degree model. In general, the overall development of CTR in Luoyang is very good. The development of historical and CTR is the best, but the development of religious culture and calligraphy and painting resources is still sufficient. The research provides a good theoretical basis and time value for the mining of the same type of CTR cities. In addition, the research also makes a deeper discussion on the existing problems based on the current situation. Aiming at the development of CTR in Luoyang city, this paper puts forward the principle of equal emphasis on development and protection, highlighting regionalism, integrity and participation. And the corresponding development strategies are put forward from the aspects of development space layout, market competitiveness, and protection. Although the research has achieved certain results, the evaluation results obtained may have slight deviation due to the limited data collected. In the future, the research methods will be further improved.

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INFLUENTIAL EFFECTS BETWEEN POSITIVE HR PRACTICES AND EMPLOYEE PERFORMANCE – MEDIATING MODERATING EFFECTS BASED ON WORK ENGAGEMENT

BIN ZHANG*

Abstract. The development of the knowledge economy society has made enterprises pay more attention to the subjectivity and initiative of "people" in their human resource management practices, and the performance of employees is related to their level of work engagement. Therefore, this study is based on the impact of positive human resource practices on employee performance, and analyzes the mediating effect of work engagement through experimental data processing, scale design, and hypothesis testing. The results showed that: a) There is a significant positive correlation between positive human resource practices and employee performance, and the regression coefficients corresponding to work performance and relationship performance are both above 0.35 and 0.40. b) There is a significant correlation between positive human resource practices and work performance, and a significant correlation between positive human resource practices and work engagement. c) Work engagement plays a mediating role between positive human resource practices and work performance. Mastering the mediating effect of work engagement can effectively provide management insights for enterprises to promote human resource practices.

Key words: Human resources; Performance; Work input; Mediating moderating role; Principal component analysis

1. Introduction. With the emergence of the knowledge-based economy, the importance of human capital in the organization of resources has grown, and the competition between businesses is now more focused on the competition for talent among businesses rather than a single material or resource. Strengthening the management of talent can significantly improve the growth and overall success of the company [1] as it is a resource with development and potential. Positive human resource practices (PHRPs) convey a positive emotional commitment to employees, which in turn increases motivation and creates better performance, by focusing on the activities that generate social support for employees and by analyzing performance behaviour [2]. Differences in language and cultural connotations make the dimensions of positive human resource (HR) practices different in China and abroad. But they are largely the same, with the domestic HR practices focusing more on collectivism, i.e. the individual will be in the expectation of the organization and the leader while building themselves up with a greater focus on consistency of perception and appropriateness of care [3]. The performance of employees is, to a certain extent, an effective reflection of their ability and attitude to work, and good or bad HR practices can make employees judge their own value and ability to work [4]. Examining the variables that affect how to appropriately direct the positive guiding influence of HR practices on employees, and how to successfully bring into play and stimulate their work potential and motivation, is of considerable practical significance and theoretical worth. The goal of this study is to improve HR practices by analyzing the impact of good HR practices on employee performance and investigating the mediating function of work engagement elements in this process. The study provides a literature review of the current research on HR practices and employee performance, analyzes the mediating effect mechanism proposed by the study through scale design, hypothesis testing and analysis of empirical results in Part II and Part III, and concludes the full text in Part IV.

2. Literature review. PHRP refers to a series of strategies and procedures developed and implemented by a company, aiming at improving employee satisfaction, job performance, and organizational efficiency. The practical content includes establishing an efficient and fair recruitment system, providing continuous training and career development opportunities for new and existing employees (including job training, career planning, leadership development, and lifelong learning plans), a fair performance evaluation system, organizational

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structure, and work environment [5]. In practice, there are several dimensions of positive HR. Many scholars believed that they include performance incentives, career development prospects and equity and justice, etc. The content of different dimensions and the needs of employees are different, but they all consider new ways of HR or aspects that need to be improved from the perspective of employees' immediate interests. Using sample analysis and the job demand-resource model, Cooke F. L. examined the connections between high-performing organizational structures and worker resilience and engagement. The results showed that high performance work systems were effective in positively influencing employees' psychological resilience and engagement and in stimulating resilience [6].

Tambe P scholars analyzed and responded to the management decision problems arising from data science and technology in HR management, which provided a reference for improving the economy and effectiveness of data information management [7]. Self-efficacy positively affects each person's ability to execute their job, and research from the field by academics like Carter W. R. has shown that this relationship should be taken into account when studying job performance [8, 9].

Bender S found that human capital reduced the association between productivity and management practices [10]. Using a mediation approach, Malik P connected learning organizations to employee resilience and work engagement. The empirical findings indicated that learning organizations were beneficial for employee resilience and job engagement and this effect was mediating and moderating [11]. Based on questionnaire results, Amor A. M. academics examined the relationship between transformative leadership and work engagement and discovered that structural empowerment had a strong mediation effect [12]. The results of Nieves J's analysis of the mediating role of human capital in HR and innovation supports his theory, however it is more challenging to sustain a better enhancing effect in actual practice [13, 14].

Aburumman O explored whether career satisfaction plays a mediating role. Results and empirical tests showed that the reasonableness of pay systems, performance legitimacy of assessment and employees' propensity to leave had a negative impact on each other, and career satisfaction had a high mediating effect. Therefore, companies should strengthen the effectiveness of their HR management [15].

Salas-Vallina et al. analyzed the relationship between welfare oriented HR management and performance in a sample experiment based on the job demand resource model and social exchange theory, and conducted a moderating mechanism analysis on the leadership of middle-level managers. The results indicated that attractive leadership behavior could effectively promote the development of HR management and have a positive impact on employee performance [16].

To enrich the content of green HR management practices, Mousa S K et al. analyzed the impact mechanism of management practices on the sustainable performance of healthcare organizations. The results showed that positive management practices could effectively promote the improvement of organizational performance levels [17].

Darmawan D et al. used regression analysis tools to explore the impact of HR quality on work performance and employee loyalty. The results showed that HR quality had a positive impact on work performance and employee loyalty [18].

Sabuhari R et al. investigated the indirect impact of HR flexibility on employee performance, as well as the mediating effects of organizational culture adaptability and job satisfaction on employee performance. Research has found that HR flexibility, employee abilities, and job satisfaction had a significant impact on employee performance, with job satisfaction partially moderating the impact of employee abilities on employee performance [27].

Based on social exchange and organizational support theory, Aboramadan M et al. used structural equation modeling to explore the impact of green HR management on the green work related outcomes of non-profit organization employees. The results indicated a positive correlation between global HR management and green work, and green organization support exhibited a significant mediating effect between the above connections [20].

Engelsberger et al. used dynamic capability theory to study the role of strategic HR management in supporting the open innovation performance of employees in four American multinational technology companies, and analyzed the mediating role of open innovation mentality. The results confirmed that an open information management mindset played a mediating role between HR management and open information management performance [21].

Xu Y et al. analyzed the relationship between decent work and comprehensive work capacity building using structural equation modeling. The results showed that decent work promoted comprehensive work capacity building by increasing work participation, and intrinsic motivation and work self-efficacy had a positive mediating effect on the relationship between the two [22].

Based on the job demand resource model, the study used structural equation modeling to re-examine the role of work engagement in innovative work behavior, as well as the mediating role between antecedent variables such as interpersonal conflict and perceived organizational support. The research results indicated that there was a positive correlation between public works budget, workplace, personal wealth, personal wealth, and innovative work behavior, and there was a negative correlation between interpersonal conflict and innovative work behavior [23].

Susanto PC et al. conducted a literature regression analysis on the relationship between employee engagement and turnover rate in HR management research, and found that a clear focus on employee engagement could improve their coaching and transformational leadership abilities [24].

Tan K L et al. analyzed the relationship between work and job burnout, as well as the mediating effect of work engagement according to resource conservation theory and job demand resource theory, using questionnaire surveys and partial least squares structural equation models. The results indicated that work engagement had a moderating effect on the relationship between meaningful work and all dimensions of job burnout [25]. The development of social economy and the transformation of family structure have made the contradiction between work and family increasingly prominent. Lyu X et al. explored and analyzed the participation of women in the work environment under the dual role pressure. The results indicated that there was no significant difference between males and females in terms of work family conflict (work interfering with family and family interfering with work), and work design helped to reduce the impact of family on the work of female employees [26].

Darban G et al. conducted a survey and analysis of 182 respondents, examining the mediating effect of work engagement as a mediator between green HR management, absenteeism, and green recovery performance. The results showed that WENG could alleviate absenteeism, and employees' liking for cognitive assessment could improve their emotional response to work and enhance their performance response [27].

The above results suggest that positive and active management of resource practices led employees to increase their sense of organizational commitment and job satisfaction, and different forms of leadership organization and resource deployment had different degrees of impact on employees' happiness, followership and propensity to leave. The study relies on this to empirically investigate the association between effective HR practices and employee performance because there is no research that specifically tackles the mechanisms by which job commitment is influenced in employee performance.

3. Experimental protocol design for the link between PHRPs and employee performance. The study was carried out by examining the mechanisms by which effective HR practices affect employee performance. The data were processed using sample scale data to create the final scale instrument, and a protocol design and hypothesis testing were then developed based on the scale experimental instrument.

3.1. Analysis of the influence mechanism between PHRPs, employee performance and work engagement. The earliest definitions of work engagement focus on the extent to which an individual's work performance has an impact on the realisation of self-worth and how much an individual is willing to invest in their work on a psychological level. A positive mindset induces employees to invest more in their work, and positive feedback on work engagement reinforces employees' recognition of their work. The dimensions of work engagement include physical, emotional and cognitive dimensions, and by extension, concentration and commitment. Work engagement includes antecedent and outcome variables. The antecedent variables include both individual and organizational dimensions, with differences in the characteristics of each dimension, such as age, family situation. Different temperaments and personality traits can also influence how people approach their work and how enthusiastic they are about it. For instance, there is a link between extraversion and high levels of work engagement. Figure 3.1 shows a diagram of the dimensions of work engagement.

PHRPs include participation in decision-making, fair compensation and growth opportunities. The better the training process and system, and the more generous the benefits, the more likely employees are to be satisfied with their work, which in turn increases their probability and likelihood of commitment to their work [28]. This is evidenced by the fact that a significant increase in job performance and income will positively confirm the

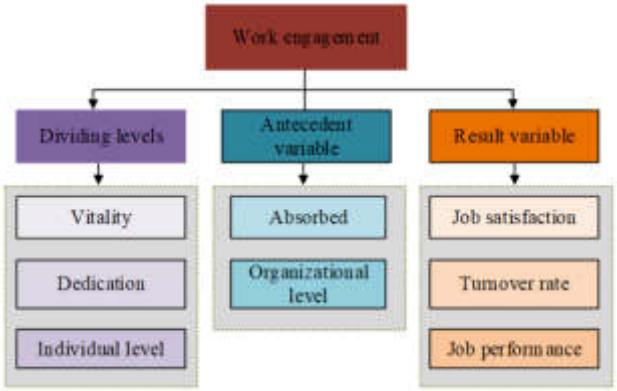

Fig. 3.1: Schematic diagram of the impact dimensions of work engagement

employee's recognition of their job. The study uses principal component analysis (PCA) to analyze the scale data to ensure that the indicators selected are objective. PCA is the process of reducing the dimensionality of the indicators involved in the scale, which satisfies equation (1). The study analyzes the relationship between PHRPs and employee performance, and selects three scales for important dimensional feature extraction. PCA can transform multiple variables into a few comprehensive indicators based on data characteristics, simplify the model, and reduce computational complexity, avoiding the interference and influence of redundant information and noise [29]. PCA removes redundant information by extracting principal components, grasps the correlation between different variables, and makes the data structure clearer, which is very helpful for understanding the relationships between variables and conducting regression analysis. When exploring the mediating effect of work engagement, PCA can help simplify the model structure, clearly identify and quantify the impact of each principal component on mediating variables, provide data support for in-depth analysis of mediating effects, and ensure the accuracy and reliability of the research. PCA, as a statistical method, simplifies the complexity of the dataset through dimensionality reduction techniques. Before conducting PCA, it is necessary to ensure that there is a linear relationship between variables in the data, there are a large number of observed sample values, and abnormal data values need to be addressed and standardized uniformly to ensure they are on the same measurement scale.

$$Y = \begin{bmatrix} u_{11} & \dots & u_{m1} \\ \dots & \dots & \dots \\ u_{1p} & \dots & u_{mp} \end{bmatrix} \begin{bmatrix} X_1 \\ \dots \\ X_p \end{bmatrix} = AX \tag{3.1}$$

In equation 3.1, p is the dimension. X_p is the indicator. Y is the linearly transformed composite variable of X that is uncorrelated with the indicator. m is the number of composite variables, and X_p is the coefficient of each principal component. The PCA constructs a data matrix by standardizing the raw data, and then determines the characteristic roots and variance contributions by calculating the characteristic equations of the matrix. Equation 3.2 is the correlation coefficient matrix.

$$R = [r_{mp}]p_x p = \frac{Z^T Z}{n-1} \tag{3.2}$$

In equation 3.2, r_{mp} indicates the correlation coefficient of the original variable. R is the correlation coefficient matrix. Z is the standardized data matrix, and n is the sample size. In the study, the objective objects are also weighed with the help of information entropy and the importance of the scale indicator data was achieved, which is calculated as shown in equation 3.3.

$$H(x) = -\sum_{i=1}^{f} q(x_i) \ln\, q(x_i) \tag{3.3}$$

In equation 3.3, x_i represents the indicator and q represents the weight of the indicator. It is assumed that there exists a total of d , f for the investigators and indicators. Entropy method refers to a mathematical method used to determine the degree of dispersion of a certain indicator. The greater the degree of dispersion of the indicator, the greater its impact on comprehensive indicators. The probability calculation value based on entropy function can be expressed as the logarithmic result of the probability of a random variable's value under the total number. On the basis of in-depth analysis of the definition, results, and impact mechanisms of variables, this study explores the dimensions that affect employee job performance, the impact of PHRPs on employee work engagement and performance, and how work engagement plays a mediating role.

The matrix variables were subsequently rotated orthogonally during the study to measure the correlation between the variables. The covariance matrix between the transformed principal components and the original variables is shown in equation 3.4.

$$\sum_{x,y}^{\wedge} = \sum xAQ \tag{3.4}$$

In equation 3.4, A represents the eigenvectors of the original vector x. Q is the unit orthogonal matrix, and y is the principal component.

3.2. Experimental programme design. Through scale design and empirical analysis, the study was done to further validate the link between HR practices, employee performance, and mediating effects. The study first used a small-scale sample to analyze the reliability and validity of the questionnaire. The designed questionnaire included three variables and eight dimensions of questions: PHRP, work engagement, and work performance, and it was evaluated using a five level scale. The content of the relevant dimensions of the three scales is shown in Table 3.1.

PHRPs have their own key elements and implementation strategies in the three dimensions of fair rewards and punishments, participatory decision-making, and growth opportunities. The performance appraisal system should be directly related to employee rewards and punishments. Employees with excellent performance should receive reasonable rewards, such as promotions, salary increases, or bonuses, while underperforming employees may face training, coaching, or other improvement measures. The reward and punishment measures must match the actual performance of the employees. It is crucial to ensure that the performance evaluation process is open and transparent, and that employees are satisfied with the evaluation process, including the fairness of evaluation standards, the appropriateness of evaluation methods, and the accuracy of evaluation results. At the same time, performance results should be based on objective standards, avoiding biases and preferences, and ensuring that each employee's efforts and achievements are fairly evaluated [30]. In addition to material rewards, positive feedback and recognition are also important motivational means. Timely and positive feedback can improve employee job satisfaction and motivation. Employees should receive sufficient information in the decision-making process so that they can effectively participate in discussions and negotiations, including transparent sharing of company strategies, policy changes, etc. This will positively give employees a great sense of participation and ownership, while encouraging them to participate in discussions related to their work. This not only improves the quality of decision-making, but also enhances their sense of participation and belonging [31]. A safe and free speech environment allows employees to fully express their opinions, which will positively enhance their recognition of the company. In the career process, providing training opportunities that align with employees' career development goals and current job requirements, including skill enhancement, career planning, and personal development plans, can effectively provide employees with opportunities for growth and development. Emphasizing the individual development space of employees and providing support for their growth paths, a fair, transparent, and conducive work environment can help improve employee satisfaction and loyalty, and significantly enhance the overall performance and competitiveness of the organization.

The work performance scale can be explained from two aspects: task execution and relationship performance. Task execution mainly focuses on the individual's performance in completing job responsibilities, including evaluating the degree of contribution of employees to project or team goals, examining the efficiency and timeliness of employees completing tasks, and the degree of utilization of their own skills and abilities. Relationship performance focuses more on how employees interact with others within the team and organization,

Table 3.1: Dimensional hierarchy meaning of three types of scales

Scale	Variable dimension	Measurement dimension	
Positive human resources practice	Fair rewards and punishments	A	Rewards and punishments corresponding to performance evaluation
		B	Satisfaction with the performance evaluation process
		C	Fairness of performance results
		D	Reasonable positive result feedback
	Participatory decision making	A	Early notification of negotiations
		B	Participate in problem discussions
		C	Freedom and feasibility of expression
	Growth opportunities	A	Rich training process
		B	Suitability of training
		C	Channels for reasonable promotion
		D	The spatial nature of individual talent development
Work performance	Task performance	A	Contribution to work
		B	Timeliness of work completion
		C	Maximum satisfaction with one's own abilities
		D	Leadership satisfaction with work
	Contextual performance	A	Affirmation of colleagues' abilities
		B	Solving Colleague Difficulties
		C	Communication in work
		D	Positive communication of work intentions and opinions
		E	Relative fairness in work interaction
		F	Respect the differences of colleagues
Work involvement	Validity	A	Motivation of work
		B	Work enthusiasm
		C	Overcoming work difficulties
		D	Continuity of working hours
		E	The energy of work
	Dedication	A	The value of work
		B	Recognition of work
		C	Work satisfaction
		D	Positive affirmation of work
	Attraction	A	Neglectiveness of work time
		B	Uniqueness of work
		C	Favorability of work

and how this interaction affects the work environment and team dynamics [32]. Leadership's satisfaction with work, recognition of colleagues' abilities, problem-solving skills, communication skills, fair and just treatment of each colleague, and respect for differences in background and perspectives among colleagues, the above contents work together to improve the overall efficiency of employees, enhance team collaboration, promote a positive work environment, and thus enhance the overall performance of the organization. The work participation scale is an important indicator to measure the level of employee participation and engagement in work, usually including three dimensions: vitality, dedication, and attractiveness. Each dimension has a significant impact on the overall work performance of employees and the health of the organization. Work validity includes the persistence of employees in their work, including intrinsic drive, work enthusiasm, ability to solve difficulties, and focus. Dedication reflects the emotional investment and sense of identification of employees in their work, including their understanding of the importance and value of work, as well as their satisfaction with the work environment, conditions, and content. Attraction refers to the degree to which a job attracts employees, which affects their loyalty and long-term engagement in the job. High levels of job engagement are usually associated with higher job satisfaction, lower employee turnover rates, and higher job performance. PHRP is the process by which an organization develops and implements policies that address the individual needs and development of its employees. Employee performance and job content are significantly impacted by management effectiveness, which also helps to promote employee loyalty to the company, lower turnover rates, and successful long-term personal development. Employees therefore place greater emphasis on performance appraisal, training and

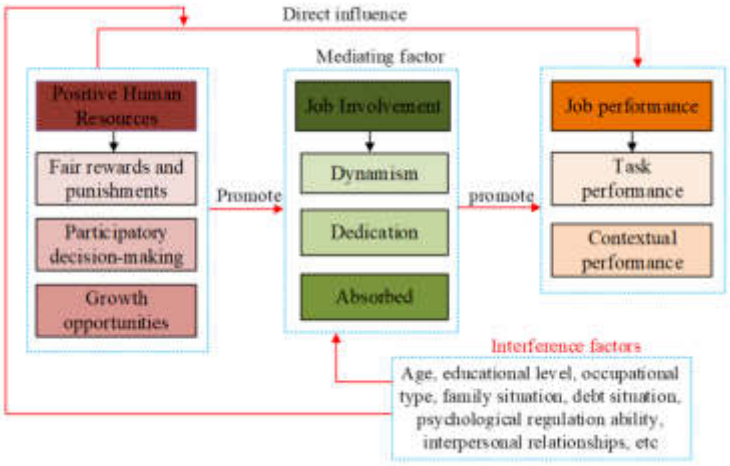

Fig. 3.2: Schematic diagram of internal mechanism relationship

promotion under the scale dimension, as well as on their sense of autonomy and the growth of their personal talents. Communication is key to the success of positive HR. Leaders use good communication to build trust and transparency between themselves and their employees, so that employees feel that their work is taken seriously [33]. It can be said that there is a certain backward and forward linkage and influence effect between HR practices, work performance and work commitment, and grasping this effect can effectively provide reference value for enterprise development and personal growth. The purpose of the study is to use questionnaire results and statistical analysis to understand how PHRPs affect employee performance, and to reveal its underlying mechanisms, including the impact of work engagement on PHRPs and employee performance, as well as related mediating effects. At the same time, based on literature review and empirical results, it aims to provide better guidance and suggestions for enterprise managers and HRs professionals in formulating and implementing HRs strategies, promote enterprise development, and apply HRs practices to improve overall employee performance and drive organizational goals in a timely manner. Figure 3.2 is a schematic diagram of the internal mechanism relationship of the research content.

In this graph, work engagement is mainly a mediating factor, manifested in three aspects: validity, dedication, and abstraction. Positive work engagement can promote PHRP development and also enhance employee performance capabilities. Age, educational level, occupational type, family situation, debt situation, psychological regulation ability, interpersonal relationships, and other factors can all affect the degree of work engagement. PHRPs mean that the overall management ability of the enterprise has been improved, which has a positive promoting effect on employee performance. The study collected raw data through online surveys, distributed a total of 350 questionnaires, collected 350, and had 338 valid questionnaires.

The study focused on the employees of some foreign trade enterprises in Shanghai, China, and collected data on their basic information. Subsequently, they were invited to participate in the experimental design using the three scales designed for the study. The determination of sample size is influenced by various factors, including research design, survey objectives, population size, expected confidence levels and confidence intervals, data availability, budget and time constraints, etc. Considering the issues of this study, the ratio of sample size to population size in the research design was 1:1.2, and the confidence interval of the questionnaire results was designed to be 95%. To ensure the comprehensiveness and randomness of the questionnaire distribution, this study conducted a survey using random sampling among selected foreign trade enterprises. A random number list is generated using an online random number generator to randomly select sample units and determine the research subjects to participate in the experiment. And it distributed the scale in paper form and online form such as Questionnaire Star. And when randomly generating data, it needed to ensure that the selection range and number of people are relatively large, and have a high correlation with the dimensions of the scale design as

Table 4.1: Reliability test results

Scale	Total coefficient	Variable dimension	coefficient
Positive human resources practice	0.885	Fair rewards and punishments	0.837
		Decision participation	0.749
		Growth opportunities	0.891
Work performance	0.943	Task performance	0.852
		Relationship performance	0.917
Work involvement	0.936	Vitality	0.863
		Dedication	0.942
		Abstraction	0.851

much as possible, and try to avoid invalid questionnaires, not limited to a single social group [34]. It collected data and information on their basic information, and collated and analyzed the data with three scales designed by the study. Statistical analysis, correlation analysis and regression test analysis on the variables were carried out with the software SPSS22.0, and three hypotheses were put forward:

- H0: There is a positive correlation between fair rewards and punishments, decision-making participation, growth opportunities, and work performance in PHRPs.
- H1: There is a positive correlation between PHRPs and work engagement.
- H2: Work engagement is a mediating variable between PHRPs and work performance.
- H3a: Vitality plays a mediating role in the relationship between PHRPs and work performance.
- H3a: Vitality plays a mediating role in the relationship between PHRPs and work performance.
- H3b: Dedication plays a mediating role in the relationship between PHRPs and work performance.
- H3c: Focusing on mediating the relationship between PHRPs and work performance.

4. Analysis of the empirical results. The Conbach's α coefficient was utilized as an assessment indicator, and the study started with the aid of a reliability test of the three suggested scales to confirm the validity of the data measurement results. If this coefficient was between 0.6 and 0.8, it needed to be reviewed and improved. A result of 0.8 or higher indicated good reliability. Tables 4.1 and 4.2 present the findings.

In Table 4.1, the reliability values of the three scales were all above 0.8, among which the Conbach's α coefficients for positive HR practices, work performance and work engagement were 0.885, 0.943, and 0.936, respectively, and the corresponding meaning contents also showed good reliability, except for decision making participation under resource practices which needs to be corrected. The Conbach's α coefficients of the other sub-dimensions were the KMO index, which is an important indicator of factor analysis, had a value between 0.7 and 0.9, indicating good validity, and if the Bartlett's sphericity test results were highly significant, then the scale was suitable for regression analysis. Table 4.2 displays the validity test's outcomes.

In Table 4.2, the KMO indices for the three scales were 0.867, 0.928 and 0.939, respectively, with good overall validity. The Bartlett's sphericity test results (all significant at 0.000) qualified as independent hypothesis tests. The analysis of the exploratory factors in Table 3 revealed that the factors of the corresponding scales all had eigenvalues above 1 after orthogonal rotation, and the cumulative contribution of the variable components in PHRPs, work performance and work engagement were 26.924%, 53.010%, 69.564%, 26.126%, 51.784%, 35.678%, 55.727% and 73.446%, respectively. The descriptive statistics presented by the three variable dimensions were then analyzed to obtain Table 4.3.

In Table 4.3, fair rewards and punishments had a high mean value (3.4756) in current PHRPs, followed by opportunities for growth. Relationship performance and validity were more important on the Work Performance and Work Engagement scales, with mean values of 4.0966 and 3.5076, respectively. These results suggested that companies are now more concerned with fairness, with better reward and punishment systems and space for growth prospects. Employees are more concerned about maintaining workplace relationships and their own mental state, and having good interpersonal relationships is still a more important concern in the corporate workplace [35, 36, 37]. Table 5 displays the findings from the one-way ANOVA analysis of the prior differences between the demographic factors and the research variables.

In Table 4.4, there is no correlation between the demographic variables and the study variables. But given

Table 4.2: Validity test results

Scale	Validity		
Positive human resources practice	Kaiser Meyer Olkin metric for sampling adequacy		0.867
	Bartlett test	Approximate chi square	1323.032
		Df	55
		Sig.	0.000
	Characteristic explanatory variable		
	Variable components	Extract sum of squares load	
		% of variance	Accumulated%
	1 (2.961)	26.924	26.924
	2 (2.864)	26.071	53.010
	3 (1.821)	16.539	69.564
Work performance	Validity		
	Kaiser Meyer Olkin metric for sampling adequacy		0.928
	Bartlett test	Approximate chi square	3173.687
		Df	170
		Sig.	0.000
	Characteristic explanatory variable		
	Variable components	Extract sum of squares load	
		% of variance	Accumulated%
	1 (4.961)	26.126	26.126
	2 (4.867)	25.672	51.784
Work involvement	Validity		
	Kaiser Meyer Olkin metric for sampling adequacy		0.939
	Bartlett test	Approximate chi square	2781.891
		Df	105
		Sig.	0.000
	Characteristic explanatory variable		
	Variable components	Extract sum of squares load	
		% of variance	Accumulated%
	1 (5.354)	35.678	35.678
	2 (3.012)	20.091	55.727
	3 (2.649)	17.662	73.446

Table 4.3: Descriptive statistical results of scale variable dimensions

Scale	Variable dimension	M±Mean	Std.
Positive human resources practice	Fair rewards and punishments	228±3.475	0.895
	Decision participation	228±3.064	0.947
	Growth opportunities	228±3.443	0.961
Work performance	Task performance	228±3.785	0.761
	Relationship performance	228±4.096	0.704
Work involvement	Vitality	228±3.506	0.884
	Dedication	228±3.393	1.002
	Abstraction	228±3.493	0.851

the reality of the situation where there is some influence of the demographic variables, the study used this statistical variable factor as a control variable. The Pearson correlation analysis between the three scales of the study was then investigated and the results are shown in Table 4.5.

In Table 4.5, all dimensions between positive HRs and work engagement and work performance showed good correlations and all were significantly positive at the 0.01 statistical level ($P<0.01$). The relationship between the variables was then tested with the help of regression analysis, which enables a quantitative analysis of the dependencies between the variables, and a hypothesis study was conducted with regression analysis, the results of which are shown in Table 4.6.

In Table 4.6, there were significant positive correlations between the dimensions of PHRPs and work engagement and performance, with regression coefficients of 0.657, 0.591, and 0.721 for the three dimensions of vitality and HR practices, coefficient values of 0.614, 0.615, and 0.751 for the three dimensions of dedication and

Table 4.4: Differences analysis results of variables

Statistical variables		Fair rewards and punishments	Participatory decision making	Growth opportunities	Validity	Dedication	Abstraction	Task performance	Relationship performance
Gender	F	5.472	10.294	6.214	6.114	0.385	6.208	4.032	1.598
	Sig.	0.474	0.352	0.336	0.337	1.393	0.336	4.871	0.579
Age	F	1.178	2.136	0.579	2.507	0.664	0.689	0.332	0.387
	Sig.	0.538	0.485	1.366	0.435	2.978	1.055	2.776	1.328
Education	F	1.248	1.469	0.705	1.770	0.354	2.793	0.367	0.724
	Sig.	3.155	0.654	5.830	0.539	3.072	0.383	1.101	0.623
Job content	F	0.359	2.649	0.401	3.31	0.364	1.913	0.826	2.396
	Sig.	0.586	0.395	0.421	0.352	2.627	0.512	4.699	0.424
Title	F	1.171	2.433	1.579	0.396	0.398	1.936	0.395	1.052
	Sig.	1.468	0.42	0.503	2.897	2.282	0.507	2.753	0.854
Working hours	F	0.651	1.619	1.228	0.375	0.441	1.436	0.386	0.947
	Sig.	1.467	0.596	6.214	0.692	1.289	6.208	0.545	0.919
Unit Dependency Quality	F	0.651	0.594	0.336	1.094	0.723	0.336	1.199	1.598
	Sig.	5.472	1.164	0.579	6.114	0.385	0.689	4.032	0.579

Table 4.5: Correlation analysis between PHRPs, work engagement, and work performance

Positive human resource practice and work engagement						
Variable	Fair rewards and punishments	Decision participation	Growth opportunities	Vitality	Dedication	Abstraction
Fair rewards and punishments	1	-	-	-	-	-
Decision participation	0.575**	1	-	-	-	-
Growth opportunities	0.571**	0.573**	1	-	-	-
Vitality	0.495**	0.571**	0.608**	1	-	-
Dedication	0.516**	0.513**	0.632**	0.794**	1	-
Abstraction	0.487**	0.405**	0.567**	0.736**	0.836**	1
Positive human resource practice and job performance						
Variable	Fair rewards and punishments	Decision participation	Growth opportunities	Task performance	Relationship performance	
Fair rewards and punishments	1	-	-	-	-	
Decision participation	0.575**	1	-	-	-	
Growth opportunities	0.571**	0.573**	1	-	-	
Task performance	0.319**	0.342**	0.432**	1	-	
Relationship performance	0.465**	0.371**	0.467**	0.643**	1	

resource practices, coefficient values of 0.588, 0.612, and 0.674 for the three dimensions of focus and resource practices, and Hypotheses 1 and 2 hold. The results of the correlation and regression tests between work engagement and work performance were analyzed and the results are presented in Tables 4.7 and 4.8.

In Table 4.7, there was a positive correlation between the dimensions of work engagement and work performance ($P<0.05$), and the largest correlation value was reached between focus and relationship performance (0.517). The regression results for both were analyzed and the results are shown in Table 4.7.

The regression analysis revealed a significant positive relationship between the dimensions of work engagement and job performance, with regression coefficients of 0.469, 0.466, 0.536, 0.562, 0.521, and 0.567 for the three dimensions of work engagement and work performance and relationship performance, respectively. The findings supported the validity of Hypothesis 3. According to the data above, there was a connection between HR management strategies, employee engagement, and work performance. With the aid of the SPSS 22.0 analysis tool, the study thus examined whether work engagement has a mediating influence. The results are presented in Table 4.9.

Table 4.6: Regression analysis results between positive human resource practices and work engagement and performance

Variable dimension		β	t value	Adjusted R2	F value
Vitality	Positive human resources practice	0.772	15.124***	1.541	84.661
	Fair rewards and punishments	0.657	11.727***	1.426	51.898
	Decision participation	0.591	10.176***	1.372	39.751
	Growth opportunities	0.721	13.356***	1.469	63.059
Dedication	Positive human resources practice	0.781	15.102***	1.522	14.609
	Fair rewards and punishments	0.614	10.585***	1.373	40.236
	Decision participation	0.615	10.533***	1.364	38.553
	Growth opportunities	0.751	14.115***	1.489	137.128
Abstraction	Positive human resources practice	0.691	12.392***	1.428	105.414
	Fair rewards and punishments	0.588	9.907***	1.342	34.222
	Decision participation	0.612	7.901***	1.264	42.19
	Growth opportunities	0.674	11.949***	1.412	97.932
Work performance	Positive human resources practice	0.501	8.343***	1.310	20.212
	Fair rewards and punishments	0.382	6.070***	1.247	12.163
	Decision participation	0.394	6.276***	1.253	26.635
	Growth opportunities	0.492	8.152***	1.315	19.438
Contextual performance	Positive human resources practice	0.661	10.571***	1.375	40.656
	Fair rewards and punishments	0.558	9.347***	1.331	32.024
	Decision participation	0.434	6.104***	1.227	31.116
	Growth opportunities	0.576	9.740***	1.344	34.675

Table 4.7: Correlation between work engagement and work performance

Variable	Vitality	Dedication	Abstraction	Work performance	Relationship performance
Vitality	1	-	-	-	-
Dedication	0.776**	1	-	-	-
Abstraction	0.752**	0.817**	1	-	-
Work performance	0.449**	0.508*	0.445**	1	-
Relationship performance	0.471**	0.511**	0.517**	0.617*	1

In Table 4.9, when the dependent variable was relational performance, the control variables of educational attainment and working hours showed high significance, with the coefficient in model 1(education) = 0.157 and the coefficient (work time) = 0.182, and the p-values for both were less than 0.05. And when work performance was the dependent variable, its regression coefficient under the control and independent variables had a maximum value of 0.524, which was highly significant on a two-sided test relationship (P<0.001). When work engagement was the mediating variable, the regression coefficients of relational performance and task performance on validity, dedication and concentration in work engagement under the control and independent variables were 0.257, 0.374, 0.276, 0.228, 0.287 and 0.326, respectively, and they showed a good correlation (P<0.001). The above results suggested that work dedication played a partially mediating role between HR practices and work performance, and that it was also influenced to some extent by the interference of other factors.

The results showed that HR practices and their dimensions had a significant positive impact on work engagement and its dimensions. This indicated that caring, fair, respectful, valuing, and cultivating HR practices had a significant promoting effect on employee work attitudes, and could improve employee work efficiency. As a whole, PHRPs have a greater impact on work engagement than a single dimension. Specifically, the impact of growth opportunities was most significant. When organizations enhanced employee passion and motivation through training and promotion, a fair and reasonable reward and punishment system could guide employee behavior, enhance their sense of belonging and ownership of the company. The three dimensions of positive HRs, namely fair rewards and punishments, decision-making participation, and growth opportunities, had a significant positive impact on work engagement and performance. The most significant effect was growth opportunities, followed by fair competition. Therefore, to further promote HR management in enterprises, the

Table 4.8: Regression results between job engagement and job performance

Variable dimension		Standard regression coefficient	t value	Adjusted R2	F value
Task Performance	Work engagement	0.479	9.179**	0.308	34.726
	Vitality	0.469	7.797**	0.249	26.541
	Dedication	0.466	7.716**	0.246	26.088
	Abstraction	0.536	9.226**	0.311	35.074
Contextual performance	Work engagement	0.595	10.389**	0.319	106.924
	Vitality	0.562	9.574**	0.282	90.912
	Dedication	0.521	8.679**	0.243	74.691
	Abstraction	0.567	4.212**	0.289	93.602

Table 4.9: Test results of mediating effect

Dependent variable		Contextual performance						Work Performance			
Model		1	2	3	4	5	6	7	8	9	10
Control variable	Gender	-0.048	0.034	0.034	0.032	0.035	-0.003	0.111	0.113	0.108	0.115
	Age	0.015	-0.005	-0.013	0.002	-0.013	0.126	0.135	0.125	0.137	0.127
	Education	0.157*	0.163*	0.156*	0.134*	0.157*	0.004	0.008	0.004	-0.016	0.003
	Job content	-0.032	-0.027	-0.031	0.001	-0.031	-0.084	-0.073	-0.075	-0.045	-0.075
	Title	0.091	0.056	0.027	0.033	0.053	0.075	0.025	0.004	0.008	0.019
	Working hours	0.182*	0.203*	0.186*	0.1645*	0.182*	-0.004	0.027	0.012	-0.006	-0.001
	Unit Dependency Quality	-0.006	-0.004	-0.011	0.026	0.014	-0.083	-0.081	-0.087	-0.062	-0.063
	Human resources practice	-	0.418***	0.255*	0.179*	0.258*	-	0.524***	0.367**	0.351***	0.345***
Mediating variable (work engagement)	Vitality	-	-	0.257**	-	-	-	-	0.228**	-	-
	Dedication	-	-		0.374***	-	-	-	-	0.287***	-
	Abstraction	-	-	-	-	0.276***	-	-	-	-	0.326***
δR^2		-	-	-	-	0.258	-	-	-	-	0.338
F		2.278***	8.022***	8.573***	10.438***	9.227**	1.156***	10.958***	11.054***	11.927***	13.036***

following suggestions are proposed:

1. Starting from the establishment and improvement of training mechanisms and employee career planning, providing employees with a learning foundation and growth space. Specifically, it is important to explain the importance of improving employees' self-learning ability and participating in organizational training, helping them specify learning content, focusing on capacity building, and improving their ability level. Enterprises should also provide employees with a training system that can help them develop comprehensively, make corresponding adjustments based on their work content, age, work experience, etc., enrich training methods, build a "learning organization", and motivate employees to participate in enterprise training. Enterprises also need to help employees formulate career development plans, help them recognize their strengths and weaknesses, and promote their comprehensive development in addition to realizing their contribution value to the enterprise.

2. Establish a fair competition mechanism and encourage employees to participate in management and make independent decisions: Enterprise organizations should establish a fair competition mechanism, which is fair, competitive, and selecting talents based on merit, in order to enhance employee work engagement and maximize the utilization of HRs. Encouraging employees to participate in transparent and fair decision-making can effectively convey their suggestions. Enterprises should dare to delegate power, provide employees with development opportunities, and form a good division within the organization, timely feedback on employee proposals.

3. Strive to improve employee work engagement: Regularly observe employee work attitudes and phased work results, and help them better analyze the reasons for insufficient work engagement or low work effectiveness, solve problems, and help them maximize employee work efficiency.

When using regression analysis to explore the relationship between work engagement as a mediating variable

and PHRP and work performance, choosing education level and work time as control variables is to eliminate the potential impact of these factors on relationship performance as much as possible. The reasons for selecting these specific control variables and how they affect the results are as follows: Education level is often regarded as a predictive factor for employees' ability to analyze and solve problems, which can indirectly reflect an individual's cognitive ability, skill level, and ability to obtain and process information. The level of education received can lead to different behaviors of employees when communicating and interacting with leaders and colleagues. Employees who have received higher education may have more flexible and comprehensive thinking on certain work tasks, and their communication with superiors and colleagues will be more efficient, which can better solve problems within the team. This is closely related to employee work performance, interpersonal relationships, etc.

Working time or years of experience can be used as a representative of work experience. Experienced employees may have a deeper understanding of their work content and work environment, as well as a deeper and more comprehensive understanding of work content and industry development, which can help them better adapt to the work environment and improve their work efficiency. Long term work experience may make employees more proficient in building interpersonal relationships, understanding organizational culture, and managing interpersonal relationships in their work, helping them establish more stable and long-lasting work relationships, which has a promoting effect on the development of their work abilities. Incorporating education level and work time into the model as control variables can more accurately evaluate the impact of PHRPs and work engagement on relationship performance, effectively reducing the bias caused by uncontrollable variable factors on the results, and ensuring the reliability and effectiveness of research results. Simultaneously controlling variables can help explain the variation of outcome variables other than mediator variables and independent variables, which can also enrich the content of research conclusions to a certain extent. In future research, attention can be paid to the time span, and data can be collected from different time periods to reflect practical significance. In the HRs practice testing section, measurements can be taken at the organizational level to reduce the subjectivity of the participants. At the same time, expanding the scope and age stage of sample selection, improving the applicability of application recommendations, and considering the mediating effects of other variables such as work satisfaction, organizational commitment, and power distance orientation, can provide reference value for the enrichment of HR management practice content.

5. Conclusion. The study analyzed different content dimensions based on HR practices and work performance, and explored the mediating role of finding work inputs, tested by regression analysis with variable hypothesis conditions. The results showed that all three scales proposed in the study had good reliability and validity, with their Conbach's α coefficients above 0.8 and Bartlett's sphericity test of 0.000. There was a significant positive relationship between positive HR and work engagement and work performance ($P < 0.01$). The regression results indicated that there were significant positive correlations between the dimensions of PHRPs and work engagement and performance, with regression coefficients of 0.657, 0.591 and 0.721 between the three dimensions of vitality and HR practices and coefficient values of 0.614, 0.615 and 0.751 for the three dimensions of dedication and resource practices. Hypothesis 1 and Hypothesis 2 were valid. The regression coefficients between the three variables of work engagement and task performance and relationship performance were 0.469, 0.466, 0.536, 0.562, 0.521, and 0.567, respectively, proving that Hypothesis 3 holds. And the results of the mediating effect indicated that the control variables of education and working hours showed high significance when the dependent variable was relationship performance. When work performance was the dependent variable, its maximum regression coefficient under the control and independent variables was 0.524 ($P < 0.001$). When work engagement was the mediating variable, the regression coefficients of relationship performance and task performance on energy, dedication and concentration in work engagement under the control and independent variables were 0.257, 0.374, 0.276, 0.228, 0.287 and 0.326, and they showed a good correlation ($P < 0.001$). The mediating effect shown by work engagement can effectively help companies to have better targeting in resource management and work performance adjustment. Work engagement plays a mediating role in HR practice and work performance. Based on the survey results, companies can strengthen HR practice and work performance management by increasing employee work engagement. Specifically, the content can be expanded from the following aspects:

1. Provide positive feedback and recognition, create opportunities for growth and development: Give

positive recognition and rewards to employees for their contributions and contributions to the company, and help employees recognize their importance to the company's development. At the same time, provide employees with maximum opportunities for development and promotion, help them plan their career well, and encourage them to develop personal career skills and abilities.

2. Ensure the establishment of a relatively fair and reasonable salary system, adjust working hours, and provide multiple office options when conditions permit, so that employees have other time and energy to balance work and life in their spare time.
3. Strengthen participatory management and increase work autonomy: Encourage employees to participate in the decision-making process, including project planning, goal setting, and solution selection, giving them greater control and decision-making space, enhancing their sense of belonging, mission, and responsibility towards the enterprise.
4. Create a diverse and inclusive work environment, strengthen the construction of the company's spiritual culture: Respect the differences of each colleague with an open and inclusive work attitude, ensure that they feel accepted and respected in their work, and transparent communication methods, so that employees have a clear and recognized understanding of the company's development direction and goals. At the same time, it is necessary to actively establish a team culture, organize team building activities, emphasize the importance of teamwork and positive communication, and thereby improve employee retention rates and enhance their work performance. Enhancing the sample size and scope of selection is an important element of subsequent research for improvement.

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THE RECOGNITION OF AEROBICS MOVEMENTS USING BONE DATA COMBINED WITH ST-GCN

HUAHUA YANG*, YANSHENG ZHAO† AND LI XIA ‡

Abstract. To solve the aerobics action recognition and promote the gradual intelligence and standardization of aerobics teaching and evaluation, a network model based on spatial temporal graph convolution and combined with attention mechanism was proposed. This model improved the extraction efficiency of spatiotemporal features and channel features by introducing spatiotemporal graph and channel attention mechanisms, respectively, thereby improving the accuracy of action recognition. And a time extension module was introduced into each basic module, and additional features between adjacent vertices were extracted by extending the time graph between frames. These experiments confirmed that this model exhibited high accuracy in identifying aerobics movements. The recognition accuracy of basic actions was above 93.6%, and the recognition accuracy of two actions had reached 98.4% and 98.6% respectively. For advanced actions, the recognition accuracy of the model had slightly decreased, but the average value was still above 95%. The accuracy of difficult motion recognition had also achieved good results, reaching a maximum of 94.5%. These data indicate that this model can achieve high accuracy in handling action recognition tasks of different difficulty levels, and can identify aerobics movements of different difficulty levels.

Key words: Bone data; Graph convolution; Attention mechanism; Time extension; Multi-stream network

1. Introduction. The evolution of computer vision and artificial intelligence has made action recognition increasingly important in various application scenarios. Aerobics, as a highly technical and artistic sports event, has extremely high requirements for the accuracy of movements [1-3]. The development of aerobics education has made great progress with the combination of computer learning and artificial intelligence technology. The movement recognition of aerobics provides effective help for accurate learning of aerobics and time love you. In addition, the motion recognition for aerobics has broad application prospects in education, sports rehabilitation, and personal fitness [4-5]. However, due to the complexity and diversity of aerobics movements, there are still many difficulties in using computers to achieve high-precision recognition of these movements. There is time dimension information in the aerobics movement, and the movement recognition needs to extract both spatial and temporal features. The lack of feature information will reduce the efficiency of the aerobics movement recognition. ST-GCN can extract spatial and temporal features at the same time, record joint motion information more completely, reduce the input of redundant information, and improve the efficiency of model recognition. Effective aerobics movement recognition can improve the irregular movement and improve the efficiency of teaching and training. Therefore, researching an efficient and accurate method for identifying aerobics movements has strong practical significance and scientific value. The research combines bone data and existing Spatial Temporal-Graph Convolutional Network (ST-GCN) to improve action recognition by introducing Attention Mechanism (AM), Time Extension Module (TEM), and multi-stream integration. Graph Attention Network(GAT) is introduced on the basis of ST-GCN to improve the poor flexibility of GCN. In order to strengthen the optimization of time graph, a time extension mode TEM is introduced creatively on the basis of this model. The model simply and effectively extracts the relevant features of multiple adjacent joints in human motion, which further improves the accuracy of the model. The aim is to achieve accurate recognition of aerobics actions and hope to provide valuable reference and inspiration for related fields, promoting intelligence and automation in aerobics teaching, training, and other aspects. The article first summarized the current re-

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search status of action recognition both domestically and internationally. Secondly, the improvement measures for ST-GCN were presented in detail. The third section described the results obtained from model validation through experiments. Finally, a comprehensive summary of this study was conducted, and the shortcomings and future prospects were proposed.

2. Related works. Early action recognition methods for bone data used manual feature extraction to model spatiotemporal correlations, without considering the internal connections between human joints. Deep learning effectively solved this problem. At present, there are three main methods in the human skeleton motion recognition: Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), and GCN [6-7]. Muhammad K et al. proposed an AM based on Bidirectional Long-Short Term Memory (BiLSTM) to address the visual performance issues of existing motion recognition techniques in video frames during the training phase, and combined it with an expanded CNN. The recognition rates of this method on UCF11, UCF motion, and J-HMDB datasets reached 98.3%, 99.1%, and 80.2%, respectively [8]. Yang H et al. proposed a Space-Time Attention CNN that integrated temporal and spatial AM into a unified convolutional network, and mining time fragments through temporal attention mechanism. The non-moving regions are then focused through training by averaging the auxiliary classification losses of the pooling layer. The accuracy of the proposed model on UCF-101 dataset and HMDB-51 is 95.8% and 71.5%, respectively, and the performance is relatively advanced [9]. Zhang X et al. integrated spatial and temporal neighboring edges to represent an edge in a human skeleton graph, and designed a graph edge CNN. Experiments on the Kinetics and NTU-RGB+D datasets confirmed that the graph edge convolution effectively captures moving features, and CNN's graph edge was superior to other advanced existing bone-based action recognition methods [10].

In RNN-based methods, human skeleton data are treated as a series of vectors, which help to better explore the temporal correlations between human skeleton data. Avola D et al. proposed a novel method for motion recognition in video sequences by combining 2D bone data and dual branch stacked LSTM. This method used 2D bones reconstructed from RGB video streams and used 3D-CNN to process missing bone data. The comparison on the UT Kinect and NTU-RGB+D datasets confirmed that the accuracy of this method was completely equivalent to that of works based on 3D bones [11]. Xu S et al. integrated GCN into LSTM, utilized skeletal body structure information and enhanced multi-level co-occurrence feature learning, and used parallel LSTM to model the temporal dynamics of aggregated features for action recognition. The proposed model has obvious superiority on NTU RGB+D 60/120 data set and NTU RGB+D 60/120 data set [12]. Zhu A et al. proposed an end-to-end bidirectional LSTM-CNN and employed a layered spatiotemporal dependency model to explore the rich spatiotemporal information in bone data. In the fusion framework of CNN and LSTM, bone data were constructed from a dependency model and used as input to the proposed network. Its effectiveness had been verified on different datasets [13].

Human skeleton data exists in the form of graphs, and using topology maps is more suitable for expressing skeleton data. Shi L et al. proposed a novel multi-stream attention enhancement adaptive GCN. This structure could be learned in an end-to-end manner based on input data. In addition, a multi-stream framework including moving data had shown significant improvements in recognition accuracy [14]. Zhang Z et al. proposed a novel structure feature fusion adaptive GCN model, which could effectively fuse the topological structure of bone maps and joint features. Experiments on different datasets had confirmed that the improved GCN outperformed existing state-of-the-art methods, with an average accuracy improvement of over 0.6% [15]. Tsai M F and Chen C H proposed a new training way for emotion recognizing, which used bone detecting way to obtain bone points' changing degree and used nearest neighbor algorithms for classifying speed. Compared with the basic method, the ST-GCN technology that considered changes could enhance recognizing accuracy by over 50% [16].

Based on relevant research both domestically and internationally, GCN has become a hot topic for human skeleton motion recognition due to its excellent performance in graph data with topological structures. Among them, ST-GCN is a groundbreaking research work that successfully applies GCN to human skeleton motion recognition tasks. However, ST-GCN still has drawbacks such as inflexible weight allocation and failure to distinguish redundant information. Therefore, based on bone data and combined with GCN, the study aims to use computer technology to achieve higher precision action recognition and apply it to the intelligent teaching of aerobics.

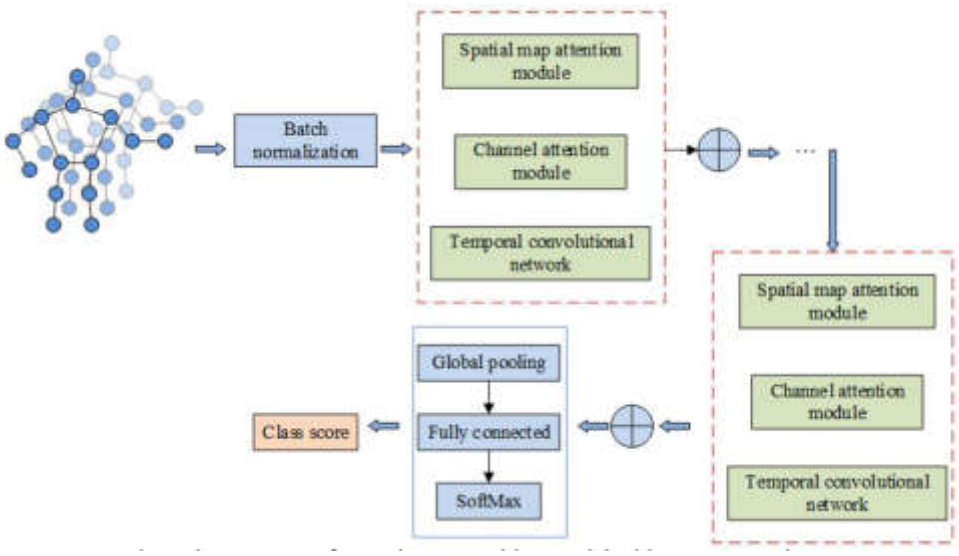

Fig. 3.1: The structure of an action recognition model with ST-GCN and AM

3. The recognition and improvement of aerobics movements using bone data combined with ST-GCN. On the basis of analyzing the existing defects of ST-GCN and combining the characteristics of bone data, an improved action recognition model is proposed. Firstly, for the weight allocation in GCN, GAT is used to improve the original GCN, and a Channel Attention Module (CAM) is added to focus on more important channel information. Although GAT can extract spatiotemporal features, it is easy to overlook the optimization of inter frame time maps. Therefore, the study further introduces TEM and proposes an integrated framework using multi-stream networks to fuse information to improve the accuracy of action recognition.

3.1. An action recognition model based on ST-GCN combined with AM. The composition of human bones and joints can naturally form a topological map. GCN has excellent performance in processing graph structured data, therefore it is widely used in action recognition based on human skeleton. However, for human motion data, the human motion skeleton map is composed of time series, and the time information covers the spatial characteristics at each time node and the temporal characteristics between frames [17]. Therefore, how to cleverly use graph convolution to extract spatiotemporal features in human motion has become a research focus of skeleton-based action recognizing way. A spatiotemporal graph attention model based on ST-GCN combined with AM is proposed to improve GCN'S poor flexibility and action recognizing accuracy in Figure 3.1.

From Figure 3.1, the improved spatiotemporal graph attention model constructs a human skeleton spatiotemporal graph using human skeleton data, and then introduces GAT [18] and multi-head graph AM on the basis of ST-GCN to enhance model's performance. In addition, to further improve its accuracy, CAM is introduced to make the model concerned with more important channel information. The basic unit of the Spatiotemporal Graph Attention Model (SGAM) consists of three parts: firstly, the spatial graph attention module, secondly, CAM, and finally, the time convolution module with a kernel size of 9. The spatial graph attention module utilizes Graph Attention Network (GAT) to partially replace the original GCN to improve recognition rate. The proposed spatial graph attention module includes a GAT layer that can better extract spatiotemporal layer features, as well as a set of batch regularization layers and a set of ReLU activation function layers. Then there is CAM, which uses AM for channels with different semantic features, making the network more focused on more important channel characteristics, thereby reducing redundant features. And each unit contains a residual module. ST-GCN applies graph convolution to the spatiotemporal graph structure, and Figure 2 shows the overall processing flow.

From Figure 3.1, ST-GCN first extracts the skeleton sequence of actions from the input video using a

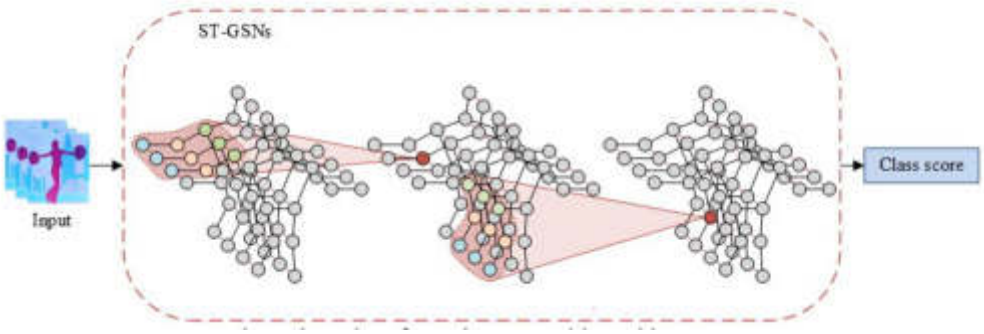

Fig. 3.2: Flow chart for action recognition with ST-GCN

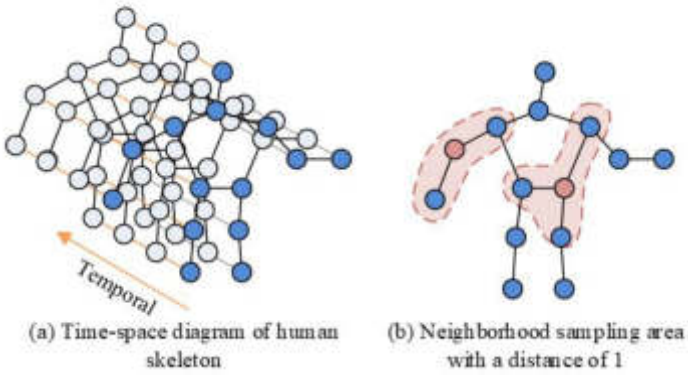

Fig. 3.3: The spatiotemporal structure of human skeleton and its sampling function

pose estimation algorithm, and constructs a spatiotemporal map of the human skeleton based on the skeleton sequence. Then, the joint coordinates of the human body are interconnected as input to ST-GCN, and multiple graph convolution modules are used to automatically extract spatiotemporal features [19]. Each module consists of GCN and TCN. Finally, the results of action classification are obtained through a SoftMax classifier. When constructing a spatiotemporal map of human skeleton, its spatiotemporal sequence is connected into a spatiotemporal map $G = (V, E)$ according to the given rules. V represents the set of joint points in a spatiotemporal graph. E represents a set of edges. The set of joint points includes the natural joint points of the human body on each frame, denoted as $V = \{v_{ti} | t = 1, 2, \cdots, T, i = 1, 2, \cdots, N\}$. T is the amount of frames in a continuous video. N is the amount of human joint points at a certain frame. The set of edges is composed of two subsets: spatial edge $E_S = \{v_{ti}v_{tj} | (i, j) \in H\}$ and temporal edge $E_F = \{v_{ti}v_{(t+1)i}\}$. H is a set of naturally connected human joints. In the spatial graph attention module, formula (3.1) is the sampling function $p(v_{tj}, v_{ti})$ of the graph structure.

$$\begin{cases} B(v_{tj}) = \{v_{tj} | d(v_{tj}, v_{ti}) \leq D\} \\ p(v_{tj}, v_{ti}) = v_{tj} \end{cases} \tag{3.1}$$

In formula (3.1), $B(v_{tj})$ is the set of neighboring pixels in the graph. $d(v_{tj}, v_{ti})$ is the shortest distance between v_{tj} and v_{ti}. D is the distance threshold. Figure 3 shows human skeleton's spatiotemporal structure and the neighborhood sampling area with a distance of 1 from the human skeleton.

To obtain the attention coefficient of the spatial graph, the feature dimension of the central node and its surrounding neighboring nodes is first improved. For the central node v_{ti} and its neighboring node v_{tj} within

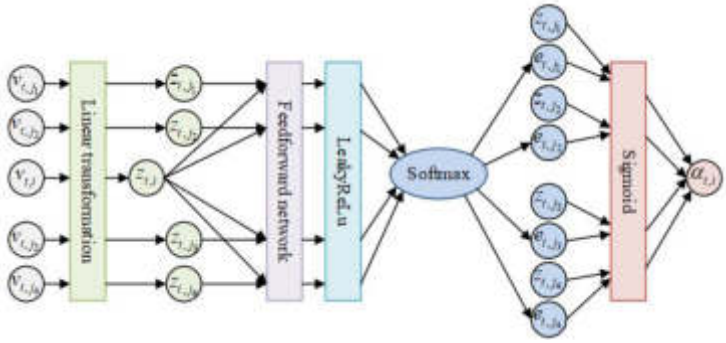

Fig. 3.4: The calculation of attention coefficients in spatial maps

a certain frame t, a weight matrix W is introduced to achieve shared linear transformation of the nodes, to obtain higher dimensional features. Formula (3.2) is a node linear transformation.

$$\begin{cases} z_{ti} = W f_{in}\left(v_{ti}\right) \\ z_{tj} = W f_{in}\left(v_{tj}\right) \end{cases} \tag{3.2}$$

In formula (3.2), $f_{in}\left(v_{ti}\right) \in \mathrm{R}^{C}$ and $f_{in}\left(v_{tj}\right) \in \mathrm{R}^{C}$ represent the input feature vectors of two nodes, respectively. The transformed vectors z_{ti} and z_{tj} are concatenated to obtain a new dimension vector, and the attention value e_{tij} of the center node i on node j is calculated in frame t in formula (3.3).

$$e_{tij} = LeakR\left(\vec{a}^{\mathrm{T}}\left[z_{ti} \| z_{tj}\right]\right), j \in B\left(v_{ti}\right) \tag{3.3}$$

In formula (3.3), $LeakR\left(\bullet\right)$ is the activation function. a represents a single-layer feedforward neural network. Formula (3.4) is the attention coefficient α_{tij} of each neighboring node towards the central node v_{ti}.

$$\alpha_{tij} = \frac{\exp\left(LeakR\left(\vec{a}^{\mathrm{T}}\left[z_{ti} \| z_{tj}\right]\right)\right)}{\sum_{k \in B\left(v_{ti}\right)} \exp\left(LeakR\left(\vec{a}^{\mathrm{T}}\left[z_{ti} \| z_{tj}\right]\right)\right)} \tag{3.4}$$

Figure 3.4 shows the calculation of attention coefficient in spatial maps.

According to the attention coefficient, the final output $f_{out}\left(v_{ti}\right)$ of the central node in the single head graph AM can be obtained in formula (3.5).

$$\left(\sum_{j \in B\left(v_{ti}\right)} \alpha_{tij} W f_{in}\left(p\left(v_{tj}, v_{ti}\right)\right)\right) = \sigma\left(\sum_{j \in B\left(v_{ti}\right)} a_{tij} z_{tj}\right) \tag{3.5}$$

In formula (3.5), σ is the activation function. The same weight when calculating the output of a single graph's attention is not conducive to the learning ability. Therefore, this study used multi-head spatial graph attention to assign different attention coefficients and weights to different features. Then, the calculated features of $f_{out}\left(v_{ti}\right) = \left\|_{k=1}^{K} \sigma\left(\sum_{j \in B\left(v_{ti}\right)} a_{tij}^{k} z_{tj}^{k}\right)\right.$ independent AMs are concatenated to obtain the final output of each node in formula (3.6).

$$f_{out}\left(v_{ti}\right) = \left\|_{k=1}^{K} \sigma\left(\sum_{j \in B\left(v_{ti}\right)} a_{tij}^{k} z_{tj}^{k}\right)\right. \tag{3.6}$$

By extending the model from the spatial domain to the temporal domain through a dataset composed of different frames of the same joint point, the final set of neighborhood nodes $B^{*}\left(v_{ti}\right)$ for v_{ti} is obtained in formula (3.7).

$$B^{*}\left(v_{ti}\right) \rightarrow \left\{v_{qj} \left| d\left(v_{tj}, v_{ti}\right) \leq K, |q-t| \leq \lfloor \Gamma/2 \rfloor \right.\right\} \tag{3.7}$$

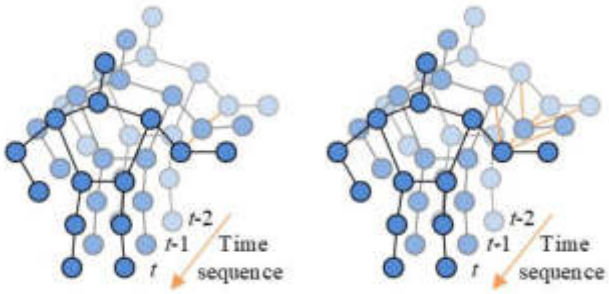

Fig. 3.5: Comparison of spatiotemporal graph connection methods

In formula (3.7), Γ controls the size of the convolution kernel in the time domain. CAM is introduced after the attention module of the spatial map, and the final output $f^*_{out}(v_{ti})$ is obtained in formula (3.8).

$$f^*_{out}(v_{ti}) = f_{out}(v_{ti}) \cdot s_c \tag{3.8}$$

3.2. ST-GCN-GAT action recognition based on multi-stream extension improvement. GAT can extract spatiotemporal features, but it focuses more on representing a more suitable spatial map within frames, which can easily overlook the optimization of inter frame time maps. Therefore, the study introduces a TEM into the model, which expands the time graph by adding connections to adjacent multiple vertices based on inter frame and additional feature extraction. In previous recognition models, most only used joint point data of the human skeleton. Aerobics movements are continuous movements that combine multiple parts. Therefore, to fully utilize bone data, enhance the expression ability and recognition accuracy of the model, a multi-stream network integrated framework model is proposed, in which each network uses the same structure to fuse multiple types of information. Ordinary time convolution can only extract the information of neighboring nodes in the same frame, and cannot extract the information of the same related node and its neighboring nodes between frames. Figure 3.5 shows the connections of the traditional spatiotemporal map [20] and the improved TEM spatiotemporal map.

In Figure 3.5 (b), TEM adds edges to vertices corresponding to the same joint and adds edges to vertices corresponding to multiple adjacent joints between frames, and calculates convolution based on the same multiple vertices between frames. TEM is used to extract inter frame features, as it is added between the spatial attention layer and temporal convolution to expand temporal dimension's sampling area. For the temporal convolution outputting of TEM, formula (3.9) is the $f^*_{out}(v_{ti})$ of the i-th vertex v_i in space at time t.

$$f_{out}(v_{ti}) = \sigma\left(\sum_{v_{(t-1)j} \in B^T(v_{ti})} \alpha_{i,j} W f_{in}(v_{t-1,j})\right) \tag{3.9}$$

In formula (3.9), $\alpha_{i,j}$ represents the attention coefficient between nodes j and i. $B^T(v_{ti})$ represents the inter frame sampling area of v_{ti} in formula (3.10).

$$B^T(v_{ti}) = \left\{v_{(t-1)j} \middle| d\left(v_{(t-1)j}, v_{(t-1)i}\right) \le D^T\right\} \tag{3.10}$$

In formula (3.10), D^T is the maximum length of inter frame sampling. After introducing the SGAM and CAM mechanisms, TEM is introduced to expand time dimension's sampling area and extract the temporal changes of multiple joints in motion. However, the entire network does not fully utilize the skeleton time sequence diagram constructed from human bone data. Therefore, the study proposes to use the same structure to process all data streams in a multi-stream structure, integrating joint and bone information along with motion information into one framework. Figure 6 shows a multi-stream network.

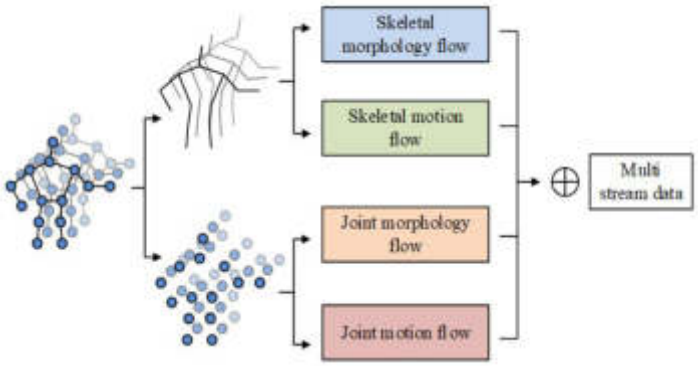

Fig. 3.6: The structure of multi-stream networks

From Figure 3.5, there are four types of branches in the multi-stream network, which are inputted into four streams. The final result is obtained by adding four streams' SoftMax scores. Each human skeleton has a center of gravity point, so the source joint point $v_{i,t} = (x_{i,t}, y_{i,t}, z_{i,t})$ in a pair of adjacent joint points is defined as the node closer to the skeleton's center of gravity, and the other node is defined as the target node $v_{j,t} = (x_{j,t}, y_{j,t}, z_{j,t})$. The vector from the source joint point to the target joint point can represent the length and direction of the bone between two joint points, i.e., the vector $b_{i,j,t}$ of bone in formula (3.11).

$$b_{i,j,t} = (x_{j,t} - x_{i,t}, y_{j,t} - y_{i,t}, z_{j,t} - z_{i,t}) \tag{3.11}$$

Because the skeleton graph is an acyclic data structure, there will eventually be an extra root node without assigning bones. Assigning an empty bone to the root node can design the bone and joint into the same graph and network. Previous studies have confirmed that optical flow fields are suitable for human motion recognition based on RGB videos. Therefore, the study defines the joint coordinate difference between consecutive frames as joint motion information, while the bone coordinate difference is defined as bone motion information. Given the connection $v_{i,t} = (x_{i,t}, y_{i,t}, z_{i,t})$ of frame t and the same joint point $v_{i,t+1} = (x_{i,t+1}, y_{i,t+1}, z_{i,t+1})$ in frame $t + 1$, then formula (3.12) shows the motion information $m_{i,t,t+1}$ between them.

$$m_{i,t,t+1} = (x_{i,t+1} - x_{i,t}, y_{i,t+1} - y_{i,t}, z_{i,t+1} - z_{i,t}) \tag{3.12}$$

The basic Pseudo code for the model is shown in the figure 3.7.

4. Performance analysis of aerobics movement recognition using bone data combined with ST-GCN. To verify the action recognition ability of this proposed model, multiple tests were conducted on two public datasets and a self-made aerobics action dataset. They included action recognition effect verification based on ST-GCN combined with AM, TEM effect verification, and multi-stream network effect verification.

4.1. Action recognition effect based on ST-GCN combined with AM. Two common datasets used in this study were NTU-RGB+D and Kinetic. NTU-RGB+D was collected by the Kinect V2 depth sensor using three different camera angles, containing a total of 56880 video samples for 60 types of actions. The standards for dividing training and testing sets using NTU-RGB+D included Cross-Subject and Cross-View. These actions were performed by 40 people, and a total of 25 skeleton points were collected in the datasets. Kinetics contained the actions of 400 categories of characters, each with at least 400 video clips, each lasting approximately 10 seconds. In order to obtain bone data from Kinetics, the captured raw video is cropped and the frame rate converted. A demonstration by a professional aerobics' teacher was used to shoot and produce sample videos, completing the aerobics dataset. The self-made dataset contained 1800 sample videos, divided into a training set and a testing set in an 8:2 ratio. The spatial dimension features started from 3, and the output feature dimensions for the first three layers, middle three layers, and last three layers were 64, 128,

```python
import torch
import torch.nn as nn
import torch.nn.functional as F

class STGraphConvolution(nn.Module):
    def __init__(self, in_channels, out_channels, graph_matrix):
        super(STGraphConvolution, self).__init__()
        self.graph_matrix = graph_matrix
        self.weight = nn.Parameter(torch.rand(in_channels, out_channels))
        self.bias = nn.Parameter(torch.zeros(out_channels))

    def forward(self, x):
        batch_size, num_nodes, num_frames, num_features = x.size()
        x = x.view(batch_size, num_nodes * num_frames, num_features)  # Reshape for graph convolution

        adjacency_matrix = self.graph_matrix.view(num_nodes, num_nodes).to(x.device)
        adjacency_matrix = F.normalize(adjacency_matrix, p=1, dim=1)  # Normalize adjacency matrix

        x = torch.matmul(x, self.weight)
        x = torch.matmul(adjacency_matrix, x)
        x = x.view(batch_size, num_nodes, num_frames, -1) + self.bias.view(1, -1, 1, 1)

        return x

class STGCN(nn.Module):
    def __init__(self, in_channels, spatial_channels, temporal_channels, graph_matrix):
        super(STGCN, self).__init__()
        self.graph_conv1 = STGraphConvolution(in_channels, spatial_channels, graph_matrix)
        self.graph_conv2 = STGraphConvolution(spatial_channels, temporal_channels, graph_matrix)

    def forward(self, x):
        x = self.graph_conv1(x)
        x = F.relu(x)
        x = self.graph_conv2(x)
        x = F.relu(x)
        return x
```

Fig. 3.7: The basic Pseudo code of the model

Table 4.1: Laboratory hardware and software environment setup

Hardware and software configuration	Version model
CPU	Intel(R)Core i7-9700K
GPU	GTX 1060
Operating system	Ubuntu 16.04.6
RAM	16G
Display memory	6G
Development editor	Pycharm
frameworks	Pycaffe
Python version	2.7

and 256, respectively. After processing through basic units, dropout features were randomly selected with a probability of 0.5. The learning rate was 0.01, multiplied by 0.1 for every 10 epochs, and the batchsize was set to 64. Laboratory environment Settings are shown in Table 1.

The value range of K in multi-head attention was $[2, 9]$. ST-GCN was combined with GAT to construct a recognition model, and the influence of K in multi-head attention was verified on NTU-RGB+D. Figure 8 showed the top-1 results obtained.

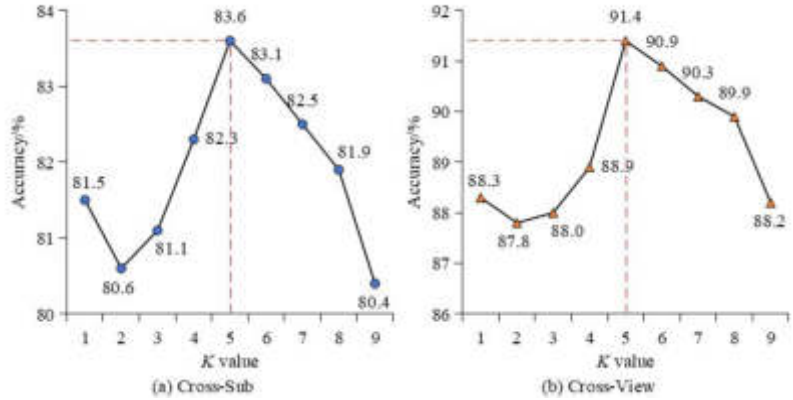

Fig. 4.1: The effect of K on the validation of multiple head attention in NTU-RGB+D

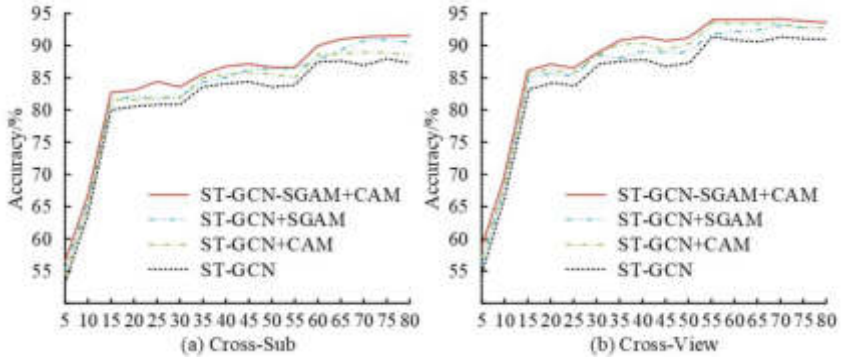

Fig. 4.2: Training curves of different models on datasets

In Figure 4.1, for multi-head AM, the accuracy of this model gradually increased with the increase of K. But before $K = 4$, the performance of this model was not as good as the benchmark ST-GCN. From Figure 8 (a), after K equaled 2, the accuracy first gradually improved, then reached the highest recognition rate of 83.6% when K equaled 5, and then gradually decreased. This indicated that selecting an appropriate K in multi-head attention might improve this recognition model's accuracy, which was consistent with the results obtained by dividing the training set according to Cross-View standard. Therefore, $K = 5$ was set in subsequent experiments. Figure 4.2 showed the training curves of the model in NTU-RGB+D and Kinect.

From Figure 4.2, although all four models tended to stabilize around 60 rounds, the accuracy of ST-GCN with the introduction of SGAM and CAM was higher than that of other models in 80 rounds of training. The study selected Lie Group, Feature Encoding (Feature Enc), Hierarchical-RNN (H-RNN) based method, Deep LSTM, Part-Aware LSTM (PA-LSTM), Temporal Convolution (Temp-Conv), Clip CNN + Muti-task learning (C-CNN+M), ST-GCN, Deep Progressive Reinforcement Learning + GCNN (DPRL+GCNN), and AM-STGCN, Actional-Structural GCN (AS-GCN) to conduct comparative experiments in Figure 4.3.

From Figure 4.3 (a), models such as Temp-Conv, ST-GCN, DPRL+GCNN achieved scores of over 80% on NTU-RGB+D, especially AS-GCN, which achieved scores of 86.8% and 94.2% on Cross-Sub and Cross-View indicators. ST-GCN, which introduced SGAM and CAM, also performed quite well on these two indicators, with scores of 84.2% and 91.9%. Although it was slightly lower than AS-GCN, the difference was not significant. These experiments confirmed that although the introduction of attention modules could effectively improve

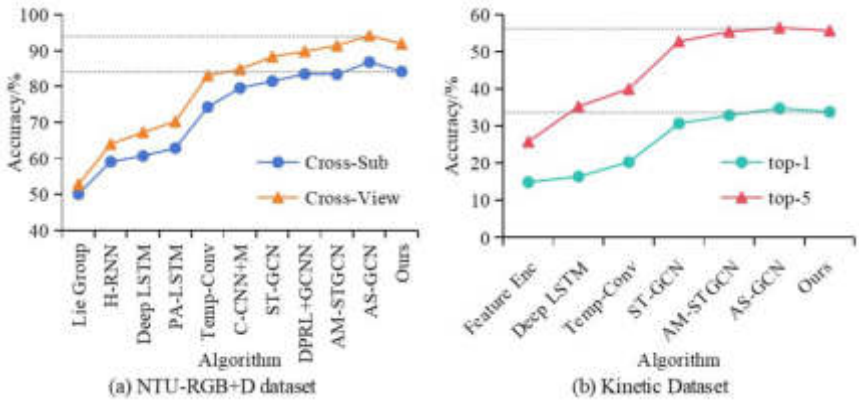

Fig. 4.3: Comparative experimental results on two datasets

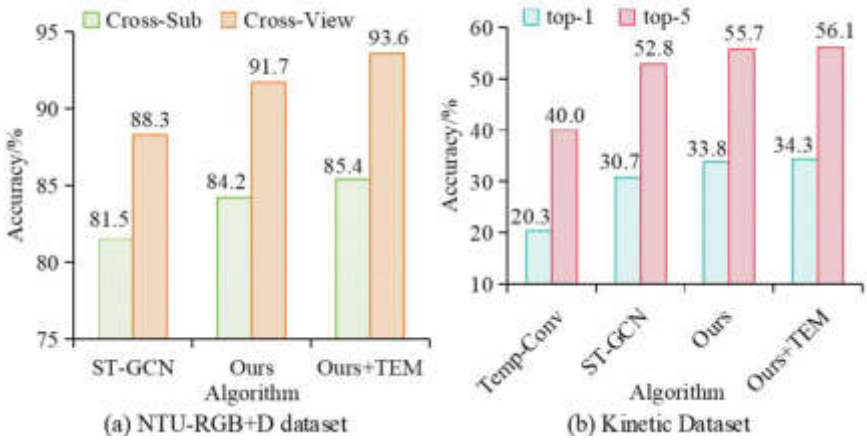

Fig. 4.4: Verification of the optimization effect of TEM

model performance, focusing solely on the relationship between physical adjacent joint points on the skeleton graph was flawed.

4.2. ST-GCN-GAT action recognition effect based on multi-stream extension improvement. The configuration and evaluation indicators of the optimization validation experiment for TEM and multi-stream networks were the same as before. To verify the improvement effect of TEM on the model, ablation experiments were conducted on two datasets in Figure 11. "Ours" in Figure 4.4 represented ST-GCN+SGAM+CAM.

From Figure 4.4 (a), after introducing TEM, the recognition accuracy in Cross-Sub and Cross-View forms had been improved to 85.4% and 93.6%, respectively. In Figure 4.4 (b), before introducing TEM, the top-1 and top-5 accuracy of ST-GCN+SGAM+CAM were 33.8% and 55.7%, respectively. However, after introducing TEM, the scores of these indicators increased to 34.3% and 56.1%. Although the improvement was relatively small, it still indicated that TEM had a certain optimization effect on this model. Figure 4.5 showed a comparative experiment of multi-stream networks on NTU-RGB+D. J represented joint morphology, B represented bone morphology, J-M represented joint motion flow morphology, and B-M represented bone motion flow morphology. The "Ours" here represents ST-GCN+SGAM+CAM+TEM.

From Figure 4.5, the accuracy of the model that only showed joint and bone morphology was similar, with 84.9%, 85.4%, and 93.0%, 92.6%, respectively. Considering the morphology of joints and bones simultaneously,

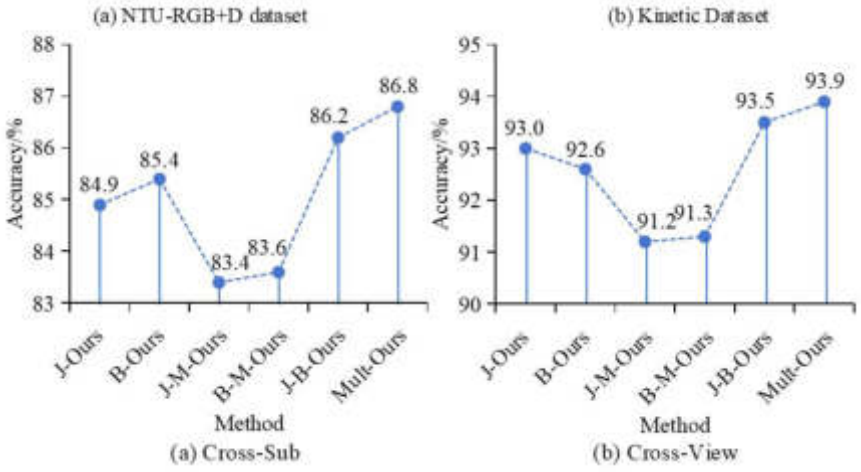

Fig. 4.5: Results of multiteam network comparison experiment on NTU-RGB+D

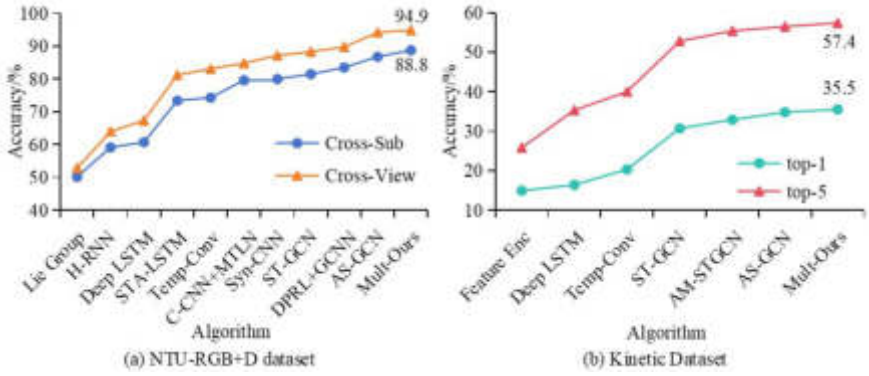

Fig. 4.6: Comparative experimental results of optimized models

the model's effectiveness would be improved, with accuracy rates of 86.2% and 93.5%. After the introduction of multi-stream networks, the accuracy of this model was further improved, reaching 86.8% and 93.9%. This indicated that using a multi-stream network would help improve the model performance. Then, the optimized model was compared with several more advanced methods on NTU-RGB+D and Kinect in Figure 4.6.

From Figure 4.6 (a), the model further optimized using TEM and multi-stream network achieved recognition accuracy of 88.8% and 94.9% under Cross-Sub and Cross-View standards, respectively, achieving better performance than AS-GCN. In Figure 4.6 (b), in Kinect, the improved model had the highest accuracy of top-1 and top-5 among all models, with 35.5% and 57.4%, respectively. This indicated that the optimization effect of this model was very significant, and the optimization strategy could effectively improve the accuracy of model prediction. Multiple models are verified on self-built data sets, and the results obtained are shown in Table 4.2.

As shown in Table 4.2, the model proposed in this study has absolute advantages in accuracy, accuracy, recall and F1-score indicators. The recall rate and F1-score of the model proposed in this study were 89.9% and 91.0%, respectively, with high aerobics action recognition ability. H-RNN model, on the other hand, has poor performance and can not accurately identify aerobics movements. Finally, comparative experiments were conducted on a self-made aerobics dataset to verify the model effectiveness in identifying aerobics movements

Table 4.2: The results of index validation of multiple models

Model	Accuracy%	Precision%	Recall rate%	F1-score%
Mult-Ours	91.8	94.8	89.9	91.0
AS-GCN	90.6	92.5	89.1	90.5
AM-STGCN	86.7	89.0	84.7	89.4
H-RNN	82.1	86.4	81.2	86.6
STA-LSTM	85.4	88.7	83.5	88.9

Table 4.3: The recognition results on a self-made aerobics dataset

Action classification	Action number	Accuracy/%
Basic Actions	A1	97.3
	A2	95.7
	A3	93.6
	A4	98.4
	A5	98.6
Advanced Actions	B1	95.4
	B2	97.6
	B3	93.2
	B4	94.5
	B5	96.2
	B6	95.7
Difficult actions	C1	93.2
	C2	90.3
	C3	91.4
	C4	92.8
	C5	94.5

in Table 4.3.

In Table 4.3, the improved model had good recognition performance for various movements in the aerobics dataset, with an accuracy rate of over 90%. For the basic action part, the recognition accuracy of all five actions was above 93.6%, among which the A4 and A5 actions had the highest recognition accuracy of 98.4% and 98.6%, respectively. For advanced actions, the recognition accuracy of this model had slightly decreased, but the average value was still above 95%. For Difficult actions, although the average recognition accuracy had slightly decreased, the recognition accuracy of C5 actions still reached 94.5%, and the lowest C2 had an accuracy of 90.3%. On the whole, the recognition accuracy of basic movements is high, and the average recognition accuracy decreases gradually with the increase of movement difficulty. Difficult actions often have multiple node data and change rapidly in a short time, and the model can not quickly extract all of them. These data indicated that when identifying difficult aerobics movements, the recognition accuracy of the model could still be maintained at a high level.

5. Conclusion. To achieve accurate recognition of aerobics movements, an improved motion recognition model was proposed by combining bone data and ST-GCN. This model enhanced the extraction of spatiotemporal and channel features by utilizing SGAM and CAM mechanisms, thereby improving action recognizing accuracy. In response to the optimization of inter frame time maps and the sufficient utilization of skeleton information, a TEM was introduced into each basic module, and a multi-stream network containing node information, skeleton information, and their motion information was proposed. This enabled the model to extract information from neighboring nodes between frames and extended the time map on the basis of additional feature extraction. The testing on the self-made aerobics' dataset confirmed that the recognition accuracy of the model for basic movements was above 93.6%. Even in the face of difficult action recognition, the accuracy of this model was excellent, such as the recognition accuracy of C5 actions still reaching 94.5%, with the low-

est C2 being 90.3%. These experiments confirmed that the model had achieved high accuracy in processing basic, advanced, and difficult motion recognition, which helped to promote the development and application of aerobics motion recognition. However, the study only considered motion recognition in single person aerobics. Further optimization can be made for recognition in interactive scenarios between humans and objects. The average accuracy of the model has decreased when it recognizes difficult movements. The subsequent research can improve the average accuracy of the model for difficult movements of aerobics. In addition, the developed model can identify aerobics movements more accurately, and subsequent work can generalize the model and apply it to more scenarios, such as the specific challenges of aerobic exercise.

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APPLICATION OF HETEROGENEOUS DATA ANALYSIS BASED ON SEA GRID IN USER INVESTMENT ANALYSIS

AQIAN LIU* AND SHUKE HUANG†

Abstract. To solve the problem of yield calculation in complex investment scenarios, a time-cost double-weighted rate of return calculation method based on SEA grid is proposed, and its effectiveness is verified by comparing with traditional methods and researching the quantitative evaluation and analysis method of user investment based on structured data. To solve the above problems, a data-heterogeneous federated learning method based on user investment analysis FedPSG is proposed, which changes the data form transmitted from the client to the server from model parameters to model scores, and only a small number of clients need to upload model parameters to the server in each round of training, thereby reducing communication costs. At the same time, a model retraining strategy is proposed, which uses server data to train the global model for second iteration, and further improves the model performance by alleviating the impact of data heterogeneity on federated learning. The method of event dimension analysis of user investment is designed, and a credibility index is proposed to evaluate the analysis results. Experiments show that by combining event data, it can effectively provide users with event factors in the fluctuation of investment profit and loss, and help users better analyze their own investments.

Key words: SEA grid, algorithm, FedPSG, Heterogeneous data, Event Research Method, Structured data

1. Intrdocution. With the continuous development of China's financial market, investors' enthusiasm is increasing, but the individual investment user group tends to be non-professional, and it is difficult to make systematic evaluation and analysis of their own investment. Investment analysis for individual users mainly focuses on some securities investment software, which often only gives simple statistical data and does not carry out systematic analysis. In the face of complex investment scenarios, the existing yield calculation methods have various problems such as yield jump, inconsistency between income and yield, which in turn affects the accuracy of investment analysis, so it is of great value to analyze user investment from a more comprehensive dimension and give intuitive analysis results.

There is currently a lot of research on the application of investment analysis methods. (Fama and French et al.,1992,2015) [1, 2] constructed three-factor and five-factor models to concretize the influencing factors of excess returns, adding the company's market capitalization factor and the ratio factor of book value to market capitalization in addition to the market portfolio return factor of CAPM (Capital Asset Pricing Model), making the model more perfect. The Brinson model (Brinson et al.,1986) [3]is based on the fund's position data to decompose investment income, and only requires the fund's position data disclosed quarterly. With the advancement of technology, methods based on machine learning have developed rapidly. (Yu et al) [4]. proposed an event extraction model combining tree-structured long short-term memory network (Tree-LSTM) and gated recurrent unit network (GRU), and added the dependent syntactic information in the text to the model through the Tree-LSTM structure, which was improved compared with other models. (Li et al.,2020) [5] proposed to treat event extraction as a multi-round question answering task, and use the good performance of the pre-trained model BERT on the machine reading comprehension task to improve the performance of the event extraction task, and (Du et al.2020) [6] designed a new question answering strategy on this basis to further improve the performance. In addition, there are event extraction methods based on graph convolutional neural networks (Nguyen et al.,2018. Yang et al.,2018) [7, 9], and event extraction methods based on adversarial training (Wang X et al.,2019) [10].

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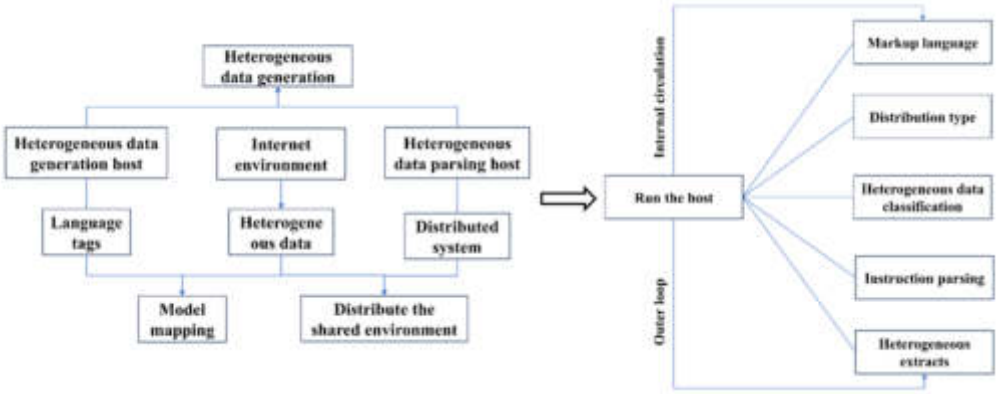


Fig. 2.1: Generate module diagrams

One is a method based on stock price prediction, which predicts the change of stock price after the news release by building a model, so as to obtain the impact of events in the news on the stock price. (Schumaker et al.,2009) [11] extracted features from news texts from the perspective of text expression, and used a support vector machine model to predict stock price trends after news releases. (Ding et al.2015) [12] used Open IE technology (Ding et al.2014) [14] and dependency syntactic analysis to extract structured events from unstructured news text, which are composed of actuators, actions, objects and time 4-tuples [13], and then used neural tensor networks to characterize events, and then used convolutional neural networks combined with short-term and long-term events to predict stock prices, and experimental results show that event representation can effectively solve the problem of event sparseness in large-scale financial news data [14], and convolutional neural network models can be used The long-term impact of events to improve predictive performance. Based on the above analysis, this paper hopes to make use of heterogeneous data composed of structured data such as user investment transaction records, stock index quotes, stock industry, and unstructured data such as financial news texts to systematically and comprehensively evaluate and analyze user investment. Based on SEA grid, a new algorithm is added to the user investment system to analyze heterogeneous data more effectively and efficiently

2. Heterogeneous data algorithm models.

2.1. Heterogeneous data algorithm generation module. In order to realize the heterogeneous data synchronization system, the design of model generation/analysis module fully follows the model markup language, and can control the distributed sharing environment of information transmission under the action of host elements [14], so as to generate completely independent data analysis and query statements. The specific connection form is shown in Figure 2.1. The transmission direction of heterogeneous Internet information can only be generated by the data generation host pointing to the external application processing structure, which does not violate the algorithm mapping relationship. The stronger the connection stability of the distributed system, the higher the application level of data sharing service in the synchronous system, and vice versa [15].

2.2. Heterogeneous pattern extraction module. As the key application structure of the distributed heterogeneous data synchronization system, the heterogeneous mode extraction module can synchronously execute the inner loop and outer loop instructions of the information parameters under the action of XML markup language [17], and finally store the information parameters that meet the distributed discrimination requirements directly in the system database host, and the specific connection principle is shown in Figure 1. In the actual application process, due to the different execution links of markup language, the classification and extraction requirements of heterogeneous data will be different, and the discrimination criteria of the running host for distributed nodes will become the only condition to determine the application stability level of heterogeneous information synchronization and sharing environment.

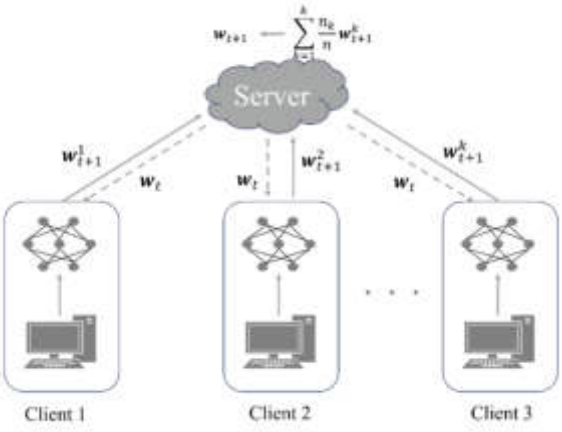


Fig. 2.2: Algorithmic models

2.3. Heterogeneous data models and algorithms. Heterogeneous data algorithm systems typically consist of a single server and multiple clients [18]. The idea of this FedPSG (Research on federated learning and particle swarm optimization) algorithm is to combine individual clients running stochastic gradient descent with servers running model averaging calculations. As shown in Figure 2.2, in order to fully apply heterogeneous data to the model, in each round of training, the client downloads the global model and trains the model with its local data, and then uploals the local model parameters to the server. The server coordinates the joint training of the clients and updates the global model by aggregating local model parameters. A smaller value of K means that the server receives fewer client models per round of training, and the less communication costs are required. However, the selection of some client models will cause other clients not to participate in the training of the global model, and some clients that perform better on the scoring dataset will dominate the training of the global model, which will cause unfairness in federated learning. When K is small, such as K equals 1, the server accepts only one client model, but the data of a single client is not representative of all clients, especially in a non-IID data environment. If a client model is simply set as a global model, the data distribution used by federated learning to train the global model is inconsistent with the real data distribution, resulting in a decrease in model accuracy.

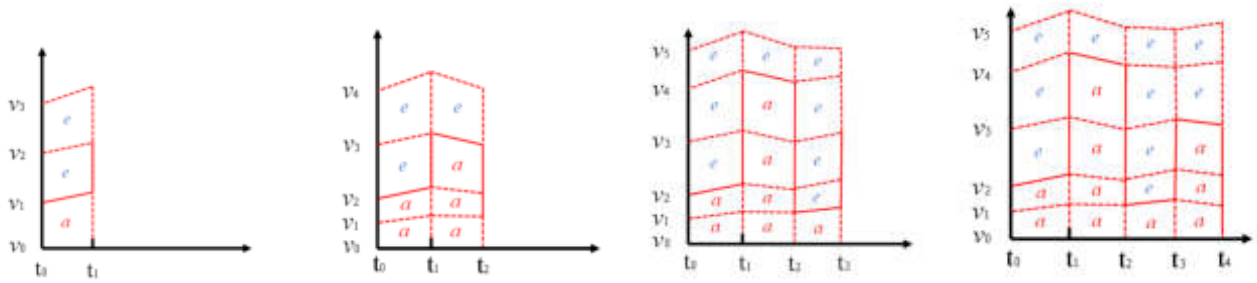
3. SEA grid.

3.1. SEA Mesh and Build. The process of building a SEA (Let all portfolios of an investor be S, in which A portfolio is A, except for A in S). The other parts are taken as combination E, and it can be seen that S is composed of A and E. network is as follows: Step 1 [19]: Initialize i to 0. Step 2: Forward scaling of the SEA mesh. When $0 \leq i < n$, in the t_i to t_{i+1} range, extend the market value line in the grid in the positive direction of the timeline T according to the proportion of the respective market value changes of S, E, and A. Mesh belonging to combination A is marked with a and mesh belonging to combination E is marked with e. Step 3: Reverse divide the SEA mesh. When $0 \leq i < n$, in the investment range from t_0 to t_i, starting from the result of A's capital change at t_i, divide the portfolio grid cells along the opposite direction of the T axis according to the changes in the respective market capitalizations of S, E, and A. The new grid is also marked with a and e. Step 4: Update $i = i + 1$. If $i < n$, go to step 2 to iterate, otherwise the SEA grid has been built. Figure 3.2 shows the SEA grid construction process at $n = 4$ and $m = 5$, which is forward-expanded and reverse-divided according to the capital change at each time point, and finally the entire market capitalization change graph is divided into $4 * 5$ for a total of 20 grid cells.

3.2. A double-weighted rate of return on time cost based on the SEA grid. The idea of double-weighted rate of return on time cost based on SEA grid is to split complex investments into simple investments by constructing the SEA network method proposed [20] in this paper, and then weighting the cost of each

Algorithm 1 Global Model Update

Enter: Number of clients N; Top-K optimal strategy parameters K; Number of communications T; Number of local iterations E; η learning rate; Inertia weights ; Acceleration factors c1, c2
Output: Global model w_T
Initialize w_0, *gbest*, $pbest_i$, L_{gid}
for $t = 1$ to T **do**
    for each round t from 1 to T do **do**
        for for each client n from 1 to N in parallel do **do**
            pbestk ← ClientUpdate(n,wt)
        end for
        L_pbest $[pbest_1, \ldots, pbest_N]$
    end for
    sort(L_pbest)
    pbest ← L_pbest [1, K]
    L_gid ← gid of pbest
    L_wt ← model of the client L_gid
    wt ← the mean of all numbers in L_wt
    if gbest < score(wt) **then**
        gbest ← score(wt)
    end if
    wt ← wt - $\eta \bigtriangledown l$(wt,Dm)
    initialize $w, \vee, wpbest$
    ClientUpdate(n,wt):
    β (split Dn into batches of size B)
    for each weight layer $\vee l \in \vee$ **do**
        $\vee l \leftarrow \alpha - \vee l + c1r1(wpbest - \vee l) + c1r1(wt - \vee l)$
    end for
    $w \leftarrow w + \vee$
end for
for each client epoch i from 1 to E **do**
    for batch $b \in \beta$ **do** $w \leftarrow w - \eta \bigtriangledown l(w, b)$
    end for
end for
return pbestn to server



(a) (b) (c) (d)

Fig. 3.2: SEA Mesh building process

simple investment, weighted into two parts:

1. Time weighting, considering that the duration of each simple investment is different, the corresponding cost has different action time, and then the impact on the overall rate of return is not the same, so the cost needs to be time-weighted;
2. Cost weighting, considering the different effects of funds on the rate of return at different points in time, it is necessary to consider the source of invested funds and the destination of the thrown funds for cost weighting. After obtaining the yield and double-weighted cost of each simple investment, it is finally combined into the yield of the complex investment.

3.3. Examples and Analysis of Results. There are various problems existing in the traditional rate of return calculation methods, which are summarized into three constraints in this paper: smooth transition constraint, that is, the return rate of the portfolio maintains a smooth transition without jumping when the capital flows in and out; The return consistency constraint, that is, the return rate and the return keep positive and negative consistency; Comparability constraint, that is, the return rate between various varieties in the same portfolio can be compared, and can be compared with the external return rate such as the return rate of the broad market index. Considering the shortcomings of the current yield calculation method, a time-cost double-weighted yield calculation method based on SEA is proposed:

1. Time-weighted, considering that the duration of each simple investment is different, the corresponding cost has different action time, and the impact on the overall yield is also different, so the cost needs to be time-weighted;
2. Cost weighting, considering that funds at different time points have different influences on the rate of return, it is necessary to consider the source of invested funds and the destination of sold funds for cost weighting. After obtaining the return and double-weighted cost of each simple investment, they are finally combined into the return rate of the complex investment.

To prove the effectiveness of the time-cost double weighted rate of return calculation method proposed, the traditional cost offset rate of return, cost accumulation rate of return, time weighted rate of return, and internal rate of return calculation method are compared below [21]. The comparison results of each return of Portfolio A are shown in Table 3.1, and the comparison chart is shown in Figures 3.2 and 3.3. The δ is a small value, minus δ indicates before the inflow and outflow of funds occur on the day, and the addition of δ indicates that after the inflow and outflow of funds occur on the day, it is used to show whether there will be a rate jump problem when the inflow and outflow of funds occur. As can be seen from Figure 3.3, the cost offset yield and the cost accumulation rate of return do not consider time weighting, that is, different costs have different action times, so there is a yield jump at the time of t1 and t3, and the cost weighting is not considered, that is, the cost at different points in time has different effects on the rate of return, so the calculated results also have errors. The time-weighted rate of return has a positive and negative inconsistency between the yield and the yield at both the t3 and t4 moments, because the cost weighting is not considered. The internal rate of return takes into account cost weighting, but when calculating cost weighting, it is assumed that the interest rate before the inflow and the interest rate after the capital outflow are the same as the internal rate of return to be calculated [22]. Only double-weighted yields satisfy all constraints. The following analyzes the double-weighted rate of return to meet the constraints. Because it is time-weighted, the time weight of the sudden inflow and outflow of funds is 0, so it does not cause the yield to jump and satisfy the smooth transition constraint. Because of the cost weighting, the positive and negative consistency of earnings and returns can be maintained, and the income consistency constraint can be satisfied. Satisfying the comparability constraint is discussed separately in two parts: internal comparison and external comparison: for internal comparison, the yield calculation method of portfolio market capitalization S, individual or combination A, and other combination E is a unified double-weighted calculation method, so the yield calculation between S, A, and E can be directly compared; For external comparison, first of all, considering that there is no external capital inflow and outflow of the portfolio market value S, the yield of S calculated by the double-weighted rate of return calculation method is consistent with the results calculated by the time-weighted method, and its double-weighted return for the entire period of time satisfies the time-weighted constraint, which is consistent with the time-weighted return calculation method used by indices, funds, etc., and they can be directly compared on this benchmark. If S has external capital inflows and outflows, at this time it is not known the returns before and after the inflow

Table 3.1: Comparison of the results of the calculation of each yield in Portfolio A

Time	Time label	Cost offset rate (%)	Cost-incremental return (%)	Time-weighted yield (%)	Internal rate of return (%)	Double weighted return (%)
2015-01-01	t0	0.00	0.00	0.00	0.00	0.00
	t1-δ	100.00	100.00	100.00	100.00	100.00
2015-06-01	t1	33.33	33.33	100.00	100.00	100.00
	t1+δ	33.33	33.33	100.00	100.00	100.00
	t2-δ	-33.33	-33.33	0.00	-48.67	-62.66
2015-10-01	t2	-55.56	-33.33	0.00	-48.67	-62.66
	t2+δ	-55.56	-33.33	0.00	-48.67	-62.66
	t3-δ	-46.67	28.00	20.00	-42.27	-55.46
	t3	-36.84	-24.14	20.00	-42.27	-55.46
	t3+δ	-36.84	-24.14	20.00	-42.27	-55.46
	t4	-26.32	-17.24	40.00	-29.98	-40.14

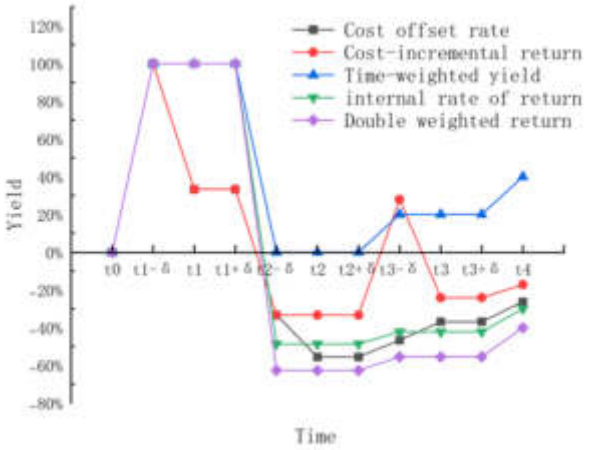


Fig. 3.3: Comparison chart of the calculation results of each yield of Portfolio A

of these funds, and it can be assumed that the yield of these funds is 0 or equal to the market yield of the broader market, which can still be calculated normally. If you want to compare the yield of portfolio A with the outside, such as with the market index of the large market, you can replace E with the market index and then through internal comparison, A can be compared with the market index of the large market index.

4. User investment analysis combined with SEA grid heterogeneous data algorithm model.

4.1. Quantify the impact of algorithmic models on user investment. When conducting event research, the event window used is $(5, 10)$ for a total of 16 days, which means that from 5 days before the event date to the 10th day after the event date, each day corresponds to an average abnormal rate of return, a total of 16 average abnormal returns, which is not convenient to show the impact of the event on the stock price [23]. Therefore, this paper divides the time into three phases, namely the early stage of the event, corresponding to the time interval $(-5, -2)$, the middle of the event, corresponding to $(-1,1)$, and the late stage of the event, corresponding to (2,5). By calculating the average cumulative abnormal rate of return in each time interval, the weight of the impact of the corresponding stage event on the stock price is obtained. Like the average rate of return, a positive average cumulative abnormal rate of return indicates that the event at that stage has a positive impact on the stock price, and a negative one is a negative impact, and the greater the absolute value, the greater the degree of impact. We refer to the average cumulative abnormal rate of return of these 3 stages as the weight factor of the impact of event types on stock prices, which is used to express the impact of event

types on stock prices.

4.2. Analysis of user investment event dimensions. Take the weight factor vector in the opposite direction 20 vector represents 0 points, as long as it performs better than the vector, it will be greater than 0 points, the better the performance, the higher the score [24]. Define the weighted logarithmic Manhattan distance for 0 points as Dmax. The confidence score is calculated as shown in Equation 4.1.

$$\text{trust\_score} = \begin{cases} \frac{D_b - D_s}{D_b - D_{\min}} \times 50 + 50, & \text{if } D_{\min} \le D_s < D_b \\ \frac{D_{\max} - D_s}{D_{\max} - D_b} \times 50, & \text{if } D_b \le D_s \le D_{\max} \end{cases} \tag{4.1}$$

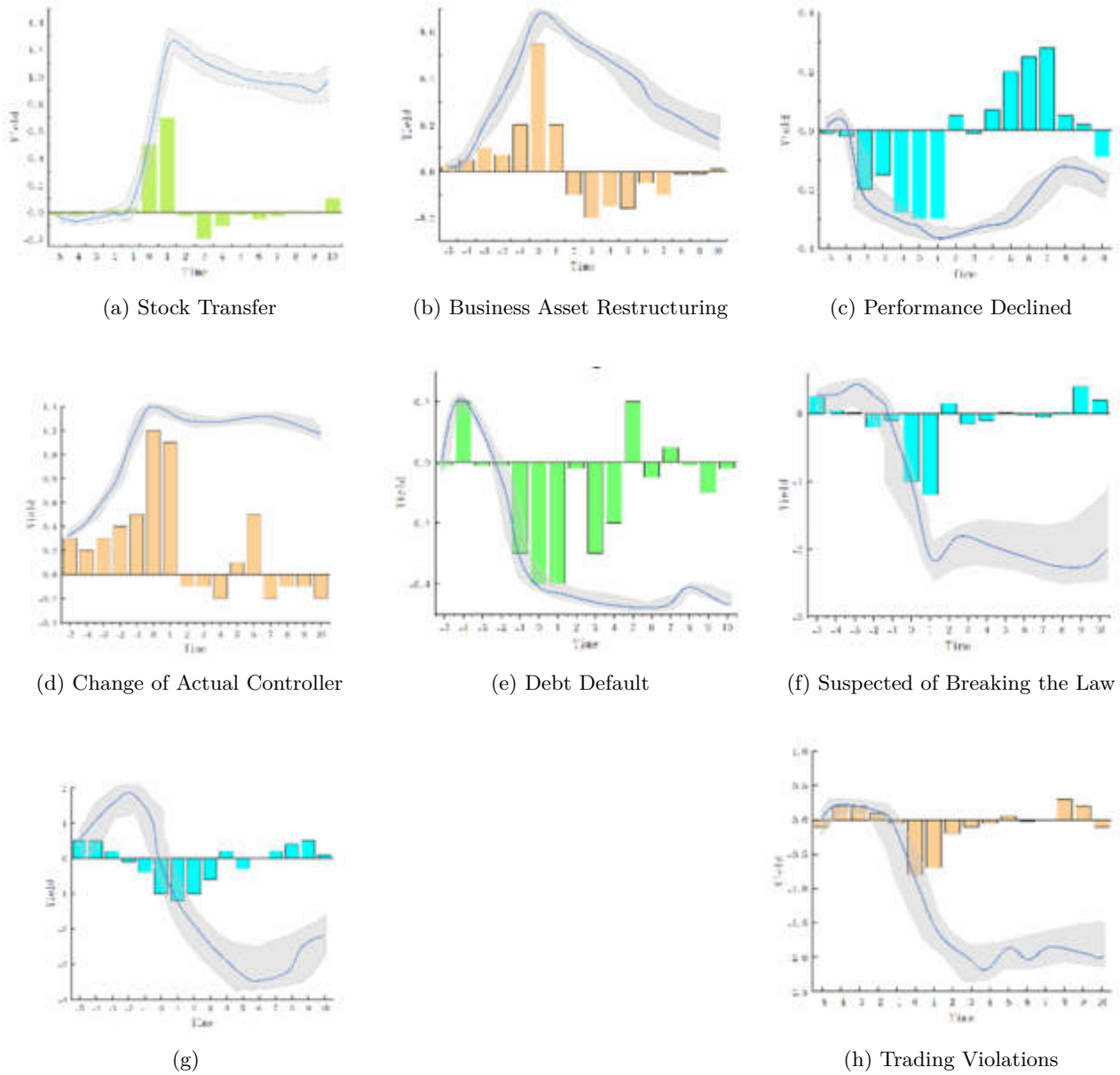
4.3. Experimental results and analysis.

4.3.1. Experimental heterogeneous data. To test the performance of FedPSG under heterogeneous client data conditions, IID, Non-IID (1) and non-IID (2) environments were set up experimentally, and the accuracy of FedPSG, FedAvg, FedShare and FedPS algorithms was compared on MNIST, FashionMNIST, and CIFAR-10 datasets. Among them, the FedPS algorithm is a simplified version of FedPSG after removing the model retraining strategy, and sets the ratio of the data volume of server data Dm to the data volume of client training data D $\gamma = 0.2$. IID data is independently and homogeneously, and there is no heterogeneity of client data. Non-IID (1) and NonIID (2) data are non-independently homogeneous, but Non-IID (1) data are more heterogeneous. The experimental results are shown in Figure 2 and Table 3.1. It can be observed that as the degree of client data heterogeneity increases, the accuracy of FedAvg algorithm on MNIST, FashionMNIST and CIFAR-10 datasets decreases significantly. After 100 rounds of training, when the data heterogeneity changed from IID to NonIID (2), the accuracy of FedAvg algorithm in MNIST and CIFAR-FashionMNIST datasets decreased by 15%, 20.08% and 28.65%, respectively. When the data heterogeneity changed from IID to Non-IID (1), the accuracy of FedAvg's algorithm on MNIST, CIFAR-10, and FashionMNIST datasets decreased by 57.53%, 35.89%, and 32.76%, respectively. It can be seen that the accuracy of the FedAvg model decreases with the deepening of data heterogeneity, which verifies that the client-side data heterogeneity has a great impact on user investment.

For the user investment event dimension analysis method that combines structured data and financial event data, it involves two parts of data, one of which is market data, which mainly includes the daily price data of all A-share companies listed on the SSE and SZSE, as well as the daily price data of the SSE Index and the SZSE Composite Index. The time period is from January 1, 2017 to October 1, 2020. The other part is the financial event data extracted from Chapter 3. Since "change of beneficial owner" and "change of beneficial shareholder" represent similar events, they are combined into one event and the event name is unified as "change of beneficial owner". In order to obtain more accurate statistical results, 11 event types with a sample size of less than 40 were removed, and 3 event types with the least significant results were removed according to the t-test results, and finally 15 event types were retained, which were: stock transfer/equity transfers, business asset reorganization, performance decline, change of actual controller, debt default, suspected violation of law, trading violation, financial constraints, violation of credit approval, falsification of financial information, change of actual controller, and so on. The event types are: stock transfer/equity transfer, performance decline, change of actual controller, debt default, suspected violation of law, transaction violation, fund tension, credit approval violation, financial information falsification, actual controller involved in litigation and arbitration, negative assets, negative executives, fund account risk, and reorganization failure. The total number of event samples is 18,047, covering 3,315 listed companies.

4.4. The results of the analysis of the impact of financial events on stock prices. This chapter uses the event research method to analyze the impact of 15 financial events extracted from Internet financial news on individual stock prices. The results of the analysis are described in detail below.

Figure 4.3 shows the AAR (Average Abnormal Rate of Return) and CAAR (Average Cumulative Abnormal Return) change chart for each event type in the event window, in which the ordinate represents the rate of return, and the abscissa represents the event window with a time range of $(5, 10)$, for a total of 16 trading days. The histogram represents AAR, the line chart represents CAAR, the gray area represents the 95% confidence interval of CAAR, the narrower the area indicates that the smaller the margin of error of the result, the more



(a) Stock Transfer (b) Business Asset Restructuring (c) Performance Declined

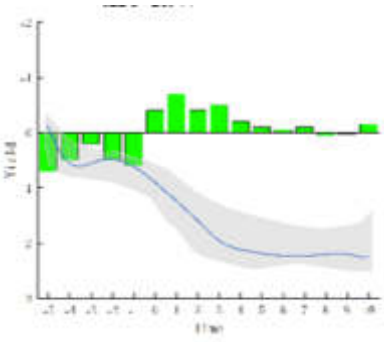
(d) Change of Actual Controller (e) Debt Default (f) Suspected of Breaking the Law

(g) (h) Trading Violations

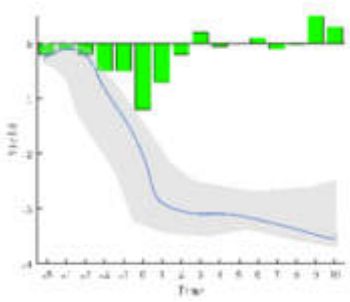
Fig. 4.2: AAR and CAAR change charts for each event type in the Events window (AAR for bar charts and line charts CAAR, gray area is CAAR 95% confidence interval)

credible the result, and vice versa, the less trustworthy the result. A negative AAR indicates that the actual yield is lower than the expected yield, indicating that the event had a negative impact. Conversely, it indicates a positive impact. CAAR is the accumulation of AAR, with an upside indicating a positive impact and a downside indicating a negative impact. The results for each event type are analyzed below [24].

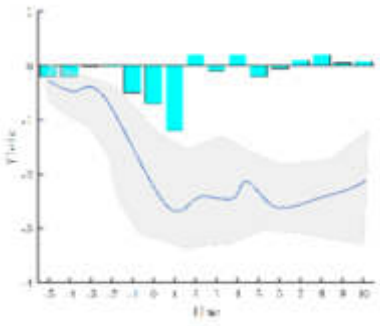
After 15 rounds of training, when the data heterogeneous condition changed from IID to Non-IID(1), the accuracy of the model ($\gamma = 0.20$) on the MNIST data set decreased by 0.08% from 97.33% to 97.25%, while the accuracy of the model ($\gamma = 0.02$) decreased from 96.54% to 92.03%, a decrease of 4.51%, and it can be seen



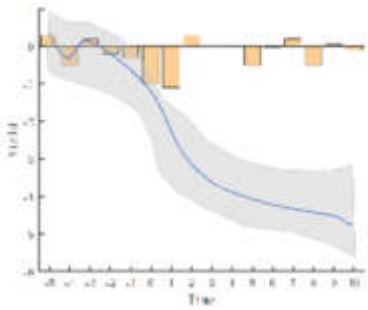
(a) Letter Approval Violations



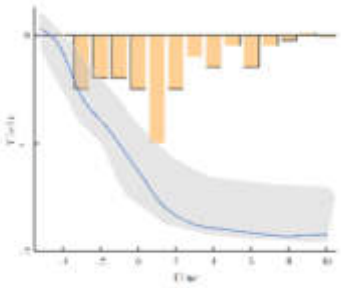
(b) Falsification of Financial Information



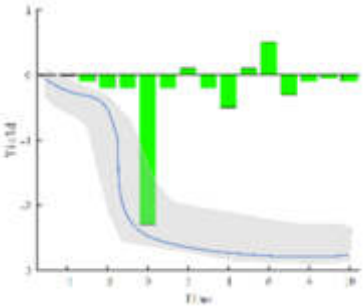
(c) The actual Controller is Involved in Litigation and Arbitration



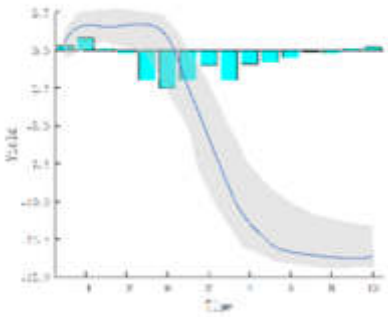
(d) Negative Assets



(e) Executives Negative



(f) Funding Account Risk



(g) Reorganization Failed

Fig. 4.3: Continued: AAR and CAAR change charts for each event type in the Events window (AAR for bar charts and line charts CAAR, gray area is CAAR 95% confidence interval)

that the accuracy of the model ($\gamma = 0.02$) on the MNIST dataset decreased more than the model ($\gamma =$).0.20) The accuracy of the model ($\gamma = 0.20$) on the CIFAR-10 dataset decreased by 1.1% from 51.16% to 50.06%, while the accuracy of the model ($\gamma = 0.02$) decreased by 8.22% from 42.79% to 34.57%, which shows that the accuracy of the model ($\gamma = 0.02$) decreased more than that of the model ($\gamma = 0.20$) on the CIFAR-10 dataset. Similarly, the accuracy of the model ($\gamma = 0.20$) on the FashionMNIST dataset decreased by 0.45% from 85.71% to 85.26%, while the accuracy of the model ($\gamma = 0.02$) decreased by 3.27% from 80.21% to 76.94%, i.e., the

Table 4.1: The accuracy of FedPSG, FedShare, FedAvg and FedPS in MNIST, CIFAR-10 and FashionMNIST after 15 rounds of training under three heterogeneous conditions of client data

	MNIST			CIFAR-10			FashionMNIST		
	IID	Non-IID (1)	Non-IID (2)	IID	Non-IID (1)	Non-IID (2)	IID	Non-IID (1)	Non-IID (2)
FedPSG	97.33	97.25	97.54	51.16	50.01	49.76	85.71	85.26	85.55
FedShare	97.94	96.02	96.38	48.39	36.59	40.82	85.7	80.52	81.89
FedAvg	97.73	40.20	82.23	52.28	16.39	32.17	86.46	53.7	57.81
FedPS	95.52	9.8	39.64	43.28	13.3	16.85	81.7	10	46.11

accuracy of the model ($\gamma = 0.02$) decreased more on the FashionMNIST dataset than the model ($\gamma = 0.20$). It can be seen that with the decrease of , the robustness of FedPSG's model accuracy when the degree of data heterogeneity changes. Therefore, in order to maintain the high quality of FedPSG training results in the case of data heterogeneity, the data amount of server data DM should be increased as much as possible [25].

Compared to FedAvg, FedShare and FedPSG performed more consistently under NonIID data conditions [25]. Especially on MNIST datasets, when the data heterogeneity conditions change from IID to NonIID (1) or non-IID (2), neither FedShare nor FedPSG accuracy changes by more than 2%. However, FedPSG's accuracy on CIFAR-10 and FashionMNIST datasets is significantly higher than FedShare's, and FedPSG accuracy decreases less than FedShare as client data heterogeneity increases. As shown in Figure 6 and Table 4.1, on the CIFAR-10 and FashionMNIST datasets, the FedPSG accuracy varies by no more than 2% as the data heterogeneity deepens [26]. FedShare's accuracy on CIFAR-10 and FashionMNIST datasets decreased by 11.8% and 5.18%, respectively, when the data heterogeneous conditions changed from IID to Non-IID (1). It can be seen that the FedPSG proposed in this paper is effective in dealing with the problem of data heterogeneity, and the effect is better than the general improvement algorithm.

5. Conclusion. This paper proposes a time-cost double-weighted rate of return calculation method based on SEA grid to solve the problem of calculating the rate of return in complex investment scenarios of users.

1. A user investment analysis method based on structured data is proposed, and six dimensional indicators of profitability, capital liquidity, timing ability, stock selection ability, action choice ability and risk control ability are designed, and multi-dimensional analysis of user investment is carried out.
2. FedPSG needs to select fewer client models when using the Top-K optimal strategy, so the training results of FedPSG are very dependent on the quality of server data. How to build high-quality server data while ensuring data privacy is one of the future research directions.
3. Combined with heterogeneous data, the dimensional analysis method of user investment events is studied. The influence of various events on the stock price is analyzed by using the event research method, the weight factor of event types on the stock price is designed to quantify the influence degree, the corresponding event dimension analysis is carried out on the stocks invested by users, and the result credibility index is calculated. The experiment shows that the introduction of financial event data can effectively provide the event factors in the fluctuation of investment profit and loss, and help users better analyze and reflect on their own investment behavior.
4. However, the heterogeneous data processing model based on SEA grid studied in this paper still has shortcomings. In order to achieve the goal of reducing communication costs, FedPSG needs to select fewer client models when using the Top-K optimal strategy, so the training results of FedPSG are very dependent on the quality of server data. How to build high quality server data while ensuring data privacy is one of the future research directions.

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APPLICATION OF BIM TECHNOLOGY IN STRUCTURAL DESIGN OF PREFABRICATED BUILDING BASED ON BIG DATA SIMULATION MODELING ANALYSIS

LILI XU*, LIN WANG, AND MINMIN ZHU

Abstract. Aiming at the complex steel bar layout problem in prefabricated building, this research proposes a structural design method of prefabricated building based on big data simulation modeling building information modeling technology. It includes the reinforcement arrangement model based on agent path planning, the intelligent reinforcement arrangement of frame based on artificial potential field method and path optimization, and the modeling of Building information modeling. When analyzing the reinforcement arrangement effect of beam column joints in Prefabricated building, the calculation time of top corner joints is the shortest, 76.8 seconds, while that of middle layer joints is the longest, 141.7 seconds. In direction Y and direction X, differential evolution has the longest calculation time, 27s and 26.57s respectively, while particle swarm optimization algorithm has the shortest calculation time, 2.84s and 3.02s respectively. The algorithm designed through research is significantly superior to other algorithms in terms of computational time. In general, through building information modeling technology and big data simulation modeling, this study realized the collision free layout of rebar in beam column joints of prefabricated building. This improves the speed and efficiency of deepening design, and provides a new solution for structural design of prefabricated building.

Key words: Big data; BIM; Prefabricated; Building structure

1. Introduction. Computer technology has led to the widespread application of Big data (BD) intelligent algorithm technology in various industries such as industry and agriculture, resulting in improved industry efficiency and the construction industry benefiting from this. The traditional engineering construction model usually involves the design and construction of buildings being independently completed by different units. The design party formulates a design plan to guide the construction party in carrying out construction [1, 2, 3]. Construction drawings are one of the important ways to present design proposals. As the main communication medium during the construction process, their precision directly affects the quality, speed, and cost of actual construction. Therefore, the deep integration of architectural design with digital technology and intelligent methods is of great significance for promoting the high-quality development of intelligent construction [4, 5, 6]. However, due to increasingly stringent design cycle requirements, engineers often do not have enough time to consider the details of the solution. In addition, excessive manual input is difficult to ensure corresponding output improvement, resulting in a low level of design deepening. Especially evident in reinforced concrete structures, the design and construction of steel bars are closely related to the overall quality of the project [7, 8, 9]. Prefabricated building (PB) steel bar designs mostly only provide reinforcement schemes. Engineers consider multiple factors based on the calculation results of the steel bars and manually complete the reinforcement work, which has the problems of large calculation amount, time-consuming, and prone to errors. Therefore, intelligent design system based on BD is essential. The study first introduced the research purpose and conducted a literature review. Secondly, a PB structure strategy based on BD simulation modeling and BIM technology was designed. Then, data testing was conducted on the designed strategy. Finally, a conclusion was drawn.

2. Related works. In recent years, research on PB has been deepening year by year. Xiao Y's team explored the application of Building Information Modeling (BIM) technology in PB design and its comparison with traditional design methods, as well as the effectiveness verification of BIM collaborative design. A conceptual model for PCP collaborative design was established in the study, and the accuracy of BIM models at different design stages was determined. The effectiveness of the BIM based building collaborative design method has been verified in examples [10]. Wasim M's team has comprehensively updated the integrated design,

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manufacturing, and assembly methods, and commented on their applications in the manufacturing and prefabrication fields. The writing of the comments followed slight modifications to the review of the preferred reporting system and the meta-analysis guidelines. There is a practical comparative relationship between prefabrication and manufacturing [11]. Wasim M uses an example of a volumetric steel structure to explore the integration of structural design and manufacturing assembly design (DfMA). DfMA principle can significantly improve the design efficiency of volumetric steel structures, enhance safety, sustainability, and production efficiency, while reducing costs and time [13]. Lee PC's team used MediaWiki to connect knowledge items with relevant BIM components, thereby expanding the knowledge ontology embedded in BIM. The proposed knowledge sharing platform and learning community model embedded in BIM have a positive impact on learning outcomes [13]. El Abidi K M A's team has revised the general motivations and limitations of PB in the construction industry. Research has found that the adaptability of PB is mainly influenced by factors such as labor shortage, labor costs, housing demand, construction process efficiency, climate conditions, and reducing waste materials and energy consumption. Although PB has inherent advantages in economy, environment, and social welfare, its application rate in the global construction industry is relatively low [14]. BIM technology application is gradually becoming more widespread. Matniyazov Z E's team studied the potential of BIM technology in solving modern design and construction industry problems. Their article carefully analyzed the problems and shortcomings of modern design technology in Uzbekistan, and further elaborated on the reasons for these problems through examples. After in-depth study, professionals will be able to understand why our economy needs new technologies [15]. Abdulmutalibovich K A's team conducted a detailed study of these competency characteristics and emphasized the effectiveness of the widespread application of modern information technology in enhancing architects' professional abilities. In addition, the advantages of fully developed professionals in solving complex problems were emphasized [16]. Xiao Y's team studied and compared BIM collaborative design with traditional design methods to promote the application of BIM in PB design. Based on the requirements of BIM technology IDM, a conceptual model of PCP collaborative design was established. The BIM based building collaborative design method has been validated in practice for its effectiveness [10]. Martins S S aims to explore the challenges faced by the application of integrated technology in 4D BIM in Brazil, a developing country, and verify them through Case study. He demonstrated the feasibility and challenges of using BIM technology to enhance communication between teams and stakeholders through visual presentation at different stages of construction [18]. In summary, the potential of BIM technology in solving modern design and construction industry problems, as well as its effectiveness in enhancing architects' professional abilities, has also been confirmed. However, BIM technology application in PB still faces many challenges. Therefore, this study will analyze BIM technology application in PB structure design based on BD simulation modeling, to improve the design efficiency and quality of PB.

3. PB Structure Design Based on BD Simulation Modeling and Analysis BIM Technology. This study aims to establish a reinforcement layout model based on intelligent agent (IA) path planning to achieve collision free arrangement of reinforcement in beam column nodes. And the original high-dimensional optimization task is decomposed into multiple low-dimensional optimization subtasks using a step-by-step optimization method that combines Artistic Potential Field (APF) and path planning. Finally, through secondary development of Revit software, a framework automatic deepening design plugin is created to improve the speed and efficiency of deepening design.

3.1. Intelligent Arrangement of Steel Bars in PB Beam Column Nodes Based on APF. In concrete beam column components, the main reinforcement generally includes two forms: longitudinal reinforcement and transverse reinforcement. When arranging steel bars, reserving space for hoops arrangement can avoid collisions between longitudinal bars and hoops. To achieve collision free layout of steel bars in beam column nodes, a steel bar layout model based on IA path planning will be established in the research. IA generally refers to any device or system that can autonomously perform complex tasks and can interact with humans through intelligent sensing devices. The IA path-planning-based rebar placement model is a method to optimize rebar placement using intelligent algorithms. In this model, the intelligent body represents an entity with autonomous decision-making capability, which is able to make decisions based on environmental information and its own state. Path planning is the core function of the intelligent body, which is used to determine its moving trajectory in the construction space. In order to ensure the accuracy and aesthetics of

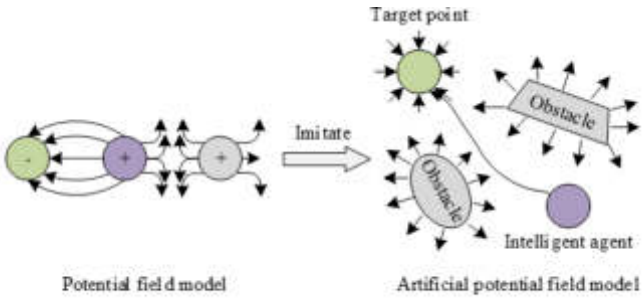


Fig. 3.1: Potential field model and artificial potential field model

the rebar arrangement, the path obtained from the search is smoothed. After completing the path smoothing, the decision quality of the intelligent body is evaluated. The performance of the intelligent body is adjusted according to the evaluation results for more accurate path planning in subsequent construction. According to the optimized path, the intelligent body performs the placement of the steel bars. In this process, the intelligent body can dynamically adjust the scheduling program according to the actual situation to ensure the smooth progress of the construction process. In the process of steel bar arrangement, the deviation between the actual trajectory of the intelligent body and the planned path is monitored by the real-time monitoring system, and the path planning strategy of the intelligent body is adjusted in a timely manner if a large deviation is found in order to ensure the construction accuracy and safety. Through the above steps, the rebar placement model based on intelligent body path planning can realize the optimization of rebar placement, improve construction efficiency, and reduce the risk of manual intervention. In this model, beam column node is defined as the three-dimensional workspace of IA, and a local coordinate system is established with the bottom left corner of the column angle as the origin. X and Y axes are parallel to transverse and longitudinal beams, and Z axis is parallel to the vertical columns. For corner or edge nodes, after the reinforcement arrangement is completed, it is necessary to arrange the longitudinal reinforcement hooks of beam. In this process, a new IA needs to be placed at the end of the corresponding steel bar to ensure that the hook part of the steel bar does not collide with other steel bars.

APF is a path planning method based on the concepts of electric potential and electric field forces in physics, which guides IAs movement by establishing a virtual force field in the environment. APF has many advantages, such as simple computation, simple environmental modeling, and fast planning speed. Figure 3.1 shows the electric potential field model and the artificial potential field model.

One advantage of using APF for path planning is its simple calculation and implementation, making it easy to establish a mathematical model of the virtual potential energy field. According to the characteristics of the path planning task of IA, it is possible to choose to establish a Cartesian coordinate system in space or plane. In the reinforcement layout problem, the artificial potential field method can be used to guide the robot how to place the reinforcement. There are many specific parameters of the artificial potential field method. The potential field function defines the potential energy at each position in the environment. In general, the target location has a lower potential energy, while the obstacle or inaccessible area has a higher potential energy. The repulsive force coefficient determines the amount of repulsive force experienced by the robot. A larger repulsion coefficient will cause the robot to move away from the obstacle, while a smaller coefficient will make it easier for the robot to approach the obstacle. The coefficient of gravity determines the amount of attraction the robot receives. A larger gravitational coefficient will cause the robot to approach the target position faster, while a smaller coefficient will cause the robot to move more slowly. In some cases, obstacles or target locations in the environment may change as the robot moves. Therefore, it may be necessary to dynamically adjust the parameters of the potential field function to ensure that the robot can adapt to these changes. The application of artificial potential field method to reinforcement layout problem is as follows. When laying out rebar, you

can set the target point to where the rebar should be placed. For example, if you need to place a steel bar between two concrete walls, you can set the target point at the midpoint of the two walls. For rebar layout problems, repulsion functions can be defined to avoid collisions between rebar and walls or other rebar. For example, if a rebar is near a wall or another rebar, the repulsive force at that location can be increased, leading the robot to adjust its path. The gravity function is used to attract the rebar to move towards the target point. In this case, the target point is usually the intended location of the rebar. The speed and direction of rebar movement can be controlled by adjusting the parameters of gravity function. Equation 3.1 is to establish gravitational field $U_a(X)$ based on agent and target point's distance.

$$U_a(X) = \frac{1}{2}k\rho^2(X, X_g) \tag{3.1}$$

In equation 3.1, k is the gravitational coefficient. X and X_g are IA and target point's position vectors, respectively. $\rho(X, X_g)$ is IA and target point's distance. The farther agent is away from target point, the more gravitational energy will increase. On the contrary, it decreases. When the agent reaches target point, gravitational energy is usually 0. The gravity received by agent has a negative gradient relationship with gravitational field, so the gravity in formula 3.2 can be obtained by taking the derivative of gravitational field with respect to this distance

$$F_a(X) = -\nabla(U_a) = -k(X - X_g) \tag{3.2}$$

Equation 3.3 represents a repulsive field function of obstacles based on IA and target point's distance.

$$U_r(X) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{\rho(X,X_r)} - \frac{1}{\rho_0}\right)^2, & 0 \le \rho(X, X_r) \le \rho_0 \\ 0, & \rho(X, X_r) > \rho_0 \end{cases} \tag{3.3}$$

In equation 3.3, η is a repulsion coefficient, X_r is obstacle's position vector, $\rho(X, X_r)$ is IA and obstacle's distance, and ρ_0 is obstacle's influence range. The repulsion force and repulsion field received by IA also exhibit a negative gradient relationship. The repulsive force in equation 3.4 can be obtained by taking the derivative of repulsive force field with respect to distance.

$$F_r(X) = -\nabla(U_r) = \begin{cases} \eta\left(\frac{1}{\rho(X,X_r)} - \frac{1}{\rho_0}\right)\frac{1}{(\rho^2(X,X_r))}\frac{\partial\rho(X,X_r)}{\partial X}, & 0 \le \rho(X, X_r) \le \rho_0 \\ 0, & \rho(X, X_r) > \rho_0 \end{cases} \tag{3.4}$$

When there are multiple obstacles in the mobile environment, IA is in the total potential field of the superposition of gravitational potential field and multiple repulsive potential fields. Equation 3.5 calculates the total potential field.

$$U(X) = U_a(X) + \sum_{i=1}^{m} U_r^i(x) \tag{3.5}$$

In equation 3.5, m is obstacles number. The path planning of traditional APF has some limitations, which result in agent being unable to reach the target point in certain situations, leading to task failure. To solve the problem of unreachable target points near obstacles, the form of repulsive potential function is optimized by introducing the square of gent and target point's distance as a product term in repulsive potential function. The improved repulsive potential function ensures that target point is always the global minimum point of total potential energy field in equation 3.6.

$$U_r'(X) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{\rho(X,X_r)} - \frac{1}{\rho_0}\right)^2\rho^2(X, X_g), & 0 \le \rho(X, X_r) \le \rho_0 \\ 0, & \rho(X, X_r) > \rho_0 \end{cases} \tag{3.6}$$

According to the value requirements of introducing the product term and graphic characteristics of Gaussian function, a deformed Gaussian function $G(X)$ is introduced as repulsion potential function's product term.

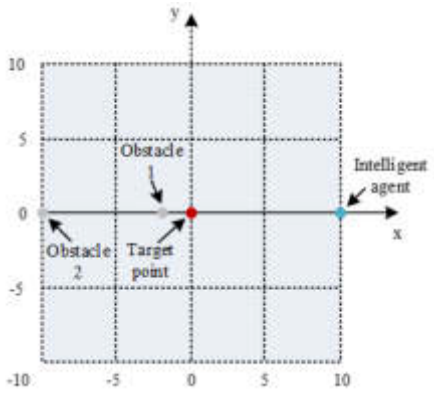


Fig. 3.2: 2D mobile environment

Introducing $G(X)$ as original repulsive potential function's product term, a new repulsive potential function in equation 3.7 is obtained.

$$U_r''(X) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{\rho(X,X_r)} - \frac{1}{\rho_0}\right)^2 \left(1 - e^{-\left(\frac{\rho^2(X,X_g)}{R^2}\right)}\right), & 0 \le \rho(X,X_r) \le \rho_0 \\ 0, & \rho(X,X_r) > \rho_0 \end{cases} \tag{3.7}$$

In equation 3.7, R is a radius of IA. Introducing $G(X)$ can effectively improve the distortion problem of total potential energy field far from target point. However. In some cases, the total potential field near target point may exhibit local minimum points. In this case, IA may stop or oscillate repeatedly, unable to ultimately reach the target point, as shown in Figure 3.2.

To eliminate the local minimum point of total potential energy field caused by obstacles near target point, this study will further reduce its value near target point by improving , and ensure that the value away from target point approaches 1. Therefore, a parameter β is introduced into $G(X)$, and a new form of Gaussian function $G_1(X)$ is proposed. The improved repulsive potential function in equation (8) is proposed by introducing $G_1(X)$ as a product term of repulsive potential function.

$$U_{r1}(X) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{\rho(X,X_r)} - \frac{1}{\rho_0}\right)^2 \left(1 - e^{-\left(\frac{\rho^2(X,X_g)}{\beta R^2}\right)}\right), & 0 \le \rho(X,X_r) \le \rho_0 \\ 0, & \rho(X,X_r) > \rho_0 \end{cases} \tag{3.8}$$

By adjusting parameter β , the improved total potential energy field does not have a local minimum point near target point.

4. Intelligent Layout and BIM Modeling of Frame Reinforcement Based on APF and Path Optimization. APF is mainly aimed at solving the reactivity of IAs in mobile environments, making it difficult to optimize the mobile path. In the case of a large and densely distributed number of obstacles, IA may be affected by multiple obstacles at the same time, and may easily fall into local minimum points and stop moving, resulting in the inability to complete path planning. Therefore, when dealing with the problem of steel bar layout in complex environments, an intelligent steel bar layout model should be used to construct the mobile environment of IA, and a global optimization model for path planning should be established.

Global optimization of path planning is an important concept, especially in complex construction environments such as steel bar layout problems. The parameters of global path planning can be adjusted according to the specific application and requirements to achieve the best performance. A global path is the complete path from the start to the end. The cost function is used to evaluate each possible path. In the case of reinforcement

layout issues, this may include considering factors such as construction difficulty, time, material use, etc. In many practical applications, the environment is dynamically changing. Path planning requires the ability to identify and avoid obstacles. In a rebar layout, this may include walls, other rebar, or other physical barriers. The update frequency of global path planning determines the response speed of the planner to environmental changes. Faster update frequency means faster response, but it can also lead to unnecessary computational burden. The application of global optimization of path planning to reinforcement layout problem is as follows. In rebar layout, global path planning is used to determine the best rebar laying sequence and path. The optimal construction path is selected by considering a variety of factors, such as avoiding collisions with other steel bars and maximizing the efficiency of material use.

The task of global optimization in path planning is for an IA to find a collision free shortest moving path given a starting point and target point. The mobile path is represented by location points coordinates passed by IA, and entire mobile path is formed by connecting adjacent path points through a straight line. Assuming that there are a total D intermediate path points in the moving path of IA, except for the starting point and target point. The starting point coordinate of IA is $p_s = (x_0, y_0, z_0)$,, target point coordinate is $p_G = (x_(D+1), y_(D+1), z_(D+1))$, the -th intermediate path point coordinate is $p_i = (x_i, y_i, z_i)$, the path is represented as $p = (p_0, p_1, , p_D, p_(D+1))$, and $u_i = (u_(i, 1), u_(i, 2), u_(i, 3)) = (x_i - x_(i-1), y_i - y_(i-1), z_i - z_(i-1))$ represents the vector between adjacent two path points. Equation (9) represents each path point's coordinates.

$$\begin{cases} x_i = x_0 + \sum_{j=0}^{i} u_{j,1} \\ y_i = y_0 + \sum_{j=0}^{i} u_{j,2} \\ z_i = z_0 + \sum_{j=0}^{i} u_{j,3} \end{cases} \tag{4.1}$$

In order to reduce the search space and improve optimization efficiency, the step size of each movement of IA is limited to L_o , and equation 4.2 is adjacent two points' distance.

$$L_0 = \sqrt{u_{i,1}^2 + u_{i,2}^2 + u_{i,3}^2} \tag{4.2}$$

When arranging steel bars, steel bars bending usually occurs in lines rather than arcs. Therefore, in path planning, IA's movement direction is limited and can only move in directions parallel to three coordinate axes. This restriction ensures that two adjacent moving vectors are either perpendicular to each other or collinear to meet the specific constraint conditions in equation 4.3.

$$\begin{cases} u_{i,1} u_{i,2} = 0 \\ u_{i,1} u_{i,3} = 0 \\ u_{i,2} u_{i,3} = 0 \end{cases} \tag{4.3}$$

Assuming there are S intermediate path points in the moving path of IA, the binary variable dimension of the global path optimization solution is $3 * (D + 1)$. Figure 4 is an example of a global path optimization model solution using 15 dimensional binary encoding. There are 4 intermediate path points between starting and target points, and IA has made a total of 5 movements, moving once in positive direction. Then IA moves in positive direction, positive direction, negative direction, and finally moves in positive direction. Figure 4.1 shows the direction and order of IA's movement along the path.

For a moving path with d intermediate path points, it contains $d + 1$ moving vectors. The length of the overall path of an IA can be calculated by adding all motion vectors' lengths. To minimize agent's path length, an objective function l for global optimization of path planning in equation 4.4 is established.

$$\min L = \sum_{i=1}^{D+1} \sqrt{u_{i,1}^2 + u_{i,2}^2, u_{i,3}^2} \tag{4.4}$$

When IAs moving, constraints such as collision and blockage of steel bars need to be considered. Considering the impact of constraint conditions on path planning results, a penalty function in equation 4.5 was established.

$$P_{po} = \begin{cases} +\infty, & \text{violation of constraints} \\ 1, & \text{others} \end{cases} \tag{4.5}$$

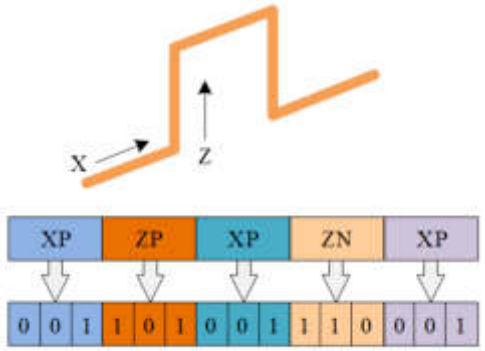


Fig. 4.1: Example of an agent path using binary encoding

Penalty function is introduced into the path length and a fitness function for global optimization of path planning in equation 4.6 is constructed

$$\min F_g = P_{po} \cdot L \tag{4.6}$$

To ensure intelligent layout of steel bars' stability and efficiency, a step-by-step optimization method for path planning is studied. This method decomposes the original high-dimensional optimization task into multiple low-dimensional optimization subtasks, which can reduce optimization time and improve optimization success rate.

In the step-by-step optimization subtask, the position of sub target point cannot be predetermined, so sub path length cannot be used as path optimization model's objective function. To solve this problem, an objective function d in equation 4.7 can be established for each subtask by minimizing the distance between end point p_T^j and target point p_G .

$$\min d = \sqrt{(x_T^j - x_G)^2 + (y_T^j - y_G)^2 + (z_T^j - z_G)^2} \tag{4.7}$$

In this model, the constraints on steel collision and blockage are still considered, and a penalty function is introduced to establish a fitness function in equation 4.8.

$$\min F_d = P_{po} \cdot d \tag{4.8}$$

When obstacles are densely distributed, IA may encounter more types of obstacle forms, making it difficult to break away from local minimum points in Figure 4.2.

In Figure 4.3, placing two obstacles between IA and the target point generates two repulsive forces. When an IA moves to a certain point, repulsive force's magnitude is equal to gravitational force, causing agent to fall into a local minimum point. At the local minimum point formed by multiple obstacles, changing repulsive force's direction makes it difficult for agent to escape local minimum point.

APF can quickly calculate the next path point of the agent, but it is easily affected by the distribution of obstacles and may fall into local minimum points, leading to task failure. Path optimization methods can find the optimal path to ensure that agent reaches target point, but due to variable dimensions influence, optimization efficiency and quality may decrease. A hybrid intelligent method was proposed by combining the characteristics of APF and path optimization. Figure 4.3 shows a path planning of IAs based on hybrid intelligence methods [19, 20, 21].

Through secondary development of Revit software, a framework automatic deepening design plugin can be created to improve the speed and efficiency of deepening design. Revit secondary development is mainly carried out through application program interfaces, and external plugins are developed to extend Revit functionality.

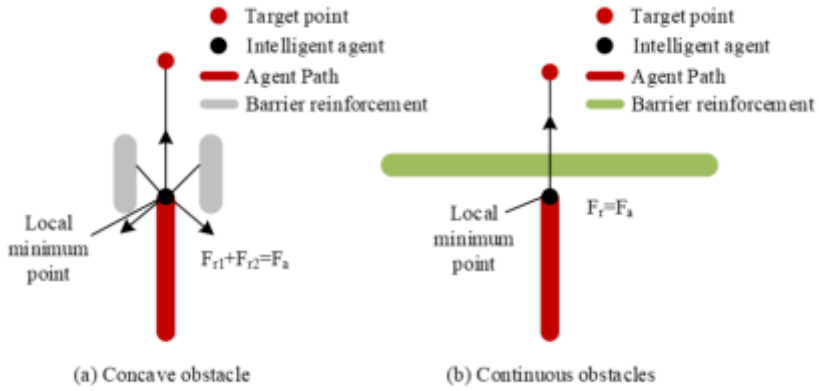


Fig. 4.2: The Local Minimum Problem of Artificial Potential Field Method in Complex Environments

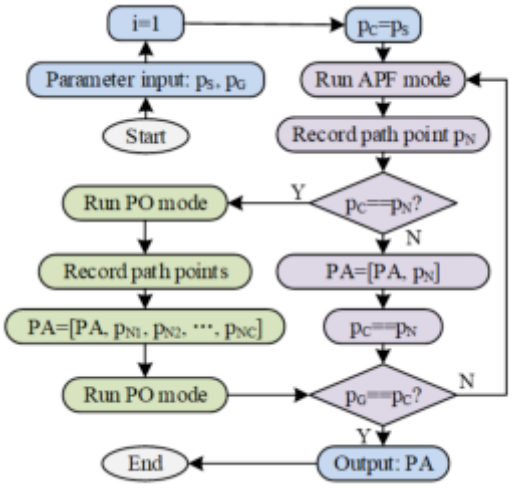


Fig. 4.3: The Path Planning Process of Hybrid Intelligent Method

The plugin creates a class library project using Visual Studio software, writes code in C # language, and debugs this program to achieve intended functionality. Plugins can establish channels for transmitting data during design phase, create BIM models based on deepening design solutions, and automatically generate instances of elements such as beams, columns, and steel bars, thereby breaking the traditional mode of manual modeling. Figure 6 shows a deepening design process of PB framework.

5. Analysis on the Effect of Reinforcement Arrangement in PB Beams and Columns. This study conducted an effect analysis on the reinforcement arrangement of PB beam column joints. In the experiment, the calculation time of different types of nodes, the number of APF planning times, and the average calculation time of APF were analyzed. The above analysis can reflect the differences in the difficulty of steel bar layout and computational complexity among different types of nodes. And a comparative analysis was conducted on the calculation time and path length of edge node beam reinforcement, middle node beam reinforcement, and corner node beam reinforcement in different directions.

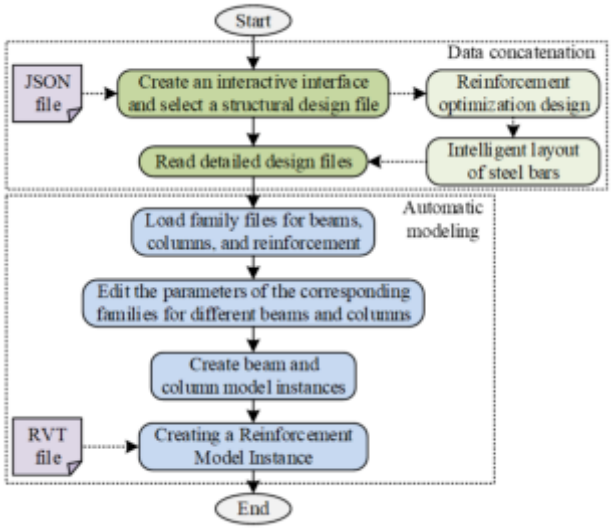
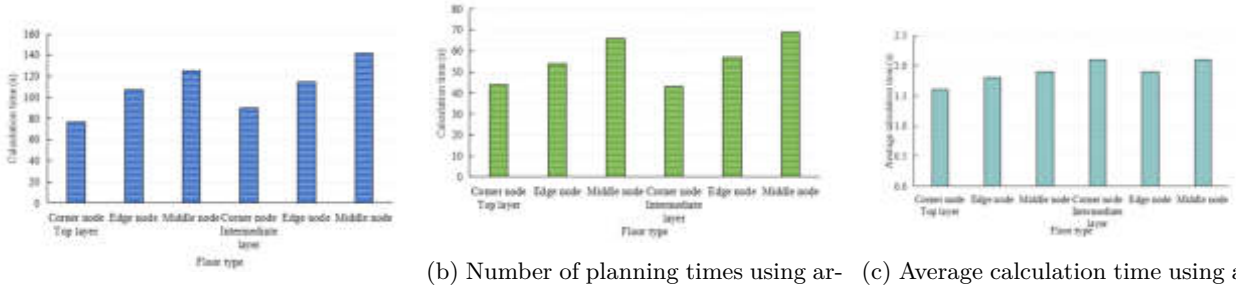


Fig. 4.4: Detailed design process of Prefabricated building frame



(a) Calculation Time

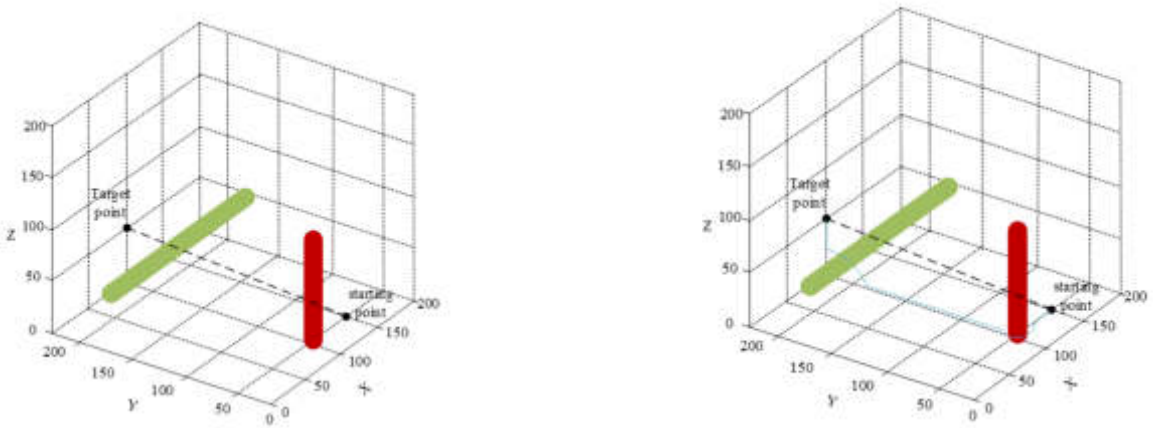
(b) Number of planning times using artificial potential field method

(c) Average calculation time using artificial potential field method

Fig. 5.2: Comparison of different node layout times

5.1. Reinforcement Arrangement Effect Analysis of APF Prefabricated Building Beam Column Nodes. In this study, an improved APF was used to analyze the intelligent arrangement of steel bars in six different types of reinforced concrete beam column joints. These six types of nodes are: top corner, top edge, top middle, middle layer corner, middle layer edge, and middle layer middle nodes. Figure 5.2 shows the comparison of different nodes arrangement times.

Firstly, the calculation time of different types of nodes was compared and analyzed. The calculation time for the top corner node is the shortest, at 76.8 seconds, while the calculation time for the middle layer node is the longest, at 141.7 seconds. This may be because the structural complexity and difficulty of steel reinforcement arrangement of nodes in the middle layer are higher than other types of nodes, resulting in longer calculation time. Secondly, APF planning times for each type of node was compared. Among them, the planning times for the top layer corner nodes and the middle layer corner nodes are relatively low, with 44 and 43 times respectively. The nodes in the top layer and middle layer have more planning times, with 66 and 69 times respectively. This indicates that when using APF for steel reinforcement layout, the arrangement of middle nodes is more difficult and requires more planning times. In addition, the average calculation time for APF is relatively short, at 1.6 seconds and 2.1 seconds, respectively. Figure 8 shows the IA 3D workspace.



(a) Path Planning Task

(b) Path Panning Results

Fig. 5.4: 3D workspace of IAs

This study validated the feasibility of APF using a three-dimensional moving space as an example. To improve space utilization and ensure the safety of path planning, the impact range of obstacles is set to 1mm. Under this setting, IA successfully moved from the starting point to the target point under the guidance of APF, and the entire process took only 1.1 seconds. APF can effectively solve the problem of unreachable target points near obstacles.

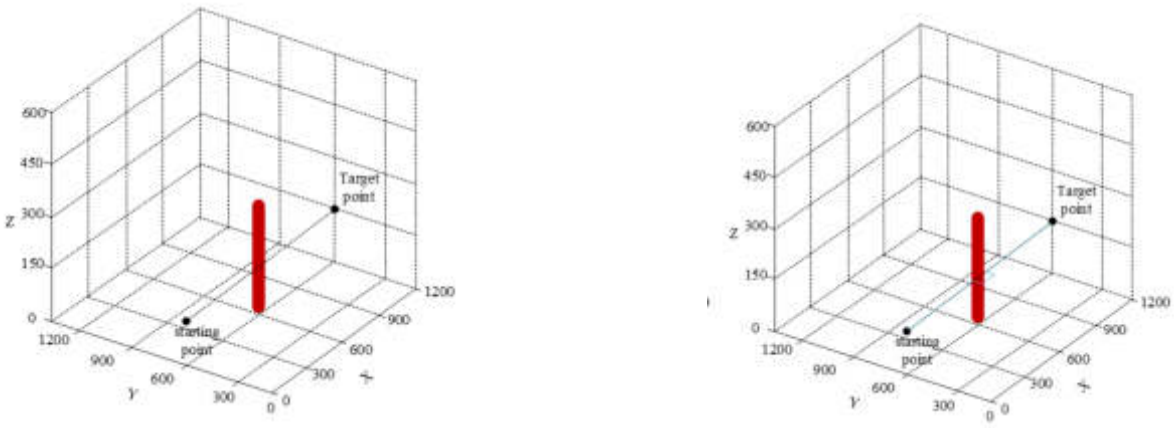
5.2. Reinforcement Arrangement Effect Analysis in APF Prefabricated Building Framework. In 3D space, the calculation of the optimal path for IA is a challenging task, involving many factors such as spatial discretization, obstacle setting, selection of starting and target points, step size setting, and number of path points. In this example, the size of IA's moving space is a 1200mm × 1200mm × 600mm rectangular cuboid, and the space is discretized into a 1mm cube. Discretization makes the path planning problem can be accurately measured and solved. In this model, a steel bar located in Z direction is set as an obstacle, with the coordinates of its upper and lower position points being (600600600) and (600600, 0), respectively. Figure 5.5a shows the IA optimization path.

The starting point and target point coordinates of IA are (0, 600, 200) and (1200, 600, 200) respectively, with a step size of 20mm, and the middle points number in path is 70. These settings specify the movement range and stride fineness of IA, as well as path complexity. The algorithm designed through research can calculate a concise optimal path, which is effective. Figure 10 shows the algorithm calculation time.

From Figure 5.8, the scale and time consumption, iteration and time consumption are all proportional, withPSO algorithm taking the least time. Table 5.1 shows the calculation time and path length of edge node beam reinforcement for the research and design method.

In Table 5.1, DE algorithm has the longest calculation time in direction Y, which is 27 seconds. In contrast, PSO only takes 2.84 seconds, while NFO takes 8.58 seconds. This indicates that PSO has the highest computational efficiency. In direction X, DE algorithm requires 26.57 seconds, PSO requires 3.02 seconds, and NFO requires 8.63 seconds. PSO still has the highest computational efficiency. Through comparative analysis, although the performance of the three algorithms in path length is the same, PSO is significantly better than DE and NFO algorithms in computational time. Table 5.2 shows the calculation time and path length of steel bars in the middle node beam.

In direction Y, total calculation time of DE algorithm is 26.85 seconds, while the calculation time of PSO and NFO algorithms is 2.71 seconds and 6.72 seconds, respectively. Similarly, in direction X, total calculation



(a) 3D Workspace of intelligent Agents (b) Optimal Path for Intelligent Agents

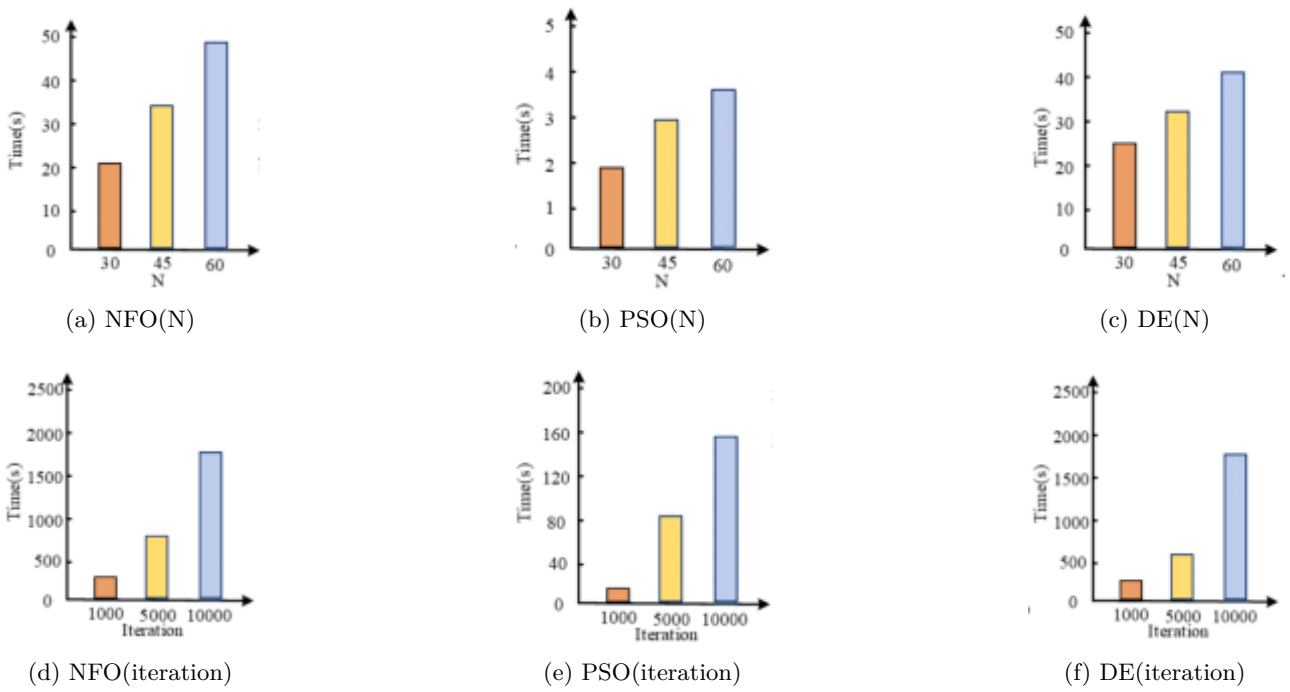
Fig. 5.6: Intelligent agent optimization path

Table 5.1: Calculation time and path length of edge node beam reinforcement

Direction	Position number	Length(mm)			Computing time(s)		
		DE	PSO	NFO	DE	PSO	NFO
Direction Y	1	1300	1300	1300	3.35	0.32	1.07
	2	1350	1350	1350	3.33	0.37	1.12
	3	1350	1350	1350	3.47	0.41	1.04
	4	1350	1350	1350	3.35	0.32	1.14
	5	1350	1350	1350	3.35	0.37	1.09
	6	1300	1300	1300	3.35	0.37	1.05
	7	1300	1300	1300	3.47	0.35	1.03
	8	1300	1300	1300	3.33	0.33	1.04
	Total	10600	10600	10600	27	2.84	8.58
DirectionX	1	1370	1370	1370	3.42	0.39	1.08
	2	1370	1370	1370	3.25	0.42	1.08
	3	1370	1370	1370	3.34	0.33	1.08
	4	1300	1300	1300	3.32	0.41	1.11
	5	1300	1300	1300	3.32	0.43	1.05
	6	1300	1300	1300	3.32	0.39	1.04
	7	1300	1300	1300	3.29	0.32	1.05
	8	1370	1370	1370	3.31	0.33	1.14
	Total	10680	10680	10680	26.57	3.02	8.63

time of DE algorithm is 24.53 seconds, while the calculation time of PSO and NFO algorithms is 2.66 seconds and 6.79 seconds, respectively. The calculation time of PSO is the shortest among all algorithms. Table 5.3 shows the calculation time and path length of corner node beam reinforcement.

In terms of path length, the path lengths of DE, PSO, and NFO algorithms remain consistent in both directions Y and X. Specifically, the path length in direction Y is 1300mm or 1350mm, totaling 10600mm. The path length in direction X is 1300mm or 1370mm, totaling 10680mm. This indicates that three algorithms' performance in path optimization is equivalent, and they can complete the arrangement of corner node beam reinforcement within the same path length. However, these three algorithms exhibit significant differences in computational time. Both in direction Y and direction X, the calculation time of DE is the longest, reaching



(a) NFO(N) (b) PSO(N) (c) DE(N)

(d) NFO(iteration) (e) PSO(iteration) (f) DE(iteration)

Fig. 5.8: Algorithm time comparison

Table 5.2: Calculation time and path length of steel bars in middle node beams

Direction	Position number	Length(mm)			Computing time(s)		
		DE	PSO	NFO	DE	PSO	NFO
DirectionY	1	1300	1300	1300	3.32	0.32	0.84
	2	1350	1350	1350	3.36	0.33	0.92
	3	1350	1350	1350	3.37	0.37	0.79
	4	1350	1350	1350	3.39	0.33	0.83
	5	1350	1350	1350	3.34	0.31	0.82
	6	1300	1300	1300	3.41	0.36	0.85
	7	1300	1300	1300	3.33	0.37	0.85
	8	1300	1300	1300	3.33	0.32	0.82
	Total	10600	10600	10600	26.85	2.71	6.72
DirectionX	1	1370	1370	1370	3.07	0.33	0.83
	2	1370	1370	1370	3.05	0.37	0.84
	3	1370	1370	1370	3.09	0.36	0.84
	4	1300	1300	1300	3.12	0.31	0.82
	5	1300	1300	1300	3.11	0.33	0.83
	6	1300	1300	1300	3.02	0.33	0.85
	7	1300	1300	1300	3.02	0.31	0.91
	8	1370	1370	1370	3.05	0.32	0.87
	Total	10680	10680	10680	24.53	2.66	6.79

Table 5.3: Calculation time and path length of corner node beam reinforcement

Direction	Position number	Length(mm)			Computing time(s)		
		DE	PSO	NFO	DE	PSO	NFO
DirectionY	1	1300	1300	1300	3.32	0.41	1.12
	2	1350	1350	1350	3.38	0.39	1.07
	3	1350	1350	1350	3.37	0.39	1.09
	4	1350	1350	1350	3.35	0.37	1.09
	5	1350	1350	1350	3.32	0.32	1.09
	6	1300	1300	1300	3.31	0.33	1.07
	7	1300	1300	1300	3.32	0.32	1.08
	8	1300	1300	1300	3.35	0.39	1.11
	Total	10600	10600	10600	26.72	2.92	8.72
DirectionX	1	1370	1370	1370	3.31	0.31	1.06
	2	1370	1370	1370	3.35	0.33	1.02
	3	1370	1370	1370	3.32	0.37	1.06
	4	1300	1300	1300	3.31	0.33	1.07
	5	1300	1300	1300	3.36	0.33	1.07
	6	1300	1300	1300	3.35	0.32	1.07
	7	1300	1300	1300	3.35	0.35	1.09
	8	1370	1370	1370	3.32	0.35	1.08
	Total	10680	10680	10680	26.67	2.69	8.52

26.72 seconds and 26.67 seconds. The calculation time of PSO is the shortest, only 2.92 seconds and 2.69 seconds. The calculation time of NFO is located in the middle, which is 8.72 seconds and 8.52 seconds, respectively. This indicates that under the same task, PSO has the highest computational efficiency, DE has the lowest computational efficiency, and NFO has a computational efficiency between these two.

6. Conclusion. This study conducts in-depth research on the collision free arrangement of steel bars in PB beam column joints by introducing BIM technology and combining BD simulation modeling analysis. Specifically, this study first proposes a reinforcement layout model based on IA path planning, and further proposes a framework reinforcement intelligent layout and BIM modeling method by combining APF and path optimization methods. The calculation time for the top corner node is the shortest, only 76.8 seconds, while the calculation time for the middle layer node is the longest, up to 141.7 seconds. Meanwhile, research has also found that different algorithms may have different efficiency when solving the same problem. Although the performance of DE, PSO, and NFO algorithms is consistent in terms of path length, PSO is significantly better than DE and NFO algorithms in terms of computational time. For example, for the edge node beam reinforcement in direction Y, the calculation time of PSO is only 2.84 seconds, while the calculation time of DE and NFO algorithms is 27 seconds and 8.58 seconds, respectively. This study achieved collision free arrangement of steel bars in PB beam column nodes, improving the speed and efficiency of deepening design.

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APPLICATION OF HEALTH EDUCATION PROGRAM BASED ON INTELLIGENT RECOMMENDATION ALGORITHM IN THE DEVELOPMENT OF SCHOOL-AGE CHILDEN'S HAND HYGIENE BEHAVIOR

XIN ZHAO*, CHONG LI†, LINGHONG WANG ‡, CHAO DONG §, AND ZHAOXUAN MENG¶

Abstract. The cultivation of hand hygiene behavior among school-age children is an important way to prevent the spread of diseases and ensure children's health. However, traditional health education methods lack personalized programs tailored to each child, which cannot effectively improve their hand hygiene awareness and behavior. In response to this issue, the study combines multi-objective particle swarm optimization algorithm to provide personalized hand hygiene behavior development recommendations for school-age children, improving their hand hygiene awareness and behavioral level. The study adopted multi-objective particle swarm optimization algorithm and convolutional neural network, combined with the personalized needs of school-age children and the goal of cultivating hand hygiene behavior, and proposed a health education plan based on intelligent recommendation algorithm. Through deep learning, match the hand hygiene needs of school-age children with corresponding health education plans to achieve personalized recommendations. The average accuracy of the health education recommendation plan for hand hygiene behavior cultivation of school-age children based on multi-objective particle swarm optimization algorithm reaches 99.07%. Meanwhile, after introducing convolutional neural networks, the feature matching error between the recommended scheme and school-age children ranges from 10-1 to 10-2. After testing, the designed algorithm performs more stably and has less fluctuations under different sparsity conditions. Health education solutions based on intelligent recommendation algorithms can provide personalized solutions for school-age children, effectively cultivate their hand hygiene behavior, and meet various health needs.

Key words: School age children; Hand hygiene behavior cultivation; Intelligent recommendation algorithm; multi-objective optimization; deep learning

1. Introduction. In today's digital age, with the continuous development of the Internet and big data technology, the application of intelligent recommendation algorithms in the field of health education is gradually receiving attention [1, 2]. Especially in the cultivation of hand hygiene behavior among school-age children, intelligent recommendation algorithms can provide personalized educational programs based on children's behavior and preferences, which helps to improve children's hand hygiene awareness and behavior development [3, 4]. Hand hygiene is one of the important ways to prevent the spread of diseases, especially among school-age children. Due to the complex environment and objects they come into contact with, the importance of hand hygiene is even more prominent. However, traditional health education methods often lack personalized programs tailored to each child, which cannot effectively improve their hand hygiene awareness and behavior [5]. Intelligent recommendation algorithms can provide customized hand hygiene education plans for each child by analyzing their behavior and preference data. Through deep learning and data mining techniques, we can understand children's acceptance of hand hygiene information, learning styles, and interests, thereby providing them with more appropriate educational content and methods. In view of this, the study comprehensively considers the personalized choices and reasonable healthy diet of school-age children, as well as the cultivation goals of hand hygiene behavior. The study uses multi-objective particle swarm optimization (PSO) algorithm to motivate the hand hygiene behavior of school-age children, improves the multi-objective PSO algorithm, and constructs a multi-objective optimization algorithm suitable for the hand hygiene behavior of school-age children. At the same time, it combines convolutional neural networks (CNN), A personalized intelligent recommendation algorithm based on particle swarm optimization and deep learning for hand hygiene behavior

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cultivation of school-age children has been proposed to promote their hand hygiene behavior cultivation. The research structure is mainly divided into four parts. The first part is a summary of relevant research results; The second part is the design of a health education solution based on intelligent recommendation algorithms; The third part is to verify the effectiveness of the algorithm; The final part is the research summary.

2. Related work. With the improvement of people's living standards, people pay more and more attention to the quality of life. Various recommendation systems are widely used in humans. How to improve the accuracy of recommendation is a key issue. To improve the accuracy and user satisfaction of the recommendation system, Janakiraman et al. proposed technologies such as ant colony and particle swarm optimization to optimize the recommendation algorithm. The recommendation algorithm of PSO is superior to other traditional algorithms, with higher performance and Accuracy [6]. To prevent the sudden appeal of diabetes-related complications, Tabassum N et al. proposed an expert recommendation system using fuzzy logic to determine individual dietary needs at the micro and macro nutritional levels. The results showed that the system can recommend the best diet plan for diabetes control. Prevention of complications is very effective [7]. In order to choose an appropriate method to build an interactive news data heterogeneous graph with an appropriate learning mechanism, M Ma et al. raised a news personalized recommendation system on the ground of a graph-based action-aware network, and the results showed that the system can focus on different users. Different degrees of user recommendation news [8]. To shorten the search room of similar users or items in social networks, Berkani proposed a personalized item recommendation combining social filtering algorithm and traditional user-based collaborative filtering algorithm. This method can effectively cut down the search space [9]. Benkessirat et al. proposed a recommendation system that uses clustering to improve the collaborative filtering algorithm in order to help users find joy that better match their personal data. Compared with classical collaborative filtering and collaborative filtering based on k-means, the proposed method significantly enhances the recommendation efficiency [10]. To address the matter of low accuracy of traditional recommendation methods and the lack of consideration of information, Zhang et al. suggested a multi-dimensional comprehensive recommendation method. This could lift the recommendation accuracy [11]. Cao B and others artificially solved the problem of big data overload and designed a distributed parallel evolutionary algorithm based on non dominated sorting and crowding distance. It discovered network nodes with fewer visits in a personalized way, thereby alleviating the pressure of data overload. The results showed that this method has good performance and efficiency [12].

CNN, as a type of neural network that specializes in processing data with similar grid structure, is widely used because of its good accuracy and efficiency in processing large data sets. To enable users to effectively search for same, related and diverse Dunhuang mural images, Zeng et al. proposed a CNN model tuned in the data set of Dunhuang murals. The finely tuned ResNet152 is the best choice for searching for similar images at the visual feature level, while improving the diversity of search results [13]. Wang et al. studied the robustness of graph convolutional network (GCN), and proposed a new "false node attack" to attack GCN by adding malicious fake nodes. The results showed that non -target attacks reduced the GCN accuracy. Up to 0.03, targeted attacks achieve a 78% successful rate on a group of 100 nodes, and an average success rate of 90% when attacking a single targeted node [14]. W El-Shafai et al. raised a CNN-based SIGTra hybrid module to accurately display the main features of pneumonia and COVID-19 diagnostic medical images, and the results showed that the SIGTra is compatible with other related CNN models for COVID-19 detection. Compared with it, it shows better performance in terms of precision, sensitivity and accuracy [15]. For solving the problem of limited prediction-accuracy of traditional network security situational awareness, Chen constructed a RBF neural network prediction model based on SA-HHGA optimization. The results showed that the predicted situation value and the actual situation value of the optimized RBF in 15 samples. It is very close and has a good predictive effect [16]. For improving the data embedding ability of the modification-free steganography algorithm (MFS), JB Wu et al. designed a semi-structured MFS combined image classification and CNN. It has great anti-attack capacity and can improve Hidden ability [17]. Zhang Q et al. designed a robust deformable denoising cellular neural network to address the issue of convolutional operations potentially altering noise distribution in image denoising. The network extracts noise features through deformable blocks, promotes contextual interaction with enhanced blocks, and solves long-term dependency problems with residual blocks. The results show that the model performs well in both qualitative and quantitative analysis [18].

To sum up, at this stage, abundant scholars have contributed to the application of various recommenda-

Fig. 3.1: Framework of Health Education Program for Hand Hygiene Training of School-age Children

tion systems and CNN from various aspects. However, there are still relatively few personalized intelligent recommendation programs for cultivating children's hand hygiene behavior and health. Therefore, this study combines the feature extraction and representation methods of children's hand hygiene behavior data with multi-objective PSO algorithm, and proposes a recommendation algorithm for children's hand hygiene behavior development that combines deep learning and multi-objective optimization to provide personalized hand hygiene behavior development recommendations.

3. Methods. With the increasingly prominent issue of cultivating children's hand hygiene behavior, users and intelligent recommendation systems are facing increasing challenges in seeking effective solutions. In order to design a health education program suitable for cultivating children's hand hygiene behavior, a health education program based on intelligent recommendation algorithms was studied and constructed. CNN was introduced to establish a health education program for cultivating hand hygiene behavior among school-age children based on deep learning, in order to help them develop good hand hygiene habits.

3.1. Design of a health education program for cultivating hand hygiene behavior among school-age children. School-age children are in a critical period of growth and development, and their immune system is not yet fully mature, making them susceptible to infection. Developing hand hygiene behavior is one of the important ways to prevent the spread of diseases and is of great significance for protecting children's health. Therefore, it is necessary to design a health education program specifically aimed at cultivating hand hygiene behavior among school-age children. This program aims to help school-age children develop correct hand hygiene habits and improve their health level through education and training [19]. Based on the needs and goals of school-age children, a health education program for hand hygiene training of school-age children is designed. The framework is shown in Figure 3.1.

In Figure 3.1, the scheme first clarifies the objectives and specific real-time plan of the scheme. Conduct user needs analysis based on the goals to understand children's hand hygiene habits, cognitive abilities, and learning styles. And according to user needs, plan content such as hand hygiene knowledge, hand hygiene animations, hand hygiene games, and hand hygiene songs [20]. In this section, attention needs to be paid to the diversity, interest, education, and systematicity of the content to attract children's attention and enhance their learning interest. At the same time, design the functional modules of the system based on the content of the plan and the target user group, including learning mode, testing mode, and interactive mode. In functional design, attention should be paid to the practicality, ease of use, and scalability of functions to meet user needs while providing a good user experience. The program comprehensively considers the physical and mental characteristics, cognitive ability and behavior habits of school-age children to enhance their hand hygiene awareness and ability, and prevent and control the occurrence and spread of infectious diseases. Its goal is to cultivate good hand hygiene habits, and through systematic education and training, it helps school-age children establish good hand hygiene habits and enhance their awareness and ability of hand hygiene.

3.2. Design of multi-objective optimization algorithm for cultivating children's hand hygiene behavior based on particle swarm optimization. Although a health education program has been designed

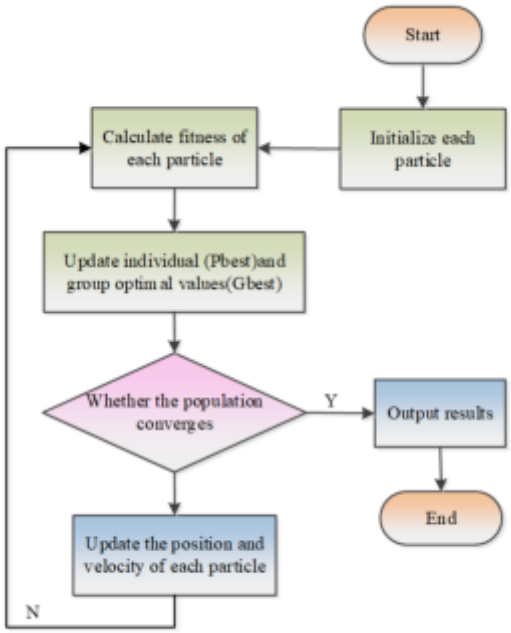


Fig. 3.2: PSO algorithm process

to cultivate hand hygiene behavior among school-age children, there are individual differences among school-age children, including age, gender, cognitive abilities, and learning styles. Therefore, it is necessary to provide more personalized and differentiated education tailored to the characteristics and needs of different children, and research the use of deep learning algorithms to optimize and improve the designed health education plans. In deep learning algorithms, the PSO is characterized by simplicity and fast convergence speed. The specific process is Figure 3.2 [21].

As shown in Figure 3.2, the Global-best solution (gBest) on single-objective optimization can be obtained through the PSO algorithm when the number of particle swarms is constant. However, when the optimization objectives become multiple, the PSO cannot complete the choice of the optimal position of the group among multiple individuals, because there are multiple optimal positions of the group in multi-objective optimization. To address this issue, the study put forward a multi-objective particle swarm optimization (MOPSO) built on the PSO to select a leader according to the degree of congestion in the optimal set [22]. The MOPSO includes five key elements, which are the initialization of the particle space, the topology of the particle neighborhood, the inertia weight, the maximum velocity of the particle, and the stopping criterion. The specific flow chart is Figure 3.3.

As shown in Figure 3.3, in the needs analysis of hand hygiene education programs for school-age children, multiple aspects of children are involved, including their hand hygiene habits, cognitive abilities, and learning styles. In order to balance multi-objective optimization and each nutrient, further research is needed on the definition rules of the five key elements of MOPSO. First of all, the research selects the particle space that includes aspects such as hand hygiene habits, cognitive abilities, and learning styles as the localization scope. The size of the particle swarm is N . Binary particles are used to initialize the initial velocity. The calculation method is shown in formula 3.1.

$$if(v_{id}^0 = max(v_{id}^0)), then \quad x_{id}^0 = 1, else \quad x_{id}^0 = 0 \tag{3.1}$$

In formula 3.1 v_{id}^0, is the initial velocity, x_{id}^0 and is the initial position. Then find the individual best particle (pBest) value of each particle, and define an objective function suitable for hand hygiene behavior. This function can evaluate whether children's hand washing habits meet hygiene standards based on indicators

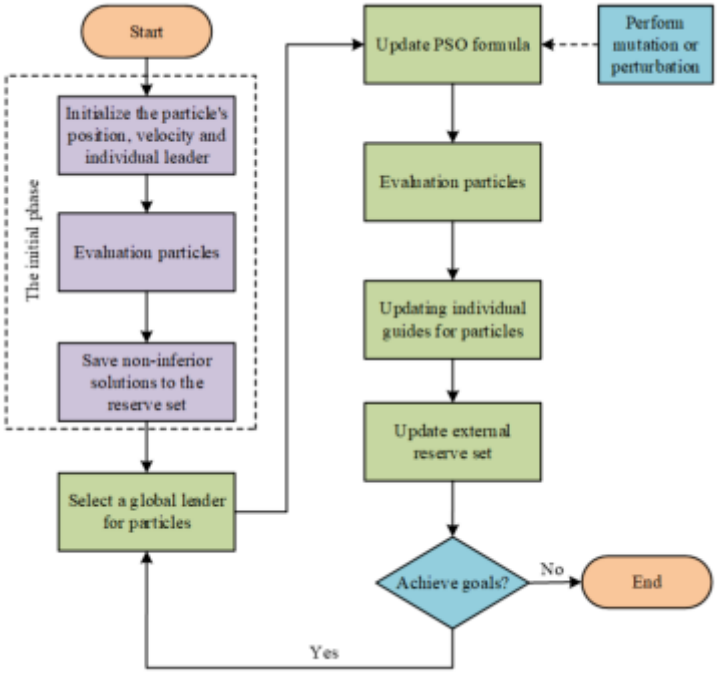


Fig. 3.3: MOPSO process

such as hand washing time and frequency. The objective function should be consistent with the evaluation criteria for hand hygiene behavior in school-age children. By calculating the objective function value of each particle, the optimal particle, namely the optimal hand washing time and frequency, can be found. Comparing the optimal position value of the objective function of the historical best position adaptation value, and updat the one with the higher fitness value is updated as the historical best position, calculated as formula 3.2.

$$\begin{cases} pBest_i = (p_{i,1}, p_{i,2}, \ldots, p_{i,D},) \\ if \quad f(x_{id}) < p_{id}, then p_{id} = x_{id}, else p_{id} = p_{id} \\ if \quad f(x_i) < pBest_i, then \quad pBest_i = p_{id}, else \quad pBest_i = pBest_i \end{cases} \tag{3.2}$$

Equation 3.2 $pBest_i$ is all the best positions that the particle-i has experienced in space, p_{id} represents the individual optimal position of particle i in d-dimensional space, x_{id} represents the current position of particle i in d-dimensional space, and $f(.)$ represents the evaluation function used to calculate the fitness of particle position. Find a global value from the calculated individual fitness value and compare it with the historical storage, update the global optimal solution to obtain the best balance of human nutritional needs, and the calculation is shown in formula 3.3.

$$\begin{cases} g_d = min(pBest_i) \\ gBest = (g_1, g_2, \ldots, g_D) \end{cases} \tag{3.3}$$

$gBest$ in equation 3.3 is the best position that the population-d has experienced in the dimensional space component, which g_d is the that of the same in the space. Then, the contraction factor D is introduced to obtain a better solution to improve the shortcoming of the slow convergence speed of the PSO, and the calculation formula of the update speed of the dimensional space component i of the particle is obtained d as formula 3.4.

$$\begin{cases} v_{id}^k = W[v_{id}^k + c_1 r_1 (pBest_{id} - x_{id}^k) + c_2 r_2 (g_d - x_{id}^k] \\ W = \frac{2}{|2-c-\sqrt{c^2-4c}|}, c = c_1 + c_2, c > 4 \end{cases} \tag{3.4}$$

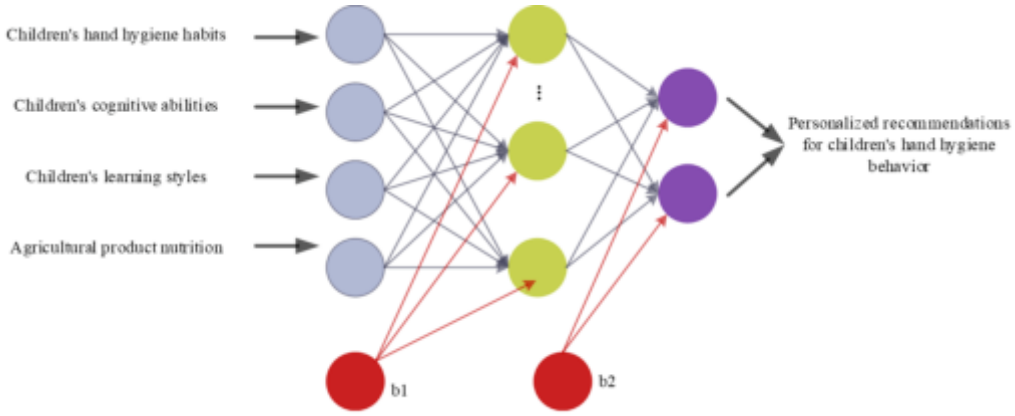


Fig. 3.4: CNN neural network structure diagram

In formula 3.4 c_1 , , c_2 is the learning factor, $c_1 = c_2$ and it is between 0 and 4; the contraction factor w is the c_1, c_2 restricted inertia weight. The velocity of the dimension changes during the update is in $d[-v_{min,d}, v_{max,d}]$ the range, when, $v_{id} > v_{max,d} v_{id} = v_{max,d}$. To further update the position of the dimensional space component i of the particle d, the calculation formula is shown in formula 3.5.

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k} \tag{3.5}$$

In formula 3.5, x_{id}^{k} and v_{id}^{k} are the d-th dimensional component of the vector position in the k-th iteration of particle i and flight velocity of particle i in the k-th iteration. During the update the position of the dimension changes in $d[x_{min,d}, x_{max,d}]$ the range, when, $x_{id}^{k} > pBest_{id} x_{id}^{k} = pBest_{id}$. At this point the value is updated k, set $k = k + 1$ until iterations equal max iterations to complete the algorithm steps.

3.3. Design of personalized recommendation algorithm for children's hand hygiene behavior development based on multi-objective optimization. Due to the different hand hygiene habits and cognitive abilities of each school-age child. Therefore, it is necessary to design personalized recommendations based on children's characteristics to meet children's needs. The research uses CNN to extract and intelligently recommend personalized health education plans [23]. CNN is divided into three parts: local receptive field, shared weight and pooling. It studies the problem of using CNN's forward and backward algorithms to adjust and update people's needs as time changes, and uses response error calculation to solve the output structure. The result deviates greatly from the user's own needs. First, personalized data on hand hygiene habits, cognitive abilities, and learning styles of school-age children are input into the input layer and standardized to unify units and formats [24, 25]. Then use the convolution layer to extract behavioral features, realize data processing and compression, and complete the preliminary screening process of AP. When the hand hygiene behavior data of school-age children is used as input, the personalized recommendation for cultivating children's hand hygiene habits are output, the hidden layer's node amounts are 4, 2, 3 hidden layers, and bias items, the specific CNN neural network structure is shown in Figure 3.4.

To provide users with a variety of choices, the research pushes different children's hand hygiene behavior development plans to users at the same time, and performs weighted summation of the non-dominated solutions that cannot be judged according to the weight. The calculation is formula 3.6.

$$F(x) = \sum_{i=1}^{n} \omega_i \times f_i(x) \tag{3.6}$$

In formula 3.6, $\omega_1, \omega_2, \ldots, \omega_n$ it is n the weight of the th behavior development plan, $f_i(x)$ which is n the fitness of the behavior development plan. In the calculation process, the research proposes a preference

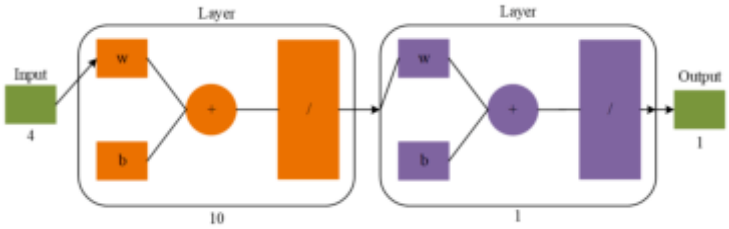


Fig. 3.5: CNN neural network specific structure diagram

strategy to solve the situation that the user cannot provide weights. First, find all the solutions and perform a fast non-dominated sorting to divide the levels. For the non-dominated solutions of the same level, the user's input order of each behavior development plan is used as the preference tendency, and the order is reduced $\omega_1 > \omega_2 > \ldots > \omega_n$. The range U is determined according to the number n of agricultural product combinations, and the calculation is shown in formula 3.7.

$$U \in (0, U_{max} = \frac{2}{n(n-1)}, \quad n = 1, 2, , \ldots \tag{3.7}$$

To sum up, the above-mentioned research input a large number of user orders and matched personalized solutions more suitable for learning hand hygiene habits and cognitive abilities through CNN self-learning, and realize the multi-objective personalized intelligent recommendation for hand behavior development in school-age children. The CNN input layer is set with 4 neurons, and the hidden layer is set with 3 neurons. The specific CNN structure is shown in Figure 3.5.

As shown in Figure 3.5, the application of CNN in the recommendation for children's hand behavior development. In summary, the personalized recommendation algorithm design for children's hand behavior development based on multi-objective optimization and deep learning has been completed.

4. Conclusion. The user's choice of an appropriate recommendation scheme is essentially a matching process between user needs and information on hand hygiene behavior cultivation for school-age children [26, 27, 28]. Users judge whether the recommended scheme meets their needs based on the intelligent recommendation algorithm, content, and the goal of cultivating hand hygiene behavior among school-age children, and ultimately choose a suitable health education plan. To verify the accuracy of the health education scheme based on intelligent recommendation algorithms in the cultivation of hand hygiene behavior among school-age children, this part focuses on the design of the convergence and distribution of non-inferior solutions of the algorithm on two-dimensional test functions, further testing the accuracy of the personalized intelligent recommendation scheme for hand hygiene behavior cultivation of school-age children based on CNN.

4.1. Performance analysis of hand hygiene behavior cultivation in MOPSO school-age children. For verifying the effect of intelligent recommendation algorithms for cultivating hand hygiene behavior among school-age children, user data was collected, such as age, gender, and hand hygiene behavior level of participating children, as well as relevant health education data, such as hand hygiene behavior goals, effectiveness evaluation, and learning feedback. From the experimental data studied, the determination of the maximum iteration value is carried out.

Figure 4.1 shows the accuracy measurements for the maximum iteration value. The results show that when the sum of particles is the same, the greater the iterations, the higher the accuracy. When the total number of particles is 70 or more, the accuracy does not change much, all above 97%. Therefore, the study further selects the particle numbers as 70 and the max amount of iterations as 10 as the stopping criterion, sets the variable of 8 to 8, and the variable of 2 to 2. On the two-dimensional test function (ZDT3, ZDT6), the Elitist-Mutated MOPSO technique (EM-MOPSO) and Speed-constrained MOPSO (SMOPSO) algorithm were compared and tested.

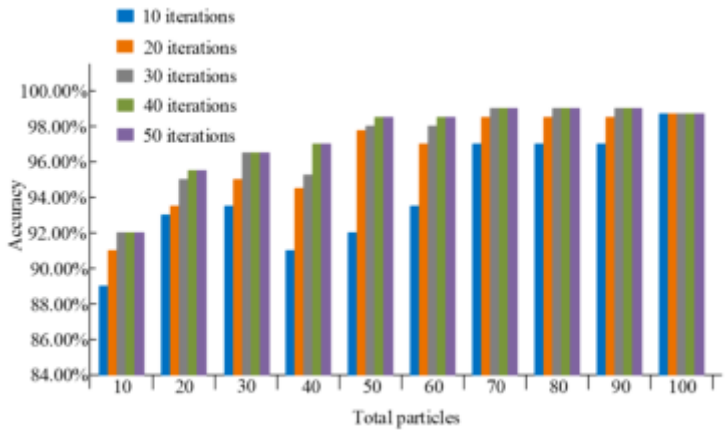
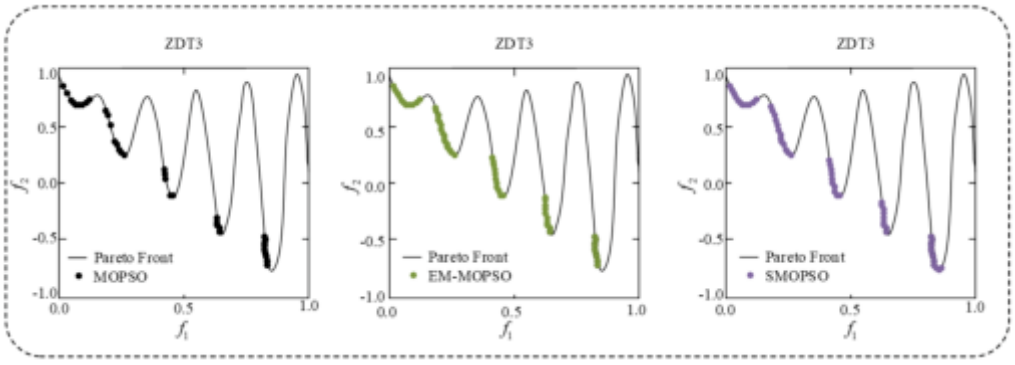
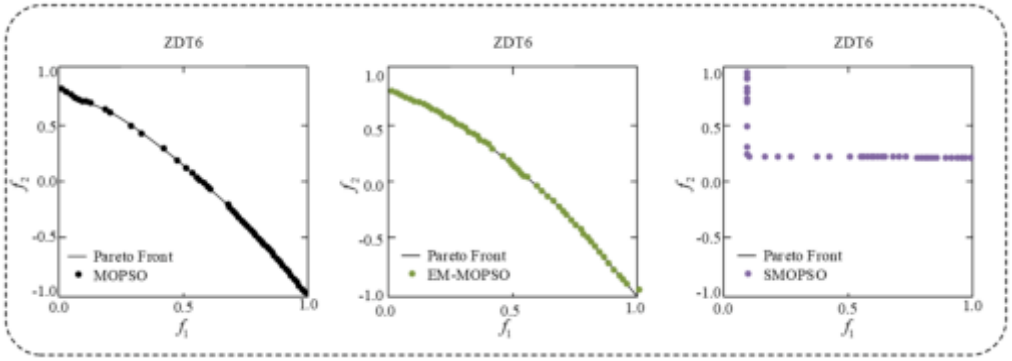


Fig. 4.1: Particle and maximum iteration value determination

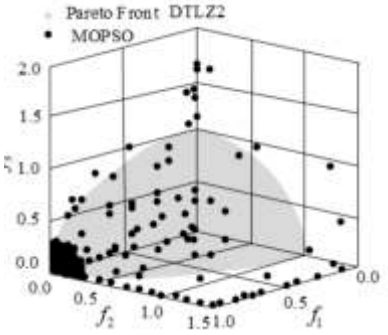


(a) True Pareto edge rendering of the algorithm on the ZDT3 function

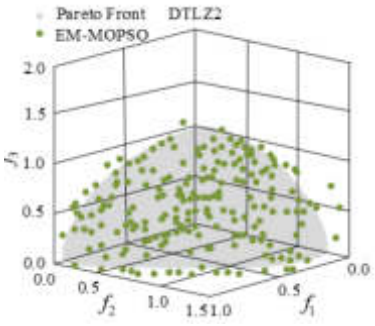


(b) True Pareto edge rendering of the algorithm on the ZDT6 function

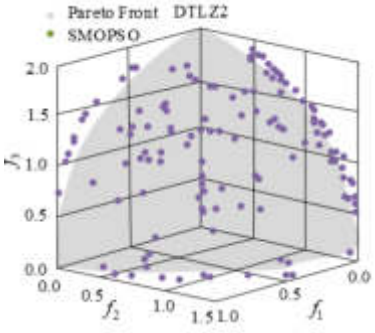
Fig. 4.3: Algorithm two-dimensional test function graph



(a) The real Pareto frontier rendering of the MOPSO algorithm on the DTLZ2 function



(b) The real Pareto frontier rendering of the EM-MOPSO algorithm on the DTLZ2 function



(c) The real Pareto frontier rendering of the SMOPSO algorithm on the DTLZ2 function

Fig. 4.5: Algorithm three-dimensional test function effect diagram

Table 4.1: The accuracy of indicator values in hand hygiene behavior training recommendation algorithms and the recommendation accuracy of different algorithms

age	Accuracy of hand washing frequency (%)	Accuracy of hand washing time (%)	Accuracy of hand washing indications (%)	MOPSO algorithm accuracy (%)	GA algorithm accuracy (%)
1	97.82	98.19	99.95	99.15	97.25
2	98.50	97.67	99.89	98.76	96.52
3	99.00	98.77	99.88	99.28	97.81
4	98.67	97.59	99.82	98.69	96.32
5	99.74	95.61	99.80	98.38	95.23
6	98.54	99.19	99.99	99.50	98.05
7	98.00	98.62	97.63	99.76	98.53

Figure 4.2a and 4.2b are the comparative test diagrams of the experiments of the three algorithms on the 2D test functions ZDT3 and ZDT6. Compared with the EMMOPSO and SMOPSO algorithms, the distribution of non-inferior solutions of the proposed MOSPO algorithm is more concentrated, indicating that the algorithm has better convergence. Further, the three algorithms are compared and tested on the three-dimensional test function (DTLZ2).

Figure 4.4a- Figure 4.4c are the comparative test results of MOPSO, EMMOPSO and SMOPSO on the3D test function DTLZ2 respectively. The solution distribution of MOPSO on the 3D-test function is relatively concentrated, while EM-MOPSO and SMOPSO are relatively scattered. In summary, among the test functions of ZDT and DTLZ series, the MOPSO owns greater convergence and distribution, which shows that the algorithm has a better running effect and is an effective strategy to improve the MOPSO. The next step is to use MOPSO and genetic algorithm (GA) to provide intelligent recommendations for personalized hand hygiene behavior cultivation for children of different age groups. The accuracy rates of different indicators compared with actual data are calculated, and the accuracy results of the two algorithms are also calculated. The results are shown in Table 4.1.

Table 4.1 shows the accuracy of the indicator values of the hand hygiene behavior training recommendation algorithm and the recommendation accuracy of different algorithms. The various hand hygiene behaviors recommended by the study can meet the needs of children's hand hygiene behavior cultivation, with an accuracy rate between 80% and 100%. Compared with GA, the MOPSO algorithm provides better hand hygiene behavior recommendation results and can achieve the best hand hygiene behavior cultivation effect. The average accuracy

Table 4.2: Recommended accuracy of different algorithms in cultivating hand hygiene behavior among students at different educational stages

Algorithm	**Accuracy rate of primary school students (%)**	**Accuracy rate of junior high school students (%)**	**Accuracy rate for high school students (%)**
MOPSO algorithm	94.76%	96.92%	99.07%
GA algorithm	92.35%	94.65%	97.87%
Unused	89.10%	91.32%	93.50%

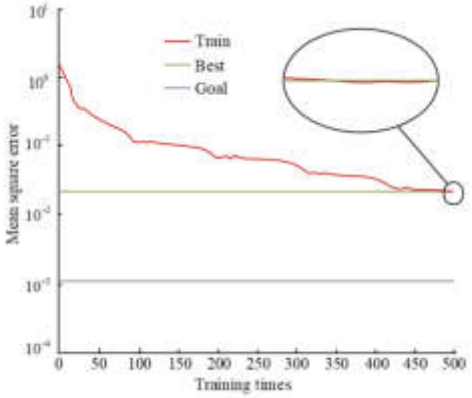


Fig. 4.6: Training Error Convergence Graph

of the MOPSO algorithm is 99.07%, while the average accuracy of the GA algorithm is 97.87%. In order to gain a deeper understanding of the developmental differences in hand hygiene behavior among school-age children and further validate the effectiveness of the designed recommendation algorithm in hand hygiene behavior cultivation, a study selected 150 high school and 150 junior high school students from a certain middle school, and 150 elementary school students from a certain primary school as subjects. These subjects were divided into three groups, and the MOPSO algorithm based health education program was used The health education program based on GA algorithm and the health education program without using the algorithm were intervened for one month. After the experiment, the recommended accuracy of different algorithms in cultivating hand hygiene behavior among students at different educational stages was calculated. The results are shown in Table 4.2.

From Table 4.2, it can be seen that after receiving the MOPSO algorithm based health education program, the recommendation accuracy of the high school student group is 99.07%, the middle school student group is 96.92%, and the accuracy of the primary school student group is 94.76%. It can be observed that as age increases, older students are more able to accurately understand and practice hand hygiene guidance. However, the MOPSO algorithm outperformed other comparison groups in all education stages, indicating that the algorithm assisted health education program has a significant effect on improving the accuracy of students' hand hygiene behavior, proving its effectiveness and emphasizing its scientific and practical significance.

4.2. Performance analysis of personalized recommendation algorithm based on multi-objective optimization model. To verify the effectiveness of a personalized recommendation algorithm for children's hand hygiene behavior development by combining multi-objective optimization models with CNN. The study extracted an appropriate amount of samples from existing databases for 500 neural network training sessions, and analyze the convergence of training errors.

Figure 4.6 is a graph of the convergence of CNN network training errors for 500 times. The results show that

Table 4.3: Experimental results of each model under different data sparsity

Model	Score data a d density					
	0.45%	1.37%	2.12%	2.89%	3.55%	3.93%
LFM	1.2081	1.0571	0.9837	0.9462	0.9201	0.9034
CDL	1.1654	1.0289	0.9555	0.9232	0.8978	0.8869
SIFT-LFM	1.1000	0.9903	0.9331	0.9096	0.8834	0.8759
CNN	1.0532	0.9618	0.9114	0.8873	0.8708	0.8625
Improve	12.82%	9.02%	7.35%	6.22%	5.36%	4.53%

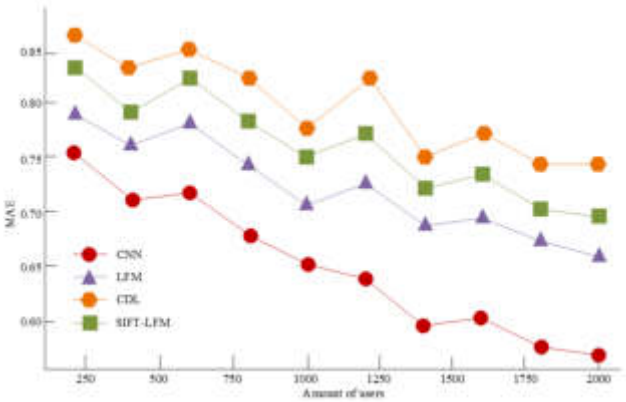


Fig. 4.7: Comparison chart of experimental results of four models

the error between the recommended scheme of by the CNN neural network and the user's features is between 10 -1 and 10-2, and the best training error value in training is 0.020065, which is a small error, indicating that the CNN network can be used to intelligently recommend children's hand hygiene behavior development plans that meet user needs. For exploring the performance of CNN under different data sparsity, a randomly sampled user dataset was studied, and the data sparsity was changed, and the CNN model is combined with common latent factor models (LFM) and collaborative deep learning (CDL) models. CDL language and the SIFT-LFM model using the Scale Invariant Feature Transform (SIFT) method to extract image features combined with LFM for comparative testing.

Table 4.3 shows the experimental test results of different models under different sparsity. CNN at each sparsity is more accurate than the others, and the results obtained are better. At the same time, compared with the LFM, the improvement rate of the CNN increases from 4.53% to 12.82%, which means that in When the data is sparse, the CNN is more stable than the LFM model, with less fluctuation. The research selected 2,000 users as test objects, and further compared the recommendation schemes of the CNN with the other three models, and used the mean absolute error (MAE) as the evaluation index. The smaller the value of MAE, the smaller the recommendation error. The result is more accurate.

Figure 4.7 is a comparison chart of the average error of the recommended schemes of the four models. The MAE value of the CNN model is smaller than that of the other three models, indicating that the CNN recommendation scheme is more accurate than other model recommendation schemes and more in line with user needs. And as the number of test users increases, the overall MAE value shows a downward trend, indicating that the larger the amount of data, the better the model's recommendation quality can be fully reflected. In summary, the personalized recommendation algorithm for children's hand hygiene behavior cultivation based on particle swarm and deep learning proposed by the above research can give the optimal personalized recommendation scheme according to user needs, further lift the life-quality of children, and meet the personalized diet of children need.

5. Discussion. In recent years, people's quality of life has significantly improved, and health education for school-age children has become more important. However, there is still a problem of non-standard hand hygiene behavior among school-age children, which may have a negative impact on their health and growth. Therefore, how to effectively cultivate correct hand hygiene behavior among school-age children has become a common concern for parents and educators. To solve this problem, a personalized recommendation scheme for hand hygiene behavior development in school-age children based on PSO and deep learning was proposed by combining MOPSO algorithm and CNN algorithm. Compared with GA, the accuracy rate of the hand hygiene behavior development in school-age children by the MOPSO algorithm is between 80% and 100%, and the average accuracy rate of its nutrient intake is 99.07%, while the mean accuracy ratio of the GA nutrient intake is 97.87%. In addition, after using the deep learning of CNN, the error of matching the recommended scheme and user features is 10 -1-10 -2, and the best training error value in training is 0.020065. When tested under different sparsity, compared with the LFM model, the improvement rate of the CNN model increased from 4.53% to 12.82%, and the performance was more stable. At the same time, the MAE value of the CNN model was smaller and the error was smaller. In summary, the above research proposes that health education programs based on PSO and deep learning can better provide personalized recommendations based on the hand hygiene behavior data of school-age children, further promoting their hand hygiene behavior development and improving their quality of life. However, current research has not taken into account the impact of different cultural backgrounds and regional differences on the hand hygiene behavior of school-age children. Subsequent research can further explore cross-cultural and cross regional plans for children's hand hygiene behavior development to meet a wider range of children's needs.

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INTELLIGENT MATCHING METHOD FOR COLLEGE DORMITORY ROOMMATES: CHAMELEON ALGORITHM BASED ON OPTIMIZED PARTITIONING

CUIPING WANG*

Abstract. A chameleon algorithm based on optimized partitioning was studied to solve the intelligent matching problem of college dormitory roommates. Using quantitative research methods, data on personal preferences and lifestyle habits of college students were collected, and the K-center object chameleon algorithm was used for data analysis and roommate matching. Test the algorithm performance on the BBC dataset, compare clustering quality indicators such as entropy, purity, and RI value, and verify the effectiveness of the algorithm. This algorithm can accurately assign students to their respective dormitories, avoiding overlapping situations and achieving excellent matching results. In terms of matching accuracy and running time, the K-center object chameleon algorithm shows superior performance compared to other algorithms. In terms of clustering quality evaluation, comparisons were made from three dimensions: entropy value, purity, and RI value. The experimental results show that the closer the entropy value is to 0, the closer the purity and RI value are to 1, and the better the matching effect. This result further validates the effectiveness of the algorithm in the intelligent matching problem of college dormitory roommates. The matching accuracy of this algorithm on the BBC dataset reached 98.82%, showing better clustering quality than other algorithms in terms of entropy, purity, and RI values. The entropy value approached 0, while the purity and RI values approached 1, verifying the efficiency of matching quality. The chameleon algorithm based on optimized partitioning proposed in the study has shown excellent performance in intelligent matching of college dormitory roommates, with the characteristics of high-precision matching and fast running time. It has important practical significance for improving the quality of life and learning efficiency of college dormitory students, and provides new research methods and ideas for related fields.

Key words: Dormitory roommates; Intelligent matching; Optimize partitioning methods; Chameleon algorithm; Big data

1. Introduction. The process of roommate matching in university environments is closely related to the quality of life, physical and mental health, learning experience, and social development of students. An effective roommate matching system not only affects daily living conditions, but also affects the welfare of students [1-2]. Simple surveys and manual coordination are existing methods for roommate matching, but due to the complexity and subtle differences in personal preferences and personalities, these methods do not meet the requirements. In addition, these methods lack the dynamic adaptability required to adapt to diverse and constantly changing student situations. Therefore, these traditional methods are prone to lifestyle and interpersonal conflicts when achieving harmonious living arrangements. The problem with roommate matching lies in accurately assessing and integrating various factors, such as habits, study plans, rest patterns, and social tendencies. Insufficient consideration of these factors can lead to disharmony and dissatisfaction, which in turn can harm students' academic and social pursuits [3-4]. The new intelligent matching method draws on the characteristics of biological chameleons to achieve optimal dormitory roommate matching, with adaptability and flexibility. This chameleon algorithm is based on optimization partitioning, inputting students' personality characteristics and interests, and using machine learning and data mining techniques for intelligent analysis and matching [5-6]. In view of this, the study introduces a chameleon algorithm based on optimized partitioning for roommate matching, to improve the quality of life in college students' dormitories. It is expected to create a harmonious and friendly dormitory environment, optimizing the learning and living environment. The research will be divided into four parts. This algorithm has been validated in over 10 different regions and types of Chinese higher education institutions. The research is mainly applied to the higher education environment in China, and the research subjects are selected from 1000 mainland Chinese university students. Using stratified random sampling to obtain students from different grades, majors, genders, and cultural backgrounds. Firstly, divide universities into first tier, second tier, and junior colleges, and then randomly select them based on their

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majors and gender ratios. The research contribution lies in the development of roommate matching algorithms that effectively improve the quality of life and learning experience of college students by taking into account various factors such as personal habits, study plans, rest patterns, and social tendencies. The first part is an overview of the chameleon algorithm based on optimized partitioning for the intelligent matching method of college dormitory roommates. The second part is the study of the chameleon algorithm based on optimized partitioning for the intelligent matching method of college dormitory roommates. The third part is the second part's experimental verification. The fourth part is a summary of the research content and points out the shortcomings.

2. Related Works. In the field of dormitory roommate matching research, a large amount of research has focused on traditional methods such as large-scale grouping and random allocation. J é rme et al. studied the fully distributed channel allocation problem in clustered wireless networks. The trial-and-error framework was expanded to prove that its direct application in random environments does not provide ideal solutions. A robust trial and error learning algorithm was proposed to restore good convergence by introducing thresholds. The random effects under Rayleigh fading were analyzed and the theoretical claims was confirmed. Online algorithms were developed to dynamically estimate the optimal threshold and adapt to instantaneous interference [7]. Zucker et al. derived the optimal power allocation for nodes and the optimal rate allocation for networks. A suboptimal scheme was proposed, with threshold scheduling for power allocation and linear adaptive scheme for rate allocation. The simulation outcomes denoted that the loss of the suboptimal scheme was less than 1.5% [8]. Kiesnetter et al. found that plants benefit from microbial composition, but changes in microbial composition also greatly affect plant performance and resource allocation. The random forest model identified fungal and bacterial families that are important for plant performance, and they significantly changed with fragmentation. Research supported the significant fragmentation effect of natural microbial communities and confirmed that fragmentation related changes in microbial communities can affect natural plant performance and investment [9]. Bistritz I's research team proposed a non cooperative energy allocation game and adopted the optimal reaction dynamics as a distributed algorithm. The results showed that the algorithm converged to a pure Nash equilibrium with a maximum of N steps within no more than N steps. However, these equilibria might be inefficient. The proposed algorithm avoided inefficient equilibrium and achieved asymptotic optimal performance in almost all games [10]. Lai et al. derived the optimal power allocation for nodes and the optimal rate allocation for networks. A suboptimal solution was proposed: threshold scheduling was used for power allocation, and linear adaptive scheme was used for rate allocation. The simulation findings indicated that the loss of the suboptimal scheme was less than 1.5% [11]. Henning Smith et al. proposed that with the aging population, barriers to accessing medical services in rural areas are particularly prominent, and it is necessary to evaluate the healthcare access of medical insurance beneficiaries in rural areas in order to develop effective strategies. The research results indicate that after adjusting for factors such as age, gender, and marital status, rural beneficiaries have significantly lower satisfaction with home visits and access to expert care compared to urban beneficiaries, and are more inclined to avoid seeking medical treatment or not informing others when sick. These differences indicate the quality and acceptability issues faced by rural beneficiaries in healthcare, which may affect their seeking behavior and ultimate health outcomes [12].

However, these methods fail to fully consider students' personalized needs and interests, often leading to tense relationships and frequent conflicts in the dormitory. The chameleon algorithm based on optimized partitioning provides a new solution for intelligent matching of college dormitory roommates. Liang Z et al. proposed an automatic clustering method that has clustering stability and can automatically detect correct structures. The experimental results showed that this method had better robustness in synthetic and real data, and was robust in parameter selection [13]. Li et al. put forward a new dynamic verifiable retrieval scheme for encrypted images to address the problems of low retrieval accuracy, low efficiency, and low validation efficiency in dynamic environments that exist in existing schemes. This scheme extracted image features by using a pre trained convolutional neural network model, designed a K-means clustering algorithm-based encrypted index, and used a chameleon hash-based dynamic verification tree to improve retrieval accuracy, efficiency, and dynamic verification efficiency [14]. Alexiadis et al. utilized a machine learning model based on the RASA framework for NLU and conversation flow classification. CIPA-Generation B can generate plans and execute them based on user requests, and has been deployed for testing in real-world scenarios in the energy and

health fields. Experimental research has shown that the developed dialogue agent system has usefulness and acceptability in multi-intention recognition and dialogue processing [15]. Nie et al. proposed a personal carbon trading (PCT) subsidy policy. Based on the Stackelberg game model and actual data from Beijing, research has found that PCT is more efficient than purchasing subsidies and can achieve higher CO2 emission reduction effects. The achievements would help promote the application of PCT subsidy mechanism and assist the transportation industry in achieving carbon peak and carbon neutrality goals [16]. Feng et al. proposed a three-step mathematical programming method to alleviate the problem of excess or insufficient passenger stations on PTU, combining discrete wavelet transform and artificial neural network to predict demand, minimizing the weighted total travel cost and unmet user needs. The research results showed that the proposed demand prediction and optimization method was significantly superior to traditional methods and had robustness [17]. Zhu X et al. proposed the impact of interpersonal relationships in dormitories on emergency evacuation behavior among college students. The research results indicate that close social connections within dormitories promote the efficiency of emergency evacuation; In emergency situations, these relationships are partially transformed into a leader follower mode, reducing evacuation efficiency. In addition, research has found that gender and grade are important factors affecting evacuation behavior, and female and lower grade students have relatively higher evacuation efficiency [18].

In summary, the chameleon algorithm based on optimized partitioning provides a new perspective on the matching problem of college dormitory roommates, improving the accuracy and efficiency of matching. However, the practical application effectiveness and stability of this algorithm still need further verification and exploration. At the same time, how to apply this theory to the actual allocation of university dormitories is also a problem that needs to be solved. Despite some challenges, it is still hoped that the chameleon algorithm can bring more harmony and comfort to the dormitory life of college students in future applications, further improving their quality of life and learning efficiency.

3. Materials and methods. Firstly, it introduces the chameleon algorithm based on optimized partitioning. Then, the original chameleon algorithm is optimized and an optimized chameleon algorithm based on optimized partitioning is put forward to improve the accuracy and efficiency of matching. Finally, a model of intelligent matching method for college dormitory roommates incorporating optimized chameleon algorithm is established, further improving the application framework of this matching method. It is hoped to provide new basis for intelligent matching of college dormitory roommates and open up new perspectives for research in related fields.

3.1. Fusion method of chameleon and K-medoids algorithms. The chameleon algorithm based on optimized partitioning reflects data objects and their similarities through sparse graphs, ensuring effective expansion of large datasets. The algorithm combines preliminary data segmentation of the graph with condensed hierarchical clustering to form clusters of different shapes, sizes, and densities. Firstly, it constructs a sparse graph and divides it into sub clusters of approximate size, and then they are merged based on the proximity and interconnectivity of the clusters. Simultaneously, it needs to calculate the real-time similarity function between clusters to guarantee that it does not exceed the threshold. The chameleon algorithm process is shown in Figure 3.1.

In Figure 3.1, the chameleon clustering algorithm can be divided into clusters of different shapes, sizes, and densities, but the effects of noise and outliers cannot be eliminated. The K-medoids clustering algorithm, as an improved version of the K-means algorithm, is based on partitioning methods for clustering. It randomly selects a set of data objects as the initial center points, and assigns each data object to the cluster represented by the closest center point. Then, it will continue to iterate and determine the new center point of each cluster until the clustering quality no longer improves. This method can process noise and outliers in stages in the graph to avoid affecting the clustering effect. The research chose the Chameleon algorithm because it can handle large datasets and effectively form clusters of different shapes, sizes, and densities. It can adaptively merge clusters based on proximity and interconnectivity, making it suitable for complex data structures often encountered in the real world. The K-means algorithm usually uses Euclidean distance to calculate the distance between data objects, and the calculation method is shown in equation (3.1).

$$D = \sqrt{(x_1 - y_1)^2 - (x_2 - y_2)^2} \tag{3.1}$$

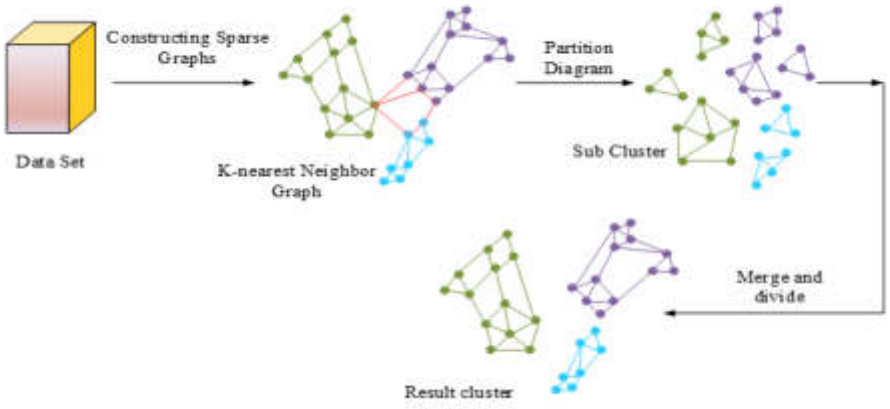

Fig. 3.1: Chameleon algorithm process

In equation (3.1), $(x_1 - y_1)$ and $(x_2 - y_2)$ are the coordinates of two points in the class cluster, and D is the Euclidean distance value. In cluster analysis, Euclidean distance measures the similarity of data points, and the closer the distance, the higher the similarity. By calculating the contour coefficient to evaluate the clustering effect, it reflects the compactness within the cluster and is an external indicator, as defined in equation (3.2).

$$S_i = \frac{b_i - a_i}{\max(a_i, b_i)} \tag{3.2}$$

In equation (3.2), a_i means the average distance between each data object in the cluster and other objects in the cluster, and b_i refers to the mini average distance between the data object in the cluster and all other clusters. The improved chameleon algorithm first uses K-Means to partition the initial dataset into subcategories with high cohesion, and then performs K-nearest neighbor graph partitioning to reduce the impact of outliers and noise. The aggregation algorithm of the chameleon algorithm is used to analyze small clusters and obtain the final clustering results. On the basis of not changing the chameleon algorithm process, the K-medoids algorithm is inserted to reduce the impact of outliers, improve intra-cluster similarity and inter-cluster difference, thereby improving algorithm efficiency and results. The chameleon algorithm based on optimized partitioning also adopts a similar approach, but further optimization and improvement have been made. The flowchart of the chameleon algorithm based on optimized partitioning is denoted in Figure 3.2.

In Figure 3.2, the K-medoids algorithm requires repeated iterations to determine the center point, resulting in an increase in clustering convergence time and limited processing ability for large datasets, making it more suitable for clustering analysis of small datasets. However, its sensitivity to abnormal data endows it with good anti-interference ability at outliers. In the chameleon algorithm based on optimized partitioning, these issues have been improved and optimized to handle large datasets more effectively while maintaining anti-interference ability against abnormal data.

3.2. Detailed explanation and process research of optimizing chameleon algorithm based on K-medoids. The optimized chameleon algorithm introduces the K-medoids clustering algorithm to replace the original graph partitioning algorithm, resulting in changes in all variables during the process of building a dynamic model. Due to changes in the weighted edges between nodes in the K-nearest neighbor graph obtained after passivation of the dataset, the calculation methods and requirements for the internal proximity and interconnection of clusters, as well as the relative proximity and interconnection between clusters, need to be redefined [19]. The schematic diagram of the algorithm clustering process is shown in Figure 3.3.

Firstly, it is necessary to determine k clustering centers and divide sub samples based on the determined center points, and continuously optimize the center points during the iteration process. Improve the K-means algorithm in terms of its ability to handle noise and outliers. It selects actual data points as the clustering

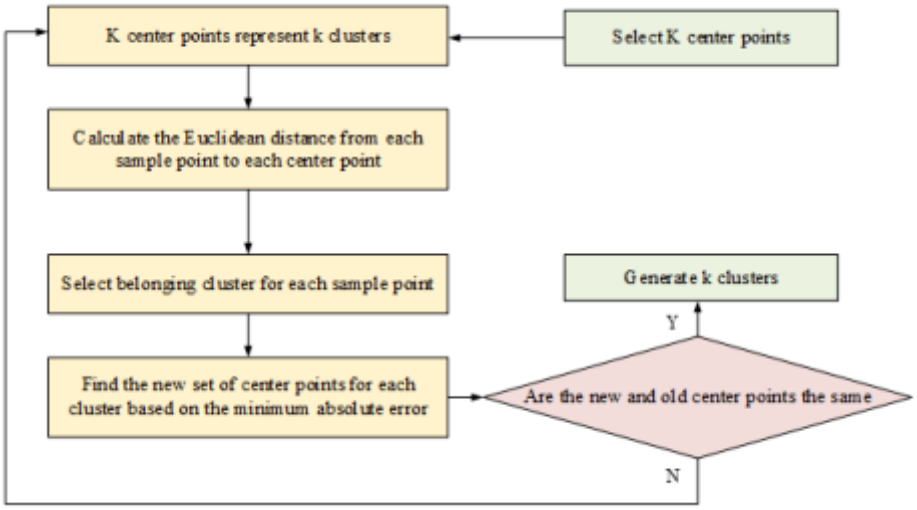

Fig. 3.2: Flow chart of chameleon algorithm based on optimized partitioning method

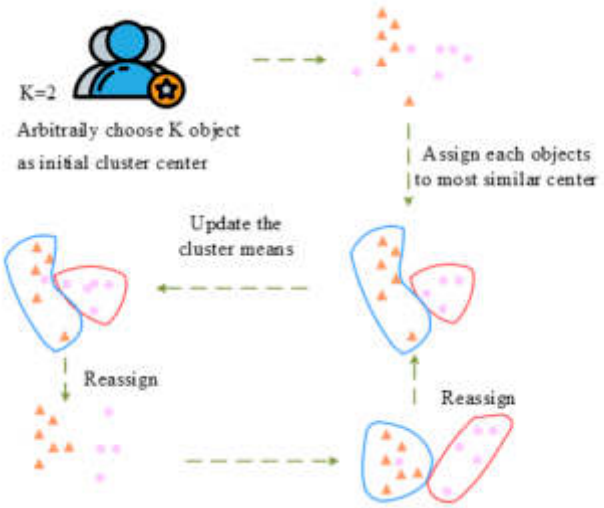

Fig. 3.3: Schematic diagram of algorithm clustering process

center instead of the average value of points in the cluster (such as k-means), providing robustness to outliers. The set of sub samples divided is represented as $(B_1, B_2, \ldots B_k)$, and the purpose of the K-medoids algorithm is to minimize the value of equation (3.3).

$$E = \sum_{i=1}^{k} \sum_{x \in B_i} \|x - \mu_i\|_2^2 \tag{3.3}$$

In equation (3.3), μ_i is the centroid of the ith subsample set B_i. In the K-means algorithm, the input sample is $A = \{A_1, A_2, \ldots, A_m\}$, and any k samples are obtained as the initial centroid, represented as $\{\mu_1, \mu_2, \ldots, \mu_k\}$. In a certain subset, the distance between the ith sample x_i and the jth centroid μ_j are calculated using equation

(3.4).

$$d_{ij} = \|x_i - \mu_j\|^2 \tag{3.4}$$

If μ_j can minimize the d_{ij} distance, it will choose μ_j as the new clustering center and update the sub samples. The K-medoids algorithm is used to optimize the chameleon algorithm to improve text feature clustering performance. However, due to the increase in data volume and random selection of initial clustering centers, this algorithm faces efficiency and accuracy challenges when processing large-scale high-dimensional data. The research divides data points into static and dynamic groups: static groups maintain existing clustering structures, while dynamic groups explore new clustering structures. This strategy improves the stability and flexibility of clustering algorithms, achieving higher clustering efficiency and accuracy when processing large-scale high-dimensional data. The separation behavior S_i, alignment behavior A_i, aggregation behavior C_i, foraging behavior F_i, and enemy avoidance behavior E_i of this algorithm can be expressed as equation (3.5).

$$\begin{cases} S_i = -\sum_{j=1}^{n} X - X_j \\ A_i = \frac{\sum_{j=1}^{n} V_j}{n} \\ C_i = \frac{\sum_{j=1}^{n} X_j}{n} - X \\ F_i = X^+ - X \\ E_i = X^- + X \end{cases} \tag{3.5}$$

In equation (3.5), X represents the position of the individual. X_j is the position of the j adjacent individual. n is the number of adjacent individuals. V_j is the velocity of the j adjacent individual. X^+ is the location of food. X^- represents the location of the natural enemy. After continuing the iteration, the step vector $\triangle X_{t+1}$ and position vector X_{t+1} of the individual can be calculated according to equation (3.6).

$$\begin{cases} \triangle X_{t+1} = (sS_i + aA_i + cC_i + fF_i + eE_i) + w\triangle X_t \\ X_{t+1} = X_t + \triangle X_{t+1} \end{cases} \tag{3.6}$$

In equation (3.6), s, a, c, f, e represent the weights of individual separation behavior, alignment behavior, aggregation behavior, foraging behavior, and enemy avoidance behavior, respectively. w is the inertia weight. Through continuous iteration, the optimal solution is found, which is the optimal initial clustering center of the K-means algorithm, thereby improving the clustering effect. However, the initial population diversity of DA is poor, and its global optimization ability is weak. The final solution obtained from its solution may not be the optimal solution, which affects the optimization effect of the K-means algorithm. If the dimension of each individual is d, during population initialization, an d dimensional individual X_{id} is generated, and then the individual is mapped to another space to obtain a new individual CX_{id}, as shown in equation (3.7).

$$\begin{cases} X_{id} = X_{\min d} + rand\,(X_{\max d} - X_{\min d}) \\ CX_{id} = X_{\min d} + X_{\max d} - X_{id} \end{cases} \tag{3.7}$$

In equation (3.7), $X_{\max d}, X_{\min d}$ are the upper and lower limit of the value, respectively. It merges the mapped population with the original population, and then selects the population with a better fitness value of $1/2$ as the initial population to complete the optimization of the initial population. The inertia weight w of the algorithm generally adopts a linear reduction method, and the convergence speed is also slowly decreasing, as shown in equation (3.8).

$$w = 0.9 - t\,(0.5/t_{\max}) \tag{3.8}$$

In equation (3.8), $t_{\max}$ is the set iteration upper limit. However, the w reduction speed under this inertia weight strategy does not match the convergence speed of the algorithm, resulting in a decrease in the convergence performance of the algorithm. The study introduces an improved chameleon algorithm based on K-medoids. The main improvement is to use the K-medoids algorithm to replace the original Metis graph segmentation algorithm for sub cluster partitioning. Then, the optimized chameleon algorithm is used to dynamically merge the sub clusters. The workflow of this improvement plan is shown in Figure 3.4.

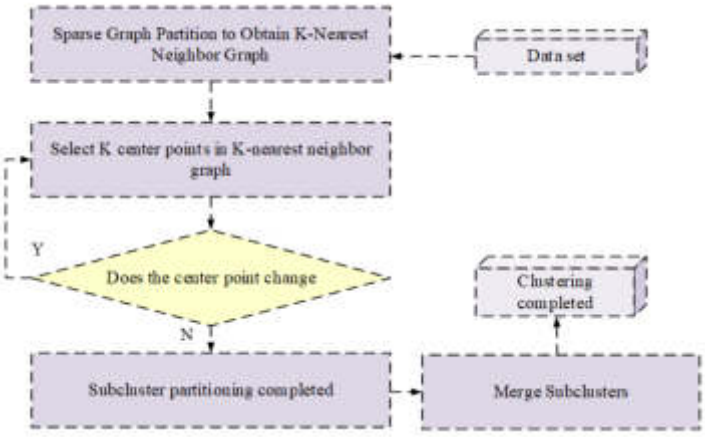

Fig. 3.4: Improved algorithm flowchart

In Figure 3.4, the algorithm first divides the dataset into K-nearest neighbor graphs, selects the initial cluster center, and divides the data into the nearest cluster. It optimizes the center point until the cluster stabilizes. After dividing the sub clusters, it needs to calculate the similarity value. If the maximum similarity value exceeds the threshold, it will merge the corresponding clusters. It will recurse to no clusters for merging, improving clustering accuracy and ensuring efficiency.

3.3. Intelligent matching model for college dormitory roommates incorporating optimized chameleon algorithm. The chameleon algorithm, which optimizes the partitioning method, exhibits advantages in processing large-scale high-dimensional data text clustering by adjusting parameters, improving similarity calculation, and adopting new clustering strategies for optimization. Data preprocessing includes cleaning and standardization, and for complex student information, data augmentation strategies such as feature crossing and encoding are adopted to improve the model's generalization ability. In the matching problem, a hierarchical matching strategy is used to enhance robustness, and possible matching is achieved through sorting to meet diverse needs [20-22]. Therefore, the label smoothing method in this article is to change the one hot label, and the specific method is shown in equation (3.9).

$$Q_i \begin{cases} 1-\diamondsuit & if i = true \\ \frac{\diamondsuit}{K-1} & else \end{cases} \tag{3.9}$$

In equation (3.9), $\diamondsuit$ is a predetermined hyperparameter much smaller than 1. i is the sample prediction label. K is the number of categories under that classification. It changes the format of one hot encoding, so that the optimization goal in SoftMax loss is not just 0 and 1. After label smoothing, the model output is no longer higher than better, thereby enhancing the robustness of the model. The parameters of the model are updated as indicated in equation (3.10).

$$\omega_t = \omega_{t-1} - \alpha \frac{\hat{m}_t}{\sqrt{\hat{v}_t + \diamondsuit}} \tag{3.10}$$

In equation (3.10), ω_t and ω_{t-1} are the updated parameter values. α is the updated learning rate. $\hat{m}_t$ is the exponentially weighted moving average of the gradient. $\hat{v}_t$ is the exponentially weighted average of the gradient squared. The relationship between the update equation and the learning rate and hyperparameters is shown in equation (3.11).

$$\omega_t = \omega_{t-1} - \alpha \frac{\beta_I m_{t-1} + (1-\beta_I)\, g_t}{\sqrt{\beta_2 v_{t-1} + (1-\beta_2)\, g_t^2}} \tag{3.11}$$

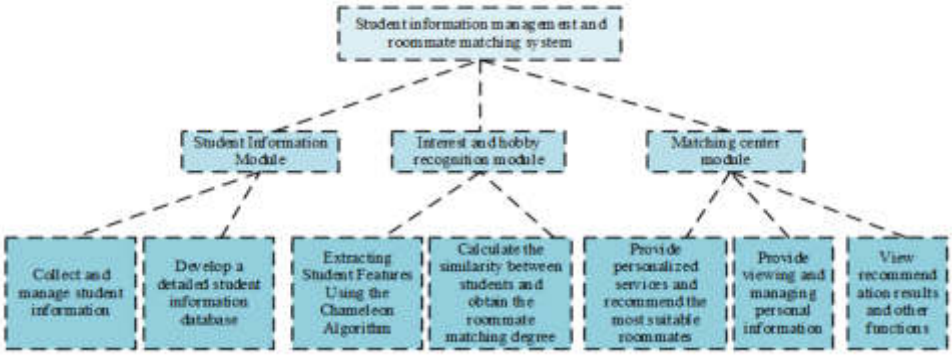

Fig. 3.5: System functional architecture diagram

In equation (3.11), β_I and β_2 are hyperparameters. To raise the accuracy and generalization ability of the chameleon algorithm in intelligent matching of college dormitory roommates, and reduce training time, the algorithm is pre trained using existing student information datasets, with training parameters as the initial parameters of the model. Then, the matching method is adjusted to adapt the algorithm to the multiple matching problem, and the appropriate similarity calculation method and clustering strategy are selected to optimize the matching effect. The intelligent matching system includes three modules: student information collection, interest and hobby recognition, and matching center. The overall system framework is shown in Figure 3.5.

In Figure 3.5, the student information module is responsible for collecting and managing student information such as interests, personality traits, etc., to form a detailed student information database. The interest and hobby recognition module utilizes the chameleon algorithm to extract student features, calculate similarity, and obtain roommate matching. The matching center module recommends the most suitable roommates and provides personalized services based on student information and recognition results. At the same time, this module also allows students to view and manage personal information and recommendation results, making it easy to use.

4. Result and Discussion. The intelligent matching of college dormitory roommates adopted the optimized chameleon algorithm, which significantly improved the matching accuracy by adjusting parameters and improving similarity calculation. By deeply mining student information and extracting features, the model's generalization ability was enhanced to adapt to different types of student groups. This method was stable and scalable, and could handle large-scale student information. It is expected that this method will provide a new direction for future intelligent matching of roommates.

4.1. Analysis of intelligent matching model for university dormitory roommates based on optimized chameleon algorithm. The application effect of the chameleon algorithm based on optimized partitioning method in intelligent matching of college dormitory roommates demonstrated the superiority of this method. Table 4.1 denotes the parameter settings of the model.

In the optimized the chameleon algorithm, the algorithm parameter was set to 0.5 to strengthen the feature weight balance. To prevent differences in the range of data values and the influence of data dimensions on the results, feature value standardization was carried out. Similarity was calculated using cosine similarity to ensure accurate matching of data in high-dimensional space. Based on the 2022 data of college student dormitories, a new algorithm was used to match student dormitories using Python 3.7 and TensorFlow 2.3.1 frameworks. The student clustering effect diagram is denoted in Figure 4.1.

In Figure 4.1, while retaining as much information as possible, the student's multiple feature values were compressed into two main dimensions, namely roommate similarity and personal satisfaction. It analyzed the matching effect by constructing scatter plots for these two dimensions. Based on roommate similarity, the

Table 4.1: Various clustering centers

Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
TnR	0.129	0.101	0.047	0.568	0.079	0.170
PR	0.104	0.168	0.290	0.381	0.071	0.051
WIN	0.135	0.036	0.025	0.034	0.038	0.075
LOSE	0.143	0.085	0.046	0.032	0.063	0.041
HT	0.079	0.040	0.028	0.024	0.058	0.063
TsR	0.124	0.095	0.051	0.062	0.056	0.079

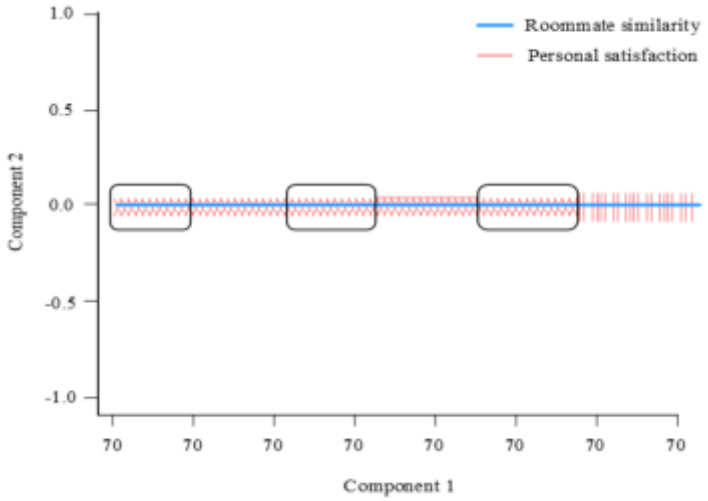

Fig. 4.1: Student clustering rendering

analysis content showed that students were clearly distinguished in this dimension, where different symbols represent different matching results. From the number of distinctions, students were accurately assigned to their respective dormitories without crossing, indicating a good matching effect. The clustering centers of six categories were divided by the clustering algorithm, as denoted in Table 4.2.

In Table 4.2, in the intelligent pairing of dormitory roommates, students were divided into six categories: freshmen, active participants, academic, sports enthusiasts, artistic, and work oriented. New students need more guidance, active participants bring vitality to the dormitory, academic students create a learning atmosphere, sports enthusiasts promote healthy living, artistic students enrich dormitory culture, and work oriented students provide management assistance. By optimizing the chameleon algorithm, efficient pairing between various types of students has been achieved, meeting the choices of students with different personalities and needs.

4.2. Analysis of intelligent matching application for college dormitory roommates based on optimized chameleon algorithm. The experiment proved the application effect of the optimized chameleon algorithm in intelligent matching of college dormitory roommates. To evaluate performance in depth and compare it with other matching algorithms, it would explore and analyze them from aspects such as matching accuracy, computational complexity, and runtime, providing theoretical reference and practical guidance for the future. The clustering efficiency comparison of different clustering algorithms in the intelligent matching method for college dormitory roommates is indicated in Figure 4.2.

In Figure 4.2, the application of the Chameleon, SKMeans-Chameleon, K-medoid-BIRCH, and K-medoid-Chameleon algorithms in intelligent matching of college dormitory roommates was compared, and the number

Table 4.2: Various clustering centers

	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
TnR	0.129	0.101	0.047	0.568	0.079	0.170
PR	0.104	0.168	0.290	0.381	0.071	0.051
WIN	0.135	0.036	0.025	0.034	0.038	0.075
LOSE	0.143	0.085	0.046	0.032	0.063	0.041
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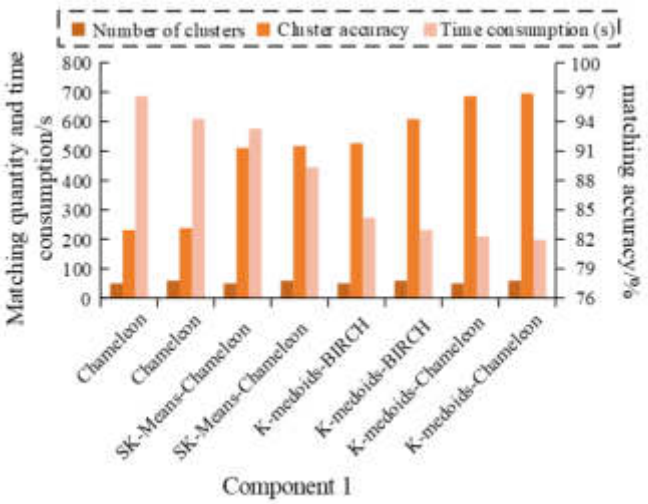


Fig. 4.2: Comparison of clustering efficiency of different clustering algorithms in intelligent matching methods for college dormitory roommates

of matches, matching accuracy, and running time were examined. The results showed that the K-medoids-Chameleon algorithm outperformed other algorithms in matching accuracy and runtime. Compared to the traditional Chameleon algorithm, its matching accuracy has been significantly improved and the running time has been significantly reduced. The clustering quality comparison of different clustering algorithms in the intelligent matching method for college dormitory roommates is expressed in Table 4.3.

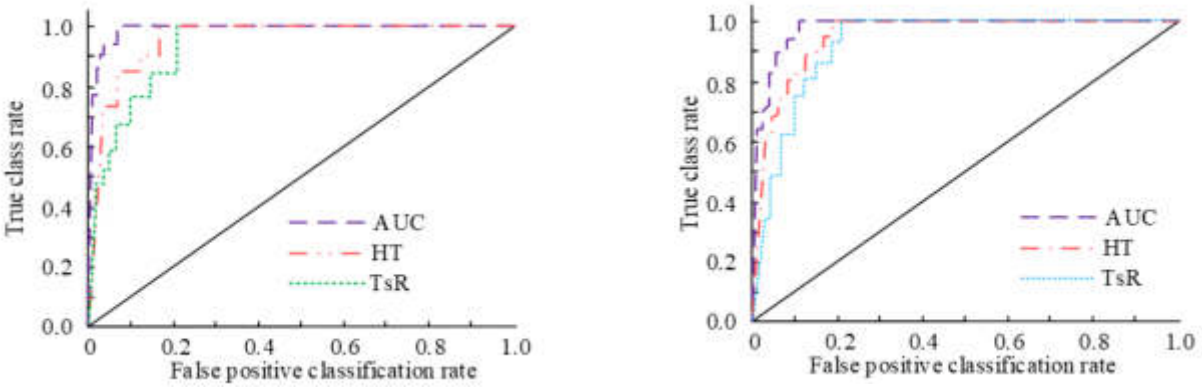
In Table 4.3, the Chameleon, SK-Means-Chameleon, K-medois-BIRCH, and K-medois-Chameleon algorithms were compared in terms of entropy, purity, and RI value for quality in intelligent matching of college dormitory roommates. The closer the entropy value was to 0, the closer the purity and RI values were to 1, and the better the matching effect. The K-medoids-Chameleon algorithm performed better than other algorithms in terms of minimum entropy, highest purity, and maximum RI value, verifying its effectiveness and superiority in roommate matching. It compared the AUC values of the chameleon algorithm based on optimized partitioning with other models on different datasets, as shown in Figure 4.4.

In Figure 4.4, the AUC value of the algorithm on the BBC dataset was 94.25%, which was higher than the other two models by 2.26% and 5.38%. On the Classic4 dataset, its AUC value was 93.13%, which was 2.08% and 5.04% higher than the other two models, respectively. These data fully demonstrated the superiority of this algorithm in intelligent matching of college dormitory roommates. The chameleon algorithm based on optimized partitioning was compared with other models in terms of accuracy, as shown in Figure 4.6.

In Figure 4.6, on the BBC dataset, the accuracy of this algorithm was 98.82%, which was 2.13% and 3.08% higher than the other two models, respectively. On the Classic4 dataset, its accuracy was 93.06%, which

Table 4.3: Comparison of clustering quality of different clustering algorithms in intelligent matching methods for college dormitory roommates

Clustering algorithm	Entropy	Purity	RI
Chameleon	0.31352	0.72453	0.54453
SK-Means-Chameleon	0.30143	0.73875	0.55098
K-medoids-BIRCH	0.29760	0.73986	0.55743
K-medoids-Chameleon	0.28607	0.75831	0.56083



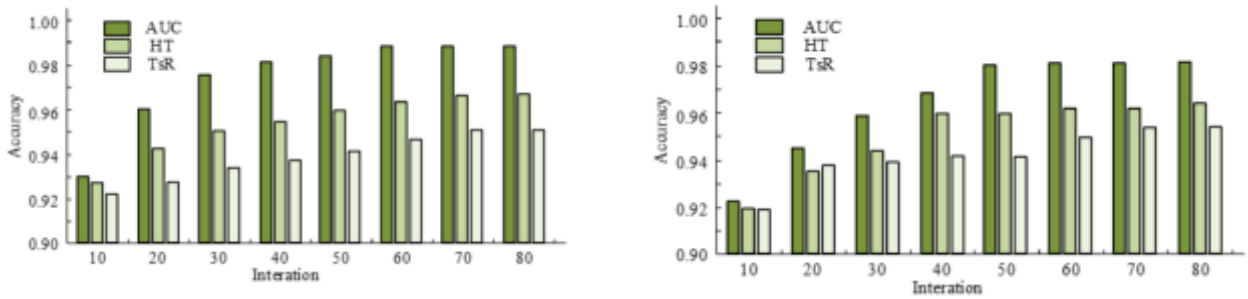
(a) BBC (b) Classic4

Fig. 4.4: AUC of several text clustering algorithms on different datasets

was higher than the other two models by 1.94% and 2.87%, respectively. These results further confirmed the efficiency and accuracy of the algorithm in roommate matching problems. The comparison between the chameleon algorithm based on optimized partitioning and other models in terms of modularity is expressed in Figure 4.7.

The chameleon algorithm based on optimized partitioning had the best flexibility when the number of modules was between 35 and 75. This might be due to the fact that in the college dormitory roommate intelligent matching scene, the data distribution within the number range of this module was more matched with the optimized division method of the chameleon algorithm, which reflected the flexibility of the algorithm. In cases where the number of modules was too low or too high, the effectiveness of the algorithm might decrease due to changes in data density or complexity. Compared with other models, this optimized partitioning chameleon algorithm had better modularity and flexibility when dealing with complex and ever-changing matching needs.

4.3. Discussion. The optimized chameleon algorithm provides an innovative method for intelligent matching of college dormitory roommates, integrating the personalities and needs of students, and improving the quality of life in dormitories. The algorithm demonstrates high matching accuracy, fast running time, and excellent clustering performance, indicating its social compatibility in the field of artificial intelligence assistance. Moreover, this high accuracy and performance translate to increased student satisfaction, as validated through satisfaction surveys post-matchmaking, aligning with the literature that correlates efficient roommate matching with enhanced student well-being and contentment. By adjusting parameters and standardizing data to achieve feature balance, the algorithm can accurately and efficiently allocate students to suitable dormitory environments. Compared with other clustering algorithms, the chameleon algorithm exhibits significant advantages in computational efficiency and matching quality, these advantages underscore the algorithm's effectiveness in creating harmonious living environments, as evidenced by longitudinal studies tracking student adaptation and



(a) BBC

(b) Classic4

Fig. 4.6: Accuracy of several text clustering algorithms on different datasets

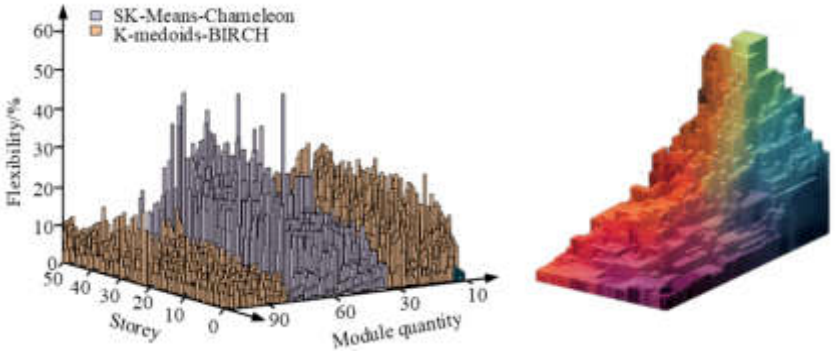


Fig. 4.7: Comparison of chameleon algorithm based on optimized partitioning with other models in terms of modularity

conflict resolution rates, thereby substantiating theories presented in the literature review regarding effective match outcomes. such as short running time, high entropy, purity, and RI index. The algorithm performs well on different datasets, demonstrating its wide applicability and reliability. The improvement results achieved through research are consistent with the trajectory of existing literature, which indicates that artificial intelligence and machine learning algorithms have great potential in solving complex human centered problems. Previous research has certainly involved algorithmic roommate matching, but the specificity of optimizing the chameleon algorithm in this situation provides a new application that adds value to existing methods. The integration of multi-objective optimization in hierarchical matching strategies goes beyond traditional one-dimensional methods and is consistent with emerging academic standards advocating the application of artificial intelligence in the human social environment. The success of this model indicates the transformation of the life paradigm of school students. In addition to the direct impact on student satisfaction and dormitory culture, these findings also indicate the potential application in a broader social matching system. In addition, the methodological advancements presented here may inspire further integration of optimized machine learning algorithms in various administrative and organizational tasks in education and other institutions, potentially leading to more data-driven, efficient, and satisfactory result oriented operations. Although this study has great potential, its application is limited by several factors, especially the scope of the dataset used. The effectiveness of algorithms mainly depends on academic centered datasets, and without significant adjustments or reconfiguration, they may not be able to be directly transformed into other environments. In addition, the dependence on algorithm efficiency overlooks the potential qualitative aspects of roommate compatibility, which

may not be fully captured through quantifiable data. Future research can explore the application of optimized chameleon algorithms in different social matching scenarios, potentially improving and adjusting models to adapt to different datasets and matching standards.

5. Conclusion. In seeking an effective solution for intelligent matching of college dormitory roommates, a chameleon algorithm based on optimized partitioning was introduced. This algorithm optimized the traditional Chameleon algorithm to improve its application effectiveness in the intelligent matching problem of college dormitory roommates. The focus of optimization was to improve matching accuracy and reduce running time to meet the needs of practical applications. The experimental results confirmed the significant advantages of the chameleon algorithm based on optimized partitioning. In testing on the Classic4 dataset, the AUC value of this algorithm reached 93.13%, which was 2.08% and 5.04% higher than the other two models. The accuracy was 93.06%, which was also higher than the other two models by 1.94% and 2.87%. These results demonstrated the excellent performance of the algorithm in matching accuracy and runtime. Although this algorithm has demonstrated significant advantages on BBC and Classic4 datasets, its performance evaluation is not yet comprehensive. Because the current testing is limited to these two datasets, it cannot cover more application scenarios. In the next research direction, more in-depth research and improvement are still necessary, including testing on more datasets to comprehensively evaluate the performance of the algorithm.

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MULTIPLE CONSTRAINT HYBRID TRAVEL ROUTE RECOMMENDATION MODEL BASED ON COLLABORATIVE FILTERING RECOMMENDATION ALGORITHM

QIONG ZHANG*

Abstract. The study presents a hybrid model for recommending travel routes that takes into account multiple constraints. This model is based on a collaborative filtering recommendation algorithm and addresses the issue of disorganized travel route recommendations. To improve upon the k-mean clustering algorithm, the proposed model introduces the Dynamic Gaussian Kernel Density K-means algorithm. After the data was processed, the initial clustering center was determined and k-means clustering was performed. Subsequently, the travel route recommendation model was created by integrating various constraints. The study's proposed algorithm was compared with alternative algorithms, and the experimental results demonstrated superior performance across a range of datasets, with the minimum sum of squared errors and a running time of approximately 1.4 seconds - a noteworthy improvement. Comparative experiments were conducted on various forgetting coefficients in the model, and the forgetting coefficient with the lowest sum-of-squares of errors was selected to replace the existing one. Upon comparing the proposed research model with other models, it was found that the former had greater accuracy and recall, amounting to 98.1% and 96.8% respectively. This suggests that the proposed research model serves as a more efficient solution for travel route recommendation.

Key words: Collaborative filtering techniques; multi-constraint mixing; travel route recommendation; cold start; sum of squared errors

1. Introduction. Travel has become a common way for people to unwind as living standards have increased, and the tourist sector is growing quickly. Travel has become a common way for people to unwind as living standards have increased, and the tourist sector is growing quickly. However, people are often overwhelmed by a vast amount of information and struggle with decision-making. In response to this, recommender systems have been developed to assist with the process. Recommendation systems research has advanced significantly in recent years as a result of the big data and artificial intelligence fields' quick advances [1, 2, 3]. Alongside the burgeoning demand for travel, the corresponding Travel Recommendation System (TRS) has emerged. Previous TRS encounter issues such as lack of data and cold start, resulting in low recommendation accuracy. Therefore, this research suggests employing Collaborative Filtering (CF) recommendation algorithm to develop a novel Multi-Constraint Hybrid Travel Route Recommendation Model (MCHTRRM). The DGKDK algorithm is utilized in an innovative way to enhance the effectiveness of the conventional clustering algorithm. Following this, the MCHTRRM is developed, which capitalizes on this improved algorithm to analyses user data and take into account multiple constraints including user information. The outcome is a personalized Travel Route Recommendation (TRR) which enables users to make more informed travel arrangements. The proposed model holds significance in increasing the efficacy of TRR and offering tailored recommendations. The research is structured into four main components. Firstly, it provides a summary of CF algorithm and recommendation technology research conducted by scholars both domestically and abroad, with the results analyzed. The second component includes an analysis of the proposed model and improvements made to the algorithms followed by its creation. The third part involves validating the model's actual effect through experimental comparison. Lastly, the research summarizes the experimental results and identifies any research shortcomings while suggesting future research directions.

2. Related Works. Deep learning has led scholars to apply CF algorithms across many fields [4, 5]. Lim et al. proposed a weighted interpolation domain single-class CF algorithm that addresses the challenge of predicting unobserved TF gene associations due to current limited understanding of genome-wide TF targeting

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profiles. This algorithm uses a neighbor regularization method to evaluate independent data. Experimental results indicated an accuracy of 37.8% for the initial 495 predicted association realizations, demonstrating the potential to enhance TF gene prediction [7]. Wu and other scholars in the field of e-commerce, propose a CF algorithm that combines restricted Bohrman and trust information. The study inputs user preferences and item ratings in a restricted Bohrmann machine model, calculates user similarity using weighted user similarity and trust information, and prediction is carried out by integrating user's historical ratings. The proposed approach has a greater prediction accuracy than other widely used algorithms, according to experimental results [8]. For the purpose of solving the information overload problem, Dun L. and other academics presented a CF algorithm based on social information and a dynamic temporal window. In order to find the closest neighbors, the study first incorporates social media data and user-submitted shares. It then dynamically modifies the time window and adds a time function to validate the method. The study's method was proven to be highly efficient and useful by the experimental results [9]. Yu and other scholars in the field of education, propose an elective course recommendation algorithm with local CF. The study created a student personalization model based on information for online learning resources. Based on the evaluation model, a similarity matrix is combined to recommend course resources. The study's proposed algorithm can more accurately recommend the knowledge students need, according to experimental data [10].

Based on the massive amount of information emerging from the development of the web, many scholars have studied recommender systems [11, 12, 13]. Liang and other scholars propose a balanced recommendation algorithm for teaching sports network based on trust relationship in response to the problems of low recommendation trust and poor recommendation resources in traditional sports network. The research first uses SVM algorithm to classify the sports recommendation video to achieve the extraction of teaching resources on sports network. Kalman filtering method is used to reduce noise and fuse similar data to achieve data preprocessing. Then the model is established to determine the relationship attributes between the data. The experimental findings demonstrated that the suggested research approach produced a resource balance of 96 with a high level of confidence in the suggested resources [14]. A content-based recommendation system was proposed by Li and other experts in the field of recommender systems. The research uses the class decision layer for image recognition, accurately identifies the commodity image features, and uses the correspondence between different commodities to make recommendations. The findings demonstrated that this method can fully synergies with commodity special discounts, and the recommendation results were highly accurate [15]. Xie N and other scholars propose a recommendation model based on personalized double matrix recommendation algorithm for customers' personalized needs. The study uses adjectives to filter image labels, which simplifies the user process and improves the model recommendation efficiency. Finally, a perceptual demand acquisition model is constructed and validated using an air purifier. The outcomes of the experiment demonstrated how quickly and accurately the research-proposed model can identify client demand, and the forecast findings were more accurate [16]. Wang and other scholars propose a gradient descent matrix decomposition collaborative model for the sparsity sensitivity and long iteration times of the traditional singular value decomposition CF recommendation algorithm. The model is based on the singular value filtering recommendation algorithm, using the mean, column mean and global mean pre-population method, the matrix is pre-populated, and then singular value decomposition is performed to reduce data sparsity. Experimental results showed that the proposed model had high recommendation accuracy and improved prediction scores [17].

In summary, numerous scholars have conducted research on recommender systems and CF algorithms. However, there are fewer studies focusing on travel information for massive user bases. Previous TRS have encountered cold-start problems, which have resulted in low recommendation efficiency. Consequently, this research proposes a MCHTRRM based on a CF recommendation algorithm, which successfully integrates the DGKDK algorithm into the model. Furthermore, this model resolves the problems posed by data scarcity and cold-start, ultimately improving recommendation efficiency.

3. TRR Model Based on CF Algorithm. The proposed TRR model is divided into two parts, the study firstly improves the traditional K-means algorithm and then builds the MCHTRRM based on several constraints such as user and travel route.

3.1. Personalized CF Algorithm Design and Implementation. The arrival of the information age has flooded people with a huge amount of information, and users are unable to obtain truly useful information.

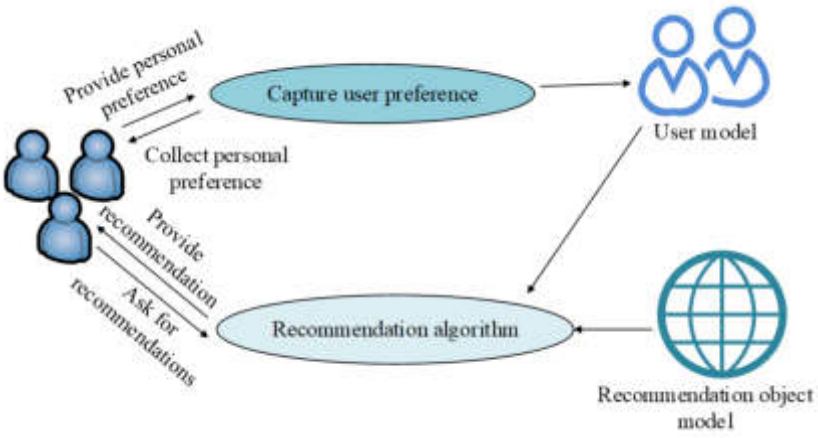


Fig. 3.1: Recommendation system model

Recommender systems emerged and developed to address this issue of information overload. After gathering data on the user's preferences, the recommender system makes educated guesses about the kind of content the user might find interesting and makes recommendations for it. A general recommender system is shown in Figure 3.1.

Figure 3.1 displays the recommender system model. The recommender system is comprised of three primary components, as seen in the figure: the recommender algorithm, the recommender object modeling component, and the user modeling component. The CF algorithm is used in the study's algorithm section. Because the CF technique requires a lot of calculations when dealing with a big number of users and products [18, 19, 20], the clustering approach can partially address this issue. Using distance as a similarity metric—closer distances signifying greater similarity—the K-means algorithm is a common clustering algorithm. The similarity between samples is calculated using the Euclidean equation, which is calculated as in Equation 3.1.

$$\text{dist}(x, y) = \sqrt{(-y_1 + x_1)^2 + \ldots + (-y_n + x_n)^2} \tag{3.1}$$

In Equation 3.1, x, y denotes the data in n dimensions. k-means algorithm selects K centers of mass for a given K categories, after which the data nodes in the vicinity of each center of mass are clustered to obtain K clusters of categories. Then the centroid of each category is updated and the similarity between the nodes and the centroid is continued to be calculated to make the points within the cluster more concentrated and at the same time to make the distance between the clusters as large as possible. Sum of the Squared Error (SSE) is calculated as in Equation 3.2.

$$SSE = \sum_{i=1}^{k} \sum_{x \in C_i} \text{dist}(\bar{x}_i, x)^2 \tag{3.2}$$

In Equation 3.2, k represents the number of clusters, C_i represents the ith category out of k clusters, and $\bar{x}_i$ represents the center of clustering of C_i. The K-means algorithm is more efficient in handling large data sets while the algorithm complexity is low. Kernel density estimation methods investigate the data characteristics of the samples, using kernel functions, which are processed and mapped in space. It is assumed that there are n data points $x_1, x_2, \ldots, x_n$ with independent distribution F. The distribution density function f obeyed by these data points is defined as in Equation 3.3.

$$\hat{f}(x) = \frac{1}{nh^2} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h}, \frac{y - y_i}{h}\right) \tag{3.3}$$

In Equation 3.3, $K(x)$ denotes the kernel function which is non-negative and integrates to 1, h represents the bandwidth and $h > 0$, n denotes the number of points that can be observed within the bandwidth, $i = 1, \ldots, n$. The kernel smoothing function used in the study is the Gaussian kernel function as in Equation 3.4.

$$K(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}x^2\right) \tag{3.4}$$

The degree of similarity between samples can be calculated using the distance between data using equation 3.4, which can effectively capture the similarity between samples. The value of bandwidth h is calculated as in Equation 3.5.

$$h_{\text{optimal}} = \frac{\int K^2(t)\,dt}{n\left(\int t^2 K(t)\,dt\right)^2 \int [f''(x)]^2\,dt} \tag{3.5}$$

The bandwidth can be calculated using equation 3.5. Through the above calculation, the K-means algorithm can be implemented. However, the K-means algorithm has the disadvantages of requiring manual input of the clustering K-value as well as randomly determining the initial center, the study proposes Dynamic Gaussian Kernel Density K-means (DGKDK) algorithm based on Gaussian kernel density for dynamically determining the initial clustering center. Firstly, the distance within the class is calculated as in Equation 3.6.

$$s_i = \frac{1}{|\bar{x}_i|} \sum_{x \in C_i} \|x - \bar{x}_i\| \tag{3.6}$$

Equation 3.6 can be used to determine the mean value of the distance between each data point and the cluster's center point. The interclass distance is then calculated as in Equation 3.7.

$$d_{i,j} = \|\bar{x}_i - \bar{x}_j\| \tag{3.7}$$

Using Equation 3.7, the distance between the centroids of two clusters can be calculated. Afterwards, the average maximum similarity within class (AMS) is calculated as in Equation 3.8.

$$AMS = \frac{1}{k}\sum_{i=1}^{k} \max\left\{\frac{s_i + s_j}{d_{i,j}}\right\} = \frac{1}{k}\left[\max\left\{\frac{s_1 + s_j}{d_{1,j}}\right\} + \max\left\{\frac{s_2 + s_j}{d_{2,j}}\right\} + \ldots + \max\left\{\frac{s_k + s_j}{d_{k,j}}\right\}\right] \tag{3.8}$$

Using Equation 3.8 the AMS can be obtained by taking the maximum value of similarity between each class and other classes and taking the mean value of the maximum value. When the AMS is smaller, the clustering effect is better. As a result, the clustering effect is at its best and the ideal number of clusters is reached when AMS takes the minimal value. Figure 3.2 depicts the DGKDK algorithm's structure.

Figure 3.2 shows the structure of DGKDK algorithm, as shown in Figure 3.2, the data samples are processed using kernel density estimation to obtain the set of extremely dense points. It is calculated accordingly to get the best clustering centre and finally K-means clustering is performed.

3.2. Design and Implementation of MCHTRRM. TRS can be categorised into content-based filtering techniques, CF-based recommendation techniques and hybrid recommendation techniques depending on the algorithm used. The study uses the CF recommendation technique, which can assist in achieving target user recommendations based on other users' past behavior toward the products and might suggest things that consumers could find interesting. User-based, model-based, and item-based CF recommendations are the three further categories into which CF techniques can be separated. In order to create a "neighbourhood" user group that is similar to the target user, user-based CF recommendation first uses correlation between users. Next, it uses the user group's historical preferences to calculate the target user's predicted score for the project. Lastly, it recommends the target user based on the score level. Fig. 3 depicts the user-based CF procedure.

Figure 3.3 illustrates the user-based CF recommendation principle. According to Fig. 2, User A indicates a preference for Commodity 1 and Commodity 3, User B for Commodity 2, and User C for Commodity 1,

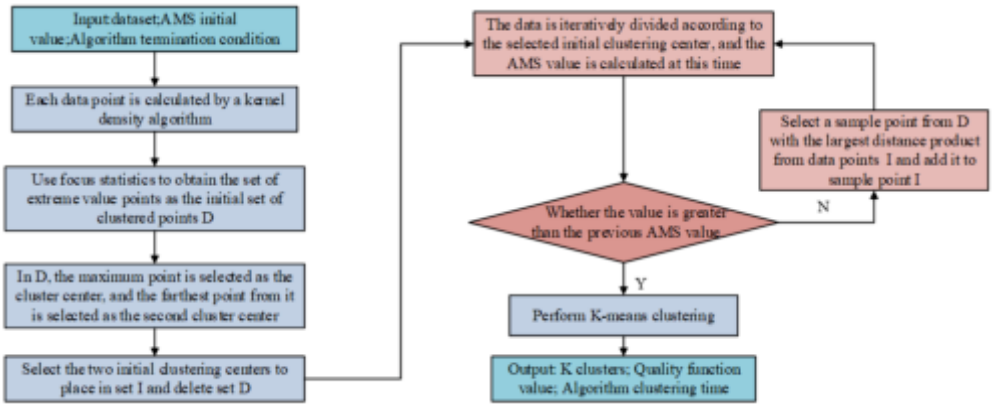


Fig. 3.2: DGKDK algorithm structure

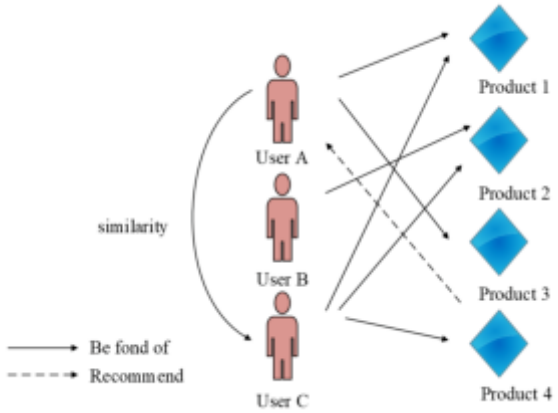


Fig. 3.3: User-based collaborative filtering recommendation schematic

Commodity 3, and Commodity 4. Drawing from the available data, it can be inferred that User A and User B do not share any preferences, however User A and User C have a shared interest in Commodities 1 and 3. Furthermore, User C shows a greater similarity to User A in terms of product preference. However, in addition to User C's liking for Commodity 1 and Commodity 3, they also prefer Commodity 4. Consequently, the system speculates that User A may also be interested in Commodity 4, and thus suggests it to User A. The user based coordinated filtering algorithm basically consists of four steps: preprocessing user data, calculating nearest neighbor set, calculating predictive scores and generating recommendation list. The raw user data is preprocessed as well as modelled using data mining and preprocessing to get the user item rating matrix. Finding the nearest neighbor set is a crucial stage in the recommendation algorithm that has an impact on the algorithm's efficiency. Three approaches are available for calculating the nearest neighbor set: Pearson's correlation coefficient, modified cosine similarity, and cosine similarity. Equation 3.9 is used to determine the cosine similarity, or Cos-S.

$$\text{sim}(\mathbf{u}, \mathbf{v}) = \cos(\mathbf{u}, \mathbf{v}) = \frac{\mathbf{u} \cdot \mathbf{v}}{\|\mathbf{u}\| \cdot \|\mathbf{v}\|} \tag{3.9}$$

In Equation 3.9, vector u represents the ratings of user u in n-dimensional space, and vector v represents the ratings of user v in n-dimensional space, and the similarity between the two users can be calculated by using

Equation 3.9. The modified Cos-S calculation is shown in Equation 3.10.

$$\mathrm{sim}(\mathbf{u},\mathbf{v}) = \frac{\sum_{i\in I_{uv}}(-\bar{R}_u + R_{ui})(-\bar{R}_v + R_{vi})}{\sqrt{\sum_{i\in I_u}(-\bar{R}_u + R_{ui})^2 \sum_{i\in I_v}(-\bar{R}_v + R_{vi})^2}} \tag{3.10}$$

In Equation 3.10, I_u and I_v represent the aggregated ratings of users u and v , respectively;R_{ui} and R_{vi} represent the ratings of users u and v , respectively, on item $\bar{R}_u$. And $\bar{R}_v$ represents the aggregated ratings of users u and v on the same item. $\bar{R}_u$ and $\bar{R}_v$ represent the mean values of the ratings of users u and v , respectively, on the aggregated I_{uv} on the same item. The corrected Cos-S corrects for inertia in user ratings. Equation 3.11 can be used to get the Pearson correlation coefficient.

$$\mathrm{sim}(u,v) = \frac{\sum_{i\in I_{uv}}(-\bar{R}_u + R_{ui})(-\bar{R}_v + R_{vi})}{\sqrt{\sum_{i\in I_{uv}}(-\bar{R}_u + R_{ui})^2 \sum_{i\in I_{uv}}(-\bar{R}_v + R_{vi})^2}} \tag{3.11}$$

Equation 3.11 can be used to calculate how similar users are to one another on various items. Based on the similarity between the target user and the nearest neighbour set, the unselected items of the target user can be predicted after the nearest neighbour set has been obtained. The list of ratings is predicted, sorted and the top N items are recommended. The study proposes a MCHTRRM based on CF recommendation algorithms and content-based recommendation algorithms. The user preference part of the recommendation model is the underlying content in which the user's preference changes over time. For example, users will decrease their interest in a particular type of attraction as their browsing and searching behaviour for that type of attraction increases. The study uses a non-forgetting curve to represent the change in user's interest as in Equation 3.12.

$$h(t_{i_c}) = (1-\theta) + \theta\left(\frac{t_{i_c} - t_{i_e}}{t_{i_l} - t_{i_e}}\right)^2 \tag{3.12}$$

In Equation 3.12, $t_{i_e} < t < t_{i_l}$, $0 \le \theta \le 1$, $0 < h(t_{i_c}) < 1$. t_{ic} represents the time of user's interaction behaviour for attractions of category i. t_{ie} represents the earliest time of user's interaction behaviour for attractions of category i in the history record. t_{il} represents the latest time of user's interaction behaviour for attractions of category i in the history record. θ represents the coefficient of forgetfulness, the larger θ is, the faster the user forgets, and conversely, the slower the user forgets. D represents the coefficient of forgetting. The study incorporates the DGKDK algorithm into CF recommendation, improves it, and proposes a hybrid attraction constraint algorithm. The hybrid constraint attraction recommendation algorithm is used to derive a set S of tourist attraction recommendations, after which a tourist itinerary is developed based on the recommendation results and other constraints, as shown in Figure 3.4.

Figure 3.4 shows the path network graph as shown in Fig. The graph contains the user's starting point Su, the attraction's ticket price SC, and the estimated playing time ST. The edge set of the paths is defined as the set $R = \{r_1, r_2, \ldots, r_{|R|}\}$, and the weights on each path are denoted as Equation 3.13.

$$TT(s_i, s_j) = \frac{\mathrm{distance}(s_i, s_j)}{V_{\mathrm{average}}} \tag{3.13}$$

In Equation 3.13, s_i, s_j denotes two attractions, $TT(s_i, s_j)$ denotes the time spent travelling between the two attractions, *distance* denotes the distance, and $v_{average}$ denotes an average speed. The time to reach the next attraction can be defined as Equation 3.14.

$$AT(s_{k+1}) = AT(s_k) + ST(s_k) + TT(s_k, s_{k+1}) \tag{3.14}$$

In Equation 3.14, $ST(s_k)$ denotes the time spent travelling to attraction s_k and $AT(s_k)$ denotes the time to reach the previous attraction s_k. The travelling time is expressed as Equation 3.15.

$$TPT(s_u, tp) = TT(s_u, s_k) + TT(s_{k+n}, s_u) + \sum_{j=1}^{n-1} TT(s_{k+j}, s_{k+j+1}) + \sum_{i=1}^{n} ST(s_{k+i}) \tag{3.15}$$

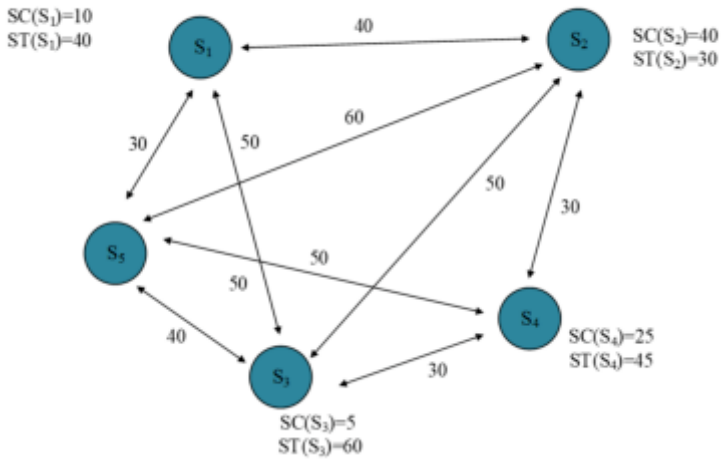


Fig. 3.4: Path network diagram

Using Equation 3.15 the travel time for a segment of attractions with a travel path of $tp = \langle s_k, s_{k+1}, \ldots, s_{k+n} \rangle$ and a start point of S_u can be calculated to represent the time spent by the user on this journey. The cost in travelling is calculated as Equation 3.16.

$$TPC(tp) = \sum_{i=1}^{n} SC(s_i) \tag{3.16}$$

Using Equation (16) the total economic cost spent can be calculated when the travel path is $t_p = \langle s_k, s_{k+1}, \ldots, s_{k+n} \rangle$. The MCHTRRM framework is shown in Figure 3.5.

Figure 3.5 shows the structure of MCHTRRM. As shown in the Figure the model enters the user data, preprocesses the data, and based on the attraction scores derived from the algorithm, recommends the user and performs route planning.

4. MCHTRRM Performance Study. The study tests the model to ensure that the TRR time criteria are satisfied before confirming the validity of the suggested algorithms in the model. This confirms the performance of the suggested model.

4.1. Performance Study of DGKDK Algorithm. By using four datasets from the University of California, Irvine Machine Learning Repository (UCI) dataset for testing, the study demonstrates the effectiveness of the proposed DGKDK method. The four datasets examined with various datasets to better validate the efficacy of the suggested enhanced algorithm are the Iris dataset, Wine dataset, Glass dataset, and Yeast dataset. Table 4.1 displays the setting of the laboratory environment used for the dataset validation.

Table 4.1 shows the laboratory hardware and software environments, and Java was chosen as the development language for the operating system. The study compares the K-means algorithm, Diversity-Aware Crossover Clustering Based on K-means (DACC-KM) algorithm, Intergrated Clustering and Classification System Based on K- means (ICCS-KM) algorithm is compared with the proposed DGKDK algorithm of the study and the results are shown in Figure 4.2.

Figure 4.2 shows the accuracy and SSE comparison of each clustering algorithm. The ICCS-KM algorithm combines similar clustering methods with the K-means algorithm to improve the accuracy and efficiency of data analysis. DACC-KM algorithm uses K-means algorithm for dynamic attribute and attribute clustering to improve the clustering effect. As can be seen in Figure 4.1a, the DGKDK algorithm is mostly more accurate than the other algorithms, and is slightly lower than the DACC-KM algorithm on the Iris dataset, but also

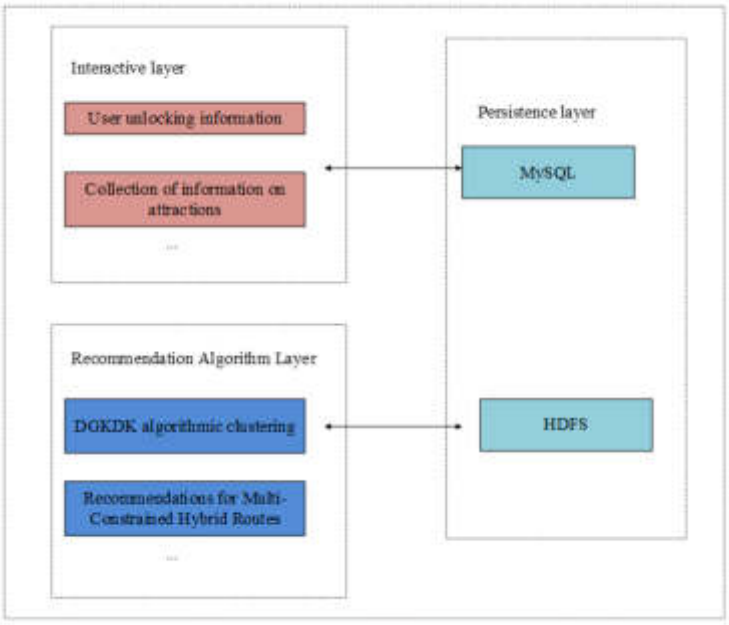


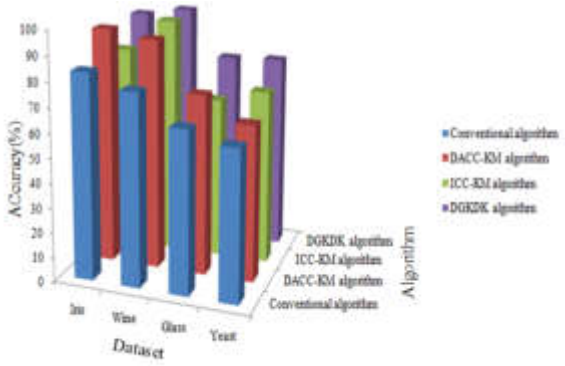
Fig. 3.5: Multi-constraint hybrid travel route recommendation model structure

Table 4.1: Laboratory environment setting

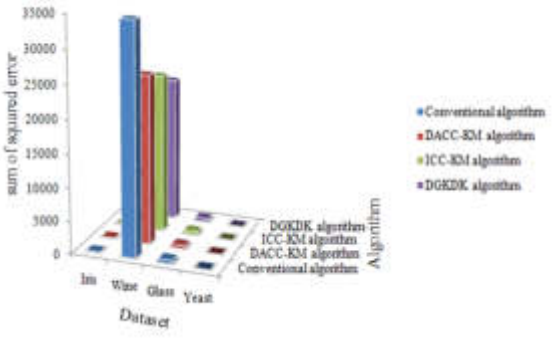
Hardware and software configuration	Version model
CPU	Intel(R)Core i7-7700@3.6GHz
GPU	GTX 1060
Operating system	Microsoft Window10
RAM	32G
Display memory	6G
CUDA	9.1
Deep learning frameworks	Pytorch1.10
Python version	3.7

maintains a high accuracy of 94.67%. At 79.33%, the DGKDK algorithm outperforms the other three clustering algorithms on the Yeast dataset. The DGKDK algorithm performs marginally better than the other algorithms on the Wine and Glass datasets, scoring 97.73% and 78.54%, respectively. In Figure 4.1b, the DGKDK algorithm has the smallest SSE and the smallest SSE on the four datasets, indicating that the DGKDK algorithm fits the data better. The running time of the experiments on the datasets using the four algorithms is shown in Figure 4.3.

On the Iris dataset, which has a small amount of data, the traditional K-means algorithm and the DACC-KM algorithm have an advantage with a shorter running time. However, on the Yeast dataset, which has a larger total amount of data, the DGKDK dataset proposed in the study has a significant advantage, with a running time of around 1.4s. The other algorithms, on the Yeast dataset, have a slower running time of around 2s. The study applies the proposed DGKDK algorithm to CF recommender system and evaluates the performance of the algorithm using actual user ratings compared to predicted ratings. The study compares the proposed algorithm with the traditional User CF algorithm, M-User CF algorithm, and the clustered CF algorithm with improved similarity. Additionally, Figure 4.5 displays the algorithm's running time as well as



(a) Comparison of Accuracy of Each Algorithms



(b) Comparison of Error of Sum of Square Across Clustering Algorithms

Fig. 4.2: Comparison of accuracy and error sum of squares of each clustering algorithm

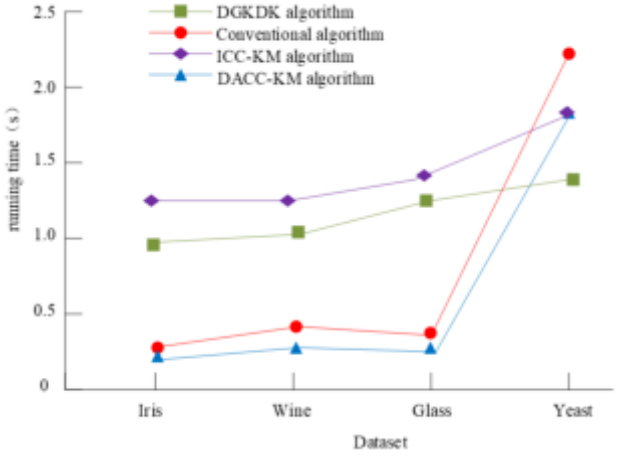
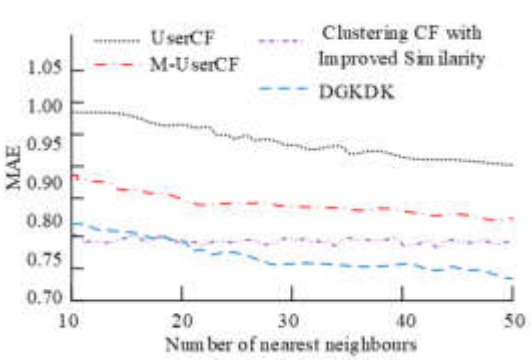


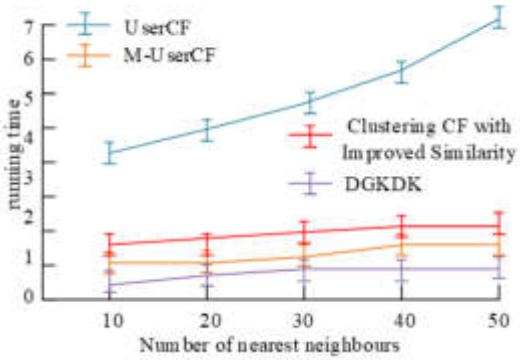
Fig. 4.3: Clustering time line plots of four algorithms on different data sets

the Mean Absolute Error (MAE) results.

Figure 4.5 shows the MAE and algorithm runtime for the four algorithms with different number of neighbors. The traditional User CF algorithm is a user-based CF algorithm that analyses the similarity of users to predict user preferences. The M-User CF algorithm solves the problem of high sparsity of the algorithmic matrix and comprehensively exploits the similarity data of users. The clustering CF algorithm with improved similarity clusters users or items and combines the clustering information to achieve prediction and recommendation. The MAE values of the various algorithms decrease as the number of nearest neighbors rises from 10 to 50 in Fig 4.4a suggesting that the recommendation algorithms' accuracy is increasing steadily and that the predicted ratings are becoming closer to the user's actual ratings. The MAE value of the study's recommended approach, which is 0.75 when the number of nearest neighbors is 50, is significantly less than the values of the other techniques. This implies that compared to other recommendation systems, the algorithm is more accurate. The study's suggested technique in Fig 4.4b runs substantially faster than the other algorithms for varying numbers of nearest neighbors, which are maintained inside a 1 s window. The M-User CF algorithm and the clustered CF algorithm with improved similarity increase from about 1s to about 1.5s with the increase in the number of



(a) Comparison of MAE values of Four Algorithms



(b) Comparison of Running Time of Four Algorithms

Fig. 4.5: The MAE and the running time of the algorithm under different neighbor numbers of the four algorithms

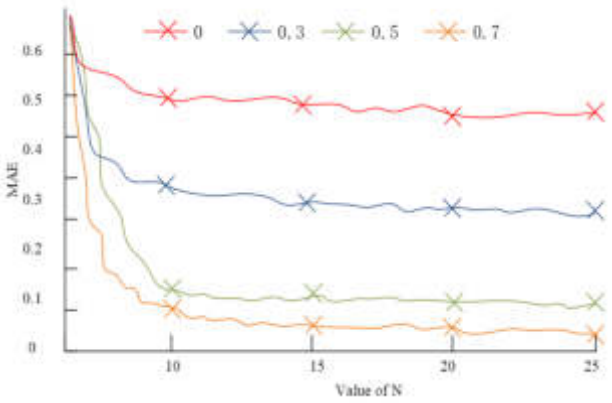


Fig. 4.6: Comparison of MAE under different forgetting coefficients

nearest neighbors, while the traditional User CF algorithm has a significant increase in running time with the number of nearest neighbors.

4.2. TRR Model Performance Study. The study analyses the performance of MCHTRRM based on CF recommendation algorithm, which randomly grabs 1480 users' basic information as well as 2389 attraction ratings data as a dataset on a travel website. There exists a forgetting coefficient θ in the user preference part of the model, and different values of N in the TopN of the recommendation list are selected, and the experimental results are shown in Figure 4.6.

Figure 4.6 shows the comparison of MAE under different forgetting coefficients. The models under different forgetting coefficients have different mean absolute errors, i.e., there is a significant difference in the accuracy of the models under different forgetting coefficients. When the forgetting coefficient θ takes the value of 0, the overall MAE value of the model is the highest, i.e., the model accuracy is the worst. The model with the highest accuracy and the lowest MAE value at various values of N is the one with the value of forgetting coefficient θ set to 0.7. The accuracy of the model grows and its MAE value lowers as N increases. Using the model with a forgetting coefficient of 0.7 as an example, the model MAE value changes more steadily when N increases from

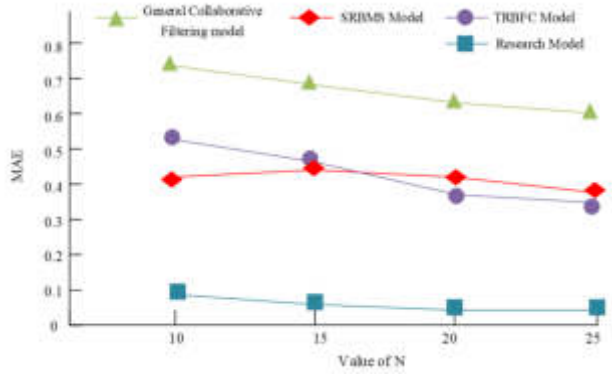


Fig. 4.7: MAE values of each model with different N values

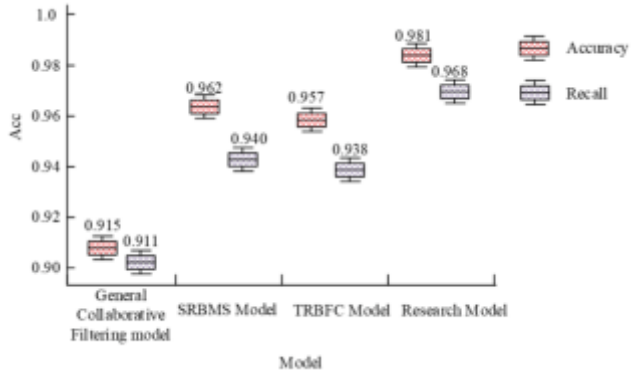


Fig. 4.8: Comparison of accuracy and recall rate of four models

20 to 25 and declines from 0.9 to 0.5 when N increases from 10 to 20. Therefore, the forgetting coefficient in the model is chosen to be 0.7. To validate the model performance, the proposed model of the study is compared with the general CF model, Sequential Rule-Based Model Selection (SRBMS) model and Takagi-Sugeno Type Radial Basis Function Fuzzy Classifier (TRBFC) model for comparison. In Fig. 10, the experimental outcomes are also displayed.

The MAE values of each model for various N values are displayed in Figure 4.7 As can be observed from the Fig., the research proposed model has the lowest overall MAE value, which suggests that the model fit is good and the prediction results have fewer error with the user's genuine value. Whereas the general CF model has the highest MAE value, indicating that the model predicts results with larger error from the user's true value and poorer model fit. The SRBMS model is optimized iteratively to improve the classification performance. The very flexible radial basis function and fuzzy clustering form the foundation of the TRBFC model. The MAE values of the general CF model, SRBMS model and the model proposed by the study are significantly affected by the N value, while the MAE values of the TRBFC model are not changed much by the N value. In the case of the model proposed by the study, for example, the model MAE value decreases from about 0.9 to about 0.5 when the N value increases from 10 to 15, while the model MAE value stabilizes when the N value increases from 15 to 25. According to the dataset, the accuracy and recall of the four models are calculated in Fig 4.8.

The accuracy and recall of the four models are compared in Fig. 11. The research-proposed model has good performance, as evidenced by the Fig., which shows that it has high accuracy and recall, reaching 0.981

and 0.968, respectively. Whereas, the semi-CF model, SRBMS model, and TRBFC model have lower accuracy and recall metrics than the research-proposed model and have average performance. Therefore, the research-proposed MCHTRRM based on CF recommendation algorithm can achieve the recommendation purpose better and meet the experimental requirements.

5. Conclusion. The study develops MCHTRRM, utilizing a CF recommendation algorithm to offer travel guidance relevant to users' information. The study improves personalized TRS from two angles to address data sparsity and cold-start issues. The kernel density function is used to find alternate centers of clustering in the DGKDK algorithm, which is presented. The K-means clustering computation is then carried out after the first centers of clustering are identified. The study introduces the MCHTRRM CF recommendation algorithm, which is informed by user information, attraction information, and interactive use information. The study conducts comparative experiments between the DGKDK algorithm proposed in the study and the traditional K-means algorithm, DACC-KM algorithm, and ICCS-KM algorithm on four datasets, specifically Iris, Wine, Glass, and Yeast. The study's experimental results demonstrate that the proposed DGKDK algorithm exhibits high accuracy in comparison to other algorithms, achieving 97.73% and 94.67% on Wine and Iris datasets, respectively. The algorithm proposed in the research also records the smallest SSE on all four datasets. Additionally, the DGKDK algorithm demonstrates prompt processing, with a running time of approximately 1.4 seconds. This indicates that the DGKDK algorithm is a good fit for the data and can process it rapidly. Based on the comparison of the effect of different forgetting coefficients on the model, the model forgetting coefficient was chosen to be 0.7, which had the lowest MAE value in the range of 0.1. Comparing the research proposed model with the general CF model, SRBMS model, and TRBFC model, the research proposed model had the lowest MAE value at different values of N. The model had the highest accuracy and recall, 98.1% and 96.8% respectively, indicating the superior performance of the research proposed model. The study suggests that the model has some limitations and that time is calculated in a more consistent manner. Further studies could enhance the model by accounting for floating tour times.

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THE APPLICATION OF MATLAB IN THE MATHEMATICS TEACHING OF COMPUTER MAJORS

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Abstract. Under the background of new engineering courses, professional mathematics teaching needs to keep pace with the times and improve the progressiveness and scientific nature of teaching methods.In order to improve the mathematics teaching effect of computer majors, This article constructs a new teaching environment through simulation system construction methods, analyzes the shortcomings of traditional teaching models through comparative analysis methods, and improves the teaching platform based on the actual needs of mathematics professionals in current society. The curve interpolation technology is improved, and a forward-looking real-time Matlab simulation algorithm is designed. Through the evaluation and analysis, it can be seen that the mathematics teaching system for computer majors based on MATLAB can effectively improve the intuitive effect of advanced mathematics teaching, and help to improve the teaching quality of advanced mathematics.

Key words: MATLAB; computer; mathematics teaching; model

1. Introduction. MATLAB is a programming language for analyzing data, developing and applying algorithms. It has powerful data visualization and mathematical statistical analysis functions, and the programming environment is simple and easy to use, making it an important auxiliary tool for mathematics learning. In European and American countries, MATALB has become a basic teaching tool for advanced courses such as applied linear algebra, automatic control theory, mathematical statistics, digital signal processing, and dynamic system simulation. In addition, it has become a basic skill that must be mastered by undergraduates and master students pursuing degrees. In design research units and industrial sectors, MATLAB is widely used to research and solve specific practical problems [1].

MATLAB language is the preferred computer mathematics language for scientific researchers in many engineering and computer fields, and it is also widely used in mathematics branches such as calculus, linear algebra, integral transformation, interpolation, probability and statistics [2]. In higher education teaching, there are some explorations and studies on how to use MATLAB software to assist professional course teaching in the teaching links such as curriculum design training and curriculum practice training. However, there are not many practical researches directly introducing MATLAB language into classroom teaching [3]. How to really introduce the MATLAB language into classroom teaching, the process of introducing it into classroom teaching and the teaching effect after the introduction will be the key issues for the transformation of MATLAB-assisted teaching from theory to practice. There are a large number of exercises in the theoretical teaching of advanced mathematics courses that need to be calculated involving limits, differential derivation, integration, series, etc. In addition, there are many two-dimensional and three-dimensional functions that need to be displayed by drawing and understand the characteristics of function trajectories, which can help Students better understand the theory [4]. The MATLAB software package contains instructions for differentiation, integration, and limit. You can directly input the corresponding instructions in the command window, and you can get the desired results with one key. In addition, loops and conditional statements in MATLAB can well complete repetitive and loop calculations, which is beneficial to improve students' enthusiasm for problem-solving and explore methods of solving problems [5]. Reference [6] takes the advanced mathematics course as an example to explore the feasibility and teaching effect evaluation of MATLAB-assisted advanced mathematics teaching, in order to enrich the teaching methods and means of this course, improve the teaching effect of this course, and lay a solid foundation for the cultivation of applied talents. a more solid foundation.

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Advanced mathematics is an important basic course for university majors in science, engineering and management. Students generally find it difficult to study this course. One of the main reasons is that advanced mathematics is more abstract than elementary mathematics. Therefore, teachers need to use some methods or means to visually display abstract knowledge to students in the teaching process [7]. There are more obvious implications in terms of comprehension and teaching [8].

Matlab can not only draw static graphics to help teachers explain functions and theorems, but also can easily achieve graphics animation effects to help students understand the effects of changes in functions or parameters. For example, the arbitrary smallness in the concept of limit, the volume of the rotating body in the application of definite integral, the forming process and transformation process of the curve and surface in analytic geometry, etc., it is difficult to express it vividly and vividly through the traditional teacher's teaching and the blackboard static diagram. [9]. Matlab shows the process and results in a visual and dynamic form, which can not only effectively improve students' interest in learning, make students' understanding more profound and thorough, but also greatly improve the teaching effect [10].

In the process of teaching "Mathematical Modeling and MATLAB", teachers should guide students to look at the world and society through the innovative method of mathematical modeling, and apply this innovative method to their learning and life. Schools can select relevant teachers to offer remedial classes for students who are interested in modeling or directly offer professional courses in mathematical modeling [11]. Using the principle of comparison, students of different ages and grades are selected for mathematical modeling training. The performance and ability of this part of students are tested for a long time and irregularly, and compared with students in the same circle who have not participated in mathematical modeling learning, analyze whether participating in mathematical modeling learning can improve students' innovative ability, and obtain a specific relationship curve , to analyze the speed and extent of the improvement of innovation ability of students with different foundations through mathematical modeling learning [12].

For students who are interested in modeling, teachers can select through the mock test to determine the excellent team members, and let the students experience the fun of mathematical modeling in the mock test. Peiyou team members can form a team freely at the beginning. Under normal circumstances, students will choose people they are familiar with to form a team. At this time, students from the same major usually form a team [13]. Analyze the strengths and weaknesses of a single discipline team in continuous learning and simulation training. In addition, schools should encourage interdisciplinary teams to form several teams with members from different disciplines through the influence of the school, and analyze the strengths and weaknesses of interdisciplinary teams through continuous learning and simulation training. Of course, during this process, students can change teammates at any time to achieve the purpose of optimizing team formation [14].

Teachers can use the winter and summer vacations to organize mathematical modeling enthusiasts to conduct intensive training to learn basic theoretical knowledge, including mathematical models, MATLAB and other commercial teaching software, paper writing, literature retrieval, and graph drawing. In the second stage, intensive training will be carried out, and students will learn advanced mathematical models, intelligent algorithm design and implementation, thesis writing skills, model method innovation paths, etc. in a targeted manner. In the third stage, simulation training is carried out, in the form of a competition team, according to the competition requirements, simulating the actual competition process, conducting thesis defense, review and revision, circular advanced training, and gradually improve students' teamwork and innovation ability [15].

On the basis of pre-competition intensive training, select teams with both profound theoretical foundation and strong innovative ability, organize to participate in provincial, national and international mathematical modeling competitions at different levels, and further exercise students' innovative ability during the competition. And constantly sum up the experience and lessons of the competition, explore the innovative path to solve practical application problems through mathematical modeling, and summarize the inherent laws of the mathematical modeling competition to improve the innovative practice ability of college students [16].

Prove the growth law of students' innovative ability at different stages such as mathematical modeling courses, pre-competition training, and competition experience. Through the questionnaire survey and summarizing experience of teachers and participating students, the opinions and suggestions on improving the innovative ability training in the teaching of "Mathematical Modeling and MATLAB" are put forward, and the innovative practice path of "course-training-competition-summary" is further optimized. strategy [17].

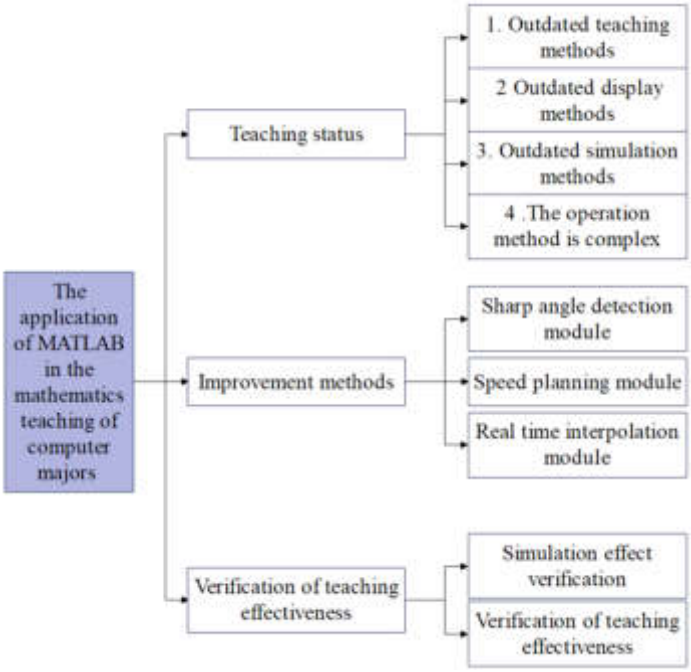

Fig. 1.1: Organizational structure of this article

Computer and mathematics are closely related. In computer science, the importance of mathematics is particularly prominent. The methods and technologies in various fields of computer science are based on one or more mathematical theories [18]. Advanced mathematics, linear algebra, probability theory and mathematical statistics, discrete mathematics and other mathematics courses are the basic courses for computer majors, which play a very important role in the training of computer professionals [19], and are important tools for students to learn subsequent professional courses. . It is also an important part of the postgraduate entrance examination.

Integrating MATLAB into high school mathematics teaching in the context of the technological era is a trend that conforms to teaching innovation. As a teacher of the new era, mastering the skills of using MATLAB software is not only a requirement of the technological era, but also meets the learning needs of students. Applying new teaching techniques to teaching practice will benefit students the most. It is reasonable to predict that MATLAB will be widely used by teachers as a teaching tool in the field of high school mathematics education in the future, and then students will initially master and apply it to mathematics learning.

The existing MATLAB application in mathematics teaching in computer science cannot meet the actual needs of computer science. Due to the influence of professionalism, new technologies need to be combined with MATLAB to meet the needs of computer science students.

The organizational structure of this article is shown in Figure 1.1.This paper analyzes the application of MATLAB in the mathematics teaching of computer majors in colleges and universities under the background of new engineering, and improves the mathematics teaching effect of computer majors in colleges and universities through intelligent models.

2. MATLAB image simulation. The real-time forward-looking MATLAB interpolation algorithm mainly includes three modules: sharp angle detection module, speed planning module and real-time interpolation module. The main process of the whole algorithm is shown in Figure 2.1:

The file reading module: it is used to read NC program files, and it converts NC characters into corresponding control vertex d_i $(i = 0, 1, ..., n)$, weight or weight factor ω_i $(i = 0, 1, ..., n)$, node vector $U = [u_0, u_1, ..., u_{n+k+1}]$.

The sharp corner detection module: it mainly determines the sharp corners on the MATLAB curve. The so-called sharp angle refers to the sensitive point on the curve where the feed rate must be reduced in order

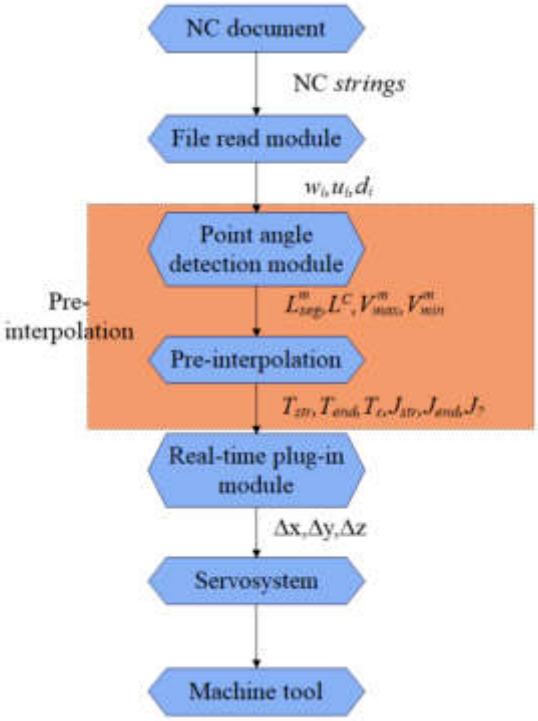

Fig. 2.1: Real-time MATLAB interpolation algorithm with look-ahead

to ensure the machining contour accuracy requirements due to the large local curvature. It divides the curve into small sub-segments using the determined sharp angles, and calculates the length L_{seg}^{m} of each sub-segment, as well as the maximum speed $V_{\max}$, starting speed V_{str} and ending speed V_{end} in each sub-segment.

The speed planning module: based on the limitations of the maximum bow height error, feed rate, acceleration/deceleration and jerk, etc., according to the length L_{seg}^{m} of each subsection, and the maximum speed $V_{\max}$, start speed V_{str} and end speed V_{end} in each subsection, the feed type of each subsection is planned, and the parameter values of acceleration and deceleration are calculated accordingly, such as T_{str}, T_c, T_{end}, J_{str}, J_{end}, etc.

MATLAB real-time interpolation: according to the parameter values of acceleration and deceleration calculated by the speed planning module, the next interpolation point, namely u_{i+1}, is calculated from the current u_i, speed $V(u_i)$, and acceleration $A(u_i)$. Then, the coordinate values $x(u_{i+1})$, $y(u_{i+1})$, and $z(u_{i+1})$ of the next interpolation point are calculated. The operation is performed by the servo system to drive and control the machine tool.

The so-called sharp angle refers to the sensitive point on the MATLAB curve where the feed rate must be reduced in order to ensure the machining contour accuracy requirements due to the large local curvature of the curve. In the vicinity of such sharp corners, the curvature is larger. If the feed rate is not reduced, the feed step length in each interpolation cycle will be too large, resulting in an increase in the bow height error, even exceeding the allowable value of the maximum bow height error. Therefore, the feed rate must be reduced at sharp corners.

In general, sharp corners occur at the extreme points of curvature in local sections of the curve. Therefore, the first criterion for determining sharp corners is at sharp corners. The derivative of its curvature is 0. The

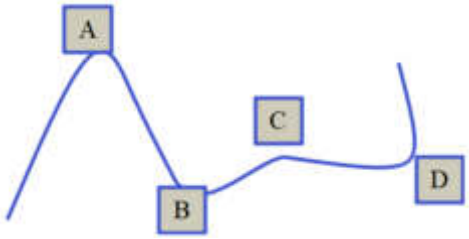

Fig. 2.2: Schematic diagram of extreme point

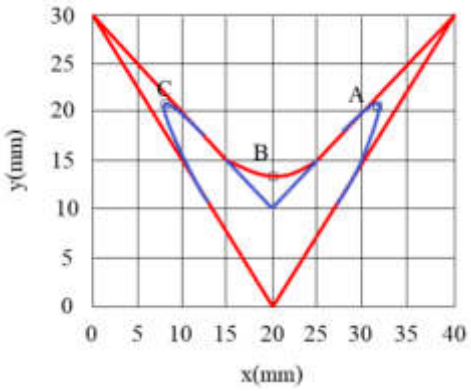

Fig. 2.3: Schematic diagram of the extreme point of the V-shaped curve

formula is as follows:

$$\frac{dk\left(u\right)}{dt}|u = u_k = 0 \tag{2.1}$$

Among them, k(u) is the curvature of the curve, and u_k is the node vector value that may become a sharp corner point. The curvature calculation formula is:

$$k\left(u\right) = \frac{|P'\left(u\right)P''\left(u\right)|}{|P'\left(u\right)|^3} \tag{2.2}$$

In this paper, a fast algorithm for $P'\left(u\right)$, $P''\left(u\right)$ is given. It is not repeated in this section. On these possible points that satisfy the first criterion for identifying sharp corners, the curvature at this point must be an extreme point in the local small segment, that is, a maximum or minimum value. However, from the perspective of larger sections, the curvature values of extreme points in some local areas may be larger than those at extreme points in other areas. This problem is evident from Figure 2.2 below.

The curve in the above figure has four extreme points A, B, C, and D, of which the curvature of point C is significantly smaller than that of other points. Taking a V-shaped curve as an example, the same problem exists. As shown in Figure 2.3, the curvature of point B on the V-shaped curve is significantly smaller than the other two points A and C.

Since it is determined to be a sharp corner, the feed rate at the sharp corner must be reduced. It can be imagined that if in the NC program, when the given feed rate F is high, the three points A, B, and C are all defined as sharp corners, and the feed rate at these points must be reduced to ensure the contour accuracy of machining. However, when the given feed rate F is not high, if point B is still determined as a sharp corner point, the tool will pass point B at a slow speed because the feed rate is too low. However, the curvature of

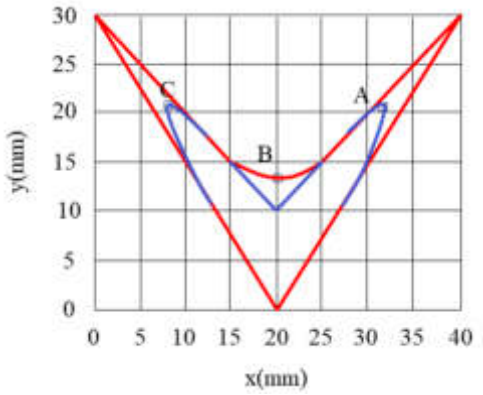

Fig. 2.4: Sharp corners at F=150mms

point B is not very large, so the feed rate at point B does not need to be reduced so much, and the contour error at point B can be controlled within the required accuracy range. At this point, point B should not be determined as a sharp corner point.

It can be seen from the above analysis that the first sharp corner identification criterion cannot fully and accurately identify sharp corner points. Therefore, the second sharp corner identification criterion is that the curvature at the sharp corner exceeds the limit value k_{th}. The formula for calculating the curvature limit k_{th} is as follows:

$$k_{th} = \frac{A_{\max}}{F^2} \tag{2.3}$$

Among them, $A_{\max}$ is the maximum allowable value of acceleration limited by the acceleration and deceleration performance of the machine tool, and F is the maximum value of the feed rate set in the NC program.

The second sharp corner identification criterion is to determine the sharp corner point by judging whether the centripetal acceleration at the above-mentioned local extreme point exceeds the maximum acceleration allowed by the machine tool. That is, if $k(u_i) > k_{th}$, then the speed must be reduced at that point. Otherwise, the tool will not be able to pass this point normally due to the limitation of acceleration. Therefore, only points that satisfy both of the above criteria will be determined as sharp corner points.

It should be noted that according to the calculation formula of the curvature limit value k_{th}, it can be found that in the same MATLAB curve, different numbers of sharp corner points may be obtained under different feed rates F. It can be seen from Figure 5 that there are 3 sharp corners when the set feed speed is F=150mm/s. It can be seen from Figure 2.5 that there are only 2 sharp corners when F=120mm/s. Therefore, the lower the given feed rate F, the less the number of sharp corners that may be determined. Conversely, the higher the feed rate F, the greater the number of sharp corners that may be determined.

After the sharp corners are determined, the curve is divided into several small subsections by the sharp corners. We assume that there are n-1 sharp corners, then the curve is divided into n segments. The curve length $L_{seg}^m\,(m = 1, 2, ..., n)$ of each subsection is calculated, and the length value of each subsection will be applied in subsequent modules. The formula for calculating the length of the tower is as follows:

$$L_{seg} = \int_{u_{str}}^{u_{end}} P'(u)\,du = \int_{u_{str}}^{u_{end}} \sqrt{[x'(u_i)]^2 + [y'(u_i)]^2 + [z'(u_i)]^2}du \tag{2.4}$$

u_{str}, u_{end} are the starting point u_ix value and the ending point u_i value of the subsection curve respectively Then, there is $f(u) = L_{seg} = \sqrt{[x'(u_i)]^2 + [y'(u_i)]^2 + [z'(u_i)]^2}$.

Using the composite Simpson formula to solve the length L_{seg}^m of each segment, the composite Simpson

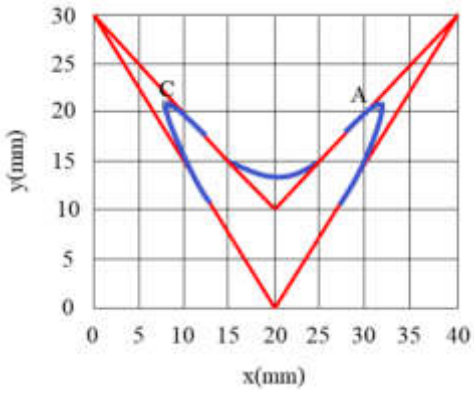

Fig. 2.5: Sharp corners when F=120mmts

formula is expressed as:

$$\int_a^b f(x)\,du \approx S_n = \frac{h}{6}\left\{f(a) - f(b) + 2\sum_{k=1}^{n}\left[2f\left(x_{k-\frac{1}{2}}\right) + f(x_k)\right]\right\} \tag{2.5}$$

Among them, $h = \frac{b-a}{n}$ is the step size.

After the integral interval [a, b] is divided into n equal parts, the S value is calculated according to the above formula, which is the approximate value of the integral. The larger the subdivision is, the more precise the approximation of the integral will be, and the closer it will be to the true value. In practical computing applications, the approximation error is estimated using the post-hoc estimation method of the error.

The algorithm divides the integral interval [a, b] into half successively, uses the same composite Simpson formula to calculate the approximate value of the integral every time, and uses the difference between the two calculation results before and after to judge the size of the error. If $|S_{2n} - S_n| < \varepsilon = 15\varepsilon'$ (ε' is the allowable error of the calculation result), the algorithm stops the calculation and takes ε' as the approximate value of the integral. Otherwise, the algorithm divides the interval into half again, calculates a new value, and then uses the difference between the two calculation results before and after to judge the error. If $|S_{4n} - S_{2n}| < \varepsilon = 15\varepsilon'$, the algorithm stops computing. Otherwise, the algorithm continues to subdivide until a result that meets the accuracy requirements is obtained.

We set the size of ε', that is, the size of the allowable error value of the calculation result, which directly determines the accuracy of the calculation result and the length of the operation time.

The algorithm accumulates the segment length L^C (C=1,2,...-,m), and increments the segments one by one. Each time a subsegment is added, the data is saved once.

$$L^C = \sum_{j=1}^{c} L_{seg}^{j}\,(C = 1, 2, ..., m) \tag{2.6}$$

After the length L_{seg}^{m} of each segment is obtained, the calculation of the cumulative segment length L^C (C=1,2,...-,m) is still very easy. Fourth, the algorithm calculates the maximum feed rate $V_{\max}$ and the minimum feed rate $V_{\min}$ on each segment.

According to the segmentation of the sharp corners, the algorithm calculates the maximum feed rate $V_{\max}$ and the minimum feed rate $V_{\min}$ on each segment. The maximum feed rate $V_{\max}$ and the minimum feed rate $V_{\min}$ generally appear at the extreme points of each curvature within the segment and at both ends of the segment.

The calculation of the maximum speed $V_{\max}$ and the minimum speed $V_{\min}$ should consider the influence of two aspects. The first is to limit the bow height error $\delta_{\max}$ to ensure that the bow height error does not exceed the limit, and the second is the change of the curvature ρ.

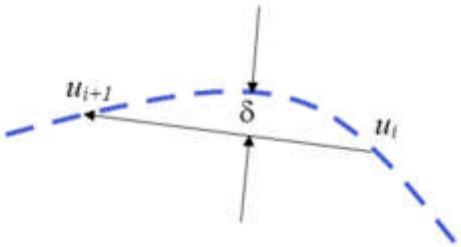

Fig. 2.6: Schematic diagram of interpolation operation

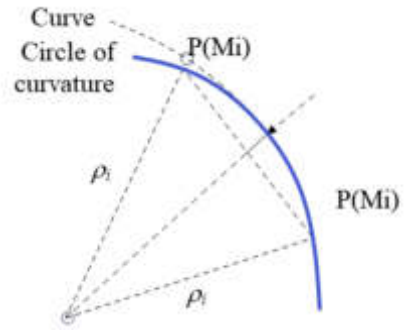

Fig. 2.7: Bow height error analysis diagram

2.0.1. Adaptive feed rate interpolation algorithm based on limited bow height error. The size of the feed rate specifically represents the length of the feed step per interpolation cycle. In order to ensure maximum processing efficiency, under the premise of ensuring that the speed limit is not exceeded, it is hoped that the longer the feed step of each interpolation cycle, the better. Figure 7 is an enlarged view of a part when interpolation is performed from u_i to u_{i+1} point in curve interpolation.

In MATLAB curve interpolation, each interpolation cycle is a process in which a straight line replaces a curved arc. Since each interpolation point is still on the MATLAB curve, the trajectory accumulation error is not introduced, but the bow height error δ is introduced, as shown in Figure 2.7. The size of the bow height error δ is related to the feed step $\triangle$L and the curvature radius ρ.

If the curved arc is replaced by a circular arc segment, under normal circumstances, $\rho >> \delta$, the bow height error relationship of MATLAB curve interpolation can be obtained:

$$\Delta L = 2\sqrt{\rho_i^2 - (\rho_i - \delta)^2} = 2\sqrt{2\rho_i\delta - \delta^2} \tag{2.7}$$

From $V_{af}T = \Delta L$, the relationship t between the speed V_{af} and δ can be known as follows:

$$V_{af} = \frac{2}{T}\sqrt{2\rho_i\delta - \delta^2} \tag{2.8}$$

In practical engineering applications, the bow height error 6 of the entire MATLAB curve interpolation trajectory is limited within the specified allowable error range. If the maximum allowable bow height error $\delta_{\max}$ is given, in order to ensure that the bow height error does not exceed the limit value, the adaptive feed rate based on the limited bow height error is:

$$V_{af}\,(u_i) = \frac{2}{T}\sqrt{2\rho_i\delta - \delta^2} \tag{2.9}$$

If the calculated $V_{af}(u_i)$ is greater than the feed rate F set in the NC program, $V_{af}(u_i) = F$ is set. If it is calculated that $V_{af}(u_i)$ is not greater than the feed rate F, then $V_{af}(u_i) = \frac{2}{T}\sqrt{2\rho_i\delta_{\max} - {\delta_{\max}}^2}$.

Therefore, there are:

$$V_{af}(u_i) = \begin{cases} \frac{2}{T}\sqrt{2\rho_i\delta - \delta^2}, if\ \frac{2}{T}\sqrt{2\rho_i\delta_{\max} - {\delta_{\max}}^2} \le F \\ F \qquad\qquad\qquad if\ \frac{2}{T}\sqrt{2\rho_i\delta_{\max} - {\delta_{\max}}^2} > F \end{cases} \tag{2.10}$$

In the formula, $\rho_i = \frac{1}{k}$, and ρ_i can be known by obtaining the curvature. The calculation of k can refer to Formula 2.

2.0.2. Curvature-based Feed Rate Interpolation Algorithm. The curvature-based feed rate $V_{cbf}(u_i)$ is calculated in formula 12, as follows:

$$V_{cbf}(u_i) = \frac{k_{cbc}}{k(u_i) + k_{cbc}} F \tag{2.11}$$

Among them, $k_{cbc} = 1.001mm^{-1}$, and k_{cbc} is the set curvature value used to maintain the continuity of the derivative of V_{cbf}. That is, when the curvature k(ui) is 0, V_{cbf}=F is made.

$k(u_i)$ is the curvature value of the MATLAB curve at point u_i, and F is the feed rate set in the NC program.

In the above two algorithms, the adaptive feed rate interpolation algorithm is used to obtain V_{af}, and this algorithm considers the bow height error to ensure that the bow height error does not exceed the maximum allowable bow height error $\delta_{\max}$. The curvature-based feed rate interpolation algorithm obtains V_{cbf}, which adjusts the feed rate based on the curvature of the curve. Therefore, the feed rate at a certain point on the curve is:

$$V(u_i) = \max\{\min(V_{af}(u_i), V_{cbf}(u_i), F_{\max}), F_{\min}\} \tag{2.12}$$

In the formula, $F_{\max}$ is the given maximum allowable feed rate, and $F_{\min}$ is the given minimum feed rate.

The maximum feed rate $V_{\max}$ and the minimum feed rate $V_{\min}$ generally appear at the extreme points of each curvature within the segment and at both ends of the segment. According to formula (2.12), the two ends of each subsection and the extreme point of curvature are calculated to determine the maximum feed rate $V_{\max}$ and the minimum feed rate $V_{\min}$ in each subsection.

For each sub-segment, according to its parameters such as L_{seg}^m, V_{str}, V_{end}, $V_{\max}$, as well as the values of $A_{\max}$ and $J_{\max}$, it can be determined which of the above 7 types the segment is. Then, for different types, the corresponding scheme is used to plan the motion trajectory of the segment.

The specific determination method and process are as follows:

1. Calculate the L_{r1}, L_{r2}, L_{r3}, L_{r4} length values

$$L_{r1} = 2V_{str}T \tag{2.13}$$

$$L_{r2} = (V_{str} + V_{end})\sqrt{\frac{|V_{end} - V_{str}|}{J_{\max}}} \tag{2.14}$$

$$L_{r3} = (V_{str} + V_{end})\sqrt{\frac{|V_{\max} - V_{str}|}{J_{\max}}} + (V_{end} + V_{\max})\sqrt{\frac{V_{\max} - V_{end}}{J_{\max}}} \tag{2.15}$$

$$L_{r4} = (V_{str} + V_{\max})\sqrt{\frac{|V_{\max} - V_{str}|}{J_{\max}}} \tag{2.16}$$

Among them, L_{r1} is the minimum length that can be planned into type II and III, L_{r2} is the minimum length that can be planned into type VI, and L_{r3} is the minimum length that can be planned into type VII. When $(V_{str} = V_{\max})$or $(V_{end} = V_{\max})$, L_{r4} is the minimum length that can be programmed into type IV or V.

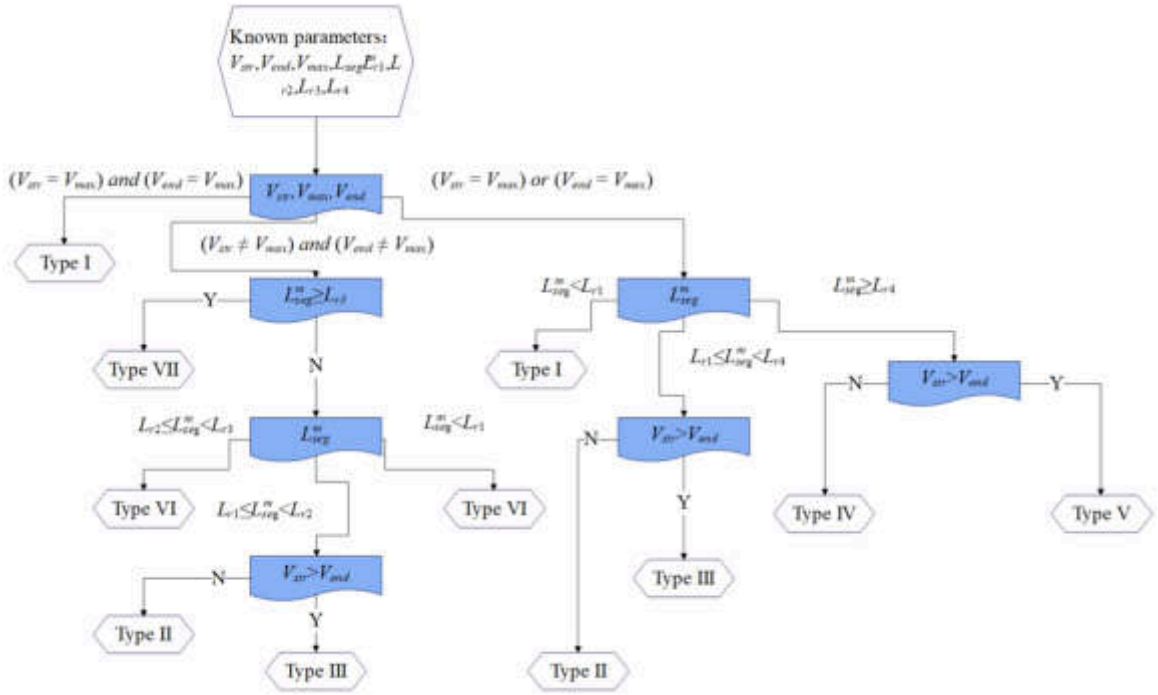

Fig. 2.8: Type judgment flow chart

2. Determine the segment type. According to its L_{seg}^m, V_{str}, V_{end}, $V_{\max}$ and other parameters, the segment type is determined according to the flow chart 9 given below.

3. Calculates the parameters of S-shaped acceleration and deceleration:T_{str}, T_c, T_{end}, J_{str}, J_{end}. Taking type V as an example, when $V_{str} \neq V_{\max}$ &$V_{end} \neq V_{\max}$ and $L_{r2} \leq L_{seg}^m \leq L_{r3}$ of a segment, it is considered that this sub-segment can be planned as a type.

From the figure 2.7, we can see that:

$$V_{\max} = V_{str} + J_{\max} T_{str}^2 = V_{end} + J_{\max} T_{end}^2 \tag{2.17}$$

$$T_{end} = \sqrt{T_{str}^2 + \frac{V_{str} - V_{end}}{J_{\max}}} \tag{2.18}$$

$$L_{seg}^m = (V_{\max} + V_{str})\, T_{str} + (V_{\max} + V_{end})\, T_{end} \tag{2.19}$$

Substituting formula (3.4) and formula (3.5) into formula (3.6), we get:

$$L_{seg}^m = \left(2V_{str} + J_{\max} T_{str}^2\right) T_{str} + \left(V_{str} + V_{end} + J_{\max} T_{end}^2\right) T_{end} \sqrt{T_{str}^2 + \frac{V_{str} - V_{end}}{J_{\max}}} \tag{2.20}$$

The formula is as follows:

$$\begin{aligned} &f\left(T_{str}\right) = J_{\max}\left(V_{str} - V_{end}\right) T_{str}^4 + 2J_{\max} L_{seg}^m T_{str}^3 - \left(V_{str} - V_{end}\right) T_{str}^2 \\ &+4V_{str} L_{seg}^m T_{str} + \frac{\left(V_{str}+V_{end}\right)^2 \left(V_{str}-V_{end}\right)}{J_{\max}} - \left(L_{seg}^m\right)^2 = 0 \end{aligned} \tag{2.21}$$

The solution T_{str} of this nonlinear equation $f\left(T_{str}\right)$ is calculated using the Newton-Lei Fusheng method. When using the Newton-Lei Fusheng method to calculate the solution T_{str}, the initial value is set as T_j, as

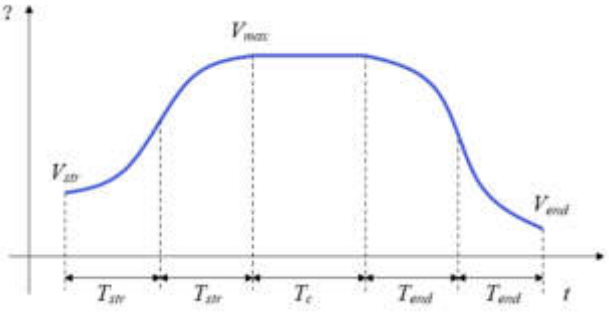

Fig. 2.9: Acc-cv-DEC acceleration and deceleration diagram

follows:

$$T_j = \frac{A_{\max}}{J_{\max}} \tag{2.22}$$

The solution of the equation T_{str} is close to the value of T_j, and the value of T_j is used as the initial value, which is conducive to the rapid convergence of the Newton-Lei Fusheng method, and will not produce unreasonable numerical solutions. After obtaining T_{str}, the value of T_{end} can be calculated by the formula.

According to the type of each segment, the T_{str}, T_c, T_{end}, J_{str}, J_{end} parameters are obtained after preliminary calculation. Among them, T_{str}, T_{end}, and T_c are the time values of each stage of the speed change, respectively, and the value obtained after the calculation in Table 1 is not an integer multiple of the interpolation period T. For example, T_{str}=0.16578, and the interpolation period is T=0.001. It can be seen that 0.00078 seconds in T_{str} is less than one interpolation period, and the time that is less than one interpolation period can neither be discarded nor simply rounded to 1 interpolation period. Its direct truncation or rounding will make the speed value inconsistent with the subsequent calculation value. In order to ensure the equal interval interpolation period of the data sampling interpolation method to ensure the accuracy and precision of the processing, the T_{str}, T_c, T_{end}, J_{str}, J_{end} parameters are further corrected.

The revised principles are as follows:

1. T_{str}, T_{end}, T_c must be corrected to an integer multiple of the interpolation period.
2. The total arc length L_{seg}^m remains unchanged in each segment.
3. The maximum processing speed of each segment is guaranteed not to exceed $V_{\max}$.
4. The jerk value of each segment is guaranteed not to exceed the allowable value $J_{\max}$.

Under the conditions of the above four principles, the parameters of each segment are corrected segment by segment according to the segment type. Now, taking the correction of Type V as an example, Figure 2.9 shows the acceleration and deceleration diagram of Acc-cv-DEC type.

The algorithm rounds T_{str} according to the number of interpolation cycles, and takes the smallest number greater than T_{str} and an integer multiple of T as the new T_{str}, which is denoted as T'_{str}.

$$T'_{str} = ceil\left(\frac{T_{str}}{T}\right) * T \tag{2.23}$$

J'_{str} is calculated while keeping $V_{\max}$ constant and the value T'_{str} as follows:

$$J'_{str} = \frac{V_{\max} - V_{str}}{{T'_{str}}^2} \tag{2.24}$$

T_c at value T_c is calculated as follows:

$$T_c = \frac{L_{seg}^m - (V_{\max} + V_{str})\, T'_{str} - (V_{\max} + V_{end})\, T_{end}}{V_{\max}} \tag{2.25}$$

The algorithm rounds T_c according to the number of interpolation cycles, and takes the largest number less than T_c and an integer multiple of T as the new T_c, which is denoted as $T_c^{'}$.

$$T_c^{'} = fix\left(\frac{T_c}{T}\right) * T \tag{2.26}$$

The remaining length of this curve is calculated, that is, the deceleration interval curve length L_3, as follows:

$$L_3 = L_{seg}^m - (V_{\max} + V_{str})\, T_{str}^{'} - V_{\max} T_c^{'} \tag{2.27}$$

T_{end} is calculated as follows:

$$T_{end} = \frac{L_3}{V_{\max} + V_{end}} \tag{2.28}$$

The algorithm rounds T_{end} according to the number of interpolation cycles, and takes the smallest number greater than T_{end} and an integer multiple of T as the new T_{end}, which is denoted as $T_{end}^{'}$.

$$T_{end}^{'} = cell\left(\frac{T_{end}}{T}\right) * T \tag{2.29}$$

The algorithm calculates $V_{end}^{'}$ at the value $T_{end}^{'}$ when the length L_3 of the deceleration section and the initial speed of the deceleration section are still unchanged at $V_{\max}$, as follows:

$$V_{end}^{'} = \frac{L_3}{T_{end}^{'}} - V_{\max} \tag{2.30}$$

In $2T_{end}^{'}$ time, the deceleration of $V_{end}^{'}$ from $V_{\max}$ to the required $J_{end}^{'}$ is calculated as follows:

$$J_{end}^{'} = \frac{V_{\max} - V_{end}^{'}}{{T_{end}^{'}}^2} \tag{2.31}$$

So far, the revised parameters $T_{str}^{\prime}$, $T_c^{\prime}$, $T_{end}^{\prime}$, $J_{str}^{\prime}$, $J_{end}^{\prime}$, $V_{end}^{\prime}$ are all calculated.

It should be noted that the revised parameters will affect the next segment. For example: the value of $V_{end}^{\prime}(i)$ in the i-th segment should be used as the starting speed $V_{str}(i+1)$ of the next segment, that is, the first segment.

3. Research method.

3.1. MATLAB curve end deceleration planning. Because the feed rate at the end of the MATLAB curve is zero, that is, $V_{end} = 0$ for the last subsection. If the L_{seg}^m length of the last subsection is too short, or the initial speed V_{str} is too large, or both, it may result in a Type llI (DEC) velocity plan from the start of the last sub-segment starting at V_{str} toward the end of that sub-segment (i.e., the end of the curve). When it reaches the end point, V_{end} falls below zero. To make the end speed V_{end}=0, you need to use a jerk greater than $J_{\max}$ to plan this last curve. Obviously, this violates the jerk limitation principle and exceeds the allowable value of the machine tool. Therefore, if the length L_{seg}^m of the last subsection is too short, or the initial speed V_{str} is too large, it is necessary to re-plan the feed rate scheme of the last several subsections.

In order to judge whether the length L_{seg}^m of the last subsection is sufficient, the maximum deceleration distance L_{dec} and the remaining section length R are introduced.

The maximum deceleration distance L_{dec} refers to the deceleration distance required to reduce the feed rate from the feed rate F given by the NC program to ? under the limit of the jerk $J_{\max}$. The calculation formula t is as follows:

$$L_{dec} = FT_{end} = F\sqrt{\frac{F}{J_{\max}}} \tag{3.1}$$

The remaining segment length R refers to the length from the current segment to the last segment. The calculation formula is as follows:

$$R^r = \sum_{j=r+1}^{c} L_{seg}^j \tag{3.2}$$

Among them, r is the segment number currently performing interpolation, and c is the total number of segments in the curve.

When the program file is long, the method of pre-reading a certain number of steps is adopted, so the deceleration planning at the end of the MATLAB curve must be carried out after all the steps are pre-read. When the condition satisfies $R^{r+1} \leq L_{dec} \leq R^r$, all the remaining segments $L_{seg}^{r+1}, L_{seg}^{r+2}, ..., L_{seg}^c$ can be merged into one segment to become a new segment L_{seg}^{r+1}. The feed rate planning is carried out, and the parameters T_{str}, T_c, T_{end}, J_{str}, J_{end} of the new acceleration and deceleration mode are calculated.

Finally, the algorithm transmits the parameters T_{str}, T_c, T_{end}, J_{str}, and J_{end} of the acceleration and deceleration mode to the real-time interpolation module, and the real-time interpolation module generates instructions, drives the servo system, and controls the machine tool movement.

After calculating the parameters T_{str}, T_c, T_{end}, J_{str}, and J_{end} of the acceleration and deceleration mode, the real-time interpolation module can use these parameters to calculate J_{end} by using the second-order Taylor series expansion method, namely:

$$u_{i+1} = u_i + \frac{V(u_i)T}{|P'(u_i)|} + \frac{T^2}{2}\left\{\frac{A(u_i)}{|P'(u_i)|} - \frac{V^2(u_i)[P'(u_i)P''(u_i)]}{|P'(u_i)|^4}\right\} \tag{3.3}$$

Among them, the specific process of the fast calculation method of $P'(u_i)$ and $P''(u_i)$ values is detailed in Section 3.3.

The $V(u_{i+1})$ and $A(u_{i+1})$ corresponding to the next point u_{i+1} are:

$$V(u_{i+1}) = V(u_i) + A(u_i)T \tag{3.4}$$

$$A(u_{i+1}) = A(u_i) + JT \tag{3.5}$$

3.2. Trajectory calculation. The algorithm brings the new parameter u calculated by formula (3.3) into the MATLAB curve equation (2.2) to obtain the position coordinates of the next interpolation point and the incremental value of each coordinate:

$$P_{i+1} = P(u_{i+1})$$

It is equivalent to:

$$\begin{cases} x_{i+1} = x(u_{i+1}) \\ y_{i+1} = y(u_{i+1}) \\ z_{i+1} = z(u_{i+1}) \end{cases} \tag{3.6}$$

$$\begin{cases} \Delta x = x_{i+1} - x_i \\ \Delta y = y_{i+1} - y_i \\ \Delta z = z_{i+1} - z_i \end{cases} \tag{3.7}$$

After obtaining the parameters T_{str}, T_c, T_{end}, J_{str}, J_{end} of the acceleration and deceleration mode, the real-time interpolation module obtains the interpolation position of the next point by real-time interpolation within the same interpolation period T. It sends out each axis feed command to the servo system, drives the machine tool to perform the movement, and completes the interpolation task of this cycle. Moreover, the real-time interpolation continuously repeats the above two real-time interpolation steps, parameter densification, trajectory calculation, until $u_{i+1} \geq 1$ and $V_{end} = 0$, reaching the end point of the curve, the entire MATLAB curve interpolation trajectory can be completed.

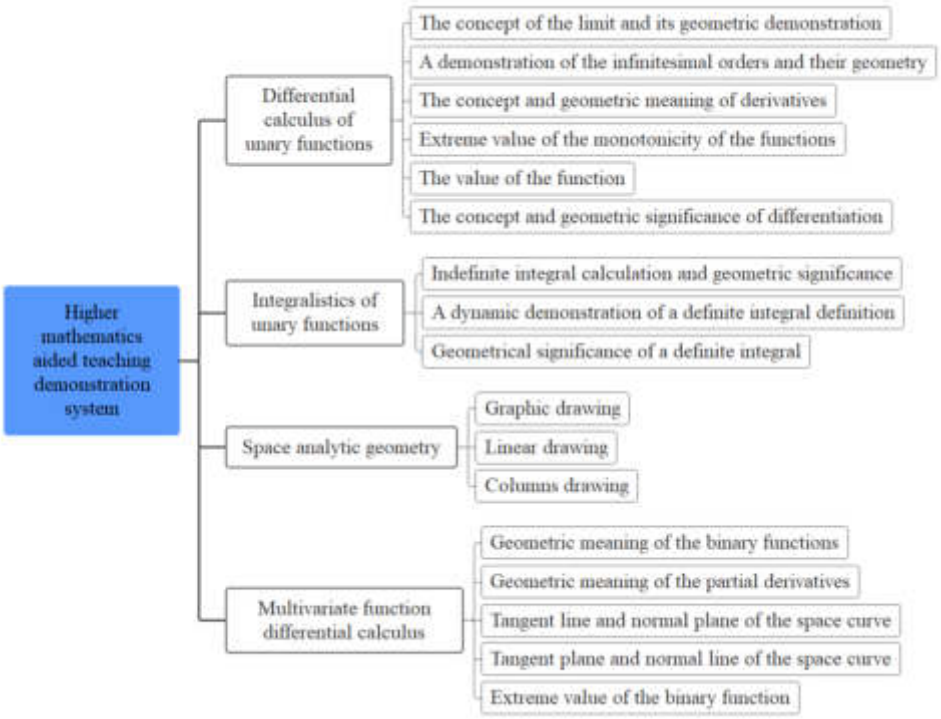

Fig. 3.1: Structure diagram of the teaching demonstration module of the system

3.3. Result. This article uses the Matlab platform for teaching mathematics in computer majors, which not only effectively improves teaching efficiency, but also helps students with poor mathematical foundations to strengthen their understanding and reduce the difficulty of mathematical understanding through intuitive displayThere are many teaching contents in advanced mathematics courses. This system focuses on four teaching contents, namely differential calculus of unary functions, integral calculus of unary functions, spatial analytic geometry and differential calculus of multiple functions. In these four teaching contents, each part contains many important mathematical concepts, such as derivatives, differentials, space surfaces and partial derivatives, etc. There are 17 teaching demonstration modules in the whole demonstration system, as shown in Figure 3.1.

The evaluation of the simulation effect of computer major teaching in this experiment is mainly carried out through the intelligent method proposed in this article to display the simulation of teaching content. After constructing the teaching system through Matlab, the real-time display of teaching content is simulated, and quantitative evaluation is carried out through manual evaluation.

The evaluation of the teaching effectiveness of computer science in this experiment is mainly carried out through the intelligent method proposed in this article to display and simulate the teaching content. The teaching effectiveness of this article is quantitatively evaluated through the experimental teaching mode, and data processing is carried out using mathematical and statistical methods

The mathematics teaching system for computer majors based on MATLAB proposed in this paper is evaluated, and the simulation effect of mathematics teaching images is evaluated, as shown in Table 3.1.

After verifying that the mathematics teaching system for computer majors based on MATLAB has a good simulation effect, the teaching effect of the mathematics teaching system for computer majors based on MATLAB is verified, as shown in Table 3.2.

Comparing the model presented in this article with the teaching model presented in reference [10], it is agreed to conduct mathematical teaching for computer major students. The teaching effectiveness is verified through teaching evaluation methods, and the teaching evaluation results are shown in Table 3.3.

Table 3.1: Simulation effect of the mathematics teaching system for computer majors based on MATLAB

Num	Simulation effect	Num	Simulation effect	Num	Simulation effect
1	96.36	14	95.21	27	95.23
2	95.49	15	97.70	28	97.22
3	96.82	16	96.42	29	95.28
4	95.85	17	95.24	30	95.80
5	97.55	18	97.70	31	95.88
6	95.12	19	94.83	32	97.47
7	96.83	20	96.05	33	97.87
8	96.08	21	97.86	34	96.75
9	95.77	22	96.40	35	96.78
10	95.02	23	97.84	36	95.08
11	97.98	24	94.87	37	96.54
12	96.67	25	94.83	38	94.77
13	97.42	26	96.30	39	94.51

Table 3.2: The teaching effect of the mathematics teaching system for computer majors based on MATLAB

Num	Teaching effect	Num	Teaching effect	Num	Teaching effect
1	80.12	14	83.56	27	84.43
2	81.99	15	83.72	28	79.62
3	82.11	16	82.39	29	84.47
4	79.90	17	82.78	30	82.26
5	81.92	18	82.29	31	85.58
6	81.73	19	81.96	32	81.22
7	85.91	20	82.83	33	83.72
8	81.82	21	84.63	34	81.32
9	82.13	22	83.62	35	79.12
10	85.15	23	85.11	36	84.38
11	81.86	24	84.45	37	85.71
12	80.29	25	79.89	38	80.91
13	80.13	26	81.81	39	80.94

3.4. Analysis and Discussion. Mathematics is an important foundational course in computer science, which plays an extremely important role in cultivating students' logical thinking ability and problem-solving ability, as well as in the study of professional courses and subsequent courses. However, some computer science students have basic mathematical knowledge, and most of them find mathematics difficult to understand. They believe that mathematics is just boring calculations and lack interest in it. To solve these problems, we can timely and appropriately apply MATLAB software in mathematics teaching for computer majors. This can not only help students understand abstract concepts and theorems in mathematics more intuitively, stimulate their interest in learning, but also help them free themselves from tedious calculations. MATLAB, as a powerful mathematical software, has efficient numerical calculation functions and complete graphic processing functions. At the same time, due to its proximity to the natural language of mathematical expressions, it is also easy for students to learn and master. Therefore, in teaching practice, we can use MATLAB as a teaching aid, so that students no longer need to perform complex mathematical operations, and classroom teaching is more vivid and vivid. At the same time, we can strengthen the use of MATLAB in mathematical modeling activities, so that students can better use software to solve practical problems.

Therefore, in mathematical modeling activities, it can be said that students must master certain MATLAB skills. Mathematical modeling problems come from real life and are all aimed at solving practical problems, which are complex and often require the use of computational software. In our school's mathematical modeling

Table 3.3: Comparative Evaluation of Teaching Effectiveness

Serial Number	The model of this article	The model of reference [10]	Serial Number	The model of this article	The model of reference [10]
1	85.49	78.30	9	81.70	81.24
2	84.94	79.03	10	83.88	76.32
3	84.97	73.43	11	79.36	74.87
4	84.16	80.78	12	81.89	81.09
5	87.24	73.17	13	87.91	76.32
6	87.56	81.72	14	85.86	80.67
7	87.28	73.70	15	82.76	77.22
8	79.05	77.14			

activities, we have developed an active programming training plan centered on solving specific problems. Students first find the steps to solve the problem, and then implement them step by step in MATLAB. Through problem-solving, they strengthen their understanding of the training knowledge and experience the joy and sense of achievement of learning after solving the problem.

In recent years, the use of MATLAB software platform has gradually increased some practical teaching content in the process of university mathematics teaching, which can make certain abstract mathematical concepts, formulas or theorems visual and vivid, effectively helping students grasp the essence of mathematical problems. This effectively resolves many teaching difficulties in university mathematics, promotes the coordinated development of abstract thinking and visual thinking among students, Cultivate students' learning enthusiasm and innovation. MATILAB is a powerful mathematical software. The graphical user interface GUI technology of MATILAB provides an interactive environment for the teaching of university mathematics. The introduction of MATILAB's graphical user interface GUI technology in university mathematics teaching provides an interactive environment for teaching. Further development of graphical user interfaces for courses such as numerical analysis, probability statistics, and operations research is carried out on the MATILAB platform, Changing the traditional mathematics teaching mode, integrating theoretical teaching and experimental demonstration, is conducive to enhancing the intuitiveness and interactivity of university mathematics teaching, enriching teaching methods, improving teaching effectiveness, and more conducive to mobilizing students' learning enthusiasm.

As shown in Tables 3.1 and 3.2,From the above research results, it can be seen that the simulation effect evaluation of computer mathematics teaching systems based on Matlab is distributed between [94,98], and the teaching effect evaluation of computer mathematics teaching systems based on Matlab is distributed between [79,86].

From the results of the teaching control experiment, it can be seen that the teaching model proposed in this article can better leverage the advantages of intelligent teaching in mathematics teaching for computer majors compared to traditional teaching models

Through the evaluation and analysis, it can be seen that the mathematics teaching system for computer majors based on MATLAB can effectively improve the intuitive effect of advanced mathematics teaching and help improve the teaching quality of advanced mathematics.

In addition, the model proposed in this article can not only be used for mathematics teaching in computer majors, but also for abstract teaching in other majors. Through more specific methods, it helps students understand abstract knowledge that is difficult to understand. Therefore, the model proposed in this article can not only play a role in mathematics teaching in computer majors, but also in teaching other professional disciplines

In actual teaching, the following teaching methods can be used to carry out teaching:

The Fourier series has a relatively wide range of applications in engineering and technical practice, and is an important tool in signal processing. In practice, the Fourier series is mainly formed by the superposition of sine curves. During the learning process, students have great difficulties in understanding the curves with sharp points that are superimposed. If it is difficult to achieve Fourier series by manual demonstration, MATLAB

can be used to draw specific images and conduct comparative analysis to guide students to learn concepts more intuitively and improve understanding.

In the drawing of univariate function graphs, MATLAB software can be used to better guide students to learn and understand the meanings of extreme points, inflection points, etc., thereby more efficiently mastering relevant concepts and knowledge points. MATLAB can quickly create univariate function graphs, store data on the x-axis and y-axis in two vectors of the same dimension, and use commands to draw function graphs. You can also use MATLAB to create animations. Multivariate function integration is an important part of basic mathematics teaching. In learning, it is necessary to draw graphs of multivariate functions. For some relatively complex function graphs, it is difficult to complete them without the help of software, which can affect the teaching effect. The graphics drawn based on textbooks and blackboard writing are flat and stationary, and errors are prone to occur during drawing, making it difficult for students to understand spatial graphics. In teaching, MATLAB software can be used to create three-dimensional spatial function graphics, and the formation process can be demonstrated in the form of animation to help students better understand relevant knowledge points.

In basic mathematics teaching, it is very difficult for teachers to manually draw spatial geometry, and the operation is not convenient. For example, rotating a quadratic surface can only be statically displayed, and students need to rely on imagination and abstract thinking to facilitate understanding and mastery. MATLAB software can dynamically demonstrate complex graphics, rotating quadratic surfaces, etc., such as displaying the dynamic formation process of elliptical paraboloids in the form of animation through program settings, making mathematics classes more vivid and enhancing students' enthusiasm for learning mathematics.

In the teaching of qualitative theory of equations, most general solutions cannot be expressed using elementary function integrals, and there is no need to solve equation solutions in practical applications such as biology, physics, and chemistry. Specific equation solution images can be simulated using MATLAB systems to help students better understand and reduce the difficulty of learning ordinary differential equations

4. Conclusion. Algorithms, graphics and images, programming and artificial intelligence courses in computer science are closely related to mathematics. Computer major is one of the important disciplines in the development of new engineering. According to the requirements of new engineering education, students majoring in computer should have good logical reasoning ability and practical innovation ability, as well as good mathematical foundation and application ability of mathematical knowledge. In order to cultivate computer professionals who, meet the needs of society, the main research is on the application of the mathematical software MATLAB in the mathematics teaching of computer majors, so as to further improve the students' innovation and practice ability. Through the evaluation and analysis, it can be seen that the mathematics teaching system for computer majors based on MATLAB can effectively improve the intuitive effect of advanced mathematics teaching and help improve the teaching quality of advanced mathematics.

This article uses the Matlab platform for teaching mathematics in computer majors, which not only effectively improves teaching efficiency, but also helps students with poor mathematical foundations to strengthen their understanding and reduce the difficulty of mathematical understanding through intuitive display

The computer mathematics teaching system based on MATLAB can change the traditional teaching mode of computer mathematics. In the future, this method and intelligent machine learning methods can be combined to further improve the teaching methods and enhance the effectiveness of computer mathematics teaching.

In terms of technological improvement, a PC based CNC system based on a new high-performance processor can be adopted. Through efficient algorithms and simplified software design that directly manipulates the CPU core, the comprehensive advantages of the best combination of software and hardware can be fully utilized, effectively ensuring the implementation of high-speed and high-precision interpolation technology.

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INTERIOR SCENE COLORING DESIGN MODEL COMBINING IMPROVED K-MEANS AND SAA

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Abstract. Due to technological progress and changes in people's aesthetic standards, traditional design models need to be constantly broken through, seeking more efficient and accurate design methods. Seeking effective design models to improve design efficiency and prediction accuracy is an important task. Therefore, this study proposes an indoor scene coloring design model that combines improved K-means clustering and simulated annealing algorithm for this important task. Based on the analysis of indoor scene coloring, particle swarm optimization algorithm is used to optimize K-means clustering to achieve color classification. Combined with simulated annealing algorithm, adaptive adjustment of lighting conditions is achieved to enhance the naturalness and realism of coloring. These results confirmed that the proposed method had the highest average F-value, with an average F-value of 92.524 and 143.601 on both datasets, respectively. The average ARI values were 0.361 and 0.897, respectively. The designed algorithm performed the best and converged faster than other three. Therefore, the proposed method can effectively ensure the consistency between the distribution of data objects after clustering and the actual situation. For indoor scene coloring design, it has important practical significance and provides new possible paths for improving design efficiency and prediction accuracy.

Key words: Scene coloring; K-means; SAA; Interior design; Color compatibility

1. Introduction. In the current digital era, Indoor Scene Coloring Design (ISCD) plays a crucial role in architectural design, film production, game development, and more [1]. With the rise of virtual reality technology and consumers' high requirements for visual experience, interior scene coloring design has become more complex and the demand has increased [2]. The color design of indoor scenes can not only affect the visual perception of viewers, but also to a certain extent affect their emotions and psychological states [3]. Traditional ISCD usually requires designers to invest a lot of time and energy, and requires rich color knowledge and good artistic aesthetics [4]. Studying an effective ISCD has important research value and practical significance, in order to reduce the workload of designers, improve design efficiency and quality [5]. With the growth of visual experience requirements, the demand for interior scene design also rises. The double pressure on designers is to quickly master emerging tools and technologies and build on them to increase productivity without sacrificing design aesthetics. This challenge has led to the need for an efficient interior scene coloring design model, which aims to reduce the burden on designers and improve the efficiency and quality of the design, which has far-reaching implications for research and practice. Based on this background, this study proposes an ISCD that combines improved K-means Clustering Algorithm (K-means) with Simulated Annealing Algorithm (SAA). The aim is to cluster colors using K-means to determine the main colors of scene, and then optimize colors using SAA to achieve better visual effects. This study innovatively combines two color processing techniques, taking into account both the distribution characteristics of colors and the visual effects of colors. In addition, the model also considers the characteristics of indoor scenes and can effectively design colors for different scenes. This design model not only provides a new ISCD method and new tools for designers, but also provides a new research direction for color processing technology research. The article hopes to have an important impact on interior design, movies, and games, and promote further development in these fields. The research will be conducted in four parts. The first is an overview of indoor scene coloring analysis. Next is the study of indoor scene coloring models that integrate Particle Swarm Optimization (PSO) to optimize K-means and SAA. The third part is experimental verification. Finally, there is a summary and outlook on the research methods and results of this study.

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2. Need of the Study. Interior scene coloring design is of great significance to enhance the aesthetic sense of space and functional practicability. In the existing research, K-means algorithm is widely used in color clustering because of its simplicity and efficiency, but it is sensitive to the initial cluster center and is easily affected by local optimal solutions. In contrast, SAA shows great potential in optimization problems with its global search capability, but the computational cost is high. Therefore, for interior scene color design, there is a need to improve the combination of K-means algorithm and SAA, aiming to improve the accuracy and efficiency of color clustering through hybrid algorithms, and provide a new color optimization tool for the field of interior design. Research in this area aims to address the limitations encountered when applying existing single algorithms to interior scene coloring design and explore the potential advantages of algorithm fusion for design results and performance.

3. Objectives of the Study. A coloring design model of indoor scene based on improved K-means algorithm and SAA is proposed. This paper aims to improve the selection mechanism of initial clustering center of K-means algorithm, reduce its dependence on random initial value, and improve the stability and accuracy of the algorithm. Secondly, SAA optimization process is introduced to overcome the limitation that traditional K-means algorithm is easy to fall into local optimal, and to enhance the optimization ability of the model in the global search space. Through the application of mixing algorithm, the color matching scheme of indoor scene is optimized to achieve uniform and harmonious color distribution. Finally, it is expected that the model can effectively improve the generation efficiency and quality of interior design color scheme, and provide a scientific decision support tool for interior designers in the development of color scheme. Through this research, we explore the application value and practical significance of algorithm mixing in the field of interior design.

4. Related works. The core of indoor scene layout design is the synthesis of indoor home scenes, which includes optimization of object selection, object placement, and style matching within the scene. Numerous scholars have actively studied indoor spatial layout. A Fahim et al. were committed to finding suitable k-values or improving the selection method of initial centers, using density-based strategies to obtain initial clusters. This strategy did not require predicting the clusters, but calculated the average value of each cluster object and used this information for k-means to improve the results quality. The preprocessing step adopted a density-based noisy application spatial clustering method, which could converge the results to the global minimum and improve the results quality [6].

Rezaee et al. explored a new k-means variant to cluster data through a bargaining game model. The competition between cluster centers attracted as many similar targets or entities as possible to their respective clusters. These experiments confirmed that it exhibited higher clustering accuracy based on eight evaluation indicators such as f-measure, Dunn, and Rand index [7].

Hu et al. proposed a K-means based on slimy flight trajectory. These experiments confirmed that LK-means had better search results and a more uniform distribution of cluster centroids, significantly improving global search capabilities and big data processing capabilities [8].

Zhao et al. proposed an iterative difference de-blurring algorithm based on LCL. The keys were to remove the contribution of OFL from the projection data, eliminate the blurring of IFL, and then use SAA to reconstruct the corrected projection. These experiments confirmed that this algorithm could achieve PLO reconstruction of LCL systems under extremely sparse sampling conditions and effectively reduce inter chip aliasing and blur [9].

M Ehsani et al. studied the multiple variables to predict the fracture failure of jointed plain concrete pavement. Four feature selection methods were developed by combining Multi-objective PSO (MPSO) with decomposition-based multi-objective evolutionary algorithm. These experiments confirmed that the model had the best performance and could identify 17 input variables that affect faults [10].

Indoor spatial layout is a key part that reflects the details of indoor scenes and has been widely used in various fields. In computer vision, indoor scene synthesis and layout design have overall color style compatibility. Numerous scholars have actively studied indoor scene synthesis. S Guo et al. proposed a representative view selection method using visual attention. A progressive method of integrating user preferences through eye tracking was used to support innovation and make convergent thinking possible. The validation experiment confirmed the effectiveness of this proposed view selection method, preference inference model, and innovation support mechanism [11].

Table 4.1: Symbol table

Symbol table	
$E_1E_2E_3$	Constraints on the target scene palette
$\lambda\ \mu$	Balance the corresponding weights of the three energy terms
C_i	Every furniture theme color
C_j	The fourth color of the target scene palette
P_j	The percentage of the corresponding color in the color palette extracted from the target scene
N_f	The total number of furniture in the scene
P_i	Furniture i category
P_j	Furniture j category
m_i	Furniture i color
m_j	Furniture j color
$C(P_i, P_j)$	The number of times furniture i and j simultaneously assign all colors in the color database
$C(P_i, P_j, m_i, m_j)$	The number of times furniture i and furniture j are simultaneously assigned to m_i and m_j colors
$C(m, n)$	Furniture i has the number of specific colors n in the color database
$C(n)$	The number of all available colors in the color database
T_0	Initial temperature
i	Current iterations
ρ	Temperature drop for each iteration
x_i	Coordinates for each signal sample
N	The number of samples of the signal
ω	Inertia weight
c_1c_2	Learning factor
r_1r_2	Represents random numbers between
$d(x_jC_i)$	The distance from particle x_j to particle swarm centerC_i
x_iz	The z component of the i sample point
x_ip	The p component in the i th sample point

Park et al. proposed a framework based on object detection and so on to derive furniture pairing principles. These experiments confirmed that images with high fidelity values matched existing style descriptions, proving that this framework could be used for indoor style image retrieval [12].

Solah et al. proposed an automatic adjustment of the texture and color of virtual indoor scene objects to match target emotions. Extracting features through deep learning could assist in the optimization process of automatically coloring virtual scenes based on target emotions. This method was tested in four different indoor scenarios and its effectiveness was demonstrated through user research and statistical analysis [13].

Ren et al. proposed a new digital lighting design framework that enabled users to automatically obtain visually pleasing lighting layouts and indoor rendered images. These experiments confirmed that the framework effectively learned guidelines and principles, and generated lighting designs that were superior to rule-based baselines [14].

Xie et al. analyzed 284 complete questionnaires using a mixed effects model. Compared to the baseline, biophilic design had improved people's perception of the office, especially in designs with daylight and visibility. This made the perceived office space brighter, more comfortable, and spacious, superior to indoor plant spaces [15].

In summary, this study delves into ISCD and provides a new perspective for understanding and solving color selection issues in interior design. There may be some computational pressure when processing large-scale data. Further optimization and adjustment may be required for specific types of indoor scenes. Therefore, the study proposes an ISCD that combines improved K-means with SAA, aiming to improve the efficiency and accuracy of processing complex color matching and distribution. The article aims to achieve more automated and personalized scene color design, improve design efficiency and quality.

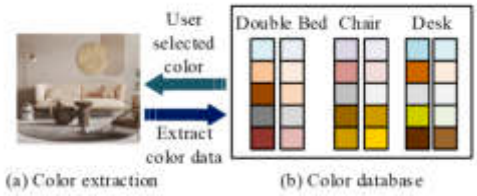


Fig. 6.1: Interior design furniture category color data extraction

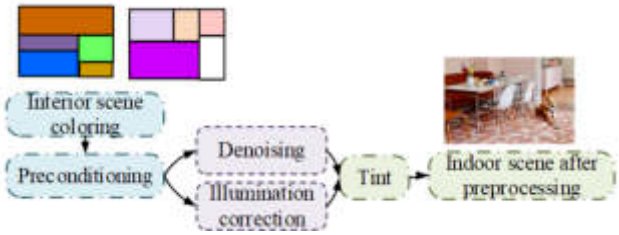


Fig. 6.2: Pre-processing of indoor scene coloring

5. Research Methadology. In the research methodology of indoor scene coloring design model, firstly, the improved K-means algorithm is adopted for color classification, and the initial clustering center is optimized by Particle Swarm Optimization (PSO) to enhance the stability and accuracy of the classification process. Then SAA algorithm is used to adjust the classification results to simulate the color changes under natural light, so as to improve the naturalness and realism of coloring. Through quantitative analysis of the visual effects of each color category and illumination conditions, the index of the algorithm optimization process can be quantified. Statistical methods such as cross-validation were used to evaluate the robustness of the model in order to ensure the scientific and reliability of the research results.

6. An indoor scene coloring model that integrates improved K-means and SAA. Deepening the analysis of indoor scene coloring can construct efficient and accurate coloring models. The indoor scene coloring model that integrates improved K-means and SAA emerges in this context. This model consists of two main parts. Firstly, the improved K-means is responsible for color classification, ensuring that various parts of scene can be reasonably divided, thereby giving more accurate coloring. Secondly, SAA adjusts lighting based on this to achieve a more natural and realistic visual effect. The fusion of these two algorithms aims to improve the rendering effect of indoor scenes by optimizing and improving traditional coloring methods, providing the possibility of achieving higher quality indoor scene coloring.

6.1. Indoor scene coloring analysis. Indoor scene coloring is widely used in the intersection of computer graphics and computer vision, aiming to achieve accurate and natural color rendering of indoor scenes through computer algorithms [16]. Currently, commonly used methods are color classification based on machine learning and lighting adjustment based on physical models. However, these methods often require a large number of computational resources, and their accuracy in processing complex scenes still needs to be improved [17]. Figure 6.1 shows the extraction of color data for interior design furniture categories.

Color data extraction in interior design is a composite study that integrates color theory, computer vision, and furniture design. By using computer algorithms and data analysis techniques, color information can be accurately extracted from different categories of furniture design, to conduct statistical analysis of the application trend of furniture color. Figure 6.2 shows the preprocessing of indoor scene coloring.

The preprocessing operations for indoor scene coloring mainly include geometric structure analysis of the scene, material feature recognition, and preliminary color classification. The application of preprocessing technology in interior scene coloring design involves advanced image analysis and color matching algorithm. Among

Fig. 6.3: Interior scene coloring process

them, image analysis technology subdivides the indoor scene into manageable areas by detecting the geometric structure of the space and object boundaries. At the same time, the color matching algorithm evaluates existing colors and suggests color schemes, taking into account factors such as light conditions and material reflectivity. These pre-processing steps provide the data foundation for the design model, enabling it to quickly identify and adjust the color distribution in the scene, laying a solid foundation for the subsequent design phase. The accuracy of preprocessing directly affects the effectiveness and performance of subsequent steps. By combining deep learning technology with traditional computer vision algorithms, the accuracy and efficiency of preprocessing can be improved. To ensure that the color combination of the entire indoor scene is compatible, energy minimization is used to represent the constraint problem of color satisfaction, and the corresponding energy function is constructed in equation 6.1.

$$E = E_1 + \lambda E_2 + \mu E_3 \tag{6.1}$$

In equation 6.1, E_1 , E_2 , and E_3 respectively represent constraints from the color palette of the target scene. λ and μ represent the corresponding weights for balancing the three energy terms, with a value of 0.5. For each furniture model in the scene, the difference between color theme and target color theme is calculated in equation 6.2.

$$M_k = \sum_{i,j=1}^{5} P_j \min \left\| \mathbf{C}_i - \mathbf{C}_j \right\|_2 \tag{6.2}$$

In equation 6.2, C_i represents the theme color of each furniture. C_j represents the j-th color of target scene's color palette. $\left\| \mathbf{C}_i - \mathbf{C}_j \right\|_2$ represents the color difference value between two sets of colors obtained by calculating the weighted Euclidean distance. P_j represents the percentage of corresponding colors in the color palette extracted from the target scene, representing the tendency of each color. Deep learning can improve the performance of each step. Figure 6.3 shows the indoor scene coloring process.

Indoor scene coloring usually includes key steps such as preprocessing, color classification, lighting adjustment, rendering, etc. [18]. Through preprocessing for scene analysis, geometric structures and object boundaries can be determined. By using machine learning and other methods to identify the colors of various objects, color classification can be achieved, providing a basis for subsequent rendering steps. Lighting adjustment will simulate the lighting of the scene based on the physical model, further improving the realism of the rendering effect. Equation 6.3 represents the energy term E_1 .

$$E_1 = \begin{cases} 0 & \text{if } N_f = 0 \\ \sum_k^{N_f} M_k & \text{if } N_f \neq 0 \end{cases} \tag{6.3}$$

In equation 6.3, N_f represents the total furniture in the scene. The energy term E_2 can evaluate the rationality of the combination of two furniture colors in indoor scenes, aiming at measuring the correlation between the problem color themes between the two furniture types, and its calculation is shown in equation 6.4.

$$E_2 = \frac{\sum_{i,j} C(p_i, p_j, m_i, m_j)}{C(p_i, p_j)} \tag{6.4}$$

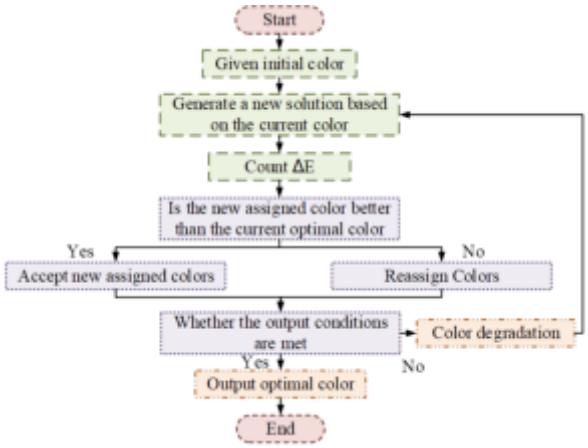


Fig. 6.4: SAA to solve the energy function flow of color allocation

In equation 6.4, p_i and p_j represent the category of furniture i, j . m_i and m_j represent the color of furniture i, j . $C(p_i, p_j, m_i, m_j)$ represents the frequency at which furniture and are simultaneously assigned to colors m_i and m_j. $C(p_i, p_j)$ represents the frequency at which furniture i and j simultaneously allocate all colors in the color database. Each furniture model selects the probability value of the corresponding color theme as the measurement standard. A low probability value indicates that the color is rare. Equation (5) is its calculation.

$$E_3 = \sum_i \frac{C_{(i,n)}}{C_{(i)}} \tag{6.5}$$

In equation 6.5, $C_{(m,n)}$ represents the number of furniture i with a specific color n in the color database. $C_{(n)}$ represents the number of all available colors for furniture i in the color database. This model improves the accuracy and efficiency of design through efficient processing and global search capabilities, providing new technical methods and reference basis for the field of indoor scene coloring.

6.2. An indoor scene coloring model that integrates PSO optimized K-means and SAA. PSO optimized K-means is used for color classification, dividing complex indoor scenes into different color regions to improve the accuracy of subsequent coloring. Combining SAA can achieve adaptive adjustment of lighting conditions, further improving the naturalness and realism of coloring. However, due to the complexity of indoor environments and the computational complexity of PSO and SAA, research has mainly focused on optimizing algorithm performance. So, it can reduce the demand for computing resources and improve algorithm applicability. Figure 6.4 shows the solution energy function of SAA for color allocation.

The energy function solving for color allocation is to use SAA to solve color allocation and achieve optimal color allocation by minimizing the energy function [19]. SAA is based on simulating the human visual system and adapting to different lighting environments to accurately reflect the true colors of the scene by adjusting color allocation. SAA is used in this experiment to find the optimal color allocation result. In the -th iteration, the probability of C_i' being accepted as C_{i+1} is represented by equation 6.6.

$$P_{(C_i' \to C_{i+1})} = \min\left[1, \exp\left(-\frac{(E(C_i') - E(C_i))}{(T_0 - \sigma_T \cdot i)}\right)\right] \tag{6.6}$$

In equation 6.6, T_0 represents the initial temperature. i represents the current iteration. ρ represents the temperature reduction value for each iteration. Clustering algorithm is an unsupervised learning method that can divide all data objects into several clusters without relying on data labels. The schematic diagram of K-means algorithm is shown in Figure 6.5.

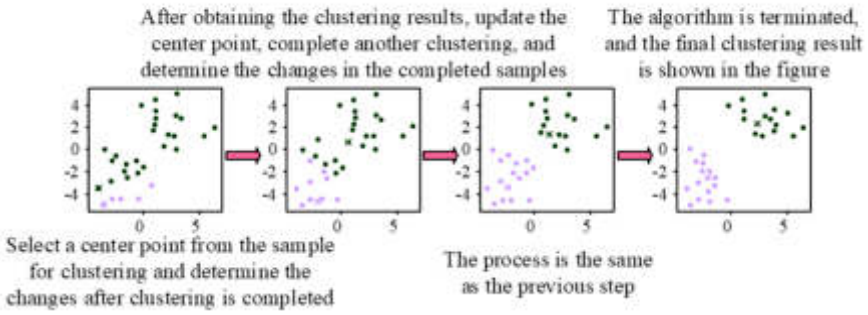


Fig. 6.5: Diagram of the K-means algorithm

K-means can partition a given dataset, making data points of the same category as similar as possible and data points of different categories as different as possible [20, 21]. The basic process includes four stages: initialization, clustering, update, and convergence. During initialization, the algorithm selects K data points as the initial category center according to certain rules. Clustering is the process of assigning each data point to the nearest category center. Update is to recalculate the center of each category based on the new category allocation results. During the convergence phase, if the change in the category center is less than the set threshold or reaches the preset number of iterations, the algorithm stops iteration. The clustering center point is selected using mathematical methods. Equation 6.7 is this algorithm's optimization function.

$$J = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \tag{6.7}$$

In equation 6.7, x_i stands for each signal sample's coordinate. μ stands for the cluster center point. N represents the sample size of signal. PSO is used to optimize it. For PSO population, the optimal location found can be recorded as the optimal location of PSO population, expressed by equation 6.8.

$$G_{\text{best}} = (P_{g1}, P_{g2}, \ldots, P_{gd}) \tag{6.8}$$

In equation 6.8, $g = 1, 2, \ldots, n$. In PSO, it is necessary to obtain the optimal individual position and the optimal group position. Equation 6.9 represents the update of particle swarm velocity and position in PSO.

$$\begin{cases} v'_{id} = \omega v_{id} + c_1 r_1 (p_{id} - x_{id}) + c_2 r_2 (p_{gd} - x_{id}) \\ x'_{id} = x_{id} + v_{id} \end{cases} \tag{6.9}$$

In equation 6.9, ω represents the inertia weight value. c_1 and c_2 represent learning factors. r_1 and r_2 represent random numbers between [0,1]. To obtain the optimal solution, the sum of squared errors in equation 6.10 is used as the fitness function.

$$f(x) = \sum_{i=1}^{k} \sum_{x_j \in C_i} d(x_j, C_i)^2 \tag{6.10}$$

In equation 6.10, $d(x_j, C_i)$ represents the distance from particle x_j to the swarm's center C_i. If the objective function is small, the algorithm performs well. The indoor scene coloring system combining PSO optimized K-means with SAA is a new type of color rendering strategy [22]. This can achieve high-quality shading rendering of indoor environments through precise color classification and adaptive adjustment of lighting conditions. Figure 6.6 shows an indoor scene coloring system that integrates PSO optimized K-means and SAA.

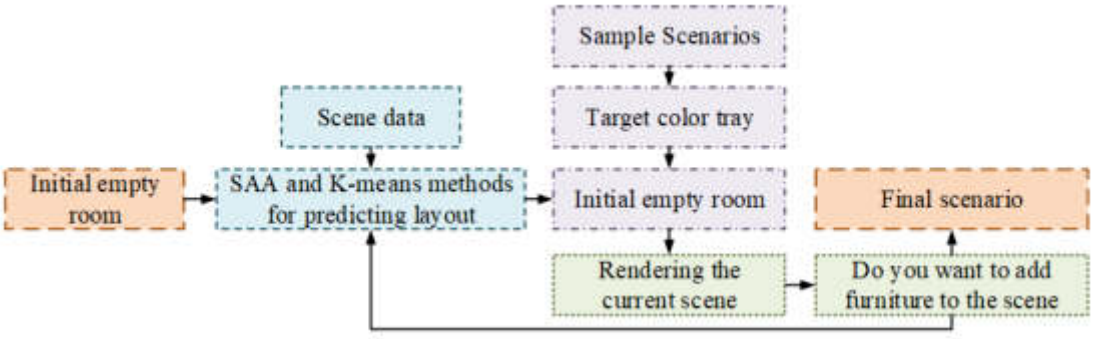


Fig. 6.6: The indoor scene coloring system by combining PSO optimized K-means with SAA

The K-means optimized by PSO is responsible for scene color classification, dividing complex indoor scenes into areas with similar color characteristics [23, 24]. SAA adjusts color allocation based on lighting conditions to achieve approximate simulation of the real environment [25]. The similarity between indoor samples is measured using Euclidean distance, and a small distance indicates sample similarity. Equation 6.11 represents the Euclidean distance between $x_i = (x_{i1}, x_{i2}, \ldots, x_{im})$ and $x_j = (x_{j1}, x_{j2}, \ldots, x_{jm})$.

$$d(x_i, x_j) = \sqrt{\sum_{s=1}^{m} (x_{is} - x_{js})^2} \tag{6.11}$$

In equation 6.11, x_i represents the m dimensional vector. To increase the degree of differentiation between data attributes, equation 6.12 represents the weight values of data from different dimensions.

$$\omega_{ip} = \frac{x_{ip}}{\frac{1}{n}\sum_{i=1}^{n} x_{ip}} \tag{6.12}$$

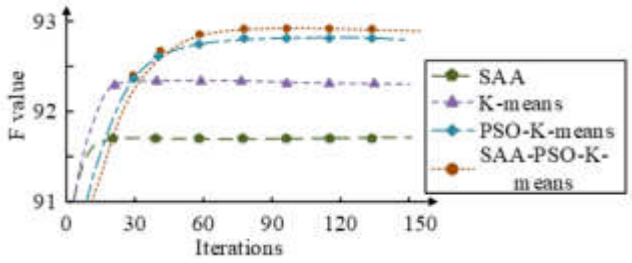
In equation 6.12, x_{ip} represents the p-th component in the i-th sample point. x_{ip} represents the average value of the p-th component of each sample point. This does not change the calculation of Euclidean distance in K-means and increases the differentiation between data features. This system has to some extent improved the effect of indoor scene coloring. It can still improve rendering quality when facing the complexity of the environment and the computational complexity of algorithms.

7. Indoor scene coloring model testing integrating PSO optimized K-means and SAA. To verify the reliability of ISCD and the effectiveness of the algorithm, an indoor scene synthesis system constructed by mixing K-means and SAA was tested and analyzed. The article aimed to assist non-professional users in efficiently completing interior design to meet the needs of layout and style. The hardware configurations required for system operation were processor of Intel®Core™i5-9300h CPU @2.40GHZ, 8GB RAM, graphics card of NVIDIA GeForce GTX1650 (4096MB graphics memory), and screen resolution of 1920*1080 (60Hz). In terms of software, the system was based on Windows 10 Enterprise Edition, using the 3D rendering tool Mitsuba to generate indoor panoramic images. The development tool was Visual Studio Code, and PyQt4 was used to display the system's graphical interface. Table 7.1 showed the experimental parameters.

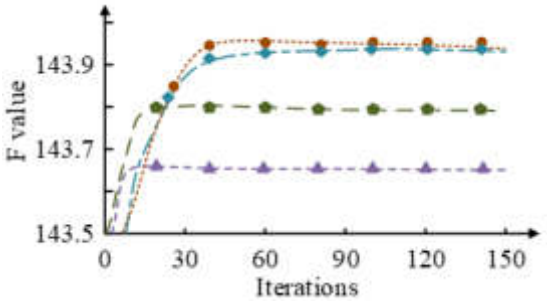
Table 7.1 listed some indoor scene coloring model data for the exploration and analysis of this research system. The experiment mainly tested the proposed SAA-PSO-K-means to obtain the parameters that could achieve the best clustering effect. Then it compared and tested SAA with K-means, PSO-K-means, and SAA-PSO-K-means on two text datasets. Several aspects such as clustering indicators, convergence, and stability were analyzed to verify this proposed algorithm's feasibility and effectiveness. Figure 7.2 showed the iterative results of different algorithms on datasets DS1 and DS2.

Table 7.1: Experimental environmental parameters

Parameter	Specification
Hardware	Intel® Core™ i5-9300h CPU @2.40GHZ processor, 8GB RAM, NVIDIA GeForce GTX1650 graphics card (4096MB VRAM), Screen resolution of 1920*1080 (60HZ)
Operating System	Windows 10 Enterprise Edition
3D Rendering Tool	Mitsuba for generating interior panorama
Development and GUI Tool	Visual Studio Code with PyQt4 for graphical interface



(a) Iterative Results of Different Algorithms on DS1 Datasets



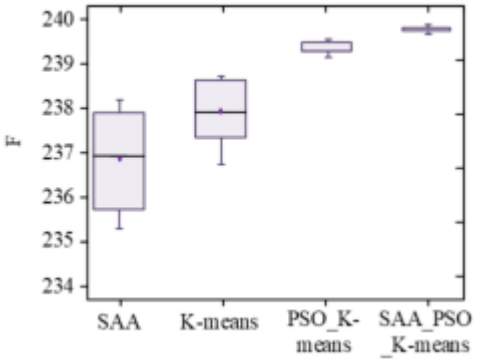
(b) Iterative Results of Different Algorithms on DS2 Datasets

Fig. 7.2: Different algorithms' iterative results on DS1 and DS2

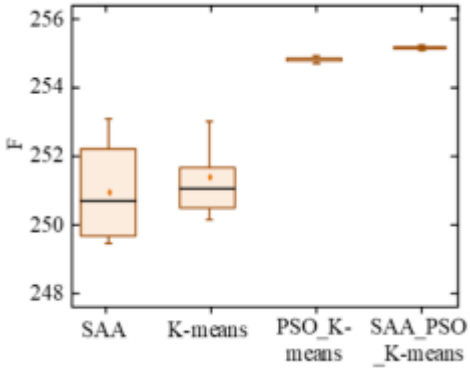
In Figure 7.2, when iterating 30 times, SAA and K-means's convergence curves on two datasets were steep and rapidly tended towards lower stable values. Although they had the fastest convergence speed, their fitness F-values were all low, as low as 91.68 and 143.64. The convergence of PSO-K-means was relatively smooth, and the F-value steadily increased. The convergence curve of SAA-PSO-K-means was close and steep, but the F-value after convergence was high, reaching 92.85 and 143.94. Therefore, these four algorithms could achieve good F-values in the early stages of population evolution. In the 30-60 iterations, SAA and K-means continued to slowly trend towards better F-values. However, PSO-K-means and SAA-PSO-K-means gradually stabilized and almost completely stagnated near the highest F-value, with values of 92.58 and 143.93. After iterating 60 times, GAI-PSO began to stabilize, while other methods had converged completely. Therefore, SAA had obvious advantages in high-dimensional text clustering, and could quickly converge to the approximate optimal solution in the early population updating stage, demonstrating excellent optimization ability and operational efficiency. Figure 8 showed the F-value boxplot of different algorithms on DS1 and DS2.

Figure 7.4 shows a boxplot of F-values calculated after 20 independent runs of four algorithms on four datasets. The performance of SAA and K-means on the dataset was not stable. In Figure 7.3a, it ranged from 235.8 to 237.9, and in Figure 7.3b, it ranged from 249.8 to 252.2. Their F-values varied greatly and exhibited significant fluctuations. Volatility might affect the reliability and prediction accuracy of algorithms. For PSO-K-means and SAA-PSO-K-means, their performance on the four datasets was relatively stable, ranging from 239.3 to 239.4 in Figure 7.3a and 255.1 to 255.2 in Figure 7.3b. The smaller variance of its F-value verified that the performance of these two algorithms was more stable and the optimization effect was more reliable. Therefore, the proposed algorithm had a certain stability and optimization effect. Figure 9 showed different algorithms' ARI values on DS1 and DS2.

In Figure 7.6, on DS1, SAA-PSO-K-means displayed the most compact boxplot with the smallest variance on the remaining three datasets. The range in Figure 7.3a was 0.66 to 0.665, and the range in Figure 7.3b was 0.85 to 0.856. The result distribution of SAA-PSO-K-means was relatively concentrated, with small fluctuations,

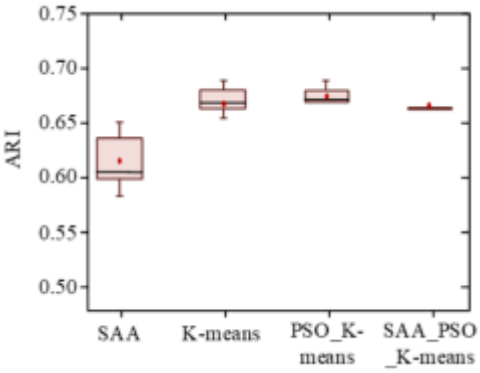


(a) F-box plots of different algorithms on the DS1 dataset

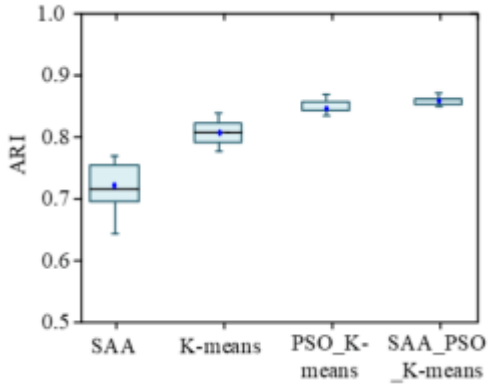


(b) F-box plots of different algorithms on the DS2 dataset

Fig. 7.4: F-value boxplots of different algorithms on DS1 and DS2



(a) ARI Box Graph of Different Algorithms on DS1 Dataset



(b) ARI Box Graph of Different Algorithms on DS2 Dataset

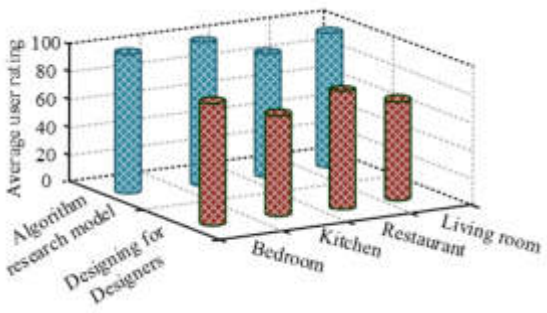
Fig. 7.6: Different algorithms' ARI values on DS1 and DS2

and the stability of this algorithm was good. SAA-PSO-K-means not only performed well in clustering accuracy, but also performed well in consistency between clustering results and real situations. Therefore, SAA-PSO-K-means was a relatively stable and efficient method. They could provide consistent and accurate clustering results in most cases, and had good adaptability to various types and sizes of datasets. Table 7.2 showed the average values of F and ARI for different algorithms in DS1 and DS2.

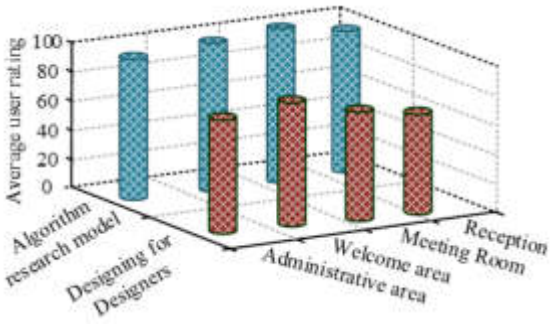
In Table 7.2, the average F-values of SAA, K-means, PSO-K-means, and SAA-PSO-K-means on DS1 were 91.106, 92.241, 92.283, and 92.524, respectively. On DS2, they were 143.437, 143.216, 143.587, and 143.601, respectively. Therefore, whether on DS1 or DS2, the average F-values of SAA-PSO-K-means were higher than other three algorithms. In terms of average ARI values, they were 0.359, 0.374, 0.346, and 0.361 on DS1, and 0.942, 0.914, 0.931, and 0.897 on DS2, respectively. In DS1, SAA-PSO-K-means performed the best, while in DS2, PSO-K-means performed better than other three. Therefore, SAA-PSO-K-means could achieve good fitness F-values and obtain good external clustering indicators. It could effectively ensure the consistency

Table 7.2: Different algorithms' F-values on DS1 and DS2 datasets

Dataset/Algorithm	SAA	K-means	PSO-K-means	SAA-PSO-K-means
Average F				
DS1	91.106	92.241	92.283	92.524
DS2	143.437	143.216	143.587	143.601
ARI average				
DS1	0.359	0.364	0.346	0.371
DS2	0.902	0.914	0.931	0.897



(a) User satisfaction results for living room types



(b) User satisfaction results for office area types

Fig. 7.8: User satisfaction results in different scenarios

between the distribution of data objects after clustering and the actual situation. To verify the effectiveness of the scene coloring algorithm, this study randomly invited 20 users to conduct a user evaluation survey. The spatial layout of living room types and office area types was provided, and some rendering scenes were presented to each investigator. Figure 10 showed users' satisfaction.

In Figure 7.8, the color beauty and richness of the scene are quantitatively evaluated. It is scored on a scale of 0-100, with higher scores indicating greater user satisfaction with the scene. Under this scoring system, the scene colored by the algorithm model gets a high evaluation. In Figure 7.7a, the satisfaction scores of the living room, dining room, kitchen and bedroom after the algorithm color adjustment reached 96.34, 95.58, 93.14 and 97.26 respectively, and the average satisfaction score of the solution provided by the algorithm model was 95.58. The average satisfaction score for hand-designed coloring schemes was 63.66. In Figure 7.7b, the satisfaction scores of the living room, dining room, kitchen and bedroom are 94.89, 95.77, 97.14 and 96.38 respectively, and the average user satisfaction of the algorithm model is further improved to 96.05. In the same scenario, the user satisfaction of the designer's solution was only 60.96 points. The effectiveness of the algorithm model in coloring scheme design is verified [26, 27, 28], and its objective score is better than that of traditional design methods, which shows the potential of the algorithm in improving user satisfaction in scene design.

8. Conclusion. Combining the efficiency of K-means with the global search ability of SAA can achieve higher accuracy and faster speed in completing indoor scene coloring design. Effective ISCD can improve design efficiency and prediction accuracy. Based on this background, this study proposed an ISCD that combined improved K-means with SAA. By combining improved K-means with SAA, the application effects of four algorithms in ISCD were compared and analyzed. These experiments confirmed that when iterating 30 times, the convergence curves of SAA and K-means were steep, but the fitness F-values were both low. Relatively speaking, the convergence of PSO-K-means and SAA-PSO-K-means was relatively smooth, but the F-value after convergence was higher. In the 30-60 iterations, SAA and K-means continued to slowly trend towards better F-values, while PSO-K-means and SAA-PSO-K-means gradually stabilized. After more than 60 iterations, all

algorithms converged basically. Therefore, SAA had obvious advantages in high-dimensional text clustering and could quickly converge to the approximate optimal solution in the early population updating stage. SAA and K-means's performance was not stable, and the range of F-values varied greatly, showing significant fluctuations. For PSO-K-means and SAA-PSO-K-means, their performance was relatively stable, and the variance of F-values was smaller. This study provided a new design model for ISCD by combining K-means and SAA, which could effectively improve the accuracy and efficiency of the design. However, there are some shortcomings in this study. The performance of four algorithms is not completely stable, which may affect the reliability and prediction accuracy of the algorithms. Therefore, further research and improvement are needed to improve the stability of this design model combining K-means and SAA, and to further verify the effectiveness and feasibility of this design model.

9. Future Scope of the Study. In the follow-up research on the hybrid improved K-means and SAA indoor scene coloring design model, it is necessary to conduct in-depth analysis on the stability of the algorithm, explore the influencing factors and their internal mechanisms, optimize the parameter setting and structure of the algorithm, and improve the applicability and robustness of the algorithm in different indoor scenes. Secondly, the research focus is extended to the parallel processing of the algorithm, so as to shorten the large-scale data processing time and improve the practical application efficiency of the algorithm. In addition, the future research should also consider integrating more advanced optimization algorithms, such as genetic algorithm, ant colony algorithm, etc., for the comparative study of algorithm performance and further improvement of the model. Through cross-field collaborative research, the application potential of the algorithm in other aspects of interior design, such as material selection, furniture layout, etc., is explored, and the application scope of the model is expanded.

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A DEEP LEARNING MODEL-BASED FEATURE EXTRACTION METHOD FOR ARCHITECTURAL SPACE AND COLOR CONNECTION IN INTERIOR DESIGN

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Abstract. In architectural interior design, color is one of the important design elements. Through the reasonable combination of various color elements, it can effectively improve the interior environment and create an atmosphere that meets the preferences and needs of users. And with the continuous development of social economy, the application of color in interior design is becoming more and more widespread. Using different colors in interior design to harmonize not only can relieve people's visual fatigue, but also can bring people a pleasant mood. Different colors have different meanings, therefore, the use of color in interior design should be more flexible and color matching should be more innovative. The warm and cold, near and far, expansion and contraction of color make the color space the most dynamic key element in design. The grasp of color and scale of architectural space and the flexible use of color will directly affect the quality of architectural space design. Color can strengthen the form of interior space or destroy its form. In order to accurately grasp the connection between architectural space and color in interior design, this paper proposes a deep learning model-based feature extraction method for the connection between architectural space and color in interior design. First, we construct a product color sentiment imagery dataset; then, we build a model for generating architectural interior space layout and color design schemes based on the product color sentiment imagery dataset and conditional deep convolutional generation adversarial network, and innovatively generate product color design schemes. This algorithm can better balance the chromaticity, saturation, and clarity of images. When determining the similarity of indoor space colors, depth features are superior to point-to-point pixel distance and aesthetic features of indoor space colors. Finally, the effectiveness and applicability of the proposed method are verified in relevant experiments.

Key words: Deep learning model, Interior Design, Architectural space, Color scheme

1. Introduction. Color is an important element of interior design, and its scientific use can not only enhance people's visual experience, but also improve the uniqueness and innovation of design. At the same time, different colors can bring different psychological and spiritual feelings to building users. In the current interior design industry, people-oriented design has become the first major principle, and the use of color has become more focused on the combination of culture, regional characteristics, personal preferences, functional needs and other aspects, in order to design a more humane interior environment [1-4]. In contemporary times, people spend more than half of their time indoors, and the quality of the indoor environment directly affects people's living conditions. The use of color is an important part of interior design, mainly divided into three parts, namely the main color of the interior space, accent color and background color, through the scientific use of these three parts of color, can play a role in optimizing the mood, stabilizing the user's emotions and reducing their psychological pressure.

And color should have an appropriate environmental state. For color, creating an appropriate color environment in harmony with the surrounding environment is its inevitable task, and to achieve this goal is bound to be constrained by the materials in the local environment. Therefore, the complementarity between materials, color and environment must be considered in an integrated manner [5-6].

The use of color in interior design can visually change the area and volume of the interior space, effectively improving the sense of constraint and oppression brought to the user by the lack of interior space and changing the poor size of the environment. For example, in a long and narrow interior environment, if warm colors are used as the main color of the ceiling and cool colors are used on both walls, it can visually improve the feeling of a long and narrow space and give the user a more comfortable psychological experience. In interior

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design, the use of color can often reflect the personality of the space user to a certain extent. In general, residents with cheerful, enthusiastic personality characteristics tend to choose warm tones as the main color of interior design, while more introverted, calm residents will choose cool tones for interior decoration; more straightforward personality will be more inclined to use light tones, with subtle, deep personality characteristics of people are more willing to choose dark and gray tones.

Color as an important factor affecting human psychology, in the use of interior design, the reasonable use of color is particularly important. If a variety of high-purity colors are used at the same time to form a strong contrast, it will give people a feeling of over-stimulation, which is also more likely to produce irritable psychology. If the color contrast is less or the use of color is too single, it will give people a feeling of coldness, easy to let users feel bored and empty [7]. Therefore, in the process of interior design, designers should select and match colors according to the character traits, occupational characteristics, gender, age, education level and other factors to meet the different needs of users visually and psychologically and should also select colors according to the purpose of each space to increase the rationality of the design.

As one of the important attributes of architectural space, color has a unique advantage in the expression of architectural space emotion and influences users' emotional preference and consumption decision to a large extent. Therefore, accurate grasp of users' emotional preferences and needs for architectural space color can significantly improve the success rate of architectural space color design, which is of great practical significance to improve the survival and competitiveness of enterprises [8-11].

In recent years, as an indispensable component of architectural works, color has become increasingly favored by people. Whether the combination of colors is suitable for architectural works, for the entire building, it can play an important role in icing on the cake; On the other hand, if color matching lacks certain artistic considerations and scientific rationality, it is very likely to cause the design style to be vulgar and not loved by professionals and the general public. Color is one of the visual form elements. For architectural forms, they often adhere to shape or light, and are particularly closely related to form. The colors in emotional expression often give a very vivid and intuitive overall visual impression, with strong regional and recognizable characteristics. At the same time, the generation of this visual impression is usually completed in an instant. Due to the "attractiveness" of colors, those that are eye-catching are more likely to attract people's visual attention, and have the power of "preemptive". Colors sometimes make everyday forms more eye-catching, transforming people's visual perception of shapes or greatly enhancing their language expression, playing a "finishing touch" role. However, colors are usually limited in terms of shape, and only when they are consistent with the language of the shape and cleverly combined with specific purposes can they achieve quite good practical effects. Color to a certain extent means life, and people's experience of color is often the most direct and common. If there were no color in this world, it would be unimaginable. Therefore, in addition to considering the physical characteristics of color itself, the matching of indoor colors must also take into account the social and cultural colors and emotional orientations of various ethnic groups, as well as the aesthetic psychology of each ethnic group. In addition, some folk customs and taboos closely related to folk culture also need to be fully mastered, which undoubtedly puts forward higher requirements for designers and requires continuous exploration and improvement of design

For example, under the theoretical framework of perceptual engineering, a neural network is used to build an architectural space color imagery evaluation model, and a genetic algorithm is used to optimize the model to generate an architectural space color design that meets the user's emotional imagery needs. Color is a medium that can infinitely evoke sensation, its inherent power to provoke significant and immediate psychological responses and is the symbolic language of the natural and man-made world. Color is gorgeous but at the same time it is silent, hiding a deep philosophical connotation under its incomparable bright veneer, which extends the use of architecture while significantly influencing the perception of architectural space and form. This paper proposes a deep learning model-based feature extraction method for the connection between architectural space and color, which can be used to realize the full integration of architectural space and color in interior design, and to ensure the unique connotation and aesthetic significance of color in a coordinated interaction with the interior environment space based on the reasonable matching of color itself aesthetic laws.

The color of traditional architectural spaces is mainly judged by human supervisors, which has significant errors and needs to be combined with intelligent computer technology for spatial color feature extraction.

Therefore, this article is based on this motivation to improve the model and algorithm, conduct effective research on the model algorithm, and improve the extraction effect of the connection between architectural space and color features.

On the basis of summarizing and researching relevant work, this article proposes the research method, analyzes the acquisition of spatial color features, proposes a feature extraction implementation method based on evolutionary deep learning, and a model for generating architectural space color design schemes. Through experimental research, the effectiveness of this method is verified.

2. Related work.

2.1. Architectural space and color in interior design. The design and expression of architectural emotion relies on the most distinctive, concise, and representative design elements such as form, color, decoration and texture to form the result of comprehensive expression, and not just one element can be fully loaded and expressed clearly [12]. The architecture of the emotional space and color space are interdependent, mutually dependent, mutually constrained and mutually integrated; the structure of the emotional space cannot be separated from the color visual space orderly provisions; and the accurate coloring is based on the positioning of the architectural emotional information, is the factor, tool and means to create and express emotions, and the color itself is also emotional, different shades of color and it's in different environments.

Emotional space and color space exist together harmoniously in the visual language environment of architectural space, giving the best visual expression and appropriate and precise psychological potential for architectural space. Architecture conveys the emotion of architecture through its unique spatial structure relationship and artistic expression. This kind of specific architectural emotion is solidified and displayed by the structure of symbols with specific connotation of perceptibility, that is, the abstract emotional concept is transformed into perceptible symbols or visual vocabulary in the form of abstract symbols or figurative forms, and the transmission of emotion is completed by symbolic vocabulary [13-15]. The shape of Shanghai Jinmao Tower consciously draws on the changing rhythm of Chinese ancient pagodas to give people an association with the positioning of Chinese ancient pagodas. The sharply accelerated rhythm of the intensified modeling perspective extends layer by layer, increasing the tower's inherent sense of height, high and majestic, straight, and majestic.

The silver-colored tower is integrated with the sky background, while the red granite podium closely relates to the earth and sets off the silver-colored tower. The design eschews the imitation of figurative forms and the mechanical and rigid repetition of tradition, instead expressing the concept of traditional Chinese tower structure and tower culture in a bright, eye-catching, and condensed abstract form. The elevated overhead structural vocabulary not only conforms to the construction logic of the building and meets the internal space requirements, but also naturally serves as a visual element of the shape. The traditional Chinese architectural culture is transformed into a modern design vocabulary, which is preserved in the specific structure, thus showing the Chinese architectural culture and the spirit of extraordinary grandeur.

The shape and layout of architectural space cannot be separated from the decoration of colors. The reason why people can see objects is because they absorb colors of different frequencies, and then the unabsorbed color frequencies are reflected, allowing people to see the colors of the objects. In different regions, seasons, and climates, the layout of light sources in building spaces is also particular. The same light source, due to differences in atmospheric molecules in different environments, has different light intensity, and the colors in building spaces also show significant differences. Therefore, the layout of colors in building spaces cannot be separated from the reasonable design of light sources. Similarly, when designing architectural space colors, attention should also be paid to color contrast, color ratio, and coordination of various colors. The use of color contrast in architectural space can make the visual image of the building unified, with changes that fully reflect the overall image. The comparison of colors should pay attention to the moderation of subjectivity and subordination. Excessive contrast can cause excessive stimulation or dominance, while weak contrast appears meaningless. The comparison of colors in architectural space should also pay attention to the master-slave relationship. If the space is entirely monochromatic, it will appear dull. Harmonious color comparison includes color quantity comparison, color brightness comparison, and cold and warm color tone comparison. The color layout of architectural space must also consider the arrangement of color quantity in visual perception, which refers to the volume sense formed by the area occupied by colors and the purity of colors. In architectural

space, within a specific range of human visual horizontal lines, color blocks are relatively rich, so that the space in the line of sight does not appear empty and boring; Floors and ceilings, which are located outside the visual horizontal line of sight, generally use large color blocks to distinguish the space within a specific range of visual horizontal lines, avoiding visual confusion. The layout of architectural space colors also appears more layered. In addition to using high-purity colors to attract attention in small areas of architectural space, colors with slightly lower brightness and purity are generally used in the overall architectural space, which is not easy to cause visual fatigue. In a high-purity color space for a long time, the human visual system, in order to balance the senses, automatically selects high-purity color contrast colors to form in the human visual nervous system, causing confusion in the sense of color in the space. The coordination of colors must also follow the aesthetic principles. The layout of colors in the space should pay attention to rhythm and rhythm, symmetry and balance, master-slave and key points, and appropriate proportions. Generally, there should not be too many color combinations in the building space. Three types are sufficient, and appropriate changes should be added to the overall design; But it also depends on the specific situation. In monotonous and simple building facades, color combinations can be appropriately enriched to make the facades more lively and vivid.

Color is an abstract symbol of representation. Color abstraction in a certain sense is a composite of abstract and figurative, sensual, and rational, universal and special, individuality and commonality. Representation and representation sometimes exist at the same time, color representational conformation and color emotional effect, and human inner emotions and other subjective forms of experience and association, under certain conditions, and cultural phenomena as the basis, which makes color has a certain system value. The subjective characteristics of color as the content of architectural science should also be taken seriously. Another major role of color in interior design is the regulation of interior light. Scientific studies have shown that the reflectivity of light varies from color to color, with the highest reflectivity being white, which can reach over 70% and up to 90%, and the lowest reflectivity being black, which is below 10%. Cool colors will have a relatively high reflectivity of light, and warm colors will have a relatively low reflectivity. Therefore, in the process of interior design, designers need to make scientific selection of colors according to the function of the room and lighting needs, the actual lighting situation, to ensure the scientific nature of color use.

2.2. Artificial Intelligence and Interior Design. The similarity between interior design and artificial intelligence is that from a disciplinary point of view, interior design is very comprehensive and involves the intersection and integration of several disciplines. For example, psychology and art and design can provide a wide scope for interior design. Interior design is a sub-discipline of architecture, which has developed along with the construction industry. The main work of interior design is to fully combine the geographical location and environmental conditions of the building, the functional nature of the building and some relevant requirements and standards, to design and create the interior space, to achieve a reasonable interior space and can fully meet the material needs of the interior occupants of the space and spiritual aesthetic needs [16-18].

Combined with digital image processing technology, and its application to the layout of architectural interior space, which is of great significance in the planning and design of architectural interior space. As the structure of building interior space becomes more and more complex, the requirements of building interior space for interior structure space layout are getting higher and higher. For this reason, researchers in this field have studied building interior space layout and achieved certain results. The method of architectural interior space layout feature extraction, i.e., the method of 3D visual feature information reconstruction, establishes a visual detection model of architectural interior space layout, and uses it to build a visual feature extraction system of architectural interior space layout to improve the ability of spatial feature extraction. The method extracts the features of spatial layout by 3D vision, and the extracted features help to optimize the spatial layout, but less consideration is given to specific spatial layout parameters, and certain extraction bias exists.

Based on the scale decomposition results of the visual image of building interior spatial layout, combined with the image recognition method and based on the regular feature distribution of the image, the visual analysis method of building interior spatial layout is obtained, to realize the visual feature extraction of building interior spatial layout. The method solves the problems of large ambiguity of key feature points and poor intelligent planning and design capability in visual feature extraction of building interior space layout. From coarse to fine spatial layout estimation method for indoor scenes, the method first divides the indoor space into different stages by obtaining local linear thresholds for indoor space; then, the full convolutional neural network method

is invoked to extract spatial boundary feature values; finally, the feature values are fused to realize the extraction of features. This method can effectively extract the boundary features of the interior layout, but the extraction process is simple and incomplete.

Facing the problem of multidimensional emotional demand in architectural space color design, we use methods such as gray theory to establish a multidimensional emotional architectural space color design model, and use non-dominated sorting multi-objective optimization algorithm for design optimization, and finally build an architectural space color intelligent design system based on this method, which can quickly generate an architectural space color design scheme that meets the user's multidimensional emotional imagery demand. Based on YOLO algorithm and DFL-CNN algorithm, the intelligent evaluation model is constructed to realize the automatic annotation of architectural space category and modeling emotional semantics [19-20]. In the face of the current development of architectural space design trends, we use multi-labeling technology and generative adversarial networks to generate innovative designs for architectural space appearance, shortening the design cycle while mastering the direction of architectural space modeling development.

3. Methods.

3.1. Acquisition of color characteristics of architectural interior space. Based on the acquisition and pre-processing of the building interior spatial visual image pixel points, to realize the building interior spatial color feature extraction, it is necessary to obtain the spatial color feature quantity for its extraction. Through the edge parameter distribution detection method, the degradation feature evolution analysis model of the building interior spatial color visual image is constructed, and the sequence of building interior spatial color parameter distribution is obtained as [21]:

$$k(p) = k(p\Delta t), p \geq 0 \tag{3.1}$$

where Δt is the time interval of visual information sampling; p represents the set of pixels of color visual feature distribution in the building interior space. The color visual feature component of the building interior space as:

$$G^r = k(p\Delta t) + (fa^w + fa^m + fa^n)^2 \tag{3.2}$$

The higher order moments within the fuzzy feature distribution region of the color visual image of the building interior space are [22]:

$$\begin{aligned} cHc &= \frac{1-k(p\Delta t)}{\cos^{-1}A + \sin^{-1}B} \\ A &= \frac{k(p)}{2\pi}\sin\left(k(p\Delta t)^2\right) + (fa^w + fa^m + fa^n)^2 \\ B &= \frac{k(p)}{2\pi}\cos\left(k(p\Delta t)^2\right) + (fa^w + fa^m + fa^n)^2 \end{aligned} \tag{3.3}$$

A high-resolution multidimensional spatial chunking combination method is used to obtain the set of pixels for the visual distribution of color in the building interior space as follows.

$$R_r(f) = \frac{G^r + v^r}{k(p\Delta t)}, v^r = 1, 2, 3, \cdots, n. \tag{3.4}$$

The first order and second-order parametric analysis models of the color visual images of the building interior space are established, and the rule function of the color visual fusion of the building interior space is determined using the hierarchical color characteristics of the building reflected by the feature parameters as [23]:

$$\mathrm{ret}_c = R_r(b) - \cos^{-1}A \tag{3.5}$$

In the feature map of the k-th layer, the visual information component of the building interior space color is extracted, to obtain the building interior space color feature quantity.

3.2. Feature extraction implementation based on evolutionary deep learning. In the process of building interior space color feature extraction, the determined feature parameters are disturbed by a variety of factors, resulting in poor convergence of feature extraction. Therefore, this paper adopts evolutionary deep learning algorithm to control the convergence of parameters, to ensure the extraction accuracy of interior spatial color features. Evolutionary deep learning is an artificial intelligence algorithm, which is widely used in several fields. It is an intelligent algorithm that integrates natural algorithms and evolutionary mechanisms and can find the optimal solution quickly, and the optimal solution obtained can solve the difficulties encountered in the research process. Therefore, this paper realizes the extraction of color features of architectural interior space with the help of evolutionary deep learning algorithm. The convergence threshold of evolutionary deep learning is set to satisfy [24]:

$$\text{tui}\ \ (h_1{+}h_2){+}y(\overrightarrow{x}) = 0{,}y{\neq}0 \tag{3.6}$$

where $(\overrightarrow{x})$ is the grayscale pixel information of the visual component of the building interior space color? The information fusion detection with high resolution by linear filtering is combined with pixel reorganization in the edge region to achieve the segmentation of the color visual feature extraction of the building interior space. The segmentation equation is:

$$fg^i{=}qr{+}\frac{xcv}{vrt} \tag{3.7}$$

where qr is the resolution of color visual feature extraction of building interior space; xcv is the segmentation time interval parameter; vrt is the joint information entropy of feature extraction. The fitting coefficients of the resolved multidimensional spatial chunked images for the color visual feature extraction of the building interior space are obtained by the two-dimensional parameter fitting method. The multilevel chunking of architectural interior spatial color visual feature extraction within a single pixel value distribution region yields the interior spatial color multilevel feature information as [25]:

$$K^{im}{=}i(nc{+}nb){+}j(nm{-}nr) \tag{3.8}$$

According to the multi-scale machine learning results, the building interior space color visual image is reconstructed, and the quaternion is used to represent the building interior space color visual feature extraction fuzziness, and y^e is the entity set of building interior space color visual feature extraction. Combined with the result of constraint parameter resolution of the recovered image, the background value fusion of the color visual image of the building interior space is realized, and the output value as:

$$CB^{re}{=}\frac{K^{im}\,(y^e{+}y^r)}{fg^i}{+}qr{+}\frac{xcv}{vrt} \tag{3.9}$$

The nearest neighbor domain function xy group is selected to establish the fuzzy degree distribution set for color visual feature detection in building interior space, and from the perspective of intermediate layer feature reuse, the building interior space color visual feature boundary feature quantity is obtained as:

$$\begin{gathered} SDR{=}\tfrac{xy}{CB^{re}}, \\ T_i\,(g_i){=}\tfrac{2\pi\left(go^i{+}gu^i\right)}{SDR} \end{gathered} \tag{3.10}$$

where go^i and gu^i are the resolution and information entropy of color visual feature extraction for architectural interior space, respectively. The evolutionary deep learning algorithm is used to improve the convergence level of color feature extraction in architectural interior space, and the implementation process is shown in Figure 3.1.

3.3. C-DCGAN-based color design scheme generation model for architectural space. The paper uses C-DCGAN to construct a product color scheme generation model, and the design flow of the model is shown in Figure 3.2.

According to the principle of mutual adversarial game between generator and discriminator of generative adversarial network, when they reach the equilibrium, the generator-generated samples should be like the real

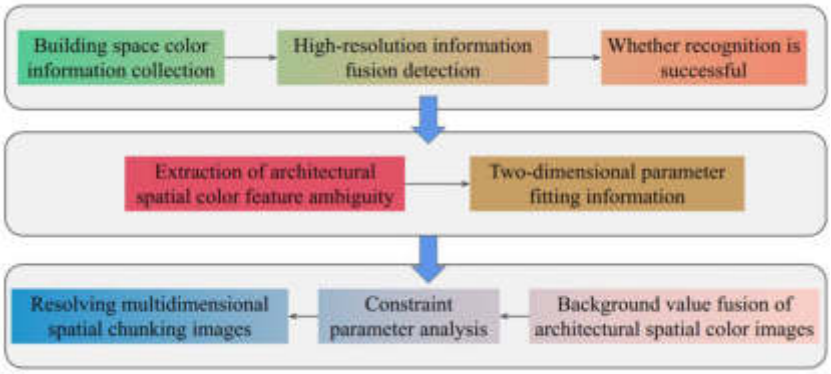

Fig. 3.1: Feature extraction implementation based on evolutionary deep learning

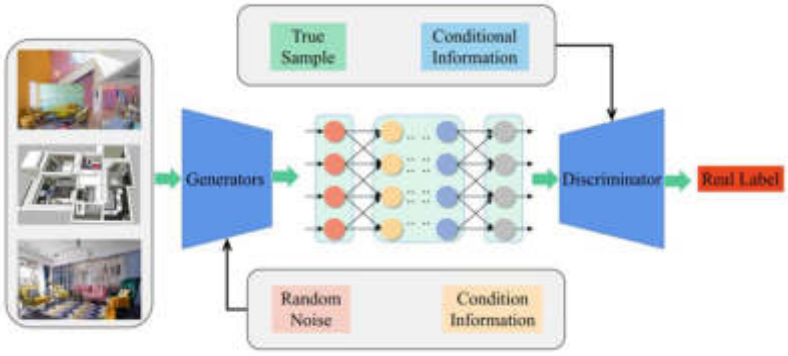

Fig. 3.2: Model Structure

samples, while the discriminator D cannot distinguish the real samples from the generator-generated samples. C-DCGAN training and optimization. The loss loss function of the system can be expressed as:

$$\min_{G} \ V(G) = E_{z\sim p(z)}[\log D(G(z|y))] \tag{3.11}$$

The discriminator in this article needs to use algorithms to judge the samples, mainly to determine the similarity of the sample data, compare the generated samples with the real samples, and use this as a basis to test the effectiveness of the generated samples. Its loss function can be expressed as:

$$\max_{D} \ V(D) = E_{x\sim p_{\text{data(x)}}} \ [\log D(x|y)] + E_{z\sim p(z)}[\log(1-D(G(z|y)))] \tag{3.12}$$

For the entire system network, its loss function can be expressed as:

$$\min_{G} \ \max_{D} \ V(D,G) = E_{x\sim p_{\text{data }(x)}}[\log D(x|y)] + E_{z\sim p(z)}[\log(1-D(G(z|y)))] \tag{3.13}$$

In the above equation, x represents the collected real samples, and z represents the noise input into the system. To improve the training effect of the model in this paper, it is necessary to optimize the parameters of the model.

4. Experiments and results.

Table 4.1: Training sample details

Test serial number	Pixel intensity/dB	Visual fusion difference	Feature recognition/%
1	19.682	5.552	75.500
2	20.761	5.856	68.833
3	19.428	5.480	69.666
4	21.142	5.964	71.166
5	18.920	5.337	72.166
6	19.174	5.409	68.333
7	18.222	5.140	74.000
8	18.730	5.283	72.000
9	19.365	5.462	64.166
10	18.158	5.122	69.666
11	17.650	4.979	71.500
12	17.269	4.871	69.666
13	17.841	5.032	62.666
14	16.507	4.656	60.833
15	20.571	5.803	74.000
16	20.381	5.749	67.333
17	19.809	5.588	67.500
18	21.142	5.964	70.000

4.1. Experiment setup. Python 3.7 programming language and Tensorflow 1.15 deep learning framework were used to build the network. All experiments were completed on a single NVIDIA GeForce GTX 1080Ti graphics card for training. The PPO network was trained using the Actor-Critic shared network structure, in which the first four fully connected layers had dimensions of 4096, 4096, 2048, 1024, and each layer was connected to a linear rectification function, and the final outputs the post-connected SoftMax layer probability value with dimension 12, and Critic outputs the state value with dimension 1. In order to prevent the gradient explosion or gradient disappearance phenomenon during the training process, the image needs to be pre-processed before input to the network. The image size is set to (224, 224) and the pixel value range is set to (0, 1). Except for the reward model, the intelligent body network needs to be trained from scratch. The training uses multi-threaded operation, taking 6 threads for experience acquisition respectively, each thread samples 4 groups of photos for sampling modification at the same time, the maximum number of steps used in each episode round is 50, when more than 50 steps or meet the termination condition $V(s) < 0$, the environment is reset and the smart body re-trains the sampling operation, a total of 300000 rounds of episodes are trained. The optimizer is selected as Adam optimizer, the minimum batch of network sampling is 64, the initial learning rate is set to 1×10-4, the decay is 0.97 times every 3000 steps, and the minimum learning rate is set to 1×10-8. The clipping clip for the estimated dominance function is 0.2, and the discount factor is set to 0.96. The experimental data were obtained from the internal data of a domestic interior design research institute in China, With the approval of the official website, data collection is carried out on the network through crawlers, and the data is classified and stored in a database, containing 20 data samples, and the data details are shown in Table 4.1.

4.2. Experimental results. To verify the effectiveness of this method, a comparison test was conducted on the data set. To conduct a comprehensive experiment, some deep learning baseline methods are added for quantitative comparison.

Figure 4.1 shows the comparison of L2 average errors on the dataset, Figure 4.2 shows the comparison of SSIM on the dataset, and Figure 4.3 shows the comparison of PSNR on the dataset. From these figures, it can be seen that the model proposed in this paper has good performance in spatial color feature extraction.

The Figure 4.1, Figure 4.2 and Figure 4.3 compare the present method with all leading pairwise training methods, bolded numbers represent the best results, and NA indicates test data where the relevant metrics are not given in the reference paper. Since not all experiments in the article were performed under the same conditions. As shown in Figure 3, Figure 4 and Figure 5, the mean L2 error evaluation criterion indoor

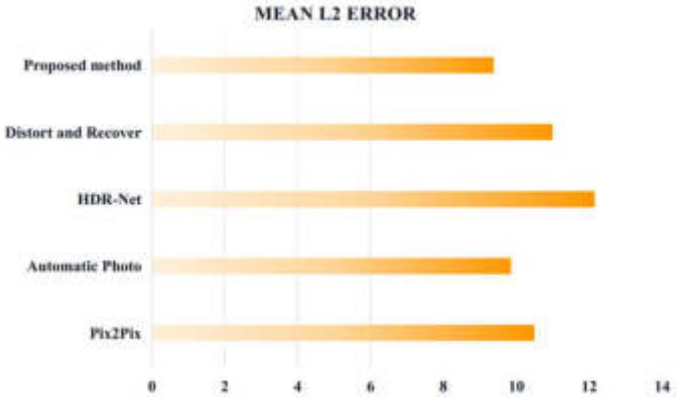

Fig. 4.1: Comparison of mean L2 error on the dataset

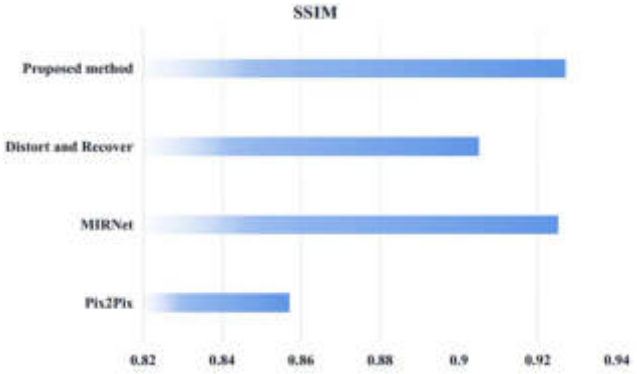

Fig. 4.2: Comparison of SSIM on the dataset

spatial color and the SSIM evaluation criterion on RGB indoor spatial color both outperform other algorithms, indicating that this algorithm can better balance the chromaticity, saturation, and sharpness of the image. Although the metric PSNR does not reach the highest in RGB indoor spatial color, it is still in an acceptable range and the image quality generally meets the requirements of image color enhancement.

To verify the effect of depth perception features and aesthetic models on the indoor spatial color enhancement method, ablation experiments were conducted Indoor spatial color experiments were conducted using a combination of different feature rewards to retain the enhancement effect of Rdist, Rdist+Rp, Rdist+Raes, Rdist+Rp+Raes on the dataset Indoor spatial color ablation experiments are shown in Table 4.2 shown Indoor spatial color from the experiments, it can be concluded that the depth feature is better than the point-to-point pixel distance and the aesthetic feature indoor spatial color in determining the similarity of indoor spatial color. At the same time, Rdist+Rp+Raes is better than other methods in the evaluation index of structural similarity, which indicates that the depth feature as well as the aesthetic feature help the model to judge the quality of indoor spatial color, and also indicates that the integration of depth perception features and aesthetic model can enhance the color enhancement effect of indoor space color and improve the visual quality of indoor space color indoor space color.

To further validate the effectiveness of the model proposed in this paper, the ability of the model to extract architectural spatial colors was compared with references [1], [2], [6], and [10]. Expert evaluation methods were used to evaluate the effectiveness, and the experimental results are shown in Table 4.3. The RoCROC curve for extracting architectural spatial features is shown in Figure 4.4.

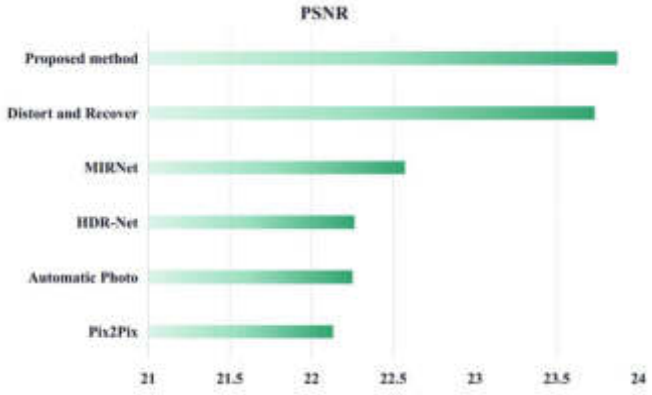

Fig. 4.3: Comparison of PSNR on the dataset

Table 4.2: Comparison of SSIM indicators of different color enhancement methods

Method	SSIM
Rdist	0.899
Rdist+Rp	0.922
Rdist+Raes	0.917
Rdist+Rp+Raes	0.925

Table 4.3: Comparison Results of Building Space Feature Extraction Capability

Method	Evaluation of feature extraction capability
The method of this article	93.52
Method of Reference [1]	82.32
Method of Reference [2]	79.64
Method of Reference [3]	68.35
Method of Reference [10]	81.65

From Table 4.3 and figure 4.4, it can be seen that the proposed deep learning model-based feature extraction method for building space and color connections in interior design has better color extraction capabilities compared to existing research.

5. Conclusion. The application of color in interior environmental art design needs to follow the principle of color moderation and the aesthetic law of color matching, so that the colors can be harmoniously matched to create a harmonious and beautiful interior space environment. In the specific application, we should take the theme of indoor environment space as the core, analyze the visual psychology, grasp the symbolic meaning of color, and pay attention to the spatial expression on this basis to ensure that the color conveys aesthetic mood and enhances cultural connotation in the indoor environment.

In order to improve the color quality of interior space, this paper proposes an evolutionary deep learning-based method for extracting color features of architectural interior space and determines its edge sequence based on the extracted interior space color parameters and uses an evolutionary deep learning algorithm to control the convergence of the feature parameters to complete the extraction of color features of architectural interior space. The results show that the method in this paper can extract features effectively and with high accuracy. In the future, we plan to develop a method for extracting the characteristics of architectural space and color connections in interior design based on big data architecture.

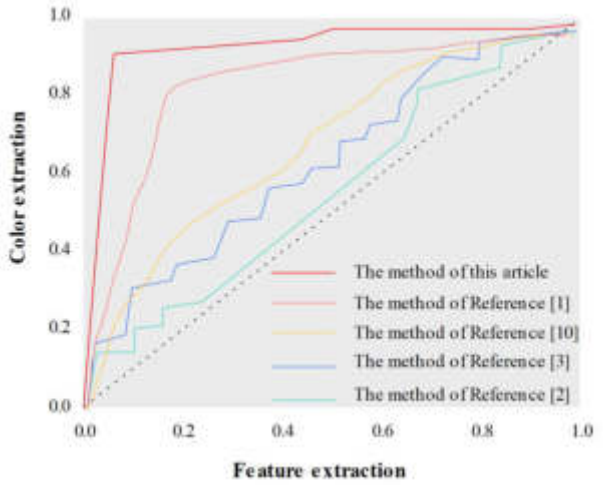

Fig. 4.4: RoCROC curve for extracting architectural spatial features

The model in this article is trained through a database, but the training data is limited. Therefore, more data is needed for training in the future, and the model in this article needs to be extended to color feature recognition outside of building spaces, which is also a future research direction.

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APPLICATION OF UNET-SE-BISRU ALGORITHM FOR MUSIC SIGNAL PROCESSING IN MUSIC SOURCE SEPARATION

TAO ZHANG*

Abstract. At present, the use of time-domain deep learning for end-to-end neural network models has the problem of long training time and poor performance in music source separation. To address this issue, a U-network squeezing excitation bidirectional simple recursive unit model was proposed based on the deep extractor model. Replace Unet SE Bisru with Unet SE Bisru in the following text. This model improves the bidirectional long short-term memory network into a bidirectional simple recurrent unit, and then introduces attention mechanisms in the generalized encoding and decoding layers. The squeezing excitation block is used to selectively extract features based on the type of audio to be separated. Finally, group normalization is added after one-dimensional convolution, And its effectiveness was verified. The experimental results show that the signal noise distortion ratio in the improved model is 5.68 decibels compared to the bidirectional simple recursive unit value, which is higher than the 5.55 decibels of bidirectional long short-term memory. After adding the squeezing excitation module, the overall increase is about 0.1-0.5 decibels. In addition, in the model comparison, the three indicators of the improved model with the same number of channels were 5.68 decibels, 5.91 decibels, and 11.28 decibels, respectively, higher than the benchmark model. Compared with other music source classification models, the improved model has better comprehensive separation performance. Although some indicators are lower than the comparison model, the signal noise distortion ratio of drum and bass is 6.11 decibels and 6.36 decibels, which is better than the comparison model. Overall, the improved model has high performance in music source separation for music signal processing and can be effectively applied in practical music source separation

Key words: Deep learning; Music source; Unet-SE-BiSRU; SDR; Number of channels

1. Introduction. Mixed audio is the most commonly encountered form of audio in production and daily life. When the current listener is interested in mixed audio, they need to separate the target audio source from it to understand its semantics [1]. The music source separation (MSS) method is a special problem of sound source separation. The actual speech content generally has harmony, specifically manifested as the frequency spectrum of different sound sources often overlapping, which makes solving the problem of MSS more challenging [2]. Effective separation of sound sources in mixed audio is the first issue to be addressed in the subsequent deep utilization of massive music resources, which has important research value and broad application prospects [3]. MSS is an important research direction in current audio signal processing (ASP). It aims to extract one or more sound sources from the sound source and effectively suppress other sound sources and noise [4]. However, traditional music ASP methods have limited complexity and insufficient expressive power in their models. The time domain deep learning of end-to-end neural network model (TDDL-E2ENN) has problems such as long training time and poor separation performance. Based on this, this study proposes the TDDL-E2ENN model, which is the U network Squeeze Exit Indirect Simple Recurrent Units (Unet-SE-BiSRU), on the basis of the current Deep Extractor for Music Source Separation model (Demucs) with the highest time domain separation performance. Its purpose is to solve the relevant problems of the current MSS method and provide theoretical support for its application in ASP.

The study consists of four parts in total. Part 1 is a summary and discussion of the current hybrid MSS methods. Part 2 is an analysis of the MSS method using the Unet-SE-BiSRU algorithm. The third part is to verify the effectiveness of Unet-SE-BiSRU. The fourth part is a summary of the entire article.

2. Related works. The rapid development of modern music signal processing and computer technology has made the study of hybrid MSS one of the increasingly popular research topics in the ASP field. Unlike traditional MSS methods, which mainly focus on the acoustic characteristics of sound sources for studying songs and instruments in mixed audio, in recent years, the growth of big data and computing technology has led to

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the introduction of more modern computing technologies into the field of audio processing, and has also brought new ideas to MSS [5-6]. Chen et al. addressed the problem of poor separation performance of multi-source mixed audio sources by utilizing three sets of channels to train the audio set based on deep learning, thereby improving separation performance and expanding its generalization [7]. Huang et al. proposed a compatible prediction model based on self supervised and semi supervised learning to address the issue of low prediction performance of audio element compatibility in current mixed audio MSS. It not only enhanced the classification system, but also enhanced the compatibility of mixed audio systems [8]. Ma B et al. proposed a method for solving blind source separation in frequency domain convolution based on typical correlation analysis to address the related issues in mixed hidden audio MSS. It effectively improved the effectiveness of convolutional mixed audio [9]. Zhou et al. proposed the optimal fusion structure based on multimodal analysis to effectively improve the performance of visual and audio separation in mixed audio MSS [10].

In addition, Colonel et al. proposed a method for constructing multi track reverberation parameters based on the reverberation module architecture to address the issue of poor actual performance of mixed audio MSS. This method not only improved separation performance but also improved the effectiveness of mixing perception [11]. Gupta et al. comprehensively discussed the perception, control, and rendering capabilities of enhanced and mixed reality technologies in audio MSS. It provided a theoretical basis for its application in mixed audio MSS [12]. Srinivasamurthy et al. explored the MSS problem of two music datasets in India through data collection, annotation, and organization processes, providing theoretical support for MSS and melody extraction [13]. Sheeja et al. proposed a lightweight convolutional neural network quantum teaching optimization algorithm based on discrete Fourier transform for MSS problems under noise interference. This algorithm effectively improved separation performance while eliminating blind separation noise [14].

From the research of domestic and foreign scholars, it can be seen that the main method to solve the problem of music source separation is deep learning, but the optimal method still chooses mask operation. In the presence of multiple instruments, there is a risk of information loss. Due to the fact that the signal cannot be simply shielded, the separation effect of the drum and bass sound sources is not good. In addition, the time-domain end-to-end model used to solve the problem of music source separation is still in the exploratory stage. Although its separation performance should theoretically reach the highest level, there is still a certain gap in performance compared to the frequency domain mask method. At the same time, the current optimal end-to-end model has problems such as long training time and poor separation performance [15]. Therefore, based on Demucs, the Unet-SE-BiSRU proposed in this study is innovative, which effectively solves three problems and improves the performance of MSS.

3. Analysis of MSS Method Based on Unet-SE-BiSRU Algorithm. The current music source signal mainly consists of mixed music audio, which is crucial for improving MSS methods. Therefore, this section mainly analyzes the mixed music audio and deep neural network models in MSS, and based on this, introduces SE and BiSRU modules to construct an improved algorithm model based on the U-shaped network.

3.1. Hybrid Music Audio and Deep Neural Network Model in MSS. The traditional music ASP method has limited model complexity and insufficient expression ability, while using TDDL-E2ENN model also has problems such as long training time and poor separation effect. Based on Demucs, Unet-SE-BiSRU is proposed. Currently, most mixed music audio is composed of a combination of human voice and instrument sound, and the time-frequency characteristics of the sound source signal are of great significance for the correct selection, understanding, and improvement of MSS technology. Therefore, this study first analyzes the characteristics of mixed music audio sources before proposing Unet-SE-BiSRU.

The human voice in mixed music audio is usually similar to a voice signal, which also includes pitch, intensity, length, and timbre. The pitch depends on the frequency at which the vocal organ vibrates within one second. Sound intensity is determined by amplitude and increases as the amplitude increases. The sound length is determined by the time it takes for the continuous vibration of the vocal organ. Timbre is a major feature that distinguishes different pronunciation units. In addition, there are two important acoustic characteristics in speech signals: pitch frequency and resonance peak. In terms of human auditory perception, differences in human voice are mainly reflected in three aspects: amplitude, duration, and fundamental frequency [16-17]. The instruments in audio can be divided into string instruments, wind instruments, and percussion instruments due to their different sound production mechanisms. Due to certain differences in the spectrum diagrams of

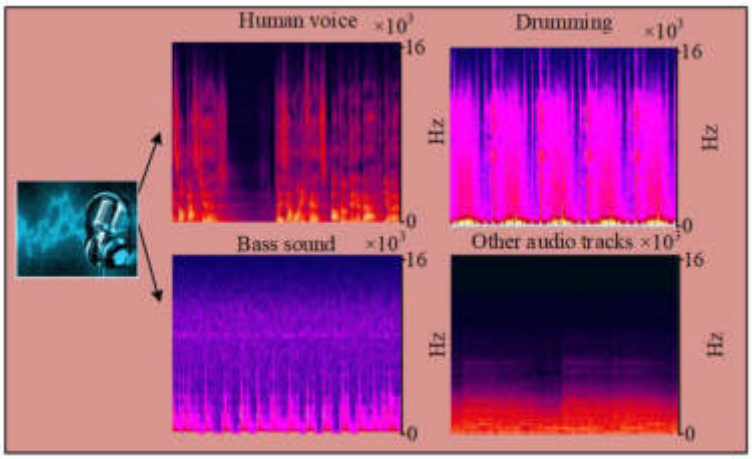

Fig. 3.1: Spectrum diagram of human sound source and some instrument sound sources in music signals

different sound sources, the spectrum diagrams of human sound sources and some instrument sound sources in music signals are shown in Figure 3.1.

The audio in Figure 3.1 is the 10 second audio of the first track in the training set from the music track splitting dataset (MUSDB18). Human voice audio has a high frequency spectrum and a wide range of energy, while the frequency spectrum of bass sound is mostly low frequency, while the high energy range of other tracks is mostly below 2 kHz. In addition, according to the differences in the collection environment, the audio source mixing model can be divided into linear and convolutional models. In MSS, the mixing signal of the linear mixing model can be represented as a linear function of each channel source, as shown in equation (3.1).

$$p_i(\tau) = \sum_{k=1}^{W} b_{ik} z_k(\tau) \tag{3.1}$$

In equation (3.1), $p_i(\tau)$ represents a mixed signal. τ is the time. b_{ik} represents the actual transmission channel from the k-th source signal to the i-th sensor in an ideal environment. W represents the actual quantity of the original model. $z_k(\tau)$ represents the source signal. However, in practical environments, sources may experience delays, reflections, and other phenomena during transmission, making the mixing form of multiple sources more suitable for convolutional mixing models as it is not simply instantaneous mixing. The signal received by the j-th microphone in this model is expressed as shown in equation (3.2).

$$p_j(\tau') = \sum_{k=1}^{W} g_{jk}(\tau') * z_k(\tau') = \sum_{k=1}^{W} \sum_{\tau'=0}^{O} g_{jk}(\gamma) z_k(\tau' - \gamma) \tag{3.2}$$

In equation (3.2), g_{jk} represents the actual transmission channel from the k-th source signal to the j-th microphone. τ' represents discrete time. γ represents the time delay of the source's transmission in the actual environment. O represents the order of the transfer function. $*$ represents the convolution operator. Of course, whether it is a linear or convolutional hybrid model, it can be simplified using a matrix, as expressed in equation (3.3).

$$q(\tau') = Mp(\tau') \tag{3.3}$$

In equation (3.3), $q(\tau')$ represents the estimated signal. M represents the separation matrix to be solved. It is very difficult to restore the original signal from the mixed signal when both the source and channel parameters are uncertain. Usually, the original signal is restored by finding the inverse matrix of the mixed matrix. Due

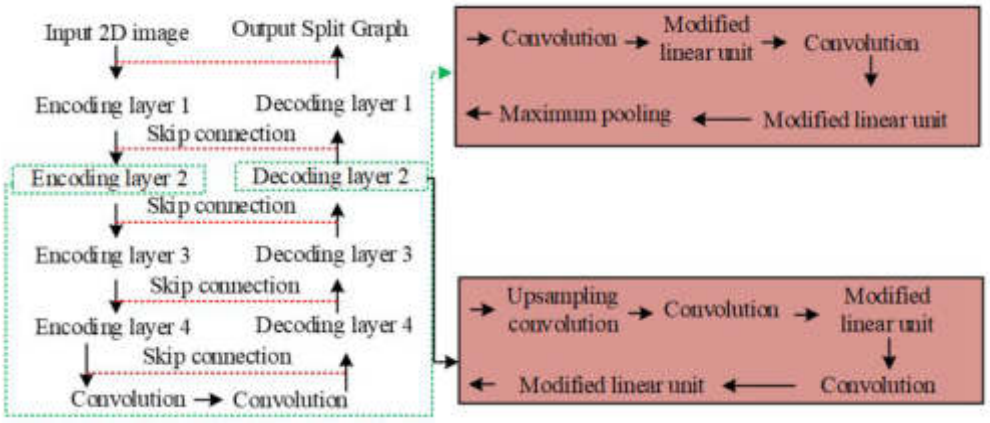

Fig. 3.2: Schematic diagram of U-net network structure

to the fact that the proposed MSS method belongs to the deep neural network class model, it is necessary to introduce the basic network algorithms it constitutes. Due to space limitations, only U-net will be analyzed here. The structure diagram of U-net is Figure 3.2.

In Figure 3.2, the U-net network consists of four levels of encoding layers and a decoder. Each layer sequentially includes convolutional layer, maximum buffer layer, exchange buffer layer, and skip connection. The U-net encoding layer requires 4 downsamples. At the same time, in response to the symmetry of U-net, the decoding layer also adopts 4 upsampling to restore the low-level high-level semantic image to the original image. Compared with traditional methods such as fully convolutional networks, U-net only performs 4 data upsampling and adopts a "skip" connection method, avoiding supervision and loss of high-level semantic features. Therefore, this method can fuse multiple low rank features to achieve multi-scale and deep supervision. To address the issue of sound source separation, the use of U-net's U-shaped structure and skip connection technology can achieve multi-scale characterization of four types of signal sources and obtain more accurate waveforms.

3.2. MSS method combined with Unet-SE-BiSRU. After analyzing the characteristics of mixed music audio sources, this study began to propose research methods for MSS. Unet-SE-BiSRU is based on the U-net network structure, combining SE module and SRU. The SE module is a component used in convolutional neural networks to enhance feature representation by explicitly modeling inter channel dependencies. The main advantage of the SE module is its ability to adaptively recalibrate feature maps, thereby improving model performance. The SE module focuses on learning inter channel dependencies in feature maps. By clearly modeling these dependencies, the network can dynamically adjust the importance of different channels at each spatial location, and its architecture is Figure 3.3.

In Figure 3.3, Unet-SE-BiSRU is mainly composed of three parts: encoder, loop network layer, and decoder. Unet-SE-BiSRU's codec also uses the skip method. Although this process is determined by experience, skip connections allow for direct access to the source signal, allowing the phase of the input signal to be transmitted directly to the output. On this basis, this study considers music audio as a time series, and therefore chooses SRU in a recurrent neural network [18], as shown in Figure 3.4.

In Figure 3.4, compared to traditional Long Short-Term Memory (LSTM), the SRU unit mainly utilizes the cell state of the previous moment to make temporal connections. Therefore, it is possible to perform gate state calculations based solely on the input of the current time, which has higher computational efficiency. The forgetting gate, reset gate, and intermediate output state expressions in Figure 3.4 are shown in equation (3.4).

$$e_t = \rho\left(C_e s_t + a_e\right) \tag{3.4}$$

In equation (3.4), e_t represents the forgetting gate. ρ represents the sigmoid activation function. C_e

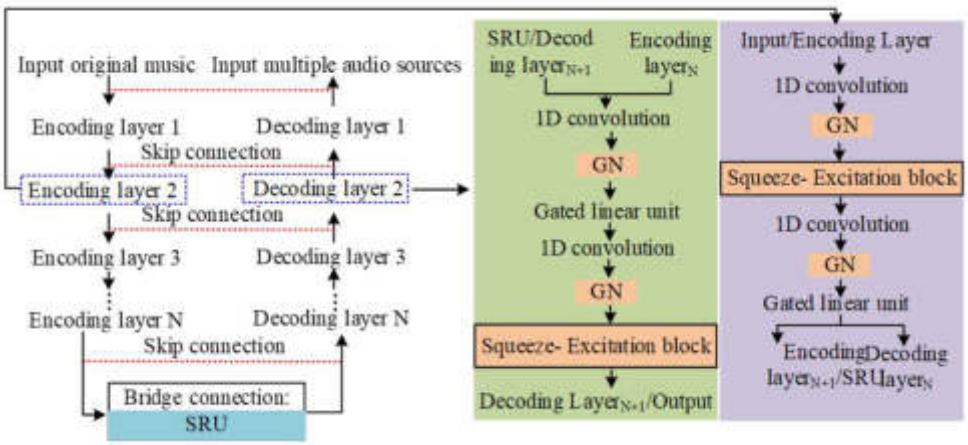

Fig. 3.3: Schematic diagram of Unet-SE-BiSRU network structure

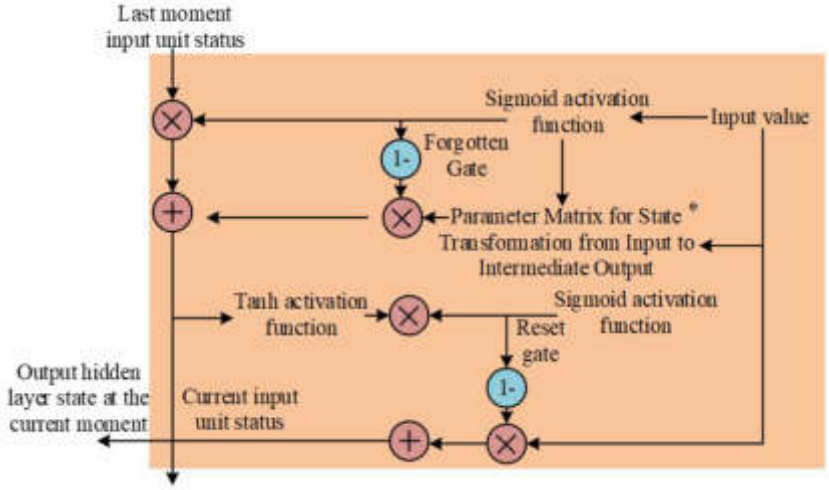

Fig. 3.4: Schematic diagram of SRU unit structure

represents the parameter matrix of the transition from the forgetting gate to the intermediate output state. s_t represents the input value. a_e represents the bias value of the forgetting gate.

$$h_t = \rho\left(C_h s_t + a_h\right) \tag{3.5}$$

In equation (3.5), h_t represents the reset gate. C_h represents the parameter matrix for the transition from reset gate to intermediate output state. a_h represents the offset value of the reset gate.

$$\tilde{b}_t = C s_t \tag{3.6}$$

In equation (3.6), $\tilde{b}_t$ represents the intermediate output state. C represents the parameter matrix of the input to intermediate output state transformation. For a sequence composed of all input values s_t, batch allocation of matrix multipliers to various time steps can significantly improve computational efficiency, and

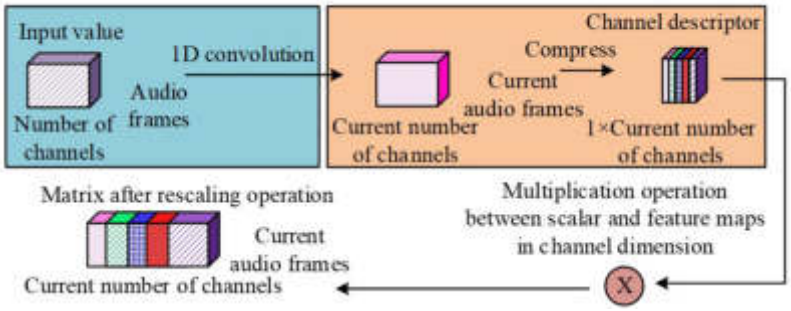

Fig. 3.5: Schematic diagram of 1D-SE basic architecture

the expression of batch multiplication is shown in equation (3.7).

$$U^T = \left[\begin{array}{ccc} C_e^T & C_h^T & C^T \end{array} \right] \left[\begin{array}{cccc} s_1 & s_2 & \ldots & s_t \end{array} \right] \tag{3.7}$$

In equation (3.7), U^T represents batch processing of multiplication values. When the input vectors are equal, SRU and LSTM networks of the same size have smaller SRU weights and can reduce the computational burden during training. In addition, Unet-SE-BiSRU adds an SE module after convolutional operation, which adaptively weights each channel through attention mechanism to improve its expression ability. Because the SE module is used to process 2D images, it needs to be improved on Unet-SE-BiSRU to adapt to one-dimensional audio signals. The two main operations of 1D-SE after one-dimensional optimization are squeezing and excitation, and the basic architecture of 1D-SE is Figure 3.5.

In Figure 3.5, the first step is to obtain the corresponding feature through one-dimensional convolution and compress it into a channel descriptor to transmit the feature. The expression of the d-th element of the channel descriptor is equation (3.8).

$$Q_d = D_{sq}\left(v_d\right) = \frac{1}{N}\sum_{c=1}^{N} v_d\left(c\right) \tag{3.8}$$

In equation (3.8), Q_d represents the value of the d-th element. D_{sq} represents a compression operation. v_d represents the characteristic of the d-th element. c represents the number of audio frames, with a maximum value of N. Secondly, adaptive recalibration is carried out, and finally, the network expression ability is improved by explicitly modeling the correlation between convolutional feature channels, as shown in equation (3.9).

$$\Im = D_{ex}\left(Q, A\right) = \psi\left(r\left(Q, A\right)\right) = \psi\left(A_2\left(A_1 Q\right)\right) \tag{3.9}$$

In equation (3.9), $\Im$ represents the expression of interdependence. D_{ex} represents the compression operation from the channel descriptor module to the interdependence expression module. ψ represents a modified linear unit function. A, A_1 and A_2 represent parameters that consider model complexity and generalization. The final output expression of this module is shown in equation (3.10).

$$\tilde{X}_d = D_{scale}\left(v_d, \phi_d\right) = \phi_d v_d \tag{3.10}$$

In equation (3.10), $\tilde{X}_d$ represents the matrix after the rescaling operation. $D_{scale}\left(v_d, \Im_d\right)$ represents the multiplication operation between scalar ϕ_d and feature maps in the channel dimension. The 1D-SE module performs channel recalibration on one-dimensional convolution, which has the characteristic of lightweight and requires less model complexity and computational complexity [19]. Finally, in the group normalization module of Unet-SE-BiSRU, this study chose Group Normalization (GN) as the improvement scheme for Batch

Normalization (BN). It groups channels without using batch dimension data, so the calculation does not depend on the number of batches. The calculation expression of GN is equation (3.11).

$$\tilde{b}_\alpha = \frac{1}{\varsigma_\alpha}\left(b_\alpha - \eta_\alpha\right) \tag{3.11}$$

In equation (3.11), ϕ_d and $\tilde{b}_\alpha$ represent channel data before and after GN. ς represents the mean of the input data. ϕ_d represents the standard deviation. α represents the 3D vector after the corresponding feature index. The expression of standard deviation and input data mean is shown in equations (3.12) and (3.13).

$$\eta_\alpha = \frac{1}{n}\sum_{l\in J_\alpha} b_l \tag{3.12}$$

In equation (3.12), J_α represents the set of average audio frame values and standard deviations. n represents the actual size of the set.

$$\varsigma_\alpha = \sqrt{\frac{1}{n}\sum_{l\in J_\alpha}\left(b_l - \eta_\alpha\right)^2 + \theta} \tag{3.13}$$

In equation (3.13), θ represents a small constant. The expression of J_α calculation is equation (3.14).

$$J_\alpha = \left\{ l \middle| \, l_\upsilon = \alpha_\upsilon, \left\lfloor \frac{l_\aleph}{\aleph/Y} \right\rfloor = \left\lfloor \frac{\alpha_\aleph}{\aleph/Y} \right\rfloor \right\} \tag{3.14}$$

In equation (3.14), l_υ and α_υ represent sub-indices along the channel axis. υ represents the index number. $\aleph$ represents the channel axis. $\aleph$ represents the number of groups, set to 32 based on actual needs. The final output formula is expressed as shown in equation (3.15).

$$f_\alpha = \mu\tilde{b}_\beta + \varepsilon \tag{3.15}$$

In equation (3.15), f_α represents the final output value. μ represents the scaling factor that can be learned. ε represents the offset.

4. Experimental Analysis of MSS Method Based on Unet-SE-BiSRU. Conducting simulation experiments on algorithms is a way to verify their performance. Therefore, this section mainly tests and evaluates Unet-SE-BiSRU, including parameter settings, analysis of different modules, and comparative experiments with other MSS methods.

4.1. Experimental parameter setting and analysis of different modules. To verify the MSS effectiveness of Unet-SE-BiSRU, this study conducted experimental and comparative validation. The open source dataset MUSDB18 used in Figure 1 was selected for the experiment, which is a commonly used dataset for music source separation research. This dataset contains a mixed version of music tracks, each containing multiple audio tracks such as vocals, guitars, drums, etc. It contains 150 pieces of music and is divided into training and testing sets in a 2:1 manner. All music audio data is dual channel, with a sampling rate of 44.1 Khz. All music audio data is dual channel, with a sampling rate of 44.1 Khz. Prior to this, to effectively enhance the generalization ability of the actual separation network, the original data was expanded in the experiment. The first step is to randomly switch between each sound source. The second is to stack and scale the amplitude of the sound source. Then, each sound source is randomly grouped and formed into a series, and then randomly mixed from different tracks. Finally, multiply each source waveform by $\pm$ 1. The experimental environment includes the Ubuntu 16.04 operating system, the Intel Core i9-10900 central processor, three 12G NVIDIA produced RTX2080Ti graphics cards, and a Python deep learning framework. The batch processing size is set to 12. The evaluation criteria selected in the experiment are Signal to Distortion Ratios (SDR), Source to Interference Ratio (SIR), and Sources to Noise Ratio (SAR). In audio enhancement tasks, SDR is more important because it directly reflects the quality of the reconstructed signal; In the task of environmental noise

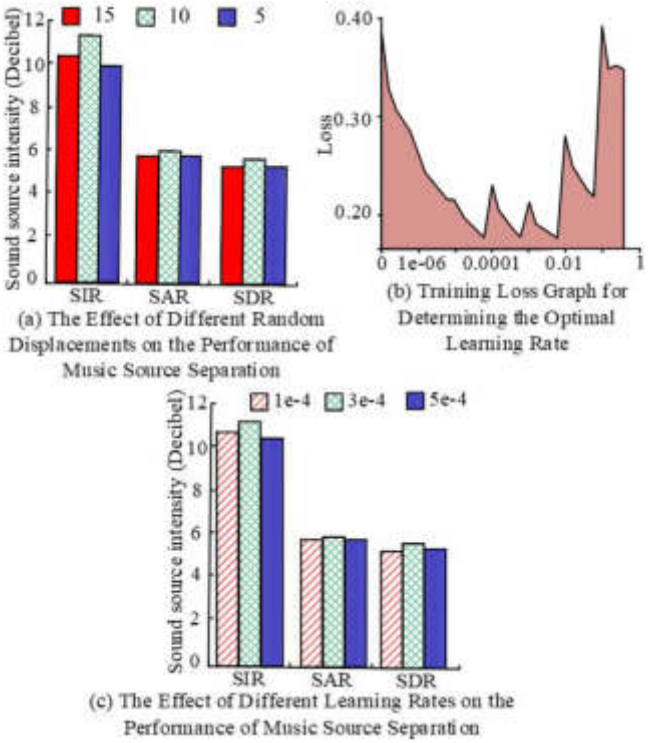

Fig. 4.1: Predicting Random Offset Values and Optimal Learning Rate Results

suppression, SIR and SAR are more crucial. In the optimal parameter setting, analysis was conducted on the predicted random offset value and the optimal learning rate, and the results are shown in Figure 4.1.

In Figure 4.1, when the predicted random offset value was 5, the values of indicators A, B, and C were 5.20 decibels, 5.79 decibels, and 9.90 decibels, and when it was 15, the values of the three indicators were 5.29 decibels, 5.79 decibels, and 10.38 decibels, respectively. At 10:00, the values of the three indicators were 5.68 decibels, 5.91 decibels, and 11.28 decibels, which were higher than the results of the other two predicted random offset values. In addition, the learning rate analysis showed a corresponding increase in learning rate every 10 rounds, resulting in a total of 70 training rounds. The results showed that at the beginning of training, the loss decreases with increasing rounds. As the learning speed increased, the loss began to increase, which meat that the accuracy learning rate of 1e-4 was sufficient to make it jump out of local optima. Therefore, when using 1e-4 as the base learning rate to validate the analysis, the SDR value at 3e-4 was 5.68, which was higher than the other learning rates. Based on this, in the experiment, the predicted random offset value was set to 10, and the learning rate was 3e-4.

In the experimental verification of Unet-SE-BiSRU, the effectiveness of its loss function and BiSRU was first verified. The L_1 norm loss function (L_1), L_2, and smooth L_1 norm loss function (Smooth L_1) was selected for comparison, and the results are shown in Figure 4.2.

In Figure 4.2 (b), 1 and 2 represent training loss and validation loss, respectively. The SDR value of L_1 is 5.68 decibels, which is higher than the comparison loss function. Therefore, L_1 was selected as the optimization target in the Unet-SE-BiSRU network. Overall, the actual training speed of BiSRU was significantly higher than that of BiLSTM. The former required a total of 18 minutes per training round, while the latter only required 12 minutes. And the actual parameter quantity of BiSRU was 3.33×10^4, only half of BiLSTM. In the comparison of SDR indicators, the BiSRU value was 5.68 decibels and the BiLSTM value was 5.55 decibels. Therefore, SRU units had higher performance and application effectiveness. This study analyzed the effectiveness of attention

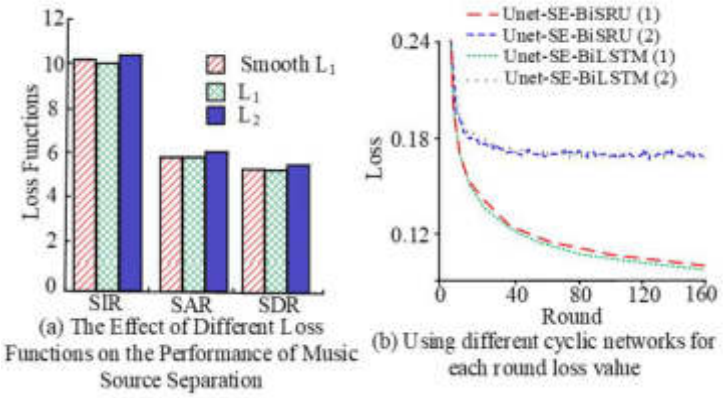

Fig. 4.2: The Influence of Different Loss Functions on the Performance of Music Source Separation and the Effectiveness Analysis of BiSRU

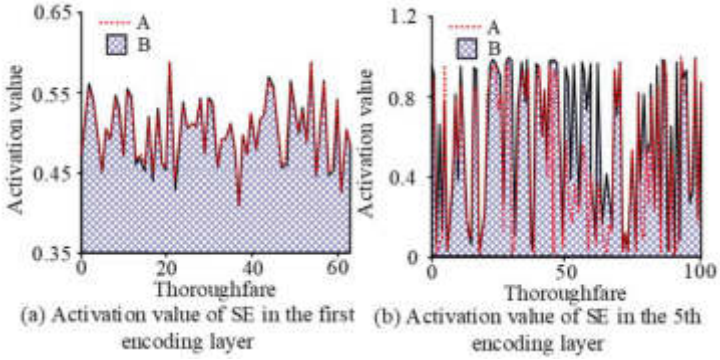

Fig. 4.3: Activation value results of SE on the first and fifth encoding layers of any two music in the test set

mechanism SE blocks and group normalization. Among them, by assigning SE activation values at each coding level, the effect of SE feature weighting could be tested. Therefore, taking any two pieces of music in the test set (represented by A and B) as examples, the activation values of SE on the first and fifth encoding layers are shown in Figure 4.3.

In Figure 4.3, in the first encoding layer of these two pieces of music, the actual activation values of SE were mainly distributed between 0.4 and 0.6. The activation values of the two songs had high similarity on different channels, indicating that during MSS, the shallow layers in the network were likely to extract common characteristics of sound. As the depth of the network increased, the characteristics of network retrieval gradually focused on differences in performance sources. In addition, the gradual deepening of network depth had led to a gradual differentiation of the activation value distribution of SE, and its practical effect had become increasingly apparent. To effectively compare the differences in activation values between two pieces of music in the fifth encoding layer and analyze the effect of adding an SE module, the results of subtracting the activation values of each channel and comparing them with the Unet-BiSRU network without an SE module were analyzed. The results are shown in Figure 4.4.

In Figure 4.4, the SE module selectively enhanced the effective feature weights and suppresses useless features through adaptive recalibration of multiple audio tracks, thereby enhancing the network's representation ability and improving the actual separation effect. After adding the SE module, the SDR values during the experimental rounds were significantly higher than those of the Unet-BiSRU network without adding the SE

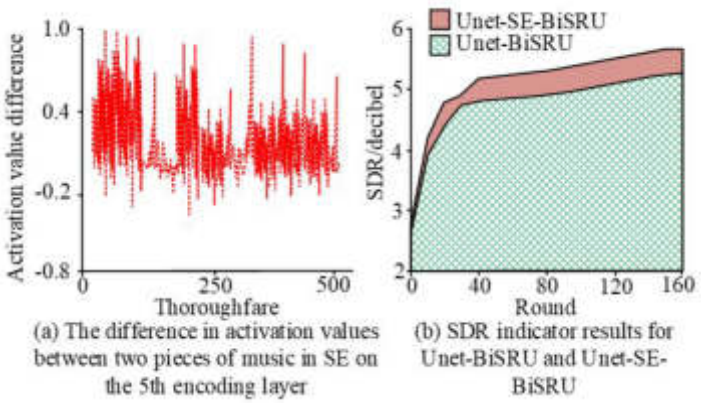

Fig. 4.4: The result of subtracting the activation values of each channel and comparing it with the Unet-BiSRU network without the SE module

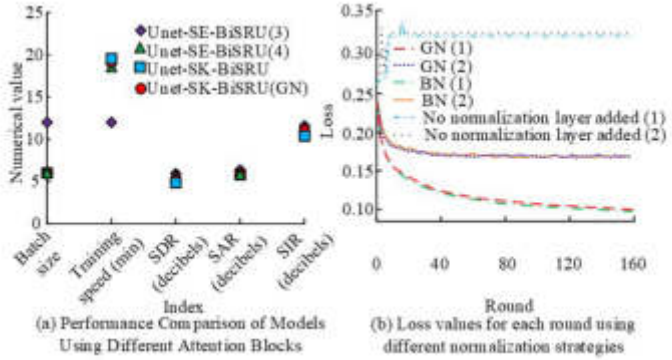

Fig. 4.5: Comparison of different typical attention mechanism modules and GN effectiveness results

module, with an overall increase of about 0.1-0.5 decibels. This indicated the effectiveness of the attention mechanism SE module. On this basis, the effectiveness of different typical attention mechanism modules and GN modules was analyzed: the introduction of Selective Kernel (SK) attention mechanism was compared. Figure 10 shows the results.

In Figure 4.5 (a), 3 and 4 represent Unet SE BiSRUs with batch sizes 12 and 6. The maximum batch processing sizes that Unet-SE-BiSRU and Unet-SK-BiSRU could support were 12 and 6, respectively, with SDR values of 5.68 decibels and 5.21 decibels for both. Overall, the SE module was more suitable for studying models under the same limitations of memory size. Meanwhile, the final SDR value obtained by GN was 5.68 decibels, significantly higher than BN's 5.34 decibels. Overall, the SE module in the proposed Unet-SE-BiSRU network had higher performance compared to GN, thereby proving the robustness of the research network.

4.2. Contribution of different modules and comparative experimental analysis. As shown in Table 4.1, based on the verification of the performance of each part in the Unet-SE-BiSRU network, this study began to analyze the contribution of innovation in each part to separation performance.

In Table 4.1, 1∼6 represent the Unet-SE-BiSRU, Unet-BiSRU, Unet-SE-BiLSTM, Unet-SE-BiGRU, Unet-SE-BiSRU (BN) and Unet-SE-BiSRU (Unnormalized), respectively. Among the three optimizations, SE had the greatest impact on the separation effect SDR, followed by GN, and finally SRU. With the removal of SE, Unet-SE-BiSRU saved time, but the SDR value decreased by 0.43 decibels. After replacing LSTM or GRU with

Table 4.1: Contribution of innovation in various parts to actual separation performance

-	1	2	3	4	5	6
Differences from Unet-SE-BiSRU	-	Remove SE	Replace SRU with LSTM	Replace SRU with Gate Recurrent Unit	Replace GN with BN	Remove GN
Training speed	12.0 min	11.5 min	18.0 min	16.7 min	12.0 min	12.4 min
SDR (decibel)	5.68	5.24	5.54	5.36	5.33	0.91
SAR (decibel)	5.91	5.86	5.88	5.76	6.06	5.18
SIR (decibel)	11.28	10.46	11.17	11.03	10.17	-2.23

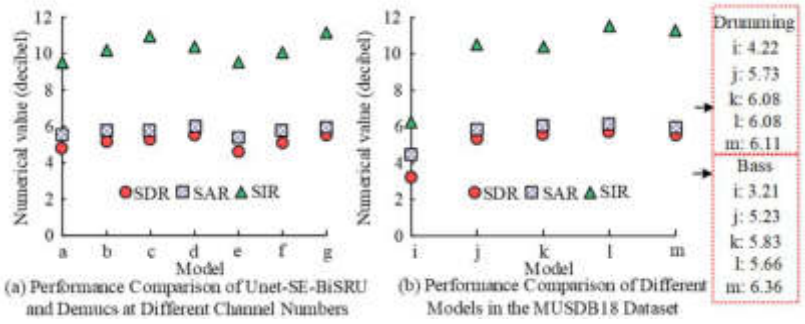

Fig. 4.6: Comparison results between Unet-SE-BiSRU and other models

bridge connected SRU, its performance decreased by 0.13 decibels. Overall, the three improvements effectively improved the actual separation performance of the network while not increasing the time complexity. Finally, the study compared it with Wave-U-Net, the Audio Separation Model using Convolutional Neural Networks (Open-Unmix), the Reference Model Demucs, and the Fully Convolutional Time Domain Audio Separation Network (Conv Tasnet). Each model is represented by i, j, k, l in sequence, and the research network model is m. The results are shown in Figure 4.6.

In Figure 4.6 (a), a∼d represent Demucs models with channel numbers of 16, 32, 64, and 100. The training speeds of the first three are 8min, 11min, and 20min respectively, with 240 iteration rounds. e∼g represents Unet-SE-BiSRU with channel numbers of 16, 32, and 64, with 160 iteration rounds. Figure 4.6 shows that the Unet-SE-BiSRU model with the same number of channels has significantly better SDR values than the Demucs model, indicating its effectiveness in optimization. Compared with other models, the SDR value of Unet-SE-BiSRU has currently shown better comprehensive separation performance. The comparison between the Wave U Net, Deep Clustering, and Deep attractor network algorithm models introduced in the study and the algorithm models proposed in this study is shown in Table 4.2 [20-22].

According to Table 4.2, the ACC, RMSE, AOC, F1, mAP, and Loss of the proposed Unet SE BiSRU algorithm model are 0.92, 0.03, 0.98, 0.97, 0.92, and 0.064, respectively. The experimental results show that the proposed Unet SE BiSRU algorithm model has excellent performance among the four algorithm models.

5. Conclusion. In response to the limited complexity and insufficient expression ability of traditional music audio signal processing methods, as well as the long training time and poor separation effect of end-to-end neural network models using time-domain deep learning, this study proposes the Unet-SE BiSRU model based on Demucs and analyzes its comprehensive separation performance. The experimental results show that when predicting a random offset value of 10, the values of the three indicators are 5.68, 5.91, and 11.28, respectively. When learning rate is 3e-4, the values of the three indicators are 5.68, 5.91, and 11.28, respectively. Therefore, the two parameters are set to 10 and 3e-4. In addition, the training speed of BiSRU is significantly higher than that of BiLSTM. The former requires a total of 18 minutes for each round of training, while the latter only

Table 4.2: Performance Comparison of Various Algorithms

Model	ACC	RMSE	AOC	F1	mAP	Loss
Wave-U-Net	0.83	0.21	0.86	0.82	0.83	0.097
Deep Clustering	0.87	0.11	0.92	0.87	0.84	0.082
Deep attractor network	0.90	0.06	0.96	0.91	0.88	0.076
Unet-SE-BiSRU	0.92	0.03	0.98	0.97	0.92	0.064

requires 12 minutes. The gradual deepening of network depth causes the distribution of SE activation values to gradually differentiate. At the same time, in model comparison, the Unet SE BiSRU model with the same number of channels has a significantly better SDR value than the Demucs model, with an overall increase of about 0.2 decibels. Compared with the current better audio separation model, it also shows good performance. Overall, the Unet SE BiSRU model is effective in music source separation for music signal processing. However, the introduction of the extrusion excitation module can improve the end-to-end network expression ability in the time domain, but there is still significant room for improvement, and the richness of the dataset used is also insufficient. In the future, it is necessary to enhance the performance of speech feature extraction and use a larger dataset to achieve better sound source separation.

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APPLICATION OF MULTI-OBJECTIVE EVOLUTIONARY ALGORITHMS FOR MULTIDIMENSIONAL SENSORY DATA PREDICTION AND RESOURCE SCHEDULING IN SMART CITY DESIGN

LIYA LIU*

Abstract. Multidimensional sensory data prediction and resource scheduling are paramount challenges in the design of smart cities. This paper delves into the utilization of multi-objective evolutionary algorithms to enhance the accuracy and efficiency of target detection through optimized YOLO_v3 network models. By integrating the YOLO_v3 model with the K-means++ algorithm for Anchor_Box generation, the novel approach exhibits superior adaptability and flexibility, particularly in handling variable-sized feature pattern mappings. This adaptability better caters to the detection of targets of diverse sizes, thus elevating the performance and precision of target detection algorithms. To further scrutinize the YOLO-v3 joint algorithm's performance in urban traffic detection, P-R curves were plotted for various loss types on the NEU-DET dataset. Comparative analysis of these curves highlights the optimized algorithms' superiority in detecting various types of losses in urban model completeness. Additionally, practical application analysis revealed that the optimized monitoring results outperform the detection time of the original YOLO-v3_means++ network model on FP_GA. Notably, post-processing with C-FENCE can reduce average single-frame image detection time to 2.01 seconds, while convolutional degree-level fusion with the BN layer cuts it down to 2.25 seconds. In summary, the FP_GA-based YOLO-v3_means++ network algorithm offers superior detection capabilities, and the multi-objective evolutionary algorithm's optimization of the YOLO-v3 model enhances target detection performance and precision.

Key words: depth-based learning network; multi-objective evolutionary algorithm; YOLO-v3_means++; multi-dimensional perception; smart city design

1. Introduction. With the deepening development of economic globalization, every scientific and technological development and progress of human society will have a profound impact on urban development [1]. In recent years, the concept of a smart city has attracted widespread attention from all walks of life, and major cities have been increasing their efforts in the development of smart cities and smart landscapes. People all hope to rely on smart city construction to make their lives more efficient and convenient. Fundamentally, the smart city concept is people-oriented [2], advocating the organic integration of information technology and knowledge to promote the development of urban wisdom and innovation. In the multi-dimensional perception design of the smart city, the public transportation-oriented urban development model (T-O-D) can be integrated into the design of transportation infrastructure. In the design practice, the traffic relationship on the street should be clarified first. This design helps to highlight the humanistic environment of the city and effectively improve the multi-dimensional design effect of the smart city [3].

Smart city refers to an urban development model that applies advanced technological means such as information technology and the Internet of Things (IoT) to comprehensive data collection, analysis, and management of the city to realize the efficient use of urban resources, intelligent services, and improved quality of life. In the construction of a smart city, target degree detection is an important technology [4-5], which is used to monitor various objects and events in the city in real time. FPGA is a programmable hardware device with parallel processing and high-performance computing capability. FPGA can be used to accelerate the execution of algorithms in target degree detection tasks, providing real-time performance and low latency [6-7]. Since smart cities need to process a large amount of data and make decisions in real-time, FPGA can provide efficient computational power so that the target degree detection system can quickly and accurately identify and track various targets in the city, such as urban traffic detection. Monitoring and analyzing the flow of vehicles on the road in real time is of great significance for the construction of smart cities and other aspects [8]. Since the concept of target degree detection was put forward, many scholars [9-11] have been plowing deeper and deeper into

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this field, and the basic theory of target degree detection class of algorithms ushered in vigorous development but was always limited by the hardware level. With the development of science and technology, hardware can gradually support the algorithms in the arithmetic demand, target degree detection algorithms are also widely used in various fields of life, such as face recognition, intelligent transportation, industrial detection, etc. [12].

In terms of traditional target detection algorithms, there are two mainstream directions of target degree detection algorithms based on deep-type learning3: the first is the two-stage deep-type learning target degree detection algorithms based on candidate frames represented by the R_C-NN46 series of algorithms [13], and the second is the one-stage deep-type learning target degree detection algorithms based on regression methods represented by the YOLO_7 series of algorithms. These depth-based learning target degree detection algorithms are essentially large convolutional neural architecture networks containing millions of neural unit connections, which require more than a billion operations to process at a time [14].

Multi-objective evolutionary algorithms are widely used in smart cities to optimize energy consumption, traffic management, and environmental monitoring. In terms of energy consumption, algorithms can be used to reduce energy consumption by adjusting the brightness of street lights or scheduling power supply plans. In traffic management, it can optimize traffic light timing, bus routes or parking space allocation. In environmental monitoring, air quality, noise pollution or water quality changes can be predicted to provide a basis for policy making. Multi-objective evolutionary algorithms can help smart cities achieve efficient and sustainable development. FP_GAs is often used in image processing due to their two main features of real-time pipelined operations and high real-time performance. FP_GAs provide a pipelined structure that matches well with product-based neural architecture network algorithms [15]. Tang et al. [16] designed a highly efficient DNN training velocimeter called E-F-Tra with a unified channel-level parallelism-based convolutional kernel, which allows for end-to-end training on a resource-limited, low-power edge-level FP_GAs for end-to-end training. A data-based reconfiguration method with intra-block sequential memory allocation and weight-based reuse is developed. To achieve high energy efficiency on edge FP_GAs, an analytical model of computational and memory resources for automatic scheduling is developed. High computational efficiency is provided by employing dynamic tiling, level fusion, and datatype layout optimization. A new generalized SA is designed to handle multidirectional convolution efficiently. The framework was tested using three complex C-NNs: Open-U-Net-E [17], and the optimization of the architecture achieved a 2.3x performance improvement. Sait et al [18] proposed a C-NN gas pedal and its automated design methodology, which employs a meta-heuristic approach to partition the available FP_GA-funded sources for the design of a Multi-CLP-type gas pedal. Its proposed design tool uses simulated annealing-type and forbidden search-type algorithms to find the number of Cs and their corresponding configurations required to achieve optimal performance on a given target FP_GA device [19]. Literature [20] deploys a speeder on an FP_GA that combines sparse Winograd convolution, a small set of pulsed arrays, and a layout design with a plannable memory to achieve a better performance performance. However, the approach does not sufficiently consider the advancement of memory technology, and the performance may be further improved by rationally optimizing the memory. Literature [21-22] designed the YOLO-v3_means++ model gas pedal, which greatly reduces off-chip class access through binary-type weights and low-bit-type activation operations. To reduce the computational complexity, this gas pedal employs Winograd-C_NN and maximizes the data reuse with a row buffer structure [23]. Multi-objective evolutionary algorithms find equilibrium solutions between multiple objectives by simulating biological evolution and are suitable for dealing with the complex challenges of predicting sensory data and resource scheduling in smart cities due to their ability to deal with conflicting objectives, uncertainty, and large-scale problems and to accelerate the search process

2. Heterogeneous FP_GA Architecture. To achieve efficient urban traffic detection and analysis, it is important to embed target degree detection class algorithms into composite systems. In this regard, porting the YOLO-v3_means++ algorithm to the FP_GA platform is a key research task.YOLO-v3_means++ is a real-time target degree detection class algorithm, and by porting it to FP_GA, it can take full advantage of the acceleration of the hardware [24-28] to realize real-time detection and analysis of the urban traffic to provide fast response data support for traffic management and intelligent transportation system to provide fast response data support. Porting the YOLO-v3_means++ algorithm to the FP_GA platform also helps to meet the low-power requirements of embedded systems.FP_GAs are reconfigurable and can be customized according to the needs of specific application scenarios to reduce power consumption and improve energy efficiency. By

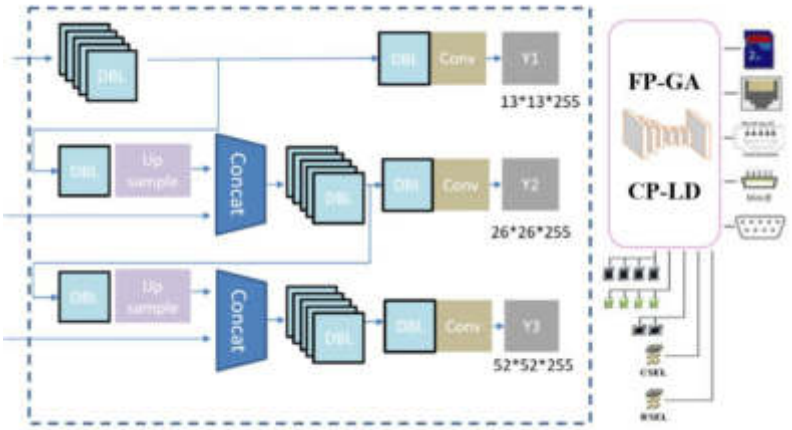

Fig. 2.1: Financial data based on mobile port photos and PDF invoices

porting YOLO-v3_means++ to FP_GA, low-power urban traffic detection, and analysis can be realized while maintaining high detection performance, which is suitable for some embedded application scenarios with high energy consumption requirements.

2.1. Pre-processing of data and information rate enhancement of data classes. In smart cities, sensory data prediction and resource scheduling are closely related. Through real-time monitoring and prediction of various types of sensory data, we can more accurately understand the city's operating conditions and demand, so as to optimize the allocation of resources. The first step in the process of accelerating target degree detection class algorithms for FP_GA hardware should be to analyze the requirements of the target degree detection task, i.e., identifying objects and their application scenarios.

We focus on four types of sensory data: video surveillance, sound, sensors, and social media. These data sources are diverse and include public cameras, environmental monitoring stations, social media platforms, etc. They provide real-time, comprehensive information for city management and help in accurate decision-making.

Next, the target degree detection class algorithm should be optimized by software optimization. According to the characteristics of the optimized target degree detection class algorithm, the hardware structure is customized. Finally, the performance of the whole hardware speeder should be evaluated. The hardware acceleration of the target degree detection class algorithm based on FP_GA can be started from software optimization and hardware optimization[24-25].

To port YOLO-v3_means++ to FP_GA[26-29], it is necessary to reasonably utilize the logic resources of FP_GA. The data format of YOLO-v3_means++ is a single degree of correctness floating-point number, and in the process of advancing and advancing, because of the multiply-add operation involving floating-point numbers, the more the number of bits is, the more the logic resources are consumed, which is not conducive to the porting of the algorithm. Therefore, it is necessary to consume as little resources as possible while ensuring the correct degree. Moreover, by optimizing the network structure as well as post-processing, the process of advancing and promoting YOLO-v3_means++ can also be accelerated. This chapter first introduces the principle of YOLO-v3_means++ target degree detection network and the network structure performs the half-correct degree floating-point quantization of the network model, fuses the convolutional degree level and the BN layer in the network to accelerate the advancement and push forward, and reduces the complexity of the post-processing algorithm by using the C-FENCE algorithm. The YOLO-v3_means++ algorithm is combined with the FP-GA's The principle of composition and its network design idea is shown in Figure 2.1.

In the post-processing stage of target degree detection, YOLO-v3_means++ uses a non-maximal value suppression operation to get the best target frame. For the different kinds of detected target frames are sorted from high to low by the confidence degree, respectively, to get a target frame with the maximum confidence

Table 2.1: Comparison of cutting algorithm results

mould
Input: B= {b1..... bN},S= {S1.... SN}
1: D-02: while B is empty do
3: m←argmaxS
4: M ←bm
5: drum: bb-m
6: for bi in B do
7: if you(M, bi) > Nt then
8: B←B-bi S←S-Si
9: end10: end
11: end
12: return D, S end

degree, assuming that the limit value of 1OU (intersection and concatenation ratio) is 0.5 at this time, and calculating the 10U of the target frame with high confidence degree and the rest of the frames, if it is greater than the limit value, then it is determined that at this time the two target frames are recognized to be the same target, and the target frame is deleted; if it is smaller than the limit value, then it is determined that at this time the two target boxes do not belong to the same target. Repeat the process for the remaining target frames until all target frames are processed. The pseudo-code of the N-MS algorithm is shown in Table 2.1 of the algorithm entry.

Since the model detection interval range boxes have different sizes and positions, the directly calculated M_H_D distance does not have a unified metric, and therefore is not comparable, so it is necessary to unify the coordinates before calculating the M_H_D distance, transforming the coordinates between 0 and 1. When evaluating the performance of multi-objective evolutionary algorithms, we focus on metrics such as accuracy, efficiency, robustness, scalability and diversity. These metrics comprehensively assess the accuracy and robustness of the algorithms, which are crucial for their practical application in smart city design[30−31]. The specific process is as follows:

$$\begin{gathered} X = \{x_1, x_2, p_1, p_2\} \\ Y = \{y_1, y_2, q_1, q_2\} \\ Nx_i = \frac{x_i - \min(X)}{\max(X) - \min(X)} \\ Ny_i = \frac{y_i - \min(Y)}{\max(Y) - \min(Y)} \\ NP_{(u,v,m,n)} = |Nx_1 - Np_1| + |Nx_2 - Np_2| + |Ny_1 - Nq_1| + |Ny_2 - Nq_2| \\ WP_{(u,v,m,n)} = \frac{NP_{(u,v,m,n)}}{c} \end{gathered} \tag{2.1}$$

After the unification operation of all coordinate pairs, the coordinate points have values between 0 and 1, and the M_H_D distance of any pair of intersecting bounding-degree index frames is less than 2. Therefore, if the P-value of any two bounding-degree index frames is less than 2, it can be determined that they belong to the same group, referring to the same object, or one or more high-density pairs. C-FENCE obtains optimally weighted proximity of the detection interval range frames by using the M_H_D distance derived after the unification of coordinates to divide by its confidence score, as shown in Figure. 2 until it has processed all the pairs. H_D distance obtained by dividing the confidence score by the M_D distance obtained after the harmonization of coordinates, to obtain the weighted proximity of the detection interval range frame, and recursively repeat the process, as shown in Figure 2.2, until all the boundedness index frames are processed, and the optimal target index frame is obtained.

YOLO-v3 is a target degree detection class algorithm improved and enhanced based on YOLO_v2, the basic idea of YOLO-v3 can be divided into two parts, firstly, a series of candidate frames are generated on the input image according to a certain rule, which are the regions that may contain the target, and they are categorized into positive samples and negative samples by annotating them with the real frames, the positive

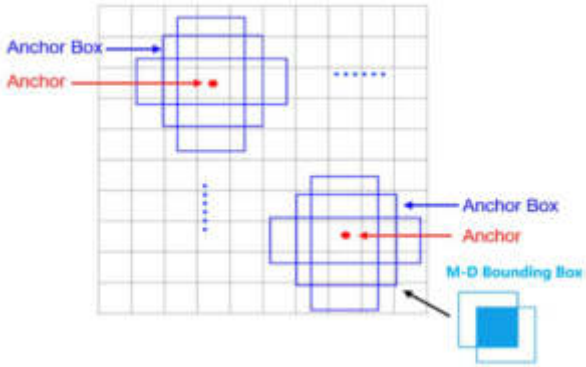

Fig. 2.2: Schematic of the MD Boundary Recognition Frame

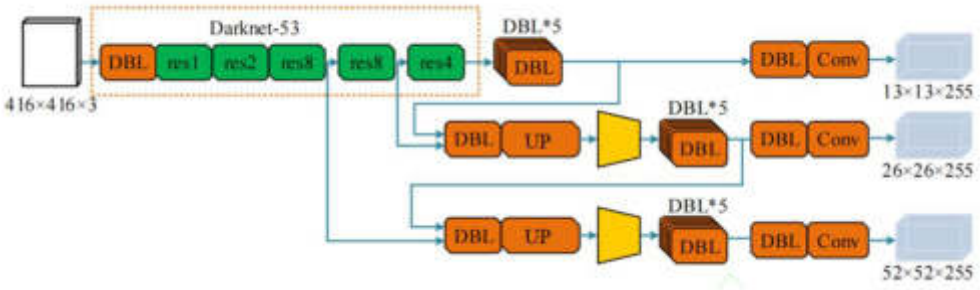

Fig. 2.3: Schematic of the MD Boundary Recognition Frame

samples are those candidate frames that are completely overlapped with the real frames, while the negative samples are those candidate frames that have some deviation from the real frames [1]. overlap with the real frame, while the negative samples are the candidate frames that have some deviation from the real frame [1]. Secondly, the K-mean++ convolutional network is used to extract features from the candidate regions and perform location localization and type recognition, and the candidate regions are inputted into the convolutional neural architecture network to obtain the feature representation related to the target. These detection results are compared with the labels of the real frames to determine whether the target is correctly detected.YOLO-v3 uses Dark-Net-53 instead of Dark-Net-19 in YOLO-v3_means++ for the feature indexing network.Dark-Net-53 is a fully convolutional network structure that consists of multiple convolutional degree levels of 1? and 3? layers, each of which is followed by a batch uniformization layer and an activation layer. Unlike YOLO-v3_means++, the Dark-Net-53 network does not have pooling and fully connected layers but performs the down sampling operation by convolution with step size 2. After 5 down samplings, the size of the feature pattern map is reduced to 1/32 of the original image. The Dark-Net-53 network also introduces a residual group block structure with shortcut connections between the convolutional degree levels. This structure effectively reduces the difficulty of the trained deep class network and enables the network to converge better. The network structure is shown in Figure 2.3.

Assuming that an image undergoes the YOLO-v3_means++ network model to generate n prediction interval range frames, both the N-MS algorithm and the C-FENCE algorithm need to store n detection interval range frames and their corresponding parameter information, so the space complexity is the same. (n), the specific prediction code program is shown in Table 2.2. For the N-MS algorithm, the degree of time-course

Table 2.2: Algorithm under detection interval range box parameter prediction

Moulid

Input.
while B+empty dobs, ss←0,0
optimal C-FENCEIp for bi, s in B, S do C-FENCE by+0
except b= bi nb,nb,←normalize(b,b)
P← proximity(nb,nb)
If <2 then
C-FENCE ↔ C-FENCE U proximity
End if
If C-FENCE < optimal
C-FENCE then
optimal C-FENCE ←C-FENCE

complexity is as follows:

1. Traverse the confidence level of n prediction interval range frames with a time-range composite level of 0(n);
2. Sort the prediction interval range boxes in ascending order of confidence with a time-range composite degree of O(nlogn);
3. Select the prediction interval range box with the highest level of confidence and place it in the results with a time-range composite degree of 0(1);
4. Calculate the area of overlap between the remaining predicted interval range frames and the predicted interval range frame with the highest confidence level, and delete those whose overlap is greater than a set limit value, with a time-range composite degree of O(n);
5. Repeat steps 3 and 4 until all prediction interval range boxes have been processed with an algorithmic complexity of O(n2).

3. Optimization of Y-K-means++ fusion algorithm under multi-objective. FP_GA-based YOLO-v3_means++ algorithm hardware speeder model YOLO-v3_means++ The network model has a total of 22 layers. In the actual operation, the input of the current layer comes from the output of the previous layer, so the network is operated layer by layer. In which to realize multi-dimensional perception, we use a multi-objective evolutionary algorithm as shown in Figure 3.1. In which to reduce the computation time in the YOLO-v3 network, the study employs a depth-separable convolution method to improve the residual group block structure. The K-means++ algorithm improves the quality and stability of clustering by optimizing the initial center of mass selection. When generating the Anchor_Box, the algorithm ensures a reasonable configuration of Anchor points to better accommodate targets of different sizes and shapes. This not only improves the accuracy and efficiency of target detection, but also enhances the adaptability and flexibility of the algorithm. Therefore, the K-means++ algorithm plays a key role in generating the Anchor_Box, which provides an effective method for solving the multidimensional sensory data prediction and resource scheduling problems in smart cities. This method reduces the computational complexity by reducing the number of parameters in the convolution operation, and the study introduces the K-means++ algorithm in the residual group block [29-31]. Such a structure is effective in reducing the computational volume of the model, but also able to extract more information about the feature pattern of the target, which improves the degree of detection correctness, and through this optimization, it is possible to increase the speed of the algorithm's fulfillment procedure while maintaining the degree of accuracy.In optimizing the YOLO_v3 network model, we set the following criteria: to improve the accuracy and efficiency of target detection, as well as to enhance the model's adaptability and flexibility to different data.

After using the K-means algorithm and K-means++ algorithm to classify the data in aggregated type, the study can show their aggregated classification results by plotting a two-dimensional coordinate graph. In the graph, each data point represents a sample object, while different colors indicate different aggregated classifi-

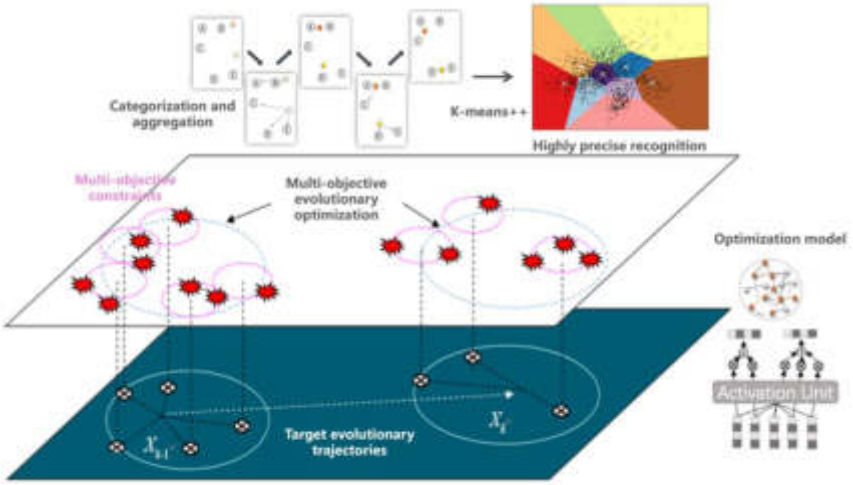

Fig. 3.1: Specific process of joint evolutionary optimization algorithm under multi-objective

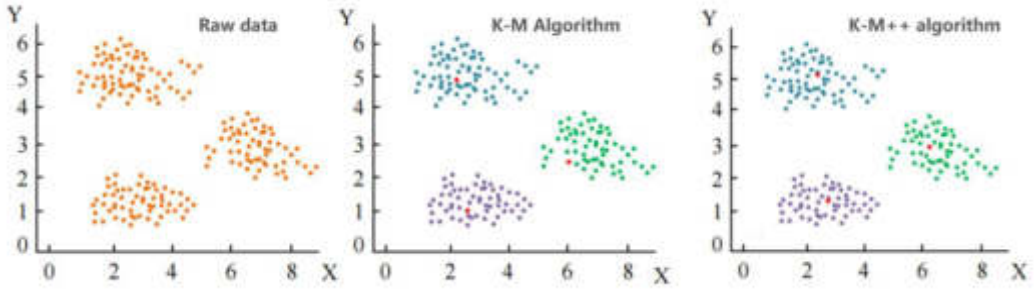

Fig. 3.2: Comparison of the degree of accuracy of different algorithms for aggregated classification under multi-objective

cation groups. A comparison of the degree of accuracy of the two algorithms' aggregation type classification is shown in Figure 5.

According to Figure 3.2, it can be found that under the K-means++ algorithm, the aggregation-type classification results demonstrate a higher degree of recognition accuracy. This is because the K-means++ algorithm is more ingenious in selecting the initial aggregation-type classification centers, which effectively avoids the influence of the initial aggregation-type classification centers on the aggregation-type classification results by setting the initial aggregation-type classification centers farther apart from each other. As a result, the K-means++ algorithm can better capture the intrinsic structure of the data, making the aggregation type classification results more accurate.

The width placement, height, and area of Anchor_Box generated by the K-means algorithm and K-means++ algorithm are compared when the number of aggregated classification centers is 9. Details are shown in Table 2.1. After assigning the aggregated classification results to the 3 feature pattern map group layers, the differences of Anchor_Box in each size feature pattern map are compared. It can be observed that the Anchor_Box generated by the K-means++ algorithm has more differences between the different sizes of feature pattern map group layers.

According to Table 3.1, it can be seen that the Anchor_Box generated by the K-means++ algorithm has

Table 3.1: Differences in Algorithmic Aggregate Classification

box-shaped	Feature size	32*32	16*16	8*8
average width	K-m	33	53	127
	K-m++	29	85	118
average height	K-m	48	114	126
	K-m++	49	107	131
average size	K-m	1417	5364	15987
	K-m++	1444	5892	17062

a greater difference between the layers of different sizes of feature pattern mapping groups. This means that the Anchor_Box generated by the K-means++ algorithm has a better degree of adaptation and flexibility in detecting the degree of targets of different sizes. In contrast, the K-means algorithm generates Anchor_Box with relatively small differences between different sizes of feature pattern map group layers. This is because targets of different sizes may require different sizes of Anchor_Box for accurate detection. By using the Anchor_Box generated by the K-means++ algorithm, it can better meet the detection needs of targets of different sizes, thus improving the performance and accuracy of the target degree detection class of algorithms. Thus, the K-means++ algorithm plays a key role in optimization in YOLO-v3.

In evaluating the performance of the YOLO-v3 algorithm for urban traffic detection, we delve into the importance of the P-R curve.The P-R curve, or precision-recall curve, is a key tool for measuring the performance of target detection algorithms. By plotting the P-R curve, we can visually compare the performance of different algorithms in dealing with various types of losses.The larger the area under the P-R curve, the better the detection ability of the algorithm. This characteristic provides us with a quantitative criterion for evaluating the performance difference between different algorithms when processing urban traffic data. On the NEU-DET dataset, we plotted the P-R curves of different algorithms for detailed comparison.It can be clearly seen that there is a significant difference in the area underneath the three curves. The largest area is the third curve, which represents the optimized algorithm showing strong performance in urban model integrity detection. In contrast, the area under the second curve is the smallest, indicating a relatively weak performance.Further analysis reveals that the loss type represented by the third curve achieves an optimal balance between precision and recall. This means that the optimized algorithm can achieve a high recall while maintaining high precision. This property is particularly important in urban traffic detection, as we want the algorithm to detect as many targets as possible while reducing false detections.

In contrast, the loss type represented by the second curve performs poorly at detection, with low precision, even at high recall. This may be due to the algorithm's difficulty in effectively identifying and classifying different types of information when dealing with urban traffic data. By analyzing the P-R curve in detail, we can clearly see the advantages of the optimized algorithm in urban traffic detection. This analysis not only helps us to understand the performance differences of different algorithms, but also provides directions for further improvement and optimization of the algorithms. The multi-objective evolutionary algorithm shows strong adaptability and robustness in dealing with complex and variable urban traffic data, which provides strong support for promoting the development of smart cities.

4. Pilot test results. Through the previous joint method, we can realize the application of multidimensional sensory data prediction and resource scheduling under various domains of smart cities. In this section, the application analysis in practice will be carried out, the processor used for model training is: Intel_Xeon_Gold_5218_CPU, the memory is 6, the kernel value is 8 cores, the graphics card is NVIDIA_DV_RTX 2080 Ti, the operating system is Windows 10_64-bit, and this training is based on the deep-type learning framework pytorch_1.7 The experimental environment is python_3.7, and the GPU acceleration software is C_UDA_10.2 and CUDNN_7. Considering that the YOLO-type algorithm itself uses the VOC dataset, the urban traffic detection dataset is constructed according to the format of the VOC dataset, and the part of the image in the dataset is the schematic diagram of the practical application results as follows, which shows

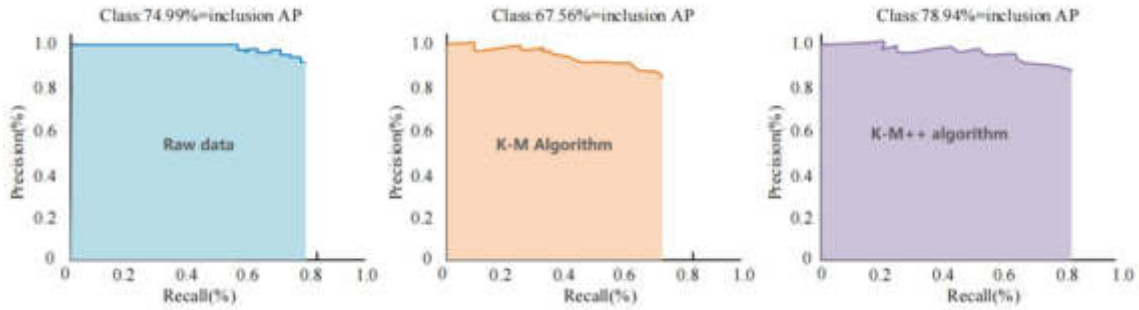

Fig. 3.3: Comparison of the degree of accuracy of different algorithms for aggregated classification under multi-objective

Fig. 4.1: Illustration of test applications such as city maps, city groundwater, city highway traffic, etc.

that we can see that the city maps, city groundwater, urban highway traffic, urban building layout, urban power layout, and other test applications can be seen. Through the optimized monitoring results (as shown in Figure 4.1), it can be seen that the ability to test the results of this paper, can be a very clear reflection of the city where we need certain detection goals.

To improve the advancing and pushing speed of the YOLO-v3_means++ network model, and to verify the feasibility of these two methods. As shown in Figure 4.2, it can be seen from the figure that the detection time of the original YOLO-v3_means++ network model for a single-frame image on FP_GA is about 2.2-2.8s, and the average detection time is about 2.4s. After the fusion of the convolutional degree level with the BN layer, the average detection time for a single-frame image is reduced to 2.25 s. While the average detection time for a single-frame image is about 2.01 s when C-FENCE is used as the post-processing algorithm, it appears that some of the detection time exceeds that of the original YOLO-v3_means++ network model. This is because when there is a partial overlap between two targets of the same class, the N-MS algorithm will directly filter out the target frame with less confidence in the same class of targets, while the C-FENCE algorithm adopts

Fig. 4.2: Schematic of test applications for city maps, urban groundwater, urban highway traffic, etc.

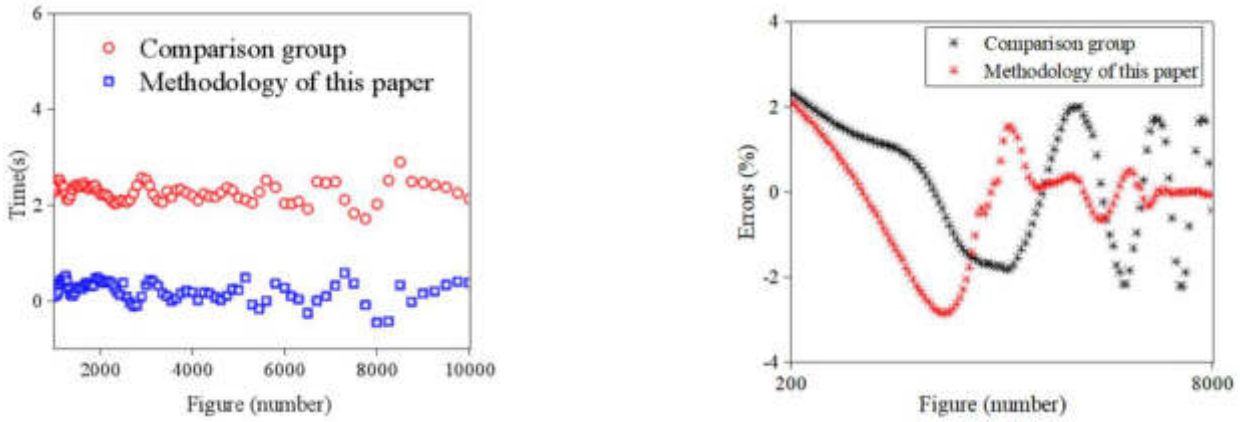

Fig. 4.4: The success rate of each algorithm's operation

an aggregated classification to avoid leakage detection, but increases the processing time. Secondly, it is also necessary to analyze and compare the detection results of GPU and FPGA. To present the detection results more intuitively, this paper draws the target frames predicted by the network and labels the target categories with their confidence levels through the Open_CV tool. Figure 4.4 shows the comparison of the two sets of detection results for two different platforms. By comparing and analyzing the detection results in Figure 4.4, it can be seen that in terms of the accuracy of the target frame and the confidence level of the target, the detection results of GPU are slightly better than those of FPGA. This is because, in the process of porting the YOLO-v3_means++ network, this paper utilizes the half-correctness floating-point number to quantize the YOLO-v3_means++ network, which results in part of the loss of correctness, although the loss of correctness is more than the loss of correctness. degree loss, although the loss of the correct degree is less, the error will still be reflected in the final detection result as the computation volume increases. In the detection results of the FP_GA platform using the C-FENCE method as the post-processing algorithm in Figure 4.4, although the target confidence level is also slightly lower than that of the GPU platform, the target frame is more in line with the target model itself, which is because the C-FENCE algorithm considers the target's confidence level and weighted proximity while calculating the target frame instead of using the confidence level as the judging criterion only. The experimental results show that the FP_GA-based, YOLO-v3_means++ network can better meet the detection needs.

5. Conclusions and discussions. The paper focuses on the application of multi-objective evolutionary type algorithms for multi-dimensional sensory data prediction and resource scheduling in smart city design. The conclusions of the related simulations and tests are as follows:

1. YOLO_v3 network model jointly with the K-means++ algorithm to generate Anchor_Box, the new algorithm has greater differences between different sizes of feature pattern map group layers, which indicates that the algorithm has a better degree of adaptability and flexibility to better meet the needs of detection of different sizes of targets and improve the performance and accuracy of the target degree detection class of algorithms.
2. To further analyze the performance of YOLO-v3 joint algorithms for urban traffic detection, the P-R curves of the various types of algorithms for some of the loss types on the NEU-DET dataset are plotted. The optimized algorithms are found to be stronger for detecting different types of losses in urban model completeness detection.

Practical application analysis revealed that the optimized monitoring results were compared with the detection time of the original YOLO-v3_means++ network model on FP_GA. We found that the average single-frame image detection time is reduced to 2.25 s after fusion of the convolutional degree level with the BN layer, while the average single-frame image detection time is about 2.01 s when using C-FENCE as a post-processing algorithm.

The results of the tested recognition applications show that this fusion algorithm based on FP_GA's YOLO-v3_means++ network can better meet the detection needs and that optimizing the YOLO-v3 network model using a multi-objective evolutionary algorithm can improve the performance and accuracy of the target degree detection class of algorithms.This study provides valuable insights for smart city planners and designers.Future research could be further extended to different types of sensory data, such as radar, infrared, etc., to provide a more comprehensive perception of the city. Meanwhile, changes and improvements in evolutionary algorithms, such as genetic algorithms and particle swarm optimization, are explored to find more efficient and accurate solutions. In addition, research could focus on the combination of multi-objective evolutionary algorithms with other advanced technologies, such as deep learning, reinforcement learning, etc., in order to promote the sustainable development of smart cities.

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CONSTRUCTION AND APPLICATION OF THREE-DIMENSIONAL INFORMATION MANAGEMENT SYSTEM FOR INTELLIGENT BUILDINGS INTEGRATING BIM AND GIS TECHNOLOGIES

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Abstract. Smart building technologies are widely used in all aspects of building structure, services, and management, helping to create a more comfortable, safe and convenient building environment. Building Information Modelling (BIM) and Geographic Information System (GIS) technologies are both widely used intelligent building technologies, and their combination can improve the analytical ability of spatial environment to a certain extent. However, it is difficult to manage them due to the huge amount of data in the Three-Dimensional (3D) information of intelligent buildings. Therefore, it is very important to improve the information management ability of intelligent building 3D information management systems (Moballeghi et al. 2023; Mahamood and Fathi 2022). BIM and GIS technologies were used to build a 3D information management system for intelligent buildings more effectively. The design and development principles of the information management system were explained, and the overall framework of the system was also designed. Research was conducted on feature extraction and matching through an improved scale invariant feature transformation algorithm to enhance the information classification and management capability of the intelligent building 3D information management system. In addition, the improvement measure for SIFI algorithm was to reduce pixel processing to reduce its memory size. The study explained the preprocessing of model normalization before feature extraction and matching. The coordinate system rotation normalization of building 3D models was achieved through principal component analysis. Finally, the calculation of covariance matrix was explained. The number of pyramid image groups was adopted to further improve the scale space and enhance computational efficiency. The Hessian matrix was introduced to eliminate unstable fixed points. And the purity of feature point matching through similarity coefficients was improved. In addition, a modified multi-view convolutional neural network was used to classify the feature data, and a modified classification architecture was designed to build a 3D model based on this algorithm to enhance its information classification management capabilities. The study explained the calculation of view weights and global descriptors and described the fully connected and classification architectures. The results showed that the improved scale-invariant feature conversion algorithm achieved a matching accuracy of 98.3% and takes only 17 s. Meanwhile, the proposed multi-view convolutional neural network achieved an accuracy of 97.6% and an F1 value of 96.4% for the classification of 3D information of intelligent buildings. Among the six types of 3D building models selected, the method achieved the highest accuracy of 94.26% and was more stable. It shows that the proposed method of 3D information management of intelligent buildings has obvious classification advantages and provides a new technical reference for the information development of intelligent buildings.

Key words: BIM; GIS; Intelligent buildings; 3D information; Management systems; Multi-view convolutional neural networks

1. Introduction. Introduction. With the gradual development of digital city construction, intelligent buildings have become a key focus of development [31, 24] . As the focal point of modelling technology in the construction industry, Building Information Modelling (BIM) enables the integration of information from planning, decision making, and design aspects of construction projects, thus enhancing economic, social, and environmental benefits to a certain extent [30, 32]. BIM mainly uses 3D digital simulation techniques to construct buildings and simulate realistic situations. The technology also enables information sharing between the various participants in a project on the same platform to facilitate their communication and decision-making. However, BIM technology has inherent drawbacks such as the small spatial scope, which makes it difficult to integrate building facilities into the environment [42, 36] Geographic Information System (GIS) technology, on the other hand, uses geospatial data of the earth as an object. When integrated with BIM technology, it can enhance the analysis of the spatial environment. However, in today's intelligent buildings, it is difficult to achieve efficient management due to the complexity of the data contained in 3D information and the excessive amount of data [38, 18]. Therefore, BIM is used for building modelling and imports it into GIS for visual presentation. The improved Scale-Invariant Feature Transform (SIFT) is also applied to extract

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and match the features of the 3D images of intelligent buildings, and the improved Multi-View Convolutional Neural Network (MVCNN)-based Deep Convolutional Neural Network (DCNN) is used. The research aims at building intelligent building 3D information management systems by combining BIM and GIS technologies, and reducing the difficulty of system management through SIFI and MVCNN. The research also aims to improve the information classification management ability of the system, provide technical support for the efficient management of intelligent building 3D information, and promote the informatization development of intelligent building. The novelty of the research is mainly reflected in four aspects. The first aspect is the introduction of the improved SIFI algorithm in the building 3D information management system. It can reduce the memory size and the computational cost of the overall process by downsizing the pixel processing, realize the feature extraction matching of the building 3D information, and reduce the memory occupation of the 3D building information. The second aspect is the adoption of the modified MVCNN, which is improved by the introduced weight calculation module. As a result, the features of multiple views are fused, the accuracy of 3D model data classification is improved, and the information management capability of the system is enhanced. The third aspect is the introduction of the Long Short-Term Memory (LSTM) and the Attention Mechanism (Att) module, through which the weight calculation is performed. The fourth aspect combines the improved SIFI and MVCNN modes, which are applied to improve the management ability of the intelligent building 3D information management system. The contribution of this research is to improve the accuracy of data classification for intelligent building 3D models and reduce the computational complexity of the overall process of 3D information feature extraction and matching. The information management capability of intelligent building 3D information management systems is enhanced and the technical and methodological support is provided for the informatization and intelligent development of intelligent buildings. The study consists of four parts. The first part is a DCNN based on the improved Multi-View Convolutional Network (MVCNN), which provides a research status on BIM-GIS integration technology and classification of 3D images. The second part explains in detail the construction of a 3D Information Management (IM) system for buildings by integrating BIM and GIS and the processing of system data. Section 1 of the second part introduces the construction of the 3D IM system by integrating BIM and GIS technologies. Section 2 focuses on the feature extraction and classification processing of the data of the management system. The third section discusses the performance of each algorithm and the effectiveness of applying each technique. The fourth part discusses the results obtained and explores future directions for improvement.

2. Related works. [1] had developed an integrated BIM-GIS model for the manufacturing and management of buildings. BIM was applied for the production, analysis, and management of building information. GIS was applied for the 3D model creation. The results showed that the model had excellent practical application and could be used to select the best location for the construction of warehouses. [11] introduced an integrated approach of BIM and GIS to achieve a more intelligent urban management. CIM models were used to enhance the intelligent management of the city. The results showed that this approach could effectively solve the management problems in infrastructure development projects. [39] addressed the data conversion problems associated with urban geotagging languages. A shapefile format was adopted to facilitate the application of BIM models in GIS, and a method was developed to convert industry base classes into shapefiles using integrated computer graphics technology. The results showed that the method could promote the application of BIM in GIS and facilitate integrated building model construction. [23] explored 24 BIM applications in the lifecycle and explored BIM applications and integration techniques from two perspectives to provide a systematic summary of BIM integration, applications, and trends. The results showed that the technology provided effective technical support for various fields in the future. [37] proposed a new approach to integrate BIM with GIS in response to the problems of large scale and technical complexity that construction projects had. A web-based integration platform was also developed to enhance building information sharing and facilitate project management. The results showed that it was effective in enabling the proper management of large projects. The problem of classifying 3D images has been the topic of much research. [32] found that current 3D model classification relied heavily on fully supervised training schemes. Therefore, a semantically guided projection method was proposed for retrieving and classifying 3D models. A bidirectional projection of visual features and semantics was also used to eliminate the difference between the visible and invisible domains. It was highly feasible according to the findings [5]. [10] designed an in-situ measurement method based on a

binocular microscopic vision system to measure the size distribution of 3D crystals during the crystallization. The shape of 3D particles was reconstructed through dual view images captured by two microscopic cameras. In addition, a microscopic dual view image analysis method was also designed to identify key corner points of particle shape in the image. The experimental results showed that the method designed by the research institute could effectively estimate the 3D size of particles and had good performance. [36] proposed an interpretable machine learning method for point cloud classification to classify 3D building model images. In the classification and integration stages, multiple point-hopping units were employed to acquire feature vectors and provide them to the classifier. The method had good classification performance according to the findings. [38] proposed a new 3D efficiency net with improved 3D moving inverse bottleneck convolution blocks for classification detection of 3D images of Alzheimer's disease to achieve classification of brain MR images. It could effectively perform the prediction and diagnosis of Alzheimer's disease according to the findings. [18] developed a new street frontage network to design urban elements that were more conducive to public space to enable quality assessment of street frontages. It was 92% accurate and could be applied to the design of urban elements according to the findings. In summary, domestic and foreign research scholars have implement extensive research on the management of building information and the classification of 3D images, but there is still room for further research and improvement on the classification of 3D images of buildings. Therefore, the study builds a building 3D IM system rely on BIM and GIS technologies, and classifies the system data effectively, in order to achieve a more intelligent system management.

3. Intelligent building three-dimensional IM under the integration of BIM and GIS technologies. Intelligent buildings mainly rely on modern computer technology. A 3D building IM system based on BIM and GIS integration technology is constructed in this section. Meanwhile, a modified scale-invariant feature conversion algorithm is introduced for pixel reduction to address the complexity and excessive memory of the system data. In addition, an improved MVCNN method is proposed to classify the data after feature matching to achieve a more refined and intelligent building IM.

3.1. Construction of 3D IM system based on BIM and GIS technologies. BIM models are able to achieve access to information about the interior and exterior structures of a building through 3D digital information. However, the space in which they are applied is too narrow and susceptible to architectural and geographical conditions, resulting in building facilities not being integrated into their environment. GIS has advantages in this area, as it takes the geospatial data of the whole earth as an object and performs a series of technical operations on it [20] GIS is now widely used in the field of exterior spatial planning and location selection of buildings. The integration of 3D BIM models with GIS platforms not only enriches the macro to micro building information, but also effectively deals with the problem of information silos from micro to macro [6, 9] The integration of both data can give full play to their respective strengths and make up for their weaknesses to achieve a more complete 3D model of the building and its surroundings. By combining BIM and GIS technologies, the 3D building IM system enables intelligent buildings to manage and maintain projects throughout their lifecycle. Meanwhile, visual displays and spatial analysis conditions are provided to achieve an increased level of intelligence and energy efficiency in intelligent buildings, saving resources and improving efficiency to a certain extent. The development phase of the 3D IM system for intelligent buildings should be based on certain design and development principles for successful construction. The study identifies six construction principles, namely security, advanced practicality, reasonable openness, standardization, scalability, and unified design, to ensure the successful construction of the 3D IM system. The principle of security is extremely important and refers to the protection of data and information in a system against information theft. The principle of advanced practicality means that the choice of technologies needs to be in line with the current mainstream technologies and meet future development trends. The principle of reasonable openness means that both the development environment and the hardware support diversity to adapt to changes in operating systems and computers [28, 4] The principle of standardization refers to the need for a unified standard specification to ensure compatibility and interoperability. The principle of scalability means that a certain number of upgrade interfaces must be reserved to meet upgrade and expansion needs, while ensuring the interoperability of the system. The principle of uniformity of design is to ensure uniformity for all parts of the system and the architecture and achieve uniform planning and design [36, 26] The role of the six construction principles identified in the study in the construction of the 3D IM system is shown in Figure 3.1.

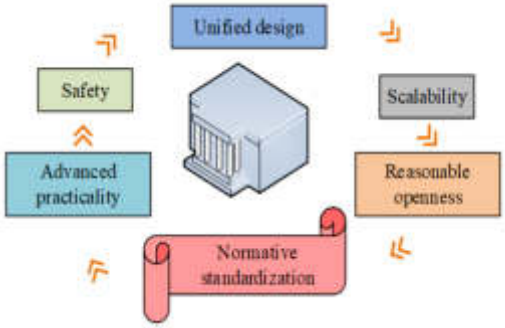


Fig. 3.1: The role of the six construction principles identified in the construction of a three-dimensional IM system

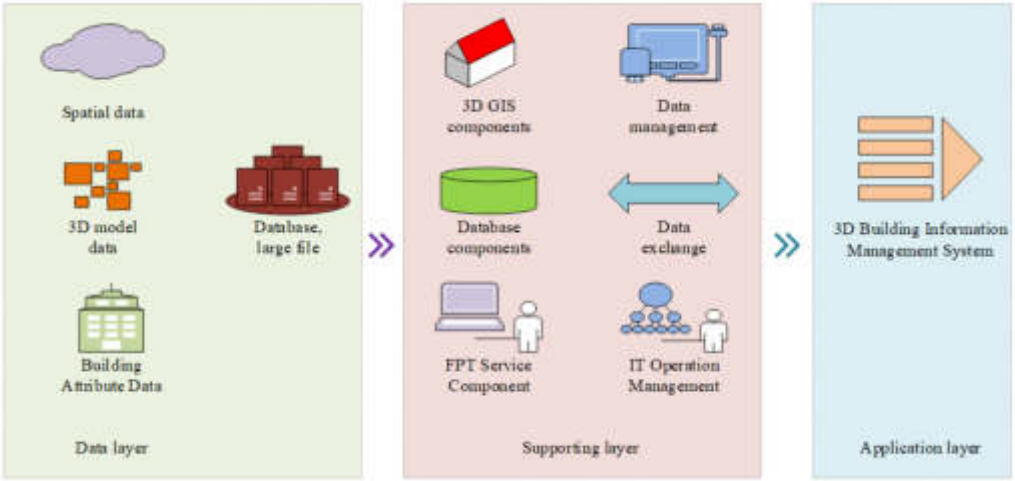


Fig. 3.2: The overall framework of intelligent building 3D IM system proposed by the research institute

The overall objective is to build a digital 3D simulation model containing architectural information with buildings and components, including manual mapping, point clouds, images, and other information. The system manages the texture data and geometric models of building complexes, and data are also aggregated on architectural artefacts, including architectural images, documents, and audio. The system allows users to fully understand the properties and spatial information of the building and its components to better manage and make decisions about the building in a systematic way, leading to a more scientific IM of the building archive. The overall structure of the proposed 3D IM system for intelligent buildings contains three parts, namely the data layer, the support layer, and the application layer, as shown in Figure 3.2.

In Figure 3.2, the bottom layer is the data layer, which mainly includes the data of the 3D model, spatial, and attribute of the building. The storage of such data is generally achieved by establishing a database or large files. Meanwhile, the support layer of the system contains two main aspects: the components and the management and exchange of data. The role of the data management and exchange layer is to provide the application layer with the ability to download, store, utilize, manage, and exchange data. The role of the component layer is to provide a variety of platforms for the development and operation, including the 3D GIS platform, database platform, and FTP service platform. In addition, the application layer is used to develop efficient applications for the 3D building IM system to complete building IM.

3.2. Intelligent building 3D IM based on data classification. The integration of BIM and GIS provides rich data support, enabling more refined management of 3D information for smart buildings and enabling intelligence of micro-information. However, the data obtained from BIM and GIS technologies have the characteristic of high resolution, which occupies a large amount of memory and brings greater difficulties for the next data management [7] For this reason, an improved SIFT algorithm is introduced, which is pixel-reduced to reduce the memory size. At the same time, the data in the IM system are classified by the improved data classification algorithm to achieve efficient management. The model is pre-processed with a normalized coordinate system before feature extraction and matching. This includes translation normalization, rotation normalization, and scale normalization of the coordinate system. The gravity center of the model is shifted to the origin of the coordinate system to achieve normalization. The x-axis coordinates of the centre of gravity of the model are calculated as shown in equation 3.1 [14, 16].

$$x_c = \frac{\sum_{i=0}^{m-1} x_i}{m} \tag{3.1}$$

In equation 3.1,x_i represents the x-axis coordinates of the model midpoint i, and the y-axis coordinates of the model centre of gravity are calculated as shown in equation equation 3.2.

$$y_c = \frac{\sum_{i=0}^{m-1} y_i}{m} \tag{3.2}$$

In equation 3.2,y_i represents the y-axis coordinates of the model midpoint i, and the z-axis coordinates of the model centre of gravity are calculated as shown in equation 3.3 .

$$z_c = \frac{\sum_{i=0}^{m-1} z_i}{m} \tag{3.3}$$

In equation 3.3, z_i represents the z-axis coordinates of the point i in the model. The converted coordinates are shown in equation 3.4.

$$P_i' = (x_i - x_c, y_i - y_c, z_i - z_c) \tag{3.4}$$

The rotation normalization of the coordinate system of the architectural 3D model is mainly achieved through principal element analysis, which first requires the calculation of the covariance matrix, which is shown in equation 3.5 [33].

$$C = \left| \begin{array}{ccc} \sum_{k=0}^{m} x^2 & \sum_{k=0}^{m} xy & \sum_{k=0}^{m} xz \\ \sum_{k=0}^{m} xy & \sum_{k=0}^{m} y^2 & \sum_{k=0}^{m} yz \\ \sum_{k=0}^{m} xz & \sum_{k=0}^{m} yz & \sum_{k=0}^{m} z^2 \end{array} \right| \tag{3.5}$$

The matrix is a real symmetric matrix with non-negative real eigenvalues. The eigenvalues are then placed in a non-increasing order.

The feature vectors are sorted to obtain the feature vectors. The feature vectors are then scaled to produce a rotation matrix, and a rotation transformation of all the points of P' in the model will result in a new set of points, which is calculated as shown in equation 3.6 (Liu. 2022).

$$P'' = \{P_l'' \mid P_l'' = P_l' R,\ P_l' \in P^i,\ l = 0, 1, ..., m\} \tag{3.6}$$

After the rotational transformation, it is then necessary to carry out a scale normalization of the coordinate system, which is calculated as shown in equation 3.7 [19].

$$P''' = \left\{ \frac{x_s''}{r_{\max}}, \frac{y_s''}{r_{\max}}, \frac{z_s''}{r_{\max}} \,\middle|\, |(x_s'', y_s'', z_s'')_s\rangle \right\} \tag{3.7}$$

Once the data of the architectural 3D model have been pre-processed, the model features are extracted and assigned. The SIFT algorithm consists of four computational steps, namely the construction of a scale

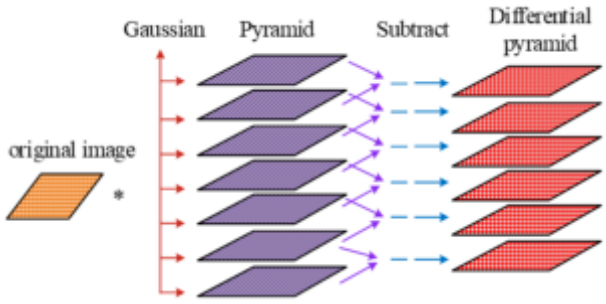


Fig. 3.3: The construction process of Gaussian difference pyramid

space, the detection of feature points, the assignment of key point principal directions, and the calculation of feature descriptors. Building a multi-scale space means extracting effective visual processing information from the changing scale parameters, while aggregating them to achieve deep mining of the essential features of the image. The feature points of the image can be better extracted when a multi-scale spatial transformation is applied to the target image [40, 3]. The scale transformation of an image is mainly achieved through a Gaussian convolution kernel, which is calculated as shown in equation 3.8 (YANG et al. 2021; Rathore et al. 2019).

$$\begin{cases} G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{\left(\frac{-(x^2+y^2)}{2\sigma^2}\right)} \\ L(x,y,\sigma) = G(x,y,\sigma) \otimes I(x,y) \end{cases} \tag{3.8}$$

In equation 3.1, σ represents the scale factor, $G(x,y,\sigma)$ is a two-dimensional Gaussian function, $I(x,y)$ refers to the input image, $\otimes$ stands for the convolution operation between images, and $L(x,y,\sigma)$ represents the scale space image after Gaussian convolution. When constructing the scale space, the Gaussian convolution function is used to generate a Gaussian pyramid with different scales, and then the two adjacent layers of this pyramid will be differentiated to be able to obtain a Gaussian differential pyramid, as shown in Figure 3.3.

Due to the huge amount of intelligent building image data collected, further improvement of the scale space is needed to enhance the computational efficiency. The number of pyramid image groups $(Octave, O)$ is reduced to achieve this purpose. The calculation of O is shown in equation 3.9 [27].

$$O = \log_2 (\min(M, N)) \tag{3.9}$$

In equation (3.9), {} represents the rounding operation. M and N stand for the number of rows and columns in the image, respectively. If the first 2 sets of images are used for feature point extraction, $O = 2$ is applied to achieve improvement. Once the differential Gaussian pyramid has been generated, the detection of the feature points is performed. Typically, a point in the image is determined to be a polar point of the image if it is a minimal or maximal point in the full range of domains corresponding to that layer and neighbouring layers. The unstable points are eliminated by means of a Hessian matrix to eliminate the edge effects that occur in this process, and a similarity coefficient is introduced to improve the purity of feature point matching. The similarity coefficients are shown in equation (3.10) [41].

$$SC = \frac{dist}{Min\_dist} (1 \le SC \le SC\_\max) \tag{3.10}$$

In equation (3.10), Min_dist represents the minimum Euclidean distance and $SC\_\max$ is the maximum value of the similarity coefficient. If the obtained similarity coefficient is small, it means that the similarity between the pixel points of the same name is greater, which acts as a purification of the matched points. The direction, scale, and position of the feature points are usually described using a vector approach, as shown in Figure 3.4.

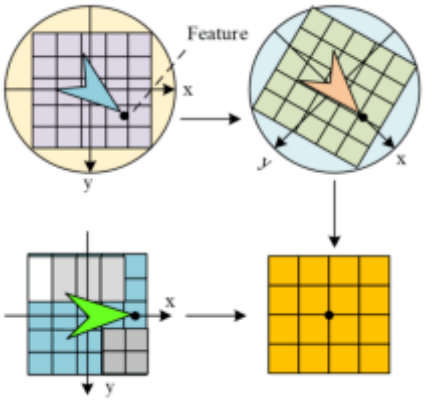


Fig. 3.4: Expression of feature direction

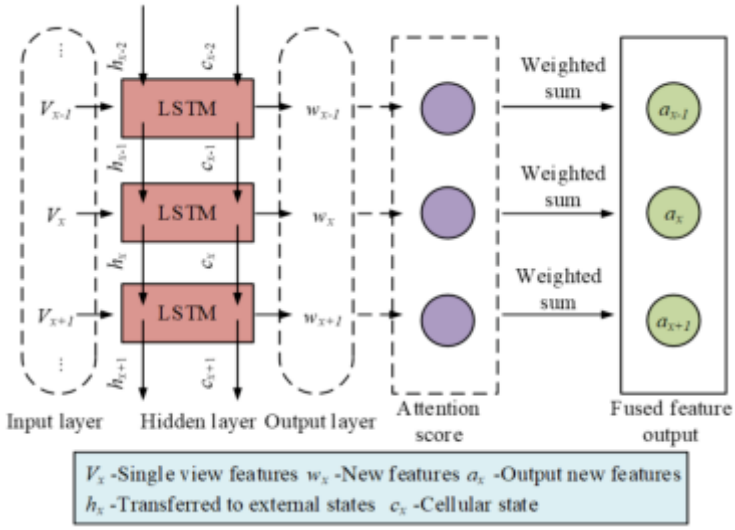


Fig. 3.5: The architecture of LSTM-Att module

After completing the extraction and matching of model features, the deep convolutional neural network based on the modified MVCNN is improved to achieve data classification of architectural 3D models. Five convolutional layers and three fully connected layers form a network structure. The input of the network is six three-channel images, and the output is the shape descriptor of the 3D architecture model. To improve the classification detection performance of MVCNN on similar building components, the model is improved by adding weight calculation modules for each view after the main five convolutional layers of the network, thus giving different weights to the more expressive and less expressive views, respectively. The newly introduced weight calculation module is an LSTM-Att module that combines LSTM and Att. LSTM can accurately capture sequential features by utilizing the spatial correlation of multi-view images. Att can subjectively place weights during model training, ignoring irrelevant information, and thereby improving classification efficiency. The architecture of the LSTM-Att module is shown in Figure 3.5.

From Figure 3.5, the LSTM-Att module includes an input layer (single-view features), a hidden layer, an output layer (new features), attention score, weighted summation, LSTM, and a fused feature output layer. LSTM-Att uses LSTM to accurately process multi-view feature data and obtain more complete features. After-

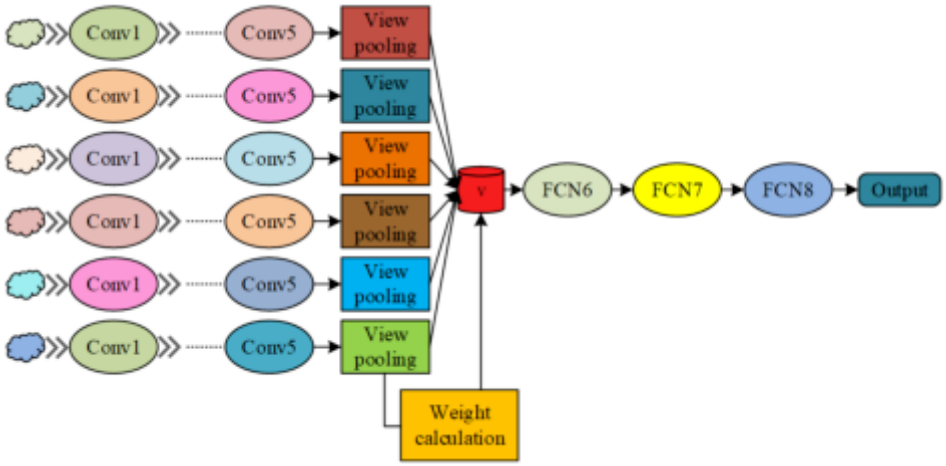


Fig. 3.6: Improved architecture for 3D model classification based on the improved MVCNN

wards, the processed data are computed based on attention value, and multi-view feature fusion is performed based on weight data to improve classification accuracy. The modified architecture of the improved MVCNN-based 3D model classification is shown in Figure 3.6.

In Figure 3.6, the six views generated by the pre-processed model are first fed into the convolutional neural network for parallel convolution, and the original view descriptors for each view are obtained after the initial extraction of features for each of the six views. The original view descriptors are then fed into the weighting layer to give higher weights to the more expressive descriptors and lower weights to the less expressive descriptors. It is assumed that the input view is represented by equation 3.11.

$$T = \{I_1, I_2, I_3, ..., I_n\} \tag{3.11}$$

The differentiation of each view is calculated as shown in equation 3.12.

$$Q(I_n) = sigmoid(abs(C_n)) \tag{3.12}$$

In equation (3.12), C_n is the output value of the convolution layer (Hosseini and Taleai 2021). The weights are calculated as shown in equation (3.13) (Kaiwen et al. 2023).

$$H(I_n) = \frac{Ceil(|G_n| \times Q(I_k))}{|G_n|}, \qquad I_k \in G_n \tag{3.13}$$

In equation 3.13, G_n represents a view group. The groups of views are then pooled to generate global descriptors, where the global descriptors are calculated as shown in equation 3.14 (Kaczorek and Ruszewski 2022).

$$V(T) = \frac{\sum_{n=1}^{6} H(I_n) \cdot J_n}{\sum_{n=1}^{6} H(I_n)} \tag{3.14}$$

In equation 3.14, j_n represents the descriptors obtained by pooling. The resulting global descriptors then need to be fed into the fully connected layer to enable the classification of the building 3D model. One of the full connectivity and classification architectures is shown in Figure 3.7.

Softmax and multi-classification are used for the classification of image features. The Softmax function is shown in equation 3.15.

$$S_i = \frac{e^{v_j}}{\sum_{i=1}^{C} e^{v_j}} \tag{3.15}$$

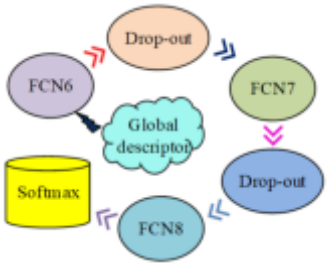


Fig. 3.7: Fully connected and classified architecture

Table 4.1: The experimental basic environmental parameters

Parameter variables	Parameter selection
CPU	Intel 8 CoreTM i7-7700HQ CPU
Memory	16G
GPU	NVIDIA Tesla P4*2
Implementation Platform	Ubuntu 16.04.6 LTS
Operating system	64 bit Wndows10
Operating environment	MATLAB
Data regression analysis platform	SPSS 26.0

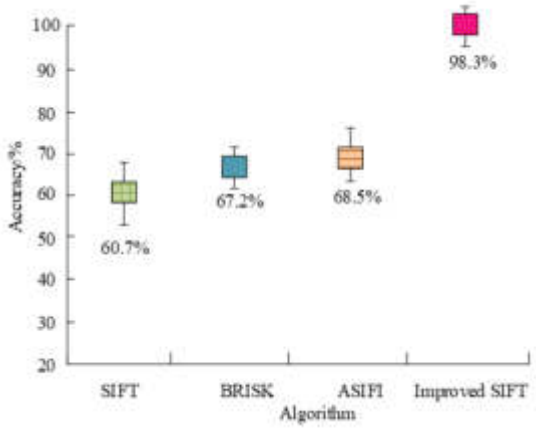
In equation 3.15, j represents the category index, v_j represents the output of the classifier's preceding output unit, and C is category quantity. S_i stands for the ratio of the output element index to the sum of all element indexes.

4. Analysis of the application effect of three-dimensional IM system for intelligent buildings.. Three feature extraction algorithms were selected to compare their performance to verify the effectiveness of the improved SIFT. These include ASIFI, BRISK, and the classical SIFT algorithm. Table 4.1 depicts the basic software and hardware environment settings.

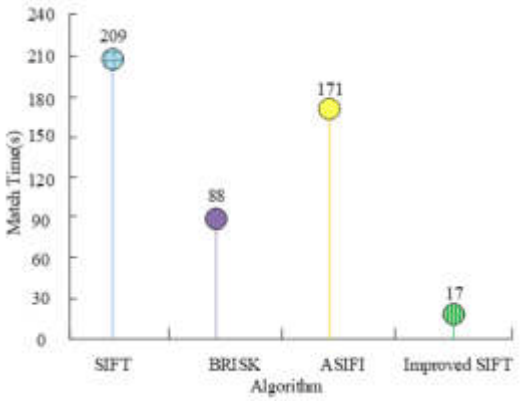
The selected dataset is the UrbanScene3D dataset, which contains 16 building scenes and 128,000 high-resolution images. 1026 images of a building were taken as the test objects. Figure 4.2 shows the comparison results of the correct matching rate and time of the four algorithms. From Figure 8, the improved SIFT algorithm had the highest matching accuracy and was as high as 98.3%. Compared with the remaining algorithms, its matching accuracy rates were improved by 29.8%, 31.1%, and 37.6%, respectively. Meanwhile, the improved SIFT had the lowest matching time of 17s, which was 154s, 71s, and 192s less than the other algorithms, respectively, indicating that the improved SIFT algorithm had very good performance.

Figure 4.4 shows the results of the four methods in this dataset. From Figure 4.3a, in terms of the search completion rate, the difference between ASIFI and the classical SIFT algorithm was relatively small, with the lowest being around 50% and the highest close to 90%, and the overall trend was first decreasing and then increasing. In contrast, the improved SIFT algorithm was able to maintain a full rate above 78% and reached a maximum of 97%, a maximum improvement of 42% compared to the pre-improvement SIFT algorithm. In Figure 4.3b, the trends of the four methods were relatively close to each other, with the ASIFI, classical SIFT and BRISK algorithms all obtaining a relatively low maximum accuracy rate in the range of 40%-50%. The modified SIFT algorithm reached a maximum of 57%. This indicated that the improved SIFT algorithm had more significant performance advantages.

The study continued with the selection of two buildings in a region as the objects, and feature matching was performed separately. The data were collected and processed for both buildings together. Figure 4.6 shows the results. In Figure 4.5a, the different circle patterns indicate the quantity of the valid matching points for building A, the rectangular pattern indicates the quantity of the matching points. Figure 4.5b shows the accuracy of

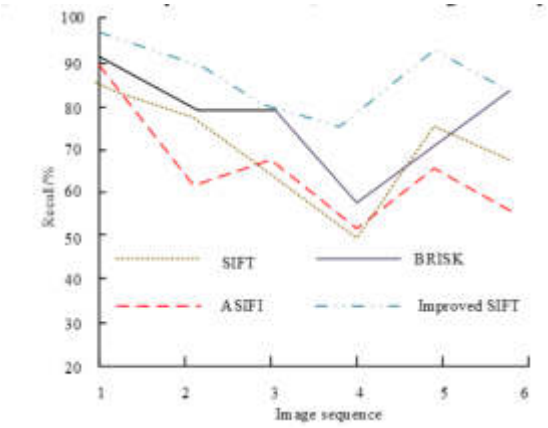


(a) Matching Accuracy of Four Algorithm

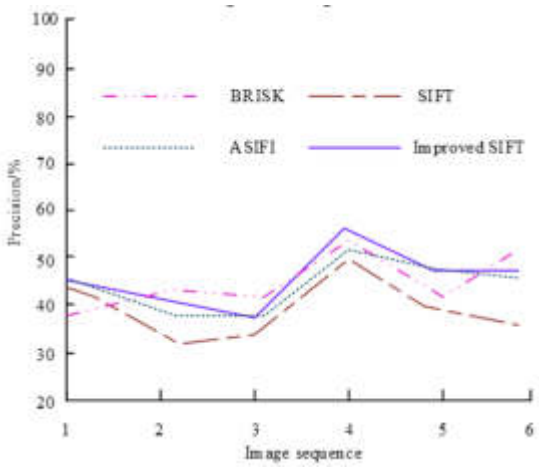


(b) Matching Time of Four Algorithm

Fig. 4.2: Comparison results of matching accuracy and time of four algorithms



(a) The Recall of Four Algorithm

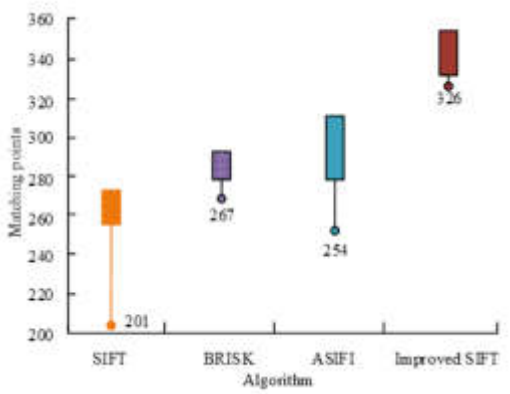


(b) Precision Results of Four Algorithm

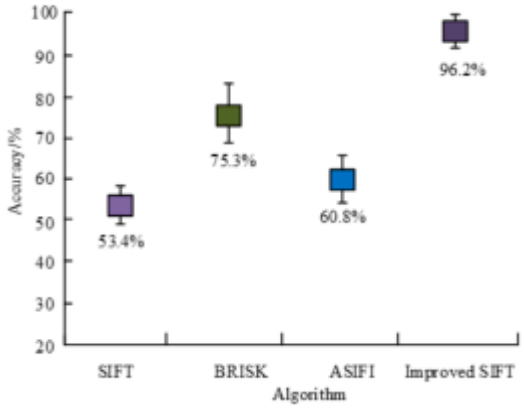
Fig. 4.4: The recall and precision results of four methods

matching points for building B. From Figure 10(a), the total matching points quantity of the traditional SIFT algorithm for building A was about 264, and the number of valid points was only 201. BRISK had more valid points but the total matching points quantity was lower than ASIFT. The improved SIFT algorithm, on the other hand, had the highest number of matching points and had 326 valid points. From Figure 10(b), the accuracy of matching points in building B for ASIFI, classical SIFT, BRISK, and the improved SIFT were 53.4%, 75.3%, 60.8%, and 96.2%, respectively, with the improved SIFT method improving by 30% on average compared to the first three. In Figure 4.5c, the improved SIFT algorithm took 23s and 47s for data acquisition and processing, respectively, with an accuracy rate of 97.2%, which was significantly better than the remaining three algorithms.

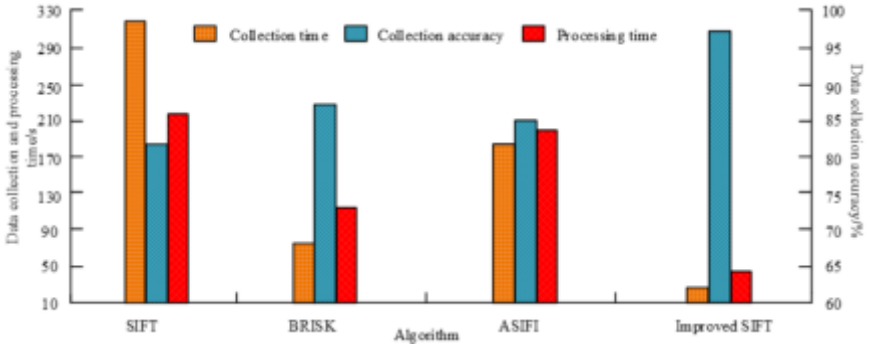
Three common classification models were chosen for comparison, namely Random Forest (RF), Logistic Regression (LR), and Support Vector Machine (SVM), to verify the classification effectiveness of the improved



(a) Matching Point Results of Building A



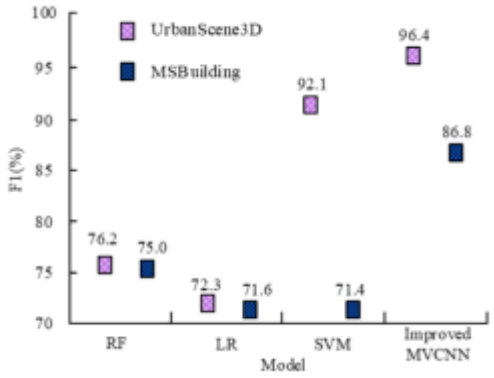
(b) Matching Point Results of Building B



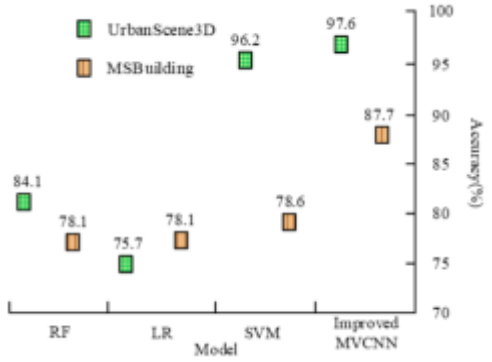
(c) Data Collection and Processing Results

Fig. 4.6: Data collection and processing results of four methods

MVCNN on 3D building model data. The datasets chosen for the study were UrbanScene3D and MSBuilding, and the F1 value and accuracy rate were used as classification evaluation metrics. Figure 4.8 shows the classification results of the four algorithms. In Figure 4.8, the improved MVCNN model had the best F1 value and accuracy rate on both datasets compared to the other three models. In particular, the improved MVCNN achieved an F1 value of 96.4% and an accuracy of 97.6% on the UrbanScene3D dataset, which was 20.2% and 13.5% higher than RF, respectively. In the MSBuilding dataset, the model had the highest F1 value of 86.8% and accuracy of 87.7%, which were 15% and 9.6% higher than the LR model, respectively. This indicated that the improved MVCNN model had significant performance advantages in the data classification of 3D building models. The study continued to validate the classification effect of the improved MVCNN model on 3D building models by selecting six categories of 3D building models for experimental validation. A total of 10 sets of tests were conducted in the study to ensure the validity of the test results. Meanwhile, a traditional CNN was chosen for comparison. Figure 4.10 shows the test results. In Figure 4.10, the improved MVCNN model outperformed the classical CNN model in the classification of the 3D model for each category. Among them, the improved MVCNN achieved the highest classification accuracy of 94.26% in model 3, an improvement of 11.57% compared to CNN. Meanwhile, the improved MVCNN achieved the highest classification accuracy of 75.09% in model 6, an improvement of 25.24% compared to CNN. The complexity of the 3D model determined the accuracy of the classification. Among them, model 3 was the simplest and therefore its accuracy was the highest, with an improvement of 19.17% and 32.84%, respectively, on the two classification models compared to the most

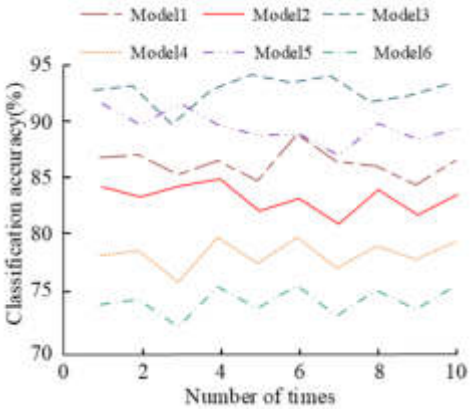


(a) F1 Values of Different Models on the Dataset

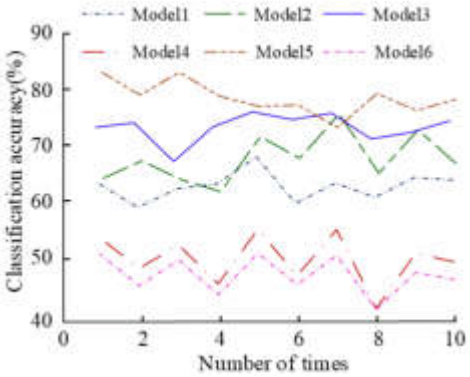


(b) Accuracy Values of Different Models on the Dataset

Fig. 4.8: Classification results of four algorithms



(a) Classification Results of Improved MVCNN model



(b) Accuracy Values of Different Models on the Dataset

Fig. 4.10: Classification Results of CNN model

complex model 6. This indicated that the improved MVCNN model was more accurate and stable in terms of classification accuracy.

Other algorithms were added for comparison to further validate the performance of the improved MVCNN model designed by the research. Comparison algorithms include Convolutional Autoencoder (CA)-based unsupervised noise rejection method, Classification and Regression Tree (CART), K-Nearest Neighbor (KNN), and Evolutionary Spike Neural Network (ESNN). The Root Mean Square Error (RMSE) index was used to better reflect the classification performance of the algorithm designed by the research on 3D building models. The dataset used in the experiment was also UrbanScene3D and MSBuilding. The comparison results of different RMSE algorithms are shown in Table 4.2.

From Table 4.2, the maximum RMSE of the improved MVCNN algorithm was 2.58% on the UrbanScene3D dataset, while the minimum RMSE values of CA, CART, KNN, ESNN, and MVCNN were 7.91%, 6.55%, 7.11%, 5.78%, and 3.99%, respectively. The maximum RMSE value of the improved MVCNN algorithm was

Table 4.2: Comparison results of different RMSE algorithms

Algorithm	Data set									
	UrbanScene3D					MSBuilding				
	Number of experiments					Number of experiments				
	1	2	3	4	5	1	2	3	4	5
CA	7.91%	10.82%	11.43%	8.95%	10.77%	9.32%	10.58%	12.79%	11.21%	9.68%
CART	6.55%	7.43%	8.95%	8.21%	7.32%	8.42%	7.38%	7.64%	8.77%	9.49%
KNN	7.59%	9.42%	10.67%	8.37%	7.11%	7.61%	8.73%	8.92%	10.85%	9.19%
ESNN	5.78%	6.42%	5.88%	7.01%	5.95%	6.35%	5.70%	7.03%	6.47%	6.51%
MVCNN	4.99%	4.03%	5.09%	4.27%	3.99%	4.86%	4.67%	4.12%	5.04%	4.65%
Improved MVCNN	2.51%	2.17%	2.58%	2.12%	1.89%	1.12%	1.37%	2.08%	1.94%	2.17%

Table 4.3: Comparison of time consumption and CPU utilization of different algorithms

Algorithm	Time consuming					CPU utilization				
	Number of experiments					Number of experiments				
	1	2	3	4	5	1	2	3	4	5
CA	67.1s	78.9s	89.8s	77.7s	76.5s	27.2%	25.7%	23.8%	21.7%	22.3%
CART	58.4s	57.1s	54.0s	53.7s	54.4s	19.0%	17.8%	15.7%	18.2%	15.5%
KNN	51.7s	49.8s	48.3s	48.1s	50.4s	18.5%	16.4%	17.2%	16.2%	18.6%
ESNN	48.7s	46.5s	43.2s	41.9s	41.7s	15.8%	14.7%	16.3%	15.9%	14.1%
MVCNN	36.8s	35.4s	36.9s	35.3s	35.5s	13.2%	12.5%	13.1%	12.9%	13.6%
Improved MVCNN	18.9s	21.3s	19.1s	18.2s	18.0s	11.2%	10.0%	11.6%	10.8%	9.8%

significantly smaller than the minimum value of the comparison algorithms. The minimum RMSE values of CA, CART, KNN, ESNN, and MVCNN were 9.32%, 7.38%, 7.61%, 5.70%, and 4.12%, respectively, on the MSBuilding dataset. The maximum RMSE value of the improved MVCNN algorithm was 2.17%, which was significantly smaller than the minimum values of the comparison algorithms. Therefore, the improved MVCNN algorithm had smaller classification errors and better performance. A comparison was conducted on the classification time and CPU utilization of different algorithms to further verify the performance of the improved MVCNN algorithm. The comparison results are shown in Table 4.3.

From Table 4.3, the maximum classification time of the improved MVCNN algorithm was 21.3 seconds, while the maximum classification time of CA, CART, KNN, ESNN, and MVCNN was 89.8s, 58.4s, 51.7, 48.7, and 36.9, respectively. The classification time of the improved MVCNN algorithm was significantly lower than that of the comparison algorithm. The maximum CPU utilization of the improved MVCNN algorithm was 11.6%, while the maximum CPU utilization of CA, CART, KNN, ESNN, and MVCNN was 27.2%, 19.0%, 18.6%, 16.3%, and 13.6%, respectively. The CPU utilization of the improved MVCNN algorithm was significantly lower than that of the compared algorithms. Therefore, the improved MVCNN algorithm had the shortest time consumption, the lowest CPU utilization, and better performance.

5. Simulation result and discussion. With the development of intelligent building technology, it is gradually being applied to various aspects of the construction field, promoting the informatization development of intelligent buildings [15]. An intelligent building 3D information management system combining BIM and GIS technologies was studied and designed to efficiently manage the 3D information of intelligent buildings. An improved SIFI algorithm was adopted for feature extraction and matching of 3D information to further enhance the management ability of the system for massive information data, and the improved MVCNN algorithm was used to classify 3D information. It was found that the SIFI algorithm could accurately match 3D building information and had good performance. This is consistent with the research findings of Attila Fej é r and other experts. Experts such as Attila Fej é r used SIFI to detect the coordinates of the transformed objects and improved the SIF algorithm. The research results showed that the average accuracy and recall values of the

SIFI algorithm were 0.84 and 0.94, respectively, indicating its good performance in the fields of detection and matching (Attila et al. 2021). In addition, the improved MVCNN algorithm performed well in information classification, with the highest accuracy reaching 97.6%. This is consistent with the research findings of Starly B et al. Starly B et al. used the MVCNN algorithm and transfer learning to classify and retrieve the shapes of computer-aided design models. The research results showed that the MVCNN algorithm could efficiently classify shapes with a classification accuracy of up to 93% [29, 43, 44, 45]..

6. Conclusion. BIM and GIS technologies were combined to construct 3D IM systems to improve the intelligent buildings management. IM was mainly implemented through the improved SIFT algorithm and the improved MVCNN algorithm. According to the findings, the improved SIFT achieved the highest matching accuracy and was as high as 98.3%. Their matching accuracy rates were improved by 29.8%, 31.1%, and 37.6%, respectively, compared with the remaining three algorithms. The difference between ASIFI and the classical SIFT algorithm was small by comparing the full search rate, with the lowest being around 50% and the highest close to 90%, and the overall trend was first decreasing and then increasing. The improved SIFT algorithm was able to maintain a completion rate of over 78% and reached a maximum of 97%, a maximum improvement of 42% compared to the improved SIFT algorithm. On the UrbanScene3D dataset, the improved MVCNN achieved an F1 value of 96.4% and an accuracy of 97.6%, which was 20.2% and 13.5% higher than RF, respectively. In the MSBuilding dataset, the model had the highest F1 value of 86.8% and accuracy of 87.7%, which were 15% and 9.6% higher than the LR model, respectively. This indicated that the improved MVCNN model had significant performance advantages in the data classification of 3D building models. In summary, the proposed 3D IM method has a high accuracy rate and can effectively improve the management of intelligent buildings. However, the study does not make use of systematic data pre-processing measures in the management of 3D information of intelligent buildings. Therefore, pre-processing methods such as data conversion need to be expanded to further optimise it.

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PERFORMANCE EVALUATION MODEL OF CORPORATE FINANCIAL SUSTAINABILITY BASED ON SWARM ALGORITHM

LINGJIE CHANG*

Abstract. In traditional financial performance evaluation models, parameter settings are often too large or too small, resulting in significant model errors. To address this issue, an improved artificial bee colony algorithm was proposed and applied to optimize the parameters of performance evaluation models. This method first constructs a corporate financial performance evaluation system, and then improves the artificial bee colony algorithm with differential evolution algorithm to optimize the parameters of the long short-term memory network, in order to improve the accuracy of the long short-term memory network in corporate financial performance evaluation. The results showed that the improvement of the ABC algorithm was effective. The improved ABC algorithm converged on the Ackley function in the 800th iteration, and the ABC algorithm converged in the 1400th iteration. The evaluation error of the proposed method is the lowest, with the algorithm having the lowest four errors of -0.0121, 0.0453, 0.0683, and 0.0047, respectively. Among the other algorithms, the comprehensive error of the financial performance evaluation model based on Long Short Term Memory (LSTM) network is relatively low, but still lower than the algorithm proposed in the study. The research proposes a long short-term memory network optimized based on improved artificial bee colony algorithm, which can accurately evaluate the financial performance of enterprises, help them review their own development level, and clarify their future development direction.

Key words: ABC; Central solution idea; Dynamic adjustment factor; Financial performance evaluation; Lstm

1. Introduction. In the current fierce market competition and constantly changing financial environment, the sustainable development of corporate finance has become a focus of attention for company managers, investors, and policy makers. Financial sustainable development refers to the ability of enterprises to maintain financial health and growth potential in the long term, effectively respond to uncertain market risks, and continuously create value for shareholders. However, how to quantitatively evaluate the financial performance of enterprises and achieve sustainable development on this basis is a complex and thorny issue that requires the comprehensive application of various theories and methods. Faced with the increasingly complex financial data and operational environment of enterprises, existing performance evaluation models often struggle to capture the nonlinear relationships and dynamic characteristics in the decision-making process, making it more difficult to effectively evaluate the long-term financial sustainability of enterprises. The research aims to develop a performance evaluation model for sustainable financial development of enterprises based on bee colony algorithm. By imitating the foraging behavior of bees in nature through intelligent algorithms, the evaluation process of financial performance is optimized, and the accuracy and adaptability of the evaluation model are improved.

Innovatively applying the bee colony algorithm to performance evaluation in the financial field, utilizing its outstanding performance in optimization problems to deeply mine and intelligently analyze enterprise financial data. Research can not only provide a new and more predictive financial performance evaluation tool for enterprise management, but also provide a scientific decision support system for investors and regulatory agencies, thereby promoting long-term and sustainable financial development of enterprises. The study will conduct research on enterprise performance evaluation from four aspects. Firstly, a review of the current research status of performance evaluation models and bee colony algorithms will be conducted; Secondly, the construction of a financial evaluation model based on the bee colony algorithm; The third is experimental analysis of the feasibility of the model; Finally, there is a summary of the research content.

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2. Related Works. The construction of performance evaluation models can clarify the development direction of enterprises and promote their rapid development. A Diab et al. established a performance evaluation system for elastomers in various environments in order to study their properties in high and medium temperature environments, and the results showed that the evaluation system accurately assessed the performance indexes of elastomers at high temperatures and provided guidance for material improvement of elastomers, the evaluation system proposed by A Diab et al. is only applicable to the evaluation of material items, but it can still clarify the future improvement direction of materials [3].

LM Ciancetta et al. designed a performance feedback evaluation system to explore the performance of the rebound effect, and this showed that the system showed that people of different genders have different sensitivities to rebound-related terms, and pointed out that women are less sensitive, the performance evaluation system proposed by LM Ciancetta only considers a single indicator and does not fully consider the evaluation objectives [4].

AI Kusumah et al. designed a structural equation model led by women to investigate the mediating and reconciling role of employee performance appraisal, and hotel employees. The transformational leadership has a prominent active influence in employee performance and provides a clear direction for the company's leadership development program, the employee performance evaluation system proposed by AI Kusumah only focuses on the performance evaluation of leadership level employees, and pays less attention to the performance evaluation of basic employees [5].

To study the performance appraisal effect on employee career development, L Rahayu et al. surveyed a sample of employees in a logistics company through questionnaires and least squares data analysis, verifying that performance appraisal also exists active impact on worker's career development has a positive and significant impact, and based on this result, this logistics company improved the performance appraisal, conducted vocational skills training for employees, and increased the staff's identification with the company, the performance evaluation proposed by L Rahayu only focuses on employee skill training and does not pay attention to the development status of the enterprise [6].

MP Soni et al. In order to study the impact of gender differences in performance appraisal, they used a closed-ended questionnaire and controlled for factors such as the educational background of the respondents, and the results showed that the impact of gender differences on performance appraisal , mainly focused on the perceived basis of employees' work-oriented behavioral attitudes, the method proposed by MP Soni has a very clear subjectivity in data sources and lacks objective facts, therefore, the evaluation effect of the system is poor [7].

MT Kuo et al, in order to find the best scheduling strategy for energy storage devices when self-healing after fault detection in microgrid, proposed the Artificial bee colony (ABC) and applied it to the operation scheduling strategy of energy storage devices, and the results showed that the control of energy storage devices by ABC can meet the resource demand of microgrid and reduce the peak load in critical period, However, the parameter settings in this method are relatively vague and can still be adjusted [8].

W Alomoush et al, in order to solve the problems of fuzzy C-mean algorithm in image segmentation, which cannot relate to the context, high noise sensitivity and easy to fall into local optimum, proposed ABC algorithm built on fuzzy clustering, and the results showed that the comprehensive performance of this method is more excellent compared with other statistics, this algorithm only solves the problem of fuzzy clustering easily falling into local optima, and its performance is still poor when facing complex data [9].

X Wang et al, to address the matter that it is difficult to efficiently and accurately perform single inversion for stratigraphic parameters Wang et al. proposed an inversion method combining ABC and damped least squares algorithm to solve the problem of inversion and reconstruction of stratigraphic parameters in a single inversion, and the results showed that the method has not only the advantage of ABC, but also the high accuracy and fast convergence of damped least squares algorithm, this method is prone to getting stuck in local optima when using ABC to optimize the parameters of the least squares method [10].

R Yao et al. found that the hysteresis model is complex and non-differentiable, which leads to the complexity of gradient acquisition, and to solve this problem, the authors proposed an improved ABC and used it for the identification of lag parameters, and finally verified the feasibility of the method in the identification of nonlinear hysteresis parameters, although this method improves the identification performance of nonlinear

Table 2.1: Detailed information of the literature survey

Author	Method	Defect
Diab	Elastomer performance evaluation systemElastomer performance evaluation system	Not universal
LM Ciancetta	Emotional rebound evaluation system	No men were considered
AI Kusumah	Employee performance evaluation system	For employees only
L Rahayu	Questionnaire survey	Do not pay attention to the enterprise development
MP Soni	Questionnaire survey	Too many subjective factors
MT Kuo	ABC	The parameter setting is not reasonable
W Alomoush	A fuzzy clustering approach based on the ABC	Easy to fall into the local optima
X Wang	Combining ABC and damping least-squares methods	Easy to fall into the local optima
R Yao	Improve ABC	The parameter setting is not reasonable
Tuncer	ABC	The improvement effect is not obvious
Xu W	LSTM	The defects were summarized but not resolved
Xu Y	LSTM	It is easy to show the overfitting phenomenon
Punia S	Combining LSTM with random forest algorithms	It is easy to show the overfitting phenomenon
Chen C	And the LSTM based on deep learning	The training sample demand is too high

hysteresis parameters, it does not consider the identification problem of other linear parameters [11].

A Tuncer found that the traditional algorithm, can only provide small-scale solutions for the N-puzzle problem, to achieve the solution of the 15-puzzle problem, the authors proposed a new algorithm built on the metaheuristic algorithm, which divides the puzzle, and uses ABC to solve the divided the results show that the method helps significantly in solving the 15-puzzle problem, this method only divides the problem, simplifies the solving steps, but has little effect on the solving calculation of the problem [12].

Long and short memory network is widely used in the field of data prediction, XuW et al. In order to evaluate the prediction effect of LSTM for river flow, the results show that the full connection layer will reduce the learning efficiency of LSTM, leading to poor training effect, the author effectively evaluated the influence of LSTM parameter setting on its performance, but did not propose how to optimize [13].

In order to assess post-earthquake disasters, XuY et al proposed a framework based on LSTM. The results show that the framework is effective in assessing disasters, but this method causes overfitting phenomenon due to parameter setting problems [14].

A regression prediction method combining LSTM with the random forest algorithm was constructed and examined in true multivariate datasets. The results show that the statistical effect of this method is better, but the demand for parameters of this method is high, and the fitting phenomenon has appeared [15].

Chen C In order to improve the accuracy of rainfall prediction, et al. proposed a LSTM network based on deep learning. The results showed that LSTM predicted better, but the training sample of this method team is large, and the data acquisition is difficult [16].

To sum up, through the careful investigation of relevant literature, it can be found that most of the existing performance evaluation system for employees, regardless of the enterprise comprehensive financial performance, the traditional ABC algorithm in the training process has been fitting or into local optimal situation, and LSTM in data prediction, there are parameter optimization and data acquisition difficulties. Therefore, an enterprise financial performance evaluation system was studied, constructed, and the ABC algorithm was improved to optimize the optimization process. Then the optimized ABC algorithm was used to optimize the LSTM parameters and realize the adjustment of LSTM parameters. Finally, LSTM is used to evaluate the financial performance of enterprises, so as to realize the future development direction planning. Details of the references of the study investigated in related work are shown in Table 2.1.

3. Construction of financial evaluation model based on swarm algorithm.

3.1. Index system construction of LSTM-based financial performance evaluation model. The performance evaluation system has a certain guiding effect on the self-reflection of enterprises. In the business world, the main body is small and medium-sized enterprises, and large enterprises and small and micro enterprises are only a few, so the financial performance evaluation model designed by the research is designed

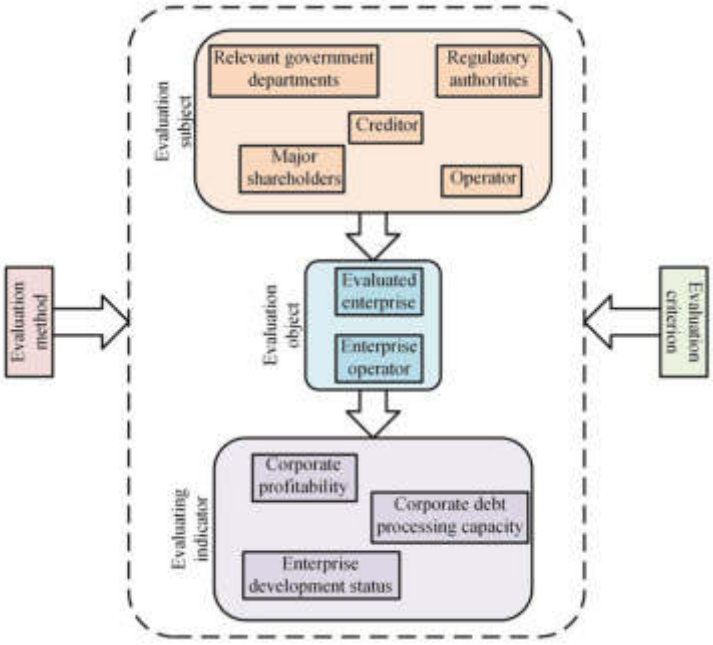

Fig. 3.1: General structure diagram of the evaluation model

for small and medium-sized enterprises (SMEs), and the financial performance evaluation model is usually composed of the following five basic elements. The first is the evaluation subject, the evaluation subject is generally the enterprise's stakeholders, the evaluation subject of SMEs is more complex, including enterprise shareholders, operators and relevant government departments, etc. The evaluation indexes of each rating subject are different, such as shareholders are generally based on the profitability of the enterprise and the rest of the indexes are supplementary, operators are based on the development content of the enterprise's operation status and enterprise development vitality, and relevant government departments are based on the social value of the enterprise. The second is the evaluation object, the evaluation object is the evaluated enterprise, and the operator of the enterprise, the evaluation object indicators, determined by the content of the evaluation subject, the third is the evaluation indicators, evaluation indicators are used to reflect the performance of the evaluation object in various aspects, the fourth is the evaluation criteria, evaluation indicators are based on the evaluation criteria, the performance of the evaluation object is evaluated, if Without evaluation criteria, the evaluation model is meaningless, and the fifth is the evaluation method, a suitable evaluation method can correctly and objectively reflect the performance of the evaluation object in all aspects. Fig. 3.1 lists the general structure of the evaluation model [1, 7].

SMEs are different from large enterprises, which usually have the following four development characteristics. Firstly, the scale of operation is small, SMEs are still in the adolescent stage in the life cycle of an enterprise, only having passed the infant and child stage with the help of capital, and have a larger scale compared to small and micro enterprises, but from the social level, the scale of operation of SMEs is still far from adequate. Secondly, the growth potential of SMEs is large, although the scale of SMEs is still small, but because they have broken through the early growth constraints, they can obtain a large amount of capital support with the help of listed financing and other means, so that they can develop rapidly, thirdly, the quality of enterprises is high and the level of debt is low, small and medium-sized enterprises are not at the early stage of development, the volume of investment and financing from various parties is low, and their own financial leverage Finally, the ability of sustainable operation is good, and SMEs can show good stability in the face of financial crisis and other problems, so that they will not collapse under the wave of financial crisis. The performance evaluation system of large enterprises has been relatively mature, as listed in Table 3.1 [18].

Table 3.1: Financial Performance Evaluation System for Central Enterprises

Asset status	Weight (%)	performance			
		Primary indicators	Weight (%)	Secondary indicators	Weight (%)
Profitability	34	Net asset income	19	Sales profit margin	11
				SSCM	8
		Total asset return	15	Cost-profit ratio	7
				RAROC	8
Asset	22	Asset turnover	16	Fixed asset ratio	9
				Current asset turnover	7
		Account turnover rate	6	cash recovery rate	6
Debt situation	22	Debt	13	quick ratio	7
				Current cash to liability ratio	6
		interest earned	9	Interest bearing debt ratio	5
				Debt ratio	4
Development status	22	Profit growth rate	10	Profit growth rate	10
		Total asset appreciation rate	12	Total Assets Growth Rate	6
				Technology investment ratio	6

The performance evaluation system constructed by the study focuses on SMEs, and the selection of financial performance evaluation indicators for SMEs should be based on the following four principles: first, systematicity, second, operability, third, comparability, and fourth, measurability. Inspired by Table 2.1, the study takes enterprise profitability, asset status, solvency and development capability as the primary indicators of enterprise financial performance evaluation, and sets up a total of 18 secondary indicators under the primary indicators. Under the indicator of profitability, there are five secondary indicators, namely Return on equity (ROE), Return on Total Assets (ROTA), Operating margin (OM), Ratio of Profits (RPC), and financial leverage coefficient (FLC), which are calculated in Equation (3.1).

$$\begin{cases} ROE = \frac{N}{A} \times 100\% \\ ROTA = \frac{P}{ATA} \times 100\% \\ OM = \frac{OP}{OR} \times 100\% \\ RPC = \frac{TP}{TC} \times 100\% \\ FLC = \frac{TP+IE}{TP} \times 100\% \end{cases} \tag{3.1}$$

In Equation (3.1),N represents net income for the reporting period,A represents average net assets,P represents net income,ATA represents average total assets,OP represents operating profit,OR represents operating income,TP represents total profit,TC represents total costs and expenses, andIE represents interest expense. Four secondary indicators are set under the asset position, namely Inventory turnover rate (ITR), Working capital turnover (WCT), Accounts receivable turnover rate (ARTR), and Current assets turnover rate (CTR). and current asset turnover (CAT), which are calculated in Equation (3.2).

$$\begin{cases} ITR = \frac{OC}{AIB} \\ WCT = \frac{IAO}{ABWC} \\ OM = \frac{NOI}{AAR} \\ CAT = \frac{NOI}{ACA} \end{cases} \tag{3.2}$$

In Equation (3.2),OC is operating cost,AIB is average inventory balance,IAO is operating income,$ABWC$ is average working capital balance,NOI is net operating income,AAR is average accounts receivable, andACA is average total current assets. Under solvency, five secondary indicators are set, namely Asset liability ratio (ALR), Interest bearing debt average interest rate (IBAIR), Quick ratio (QR), Dynamic debt repayment period (DDR), and Debt service ratio (DCR). Dynamic debt repayment period (DDRP), and cash ratio (CR), which

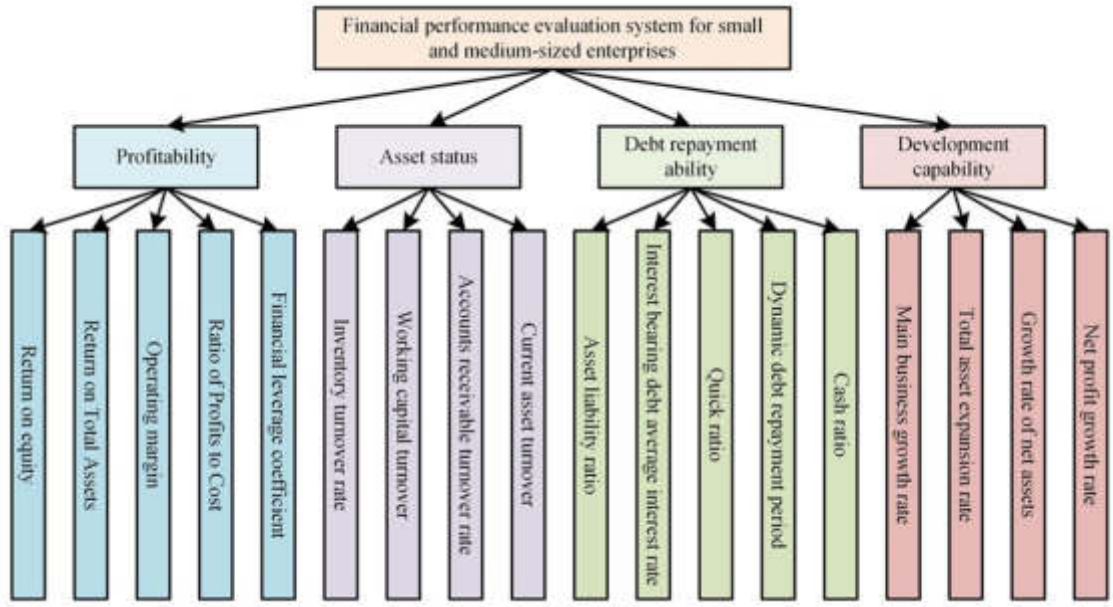

Fig. 3.2: Financial performance evaluation system for SMEs

are calculated in Equation (3.3).

$$\begin{cases} ALR = \frac{TL}{AIB} \\ IBAIR = \frac{LAO}{ABWC} \\ QR = \frac{NOI}{AAR} \\ DDRP = \frac{TL}{AOCF} \\ CR = \frac{MF+CE}{CL} \times 100\% \end{cases} \tag{3.3}$$

In Equation (3.3),TL is total liabilities,TA is total assets,IBD is interest-bearing debt,LA is quick assets,CL is current liabilities,$AOCF$ is annual operating cash flow,MF is money capital, andCE is cash equivalents. Four secondary indicators are set under development capability, namely Main business growth rate (MBGR), Total asset expansion rate (TAER), Growth rate of net assets (GRONA), Net profit growth rate (GRONA) and Net profit growth rate (GRONA), Net profit growth rate (NPGR), which are calculated in Equation (3.4).

$$\begin{cases} MBGR = \frac{C-PM}{PM} \times 100\% \\ TAER = \frac{T-TAO}{TAO} \times 100\% \\ GRONA = \frac{CNA-ONA}{ONA} \times 100\% \\ NPGR = \frac{NPG}{LY} \times 100\% \end{cases} \tag{3.4}$$

In Equation (3.4), C and PM are the main business revenue of the current and previous period. T is the total assets of the current year,TAO is the total assets of the previous year,CNA is the net assets at the end of the period,ONA is the net assets at the beginning of the period,NPG is the net profit growth of the current year, andLY is the net profit of the previous year. The financial performance evaluation system constructed by the study is shown in Figure 3.2.

Long Short-Term Memory (LSTM), an algorithm commonly used in performance evaluation, is studied as a basic method for financial performance evaluation, but the selection of its parameters is extremely important. In the LSTM algorithm, parameters such as the number of training times and the amount of hidden units will straightway affect the operation of the neural network, and the selection of parameters by experience alone will increase the training difficulty of the model and reduce the accuracy of the model, so the study uses ABC to optimize the parameter selection of LSTM [1, 9].

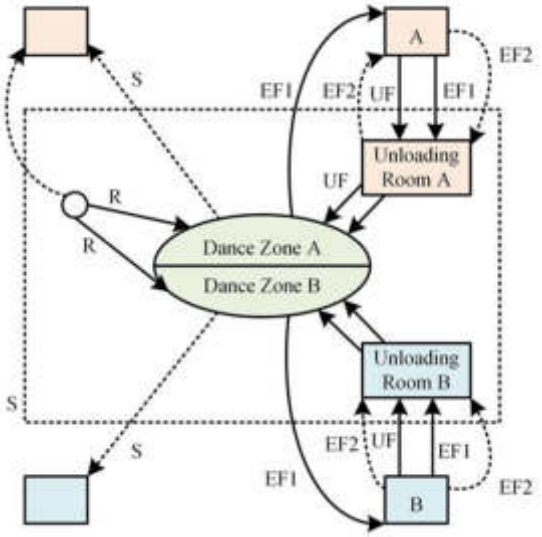

Fig. 3.3: Behavior diagram of Bees Collecting Honey

3.2. Financial evaluation model based on improved ABC. Honey bees are a swarming insect with a strict hierarchy and clear division of labor within its population. When bees go out to look for nectar sources, they have a fixed behavior pattern. Inspired by the behavior pattern of worker bees looking for nectar sources to collect honey, scholars have proposed the ABC algorithm, and the honey bee's honey collection process is shown in Figure 3.3 [20].

ABC algorithm is an intelligent optimization algorithm commonly used in image segmentation, data mining and other fields, which seeks the greatest solution by simulating the honey harvesting behavior of bees, in ABC, a honey source is the greatest plan of an issue, at the beginning of the algorithm, the honey source numbers need to be initialized, generally the number of honey sources is the same as the leading bees, assuming that the number of leading bees is B_N, the max iterations of honey sources is $Limit$, and the algorithm The max number of iterations of the algorithm is $Maxcycle$, then the bees search for the optimal honey, that is, to find the optimal solution of the objective function, as shown in Equation (3.5).

$$\min f\left(x_i\right), (i = 1, 2, \ldots, B_N) \tag{3.5}$$

The initial nectar source of the colony is randomly distributed, and the random function is given in Equation (3.6).

$$x_{i,j} = x_j^{\max} + rand\,(0,1)\left(x_j^{\max} - x_j^{\min}\right) \tag{3.6}$$

In Equation (3.6),i denotes the first$i$ honey source,j denotes the$j$ dimensional component of the solution space,$x_j^{\max}, x_j^{\min}$ is the upper and lower limits of the solution space ,$rand\,(0,1)$ denotes the random No. generated in [0, 1], and the basic flow of the ABC algorithm is shown in Figure 3.4 [21].

In the ABC algorithm, there are three kinds of bees in a colony, which are lead bees, follow bees and scout bees. After the initialization of the honey source, the lead bee determines the fuzzy location of the honey source and calculates the quality of that in the area, while the follow bee follows the lead bee and is responsible for recording the location of the optimal honey source. If a scout bee appears at this time, it will search for a new honey source location again and detect whether the maximum number of iterations is reached, or whether it meets In the ABC algorithm, each leader bee only collects its own corresponding nectar source, and if a better nectar source is collected during the collection process, the current leader bee updates the position of its own

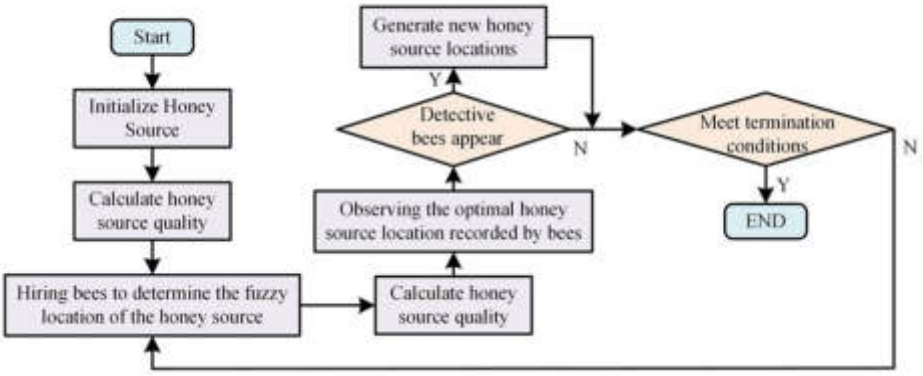

Fig. 3.4: ABC Algorithm Basic Flowchart

nectar source. In the ABC, each leader bee only collects its own corresponding nectar source, and if a better nectar source is collected during the collection process, the current leader bee updates its own nectar source location.

$$v_{i,j} = x_{i,j} + rand\,(-1,1)\,(x_{i,j} - x_{k,j}) \tag{3.7}$$

In Equation (3.7),$v_{i,j}$ denotes the location of the new nectar source,i, k denotes the first$i$ or$k$ nectar source, and$rand\,(-1,1)$ denotes the random No. generated in [-1, 1]. After searching for a new nectar source, the leader bee needs to judge the new nectar source according to the fitness function, which is shown in Equation (3.8).

$$fitness\,(i) = \begin{cases} 1/\,(1+f_i)\,, f_i \geq 0 \\ 1/abs\,(f_i)\,, f_i < 0 \end{cases} \tag{3.8}$$

In Eq. (3.8),$fitness\,(i)$ denotes the fitness function value of the$i$ honey source, andf_i denotes the objective function value of the$i$ solution. The objective function value is inversely proportional to the fitness function value, and the larger the value of the fitness function, the higher the quality of the honey source, and in each iteration, the honey source with the larger fitness function value is always retained to get the best value of the objective function. The following bee will choose a leader bee to follow and conduct a local search around the leader bee to find a better nectar source. It has been confirmed by scholars that the larger the value of the fitness function of the leader bee, the higher the probability that the follower bee will choose the leader bee.

$$P_i = \frac{fitness\,(x_i)}{\sum_{i=1}^{B_N} fitness\,(x_i)} \tag{3.9}$$

In Equation (3.9),P_i indicates the probability that the i nectar source is selected by the following bee. The fitness value of the first$i$ honey source, the percentage of the sum of the fitness values of all honey sources, that is, the probability that the leader bee at that honey source location is selected by the following bee. Therefore, after reaching the first honey source location, the following bee will generate a random value within [0, 1], if the value is smaller, it will be updated once; If it is larger than the fitness value of the honey source, it will go to the next honey source, and so on, if the If all the nectar sources are not updated, the process starts again at the first nectar source until the nectar source is updated. If the number of unrenewals reaches$Limit$, then the honey source is discarded and a new honey source is generated according to Equation (3.6) at [22]. To optimize the local search capability of ABC algorithm and the honey source location update algorithm, the central solution idea and the differential evolution algorithm are proposed in the study and applied to ABC. The

central solution idea is derived from Pontryagin's maximum principle or similar variational principles, which are based on optimal control theory and provide a systematic mathematical framework to analyze the behavior of control systems and find the optimal control strategy. To find a central solution, it is usually necessary to solve a series of nonlinear equations or inequalities, and also consider the constraints of the system, including constraints on control variables and state variables. By solving these problems, a determined optimal path can be obtained, which not only satisfies the dynamic equations and boundary conditions, but also meets the requirements of minimizing the given performance indicators. After adding the central solution idea, a central solution will be generated at the end of each swarm iteration, and the calculation of the central solution is shown in Equation (3.10).

$$x_{0,j} = \frac{1}{B_N} \sum_{i=1}^{B_N} x_{i,j}, 1 \leq j \leq D \tag{3.10}$$

In Equation (3.10),$x_{0,j}$ denotes the central solution on the$j$ th dimensional vector. DE is an evolutionary algorithm suitable for multi-objective optimization problems. DE is particularly suitable for handling continuous, high-dimensional, nonlinear, uncertain, constrained, and multimodal optimization problems, and is widely used in optimization problems in engineering design, control systems, data mining, and other scientific fields. DE is easy to implement, with fewer parameters and intuitive adjustments, making it an efficient global optimization algorithm. The algorithm continuously adapts to different problems during the iteration process, adjusting the search strategy to find the global optimal solution or acceptable solution. DE can handle various types of optimization problems, especially in nonlinear and non convex problems, demonstrating good robustness. Due to the fact that the population of DE can be dispersed for computation, this algorithm has natural parallelism and is suitable for modern multi-core processors to accelerate computation. The improvement of the differential evolutionary algorithm to the honey source location calculation is mainly to use the variational operator as the new update formula and the current optimal solution as the location update guide in the variational engineering, but in this process, due to the excessive emphasis on local search, resulting in easily falling into the local optimum, in order to solve the problem, the research not only combines the central idea in the basic algorithm, but also combines the dynamic adjustment factor, combined with the dynamic adjustment factor. After combining the dynamic adjustment factor, it can make the basic algorithm and can automatically adjust the search range, which combined with the dynamic adjustment factor is demonstrated as Eq.(3.11).

$$v_{i,j} = x_{0,j} + \varphi\omega \left(x_{i,j} - x_{0,j}\right) \tag{3.11}$$

In equation (3.11),ω is the dynamic adjustment factor, which is calculated in equation (3.12).

$$\omega = \omega_{\max} + \frac{\left(\omega_{\max} - \omega_{\min}\right)\left(iter_{\max} - iter\right)}{iter_{\max}} \tag{3.12}$$

In Equation (3.12), $iter_{\max}$ is the max iterations,$iter$ denotes the current iterations, and$\omega_{\max}, \omega_{\min}$ is a constant that indicates the honey source search range of the bee colony. The study applies the optimized ABC to the LSTM-based financial performance evaluation model, keeping the structure of the LSTM model unchanged, to find out the global optimum of the parameters and improve the accuracy of the performance evaluation model according to the objective function, which is displayed in Equation (3.13).

$$loss = \frac{\sum \left(y_i - y_{true}\right)}{n} \tag{3.13}$$

In equation (3.13),y_i is the model evaluation value,y_{true} is the true value,$loss$ the target loss value, and$n$ is the sample size. The smaller the loss value of the objective function, the more accurate the model is. The study chose the Adam algorithm in the learning algorithm of the LSTM algorithm, which is calculated as shown in Equation (3.14).

$$f\left(x\right) = \frac{1}{1 + \ell^{-2x}} \left(0 < f\left(x\right) < 1\right) \tag{3.14}$$

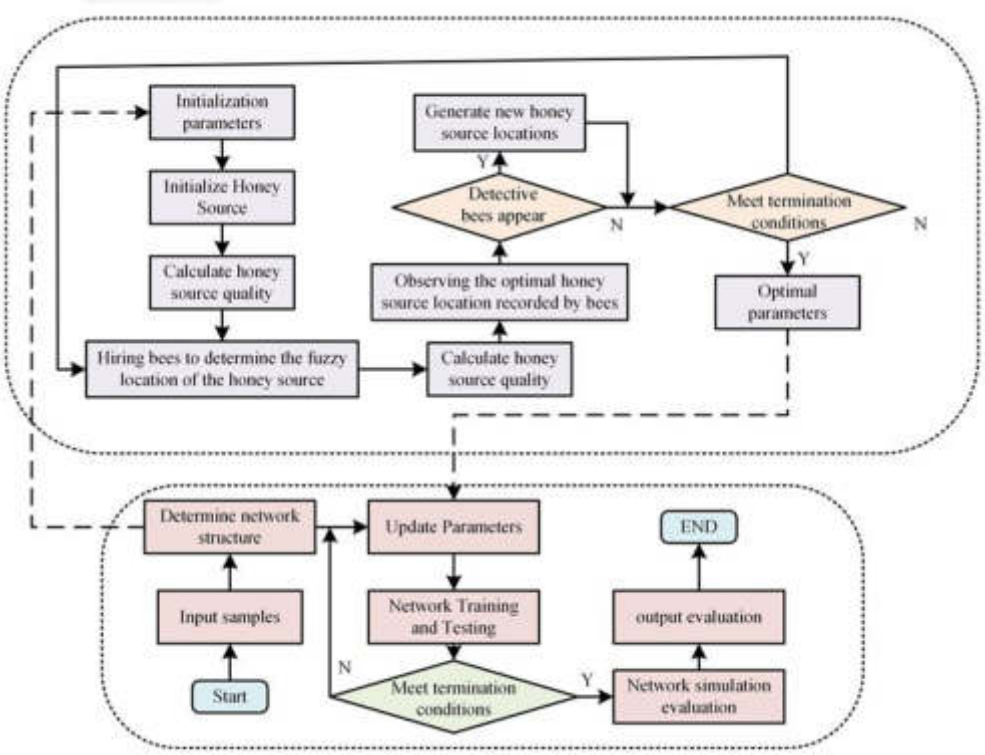

Fig. 3.5: LSTM algorithm flowchart for ABC algorithm optimization

In Equation (3.14),x denotes the parameters. The activation function of the algorithm is shown in Equation (3.15).

$$g(x) = \frac{1-\ell^{-2x}}{1+\ell^{-2x}} \, (-1 < g(x) < 1) \tag{3.15}$$

The flow of the LSTM algorithm optimized using the ABC algorithm is shown in Figure 3.5.

4. Simulation results analysis of the financial performance evaluation model grounded on ABC.

4.1. Performance analysis of LSTM algorithm optimized by improved ABC. To verify the effectiveness of the study on the improvement of the ABC, the study simulated the optimal solution of the Sphere and Rosenbrock function using the improved algorithm in the simulation environment of MATLAB 7.0, and the results are shown in Figure 4.1.

Figure 4.1(a) shows the simulation of solving the optimal solution of the two algorithms for the Ackley function. Fig. 4.1(b) is the simulation of solving the optimal solution of the two functions for the Griewank function. In Figure 6(a), the improved ABC completes the convergence of the optimal solution at the 800th iteration, and the ABC algorithm completes the convergence of the optimal solution at around the 1400th iteration. In Fig.6(b), the improved-ABC obtains the optimal solution at the 400th iteration and completes convergence at the 1000th iteration, and the ABC obtains the optimal value only at around the 1000th iteration and does not complete convergence at the 2000th iteration. The study was conducted after completing the comparison of improved ABC with ABC for the training situation of the LSTM model, and the results are displayed in Figure 4.2.

Figure 4.2(a) shows the variation of the mean square error in the model training, and Fig. 4.2(b) shows the variation of the loss degree in the model training. In Figure 4.2(a), the mean square error (MSE) of the

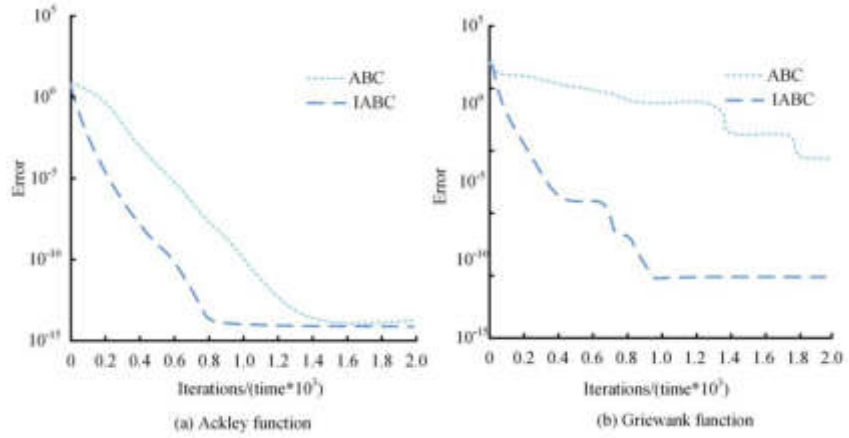

Fig. 4.1: Comparison of Improved ABC and ABC for Function Optimal Solution

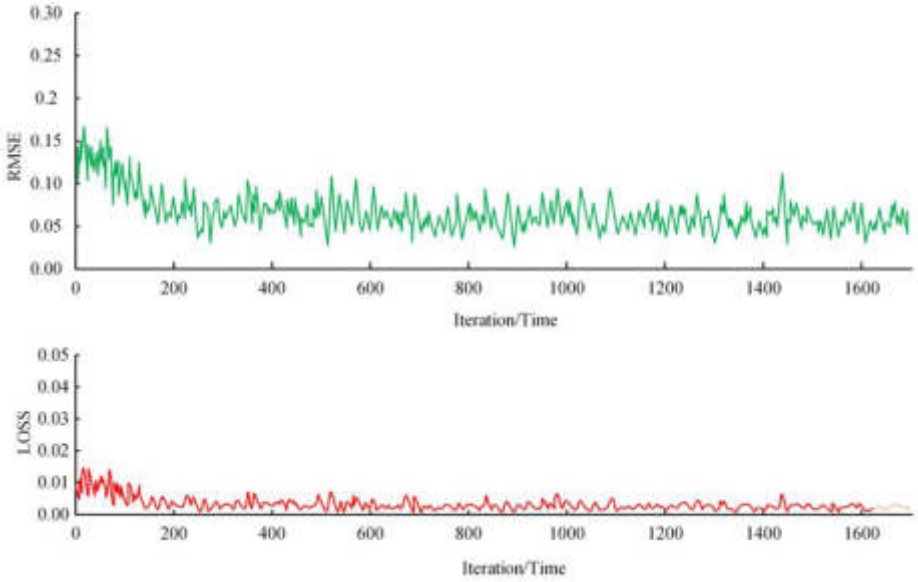

Fig. 4.2: Training Results of LSTM Network Mode

model gradually decreases with the increase of the iterations before 200, and the MSE of the model tends to be smooth after the number of iterations is higher than 200. In Fig. 4.2(b), the loss degree of the model gradually decreases to less than 0.01 before 200 iterations, and the loss degree of the model tends to be smooth and no longer decreases and tends to 0 above 200 iterations.The study finally compares the errors of the LSTM financial performance evaluation model based on the improved ABC optimization with those of the commonly used performance evaluation models such as the LSTM-based financial performance evaluation model. The results are shown in Figure 4.3.

In Figure 4.3, it can be seen that all the errors of the algorithms are lower than the other algorithms, and the ABC-LSTM algorithm has an MBE value of -0.121, MAE value of 0.0453, MSE value of 0.0683, and RMSE value of 0.0047, which is basically the same as the algorithm, and the cluster analysis algorithm has the lowest MSE value of 0.0908, and its error variation with the algorithm.

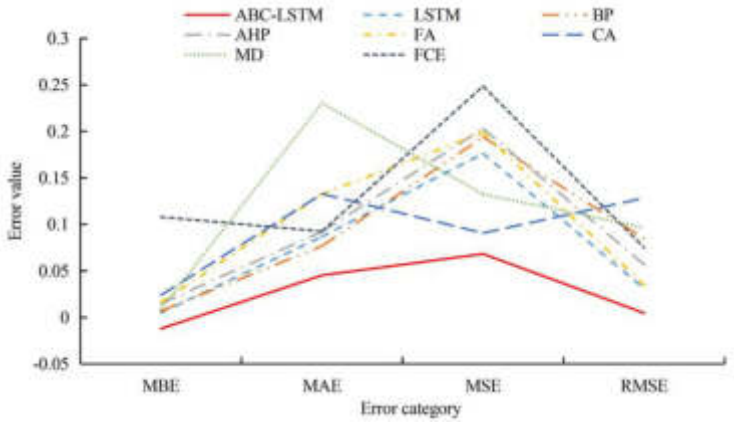

Fig. 4.3: Error Comparison of Performance Evaluation Models

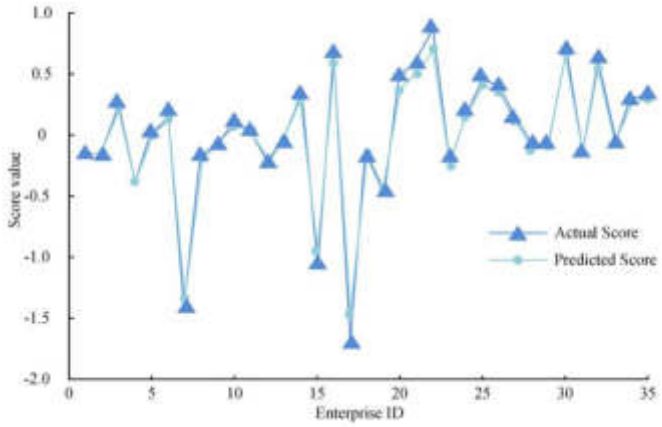

Fig. 4.4: Algorithm fitting result

4.2. Simulation results analysis of the performance evaluation model. After verifying the performance of the method proposed by the study, the study fitted the model's score for a firm to the actual score value of that firm, and the results are shown in Figure 4.4.

In Fig. 4.4, the predicted scores of the model proposed by the study fit well with the actual score values of the enterprise, where sample No. 17 has the worst fit with an error of about 0.25, samples No. 14, 15, 16, 20, 21 and 22 have the second best fit with an error less than or equal to 0.1, and the rest of the samples have an extremely good fit. The study concluded that the model has met the requirements of financial performance assessment, and then the study used the model to evaluate the financial performance of 25 samples randomly selected from SMEs in a country for the first-level indicators, and Table 4.1 shows the results.

As can be seen in Table 4.1, about half of the 25 enterprises have a composite score below 0. Among the four primary indicators of these enterprises with a score below 0, three of them have a negative score. In order to further observe the situation of these enterprises, the secondary indicators of some enterprises with negative scores were evaluated, and the specific scores are shown in Table 4.2.

In Table 4.2, it can be seen that the lowest score of TAER is -5.387 among the 18 items evaluated by company #2, and the lowest score of CAT is -8.920 for sample #7. Although sample #17 has the lowest overall score, its score for each item is not the lowest , and the lowest score of OM is -6.012 for sample #17. 8 of the

Table 4.1: Score of Enterprise Level 1 Indicators

Enterprise ID	Profitability	Asset status	Debt repayment ability	Development capability	Comprehensive score
1	0.156	-0.083	-0.674	-0.510	-0.149
2	-0.112	0.351	-0.337	-0.965	-0.150
3	0.270	0.138	0.475	0.167	0.220
4	-0.013	-0.928	-0.628	-0.268	-0.41
5	0.103	0.036	0.332	-0.602	0.002
6	0.334	0.356	-0.258	-0.262	0.132
7	-0.185	-5.301	-0.345	0.058	-1.340
8	0.221	-0.374	0.148	-0.127	-0.192
9	-0.175	0.331	-0.457	-0.002	-0.067
10	0.451	0.149	-0.667	-0.062	0.079
11	-0.224	0.767	-0.419	0.041	0.038
12	0.102	-0.074	-0.762	-0.702	-0.205
13	-0.074	0.441	-0.336	-0.378	-0.030
14	0.812	0.274	-0.437	0.021	0.320
15	-2.460	0.384	-0.198	-0.362	-0.951
16	1.128	0.512	0.476	-0.168	0.586
17	-4.018	0.653	-0.168	-0.531	-1.453
18	-0.234	0.338	-0.398	-0.501	-0.147
19	-0.852	.167	-0.352	-0.598	-0.439
20	-0.721	0.074	-0.218	5.384	0.378
21	0.637	0.682	-0.135	1.052	0.517
22	2.193	0.329	-0.827	-0.034	0.689
23	-0.035	-0.753	-0.118	-0.002	-0.244
24	0.006	-0.203	1.629	-0.345	0.163
25	0.673	0.384	0.405	0.061	0.411

Table 4.2: Score of Enterprise Secondary Indicators

/	2	7	9	12	15	17	18	1 9	23
ROE	0.231	-0.321	0.233	-2.311	3.231	-0.421	0.561	-0.321	-0.321
ROTA	-0.084	-0.361	-0.056	-3.321	-2.284	-0.381	2.684	-0.381	-0.121
OM	-0.358	3.012	-0.358	2.412	-1.358	-6.012	-3.368	2.015	-1.122
RPC	-0.121	-3.842	-0.141	-3.342	-3.121	1.442	-1.521	1.642	-3.432
FLC	0.084	-2.382	0.086	-2.372	3.084	2.382	-0.684	-3.882	-2.651
ITR	0.135	-0.351	0.835	-5.351	2.135	-1.331	3.135	-1.451	2.348
WCT	1.352	-2.384	1.362	-2.384	3.352	-3.374	-2.352	-2.286	3.014
ART	-0.130	-3.350	-0.150	-3.255	-2.130	-3.450	-0.130	-2.340	-3.450
CAT	0.653	-8.920	0.753	-2.920	1.653	3.720	0.453	-4.620	2.820
ALR	0.135	-0.341	0.125	-2.341	2.335	3.541	1.125	-0.131	1..341
IBDAI	-1.380	1.320	-1.980	1.892	-2.380	3.120	-3.150	-1.220	1.389
QR	-0.290	-0.384	-0.290	-0.484	-3.290	-2.414	1.691	-2.331	-1.364
DDRP	0.009	-2.384	0.039	-2.399	1.239	1.344	-1.139	1.384	-3.364
CR	1.235	0.312	1.835	0.319	2.235	1.132	-1.465	0.308	1.312
MBGR	0.061	-0.251	0.361	-0.161	4.361	-3.251	1.261	-0.281	0.451
TAER	-5.387	1.382	-5.379	1.366	-4.387	3.322	-2.782	-0.312	-2.382
GROA	-1.248	0.348	-1.292	0.368	-2.348	-3.148	-2.360	-1.257	-1.348
NGR	-0.310	0.320	-0.390	0.840	2.315	3.210	1.330	0.620	2.820

18 items scored by 17 have negative scores for the indicators. Among the items with positive scores in sample 17, the highest score was the CAT score, which was 3.720.

5. Conclusion. In order to verify the effectiveness of the ABC algorithm improvement, the optimal solution solving simulation of the Sphere function and Rosenbrock function was conducted in MATLAB 7.0. The experimental results show that the improved ABC algorithm obtains the optimal solution and completes convergence after 800 and 400 iterations, respectively, while the original ABC algorithm requires more iterations.

Subsequently, the training of the LSTM model showed that after 200 iterations, the mean square error and loss of the model reached a stationary state. The model compares the financial performance score of the enterprise with the actual score and finds that the predicted results of the model are consistent with the actual situation. The MBE value of the ABC-LSTM algorithm is -0.121, the MAE value is 0.0453, the MSE value is 0.0683, and the RMSE value is 0.0047. Among the algorithms, the clustering analysis algorithm has the lowest MSE value of 0.0908, indicating the best performance of the proposed algorithm. In the first level indicator evaluation of 25 samples of small and medium-sized enterprises, more than half of the enterprises have a comprehensive score below zero. The research has confirmed the effectiveness of the LSTM model optimized based on the improved ABC algorithm in enterprise financial performance evaluation. The proposed enterprise financial performance evaluation method can accurately evaluate the development of enterprise financial performance, help enterprises clarify their future development direction, and make their development more stable and rapid. Although the method proposed in the study can accurately evaluate the development status of a company's financial performance, the computational cost of this method is relatively high. Future research can further optimize algorithms to reduce computational costs and verify algorithm stability in changing environments, in order to be more widely applied to actual financial performance evaluation.

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LANDSCAPE IMAGE DEFOGGING SYSTEM BASED ON DCP ALGORITHM OPTIMIZATION

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Abstract. As the global climate environment deteriorates gradually, the collected images are covered by fog, which reduces the clarity of the images. Therefore, the processing of fog images is very important. In landscape image defogging research, the defogging process may be affected by factors such as data quality, noise interference, and computational efficiency. To improve the defogging effect of landscape fog images, a landscape image defogging system was put forward with the optimization of dark channel prior algorithm. The image defogging algorithm was combined with the improved atmospheric scattering model estimation algorithm and the dark channel convolutional network image defogging algorithm to achieve image defogging. The atmospheric light estimation method based on atmospheric scattering model combined transmittance map and grayscale map information to achieve optimization of defogging effect. In the improvement of the dark channel prior algorithm, a convolutional network was introduced for feature extraction to enhance the smoothing of image brightness changes and transmittance estimation. The research findings demonstrated that the signal-to-noise ratio of the image defogging algorithm estimated by the atmospheric scattering model could reach up to 19dB, which was about 15.4% higher than that of existing 5 image defogging algorithms on average, indicating that the image resolution of the algorithm was higher after defogging. In the Reside dataset, the image defogging algorithm based on dark channel prior increased the signal-to-noise ratio by about 9.5%, the average gradient by about 10.4%, the structural similarity by about 12%, and the information entropy by about 5.8%, indicating that the effect of the algorithm was stable and the image defogging effect was good. The dark channel convolutional network image defogging algorithm had less running time and reduced the complexity of the defogging structure, by contrast, it reduced the running time by about 67%. The average scores for the operability, stability, and defogging effect of the system were 9.87 points, 9.85 points, and 9.54 points, respectively, indicating good performance of the system. The user feedback on natural landscape fog maps, architectural landscape fog maps, and historical landscape fog maps is good, and the user experience is high.

Key words: Image defogging; Atmospheric scattering model; Dark channel prior; Landscape image; Signal-to-noise ratio

1. Introduction. Humans intuitively feel the world through vision, and visual images carry a lot of information about objects [1]. According to statistics, 75% of human information comes from visual images. Image is a way of information transmission, which contains a variety of information. The compressed space is smaller, which is benefit to improve the propagation speed, and the propagation distance can be further explored [2]. As the speed growth of science and technology and the improvement of human living standards, cameras, mobile phones and other devices can obtain images through the camera function. Image technology is widely used in traffic navigation, tourism guide and other fields, which helps human to obtain useful information and further improve work efficiency [3]. In image acquisition, the camera equipment will encounter the impact of environmental factors such as fog and stratification, resulting in the reduction of the clarity of the image acquisition, which seriously affects the subsequent image processing work [4]. The development of modern industry leads to the aggravation of environmental pollution, and the most representative is the fog weather, which seriously affects human life and work, especially the traffic [5]. The image acquisition of the camera equipment includes target scene reflection imaging and natural or artificial light source projection imaging. In hazy weather, optical fiber scattering is serious, which reduces the clarity and contrast of imaging, leading to the loss of image information [11]. To improve the function of landscape image defogging (IDF), a system based on dark channel prior (DCP) algorithm was raised in this paper. IDF was completed by improving the DCP image processing technology to improve users' system experience. The research is divided into four parts. The first part is a summary of the research on the existing IDF algorithm. The second part is the research on the landscape IDF algorithm and the design of the landscape IDF system optimized based on the DCP

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algorithm. The third part is the effect verification of the landscape IDF algorithm and system optimized based on the DCP algorithm. The fourth part is the summary of the whole article.

2. Related Works. IDF enhances the contrast and color saturation of the image, thus making the image more vivid and stark. D. Fan's research team proposed a dark channel iterative defogging algorithm based on pixel-level atmospheric illumination map, built a relationship model combining fog density and depth of field, and realized the optimal control of defogging degree by iteration. It was proved that the algorithm could well solve the problem of sky oversaturation [7]. Zhao research group proposed an IDF algorithm design, which realized the quantization optimization of atmospheric illumination by using pixel average, and introduced the understanding edge order factor to find pixel position. The laboratory findings demonstrated that the algorithm could correct the effect of white area in the image [8]. Long et al. put forward an IDF algorithm based on field programmable gate array (FPGA), which used data transmission module to realize data interaction and combined with convolutional neural network (CNN) to realize IDF. The research results showed that the algorithm had good adaptive ability [9]. He research group proposed a comprehensive IDF network based on the improved atmospheric scattering (AS) model and the fusion of attention features, and combined with the five-layer convolutional network to achieve image restoration. The experiment outcomes expressed that this method could effectively defog and has good stability [10]. Sun group proposed a three-channel RGB unmanned aerial vehicle IDF method based on the non-local feature structure tensor, combined with the dark channel theory to build an IDF model, and used the image non-local tensor to protect the image edge information. The research findings denoted that this method could effectively avoid the halo effect [11]. The DCP defogging algorithm relied on the AS model for defogging processing. Through the observation and summary of massive images with fog and without fog, some existing mapping relationships were obtained. Rafid Hashim's team used color space and DCP to realize single fog image processing, and used adaptive histogram equalization to adjust contrast and brightness. The analysis outcomes demonstrated that the image quality value of this method was high [18]. Sun et al. proposed an improved real-time IDF algorithm based on DCP and fast weighted guided filtering. K-means algorithm was used to achieve clustering of bright and dark areas in images, and the transmission map was generated by combining fast weighted guided filtering algorithm. The research outcomes expressed that this method could effectively improve the color difference and retain more image details [13]. The research team of K. Ke proposed a single IDF algorithm based on the DCP principle. Combining the median and minimum filters could obtain the accurate acquisition of the dark channel value. And combined with the AS model could obtain the fog free image. The experimental findings illustrated that the algorithm could effectively improve the degradation of image quality [14]. Aiming at the sparsity of dark channel, the research group of X. Yu proposed an IDF method based on fractional DCP, which used fractional dark channel to realize kernel estimation of intermediate image, and used semi-quadratic splitting to solve non-convex problem. The laboratory findings indicated that this method had a good effect in synthesizing real image [15]. Kwak research team proposed the optical flow technology based on the Lucas-Kanade method to detect the area of smoke, and realized the image preprocessing by using the DCP, and combined with the CNN to determine the properties of the region. The outcomes denoted that the accuracy of the method was 4% higher than that of the object detection model without image preprocessing [16].

To sum up, many scholars and researchers have conducted a great deal of research and design for IDF and DCP algorithms, but the applicability of these models and algorithms still needs to be improved. Therefore, this paper proposed a landscape IDF system optimized based on DCP algorithm, hoping to improve the function of landscape IDF and enhance the user's visual experience.

3. Landscape IDF Algorithm. In this chapter, DCP theory and clustering segmentation quad fork number are used to promote the IDF algorithm, and the algorithm estimated by AS model is proposed. The initial transmission of AS is calculated with logarithmic transformation adaptive, and the transmission optimization is completed with L1 regularization.

3.1. IDF Algorithm Based on AS Model Estimation. At present, the environmental problems are relatively serious, such as the frequent occurrence of extreme weather such as fog and sand dust, so that the quality of outdoor landscape image acquisition is seriously reduced, which influences the effectiveness of computer vision system. The degraded image restoration has become an important part of image processing

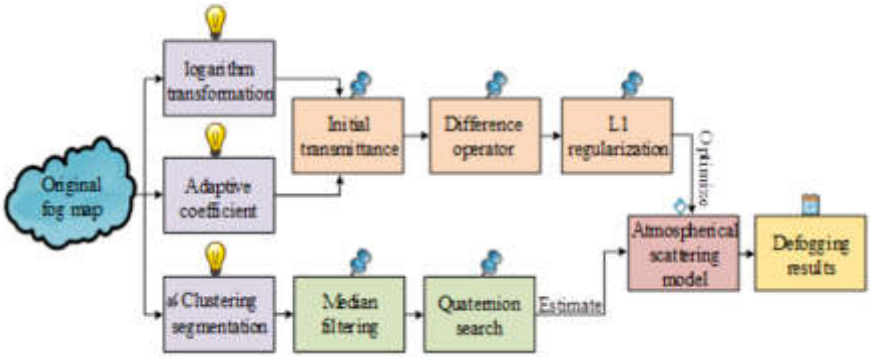


Fig. 3.1: The Principle of IDF Algorithm Based on AS Model Estimation

[17]. Based on the AS model, the DCP uses the gray law of clear outdoor images to define the channel of low pixel gray points as the dark channel. When not considering the interference of brighter areas such as the sky, there is at least one color channel in the RGB three channels of each pixel's neighborhood that has a minimum brightness value approaching 0. These very low pixel grayscale are called dark pixels. The expression of the image dark channel is shown in equation 3.1.

$$J^{\text{dark}}(x) = \min_{y \in \Omega(x)} \left(\min_{c \in \{r,g,b\}} J^c(y) \right) \Rightarrow 0 \tag{3.1}$$

In equation 3.1, the dark channel of the image is denoted by $J^{\text{dark}}(x)$. The central neighborhood window of the pixel point $J^{\text{dark}}(x)$ is denoted by $\Omega(x)$. The pixel points in the neighborhood $\Omega(x)$ are indicated by y, and one of the RGB channels of the fog free image is expressed by $J^c(y)$. The existing DCP algorithm has limitations such as Halo effect in its defogging effect. Therefore, the research improves the DCP algorithm and proposes an IDF algorithm based on AS model estimation. The principle of the algorithm is shown in Figure 3.1. The transmittance estimation of DCP is insufficient. This study improves the estimation methods of transmittance and atmospheric light, and combines logarithmic transformation to improve the adaptive ability of transmittance to defog, so as to improve the distortion in the mutation region. The foggy image degradation model is shown in equation 3.2 after small channel processing.

$$t(x,y) = \frac{\min_{c \in \{r,g,b\}} A - \min_{c \in \{r,g,b\}} I^c(x,y)}{\min_{c \in \{r,g,b\}} A - \min_{c \in \{r,g,b\}} J^c(x,y)} \tag{3.2}$$

In equation 3.2, coordinates of fog image and non-fog image are represented by (x, y). Their transmittance is expressed by $t(x, y)$. Gray values in the channel c are respectively denoted by $I^c(x, y)$ and $J^c(x, y)$, and atmospheric light at infinity is labeled by A. Equation 3.2 is simplified as shown in equation 3.3.

$$t(x,y) = \frac{A^c - I^{\text{dark}}(x,y)}{A^c - J^{\text{dark}}(x,y)} \tag{3.3}$$

In equation 3.3, it is assumed that atmospheric light is a constant and denoted by $A^c I^d ark(x, y)$ and $J^d ark(x, y)$ mean simplified forms of $\min_{c \in \{r,g,b\}} I^c(x, y)$ and $\min_{c \in \{r,g,b\}} J^c(x, y)$, respectively. The definition of existing single IDF algorithms suggests that there is a linear relationship between the minimum brightness of the channel for both fog free and non-fog free images, but the unknown parameters of the linear curve are difficult to solve [18]. In the complex terrain environment, with the change of the fog concentration, the pixel brightness of the fog image will also change, and the fog concentration at the shadow shelter is different, resulting in the uneven distribution of the fog image brightness [19]. Simple linear transformation cannot achieve the estimation of image dark channel brightness, and its grayscale difference defense cannot be described, resulting

in a large error in transmittance estimation and affecting the defogging effect. The brightness response observed by the naked eye is nonlinear. The study introduces the parameter k_d to represent the adjustable grayscale dynamic range and achieve smooth processing of brightness differences in dark channels. The linear method estimates the dark channel of the line due to the influence of fog, causing distortion during image restoration. The logarithmic change can reduce the intensity value, avoid the influence of high brightness areas, and achieve natural transition of the dark channel area image. After smoothing the edge information of the deep field area of the image, it is more suitable for estimating the dark channel of the scene brightness, which helps to improve the effectiveness of transmittance estimation. The initial transmittance expression under logarithmic variation is shown in equation 3.4.

$$t(x,y)=\frac{\left|A^c-\min_{c\in\{r,g,b\}}I^c(x,y)\right|}{\left|A^c-\log\left(\frac{\left(\min_{c\in\{r,g,b\}}I^c(x,y)\right)-\mathrm{RGB}_{\min}}{\mathrm{RGB}_{\max}-\mathrm{RGB}_{\min}\left(\min_{c\in\{r,g,b\}}I^c(x,y)\right)+k_d}\right)\right|} \tag{3.4}$$

In equation 3.4, the minimum and maximum values of $\min_{c\in\{r,g,b\}}I^c(x,y)$ are respectively expressed by $RGBmin$ and $RGBmax$. The lack of available scene structure information in a single image increases the difficulty of defogging a single image. There is a linear relationship among fog concentration, depth of field, brightness and saturation. The prior law of fog image color decay is shown in equation 3.5.

$$d(x)\propto c(x)\propto v(x)-s(x) \tag{3.5}$$

In equation 3.5, depth of field is denoted by $d(x)$. Fog concentration is represented by $c(x)$, and the difference between brightness and saturation of the image in the color model of hexagonal vertebra is expressed by $v(x)-s(x)$. The scene saturation and brightness of clear close-range and misty areas are moderate, and the difference between the two is small. When the fog gradually increases, the brightness rises with the decrease of saturation, leading to the difference between the two becomes larger, and it is difficult to distinguish the color in the scene. Compensation of transmittance in the sky area is shown in equation 3.6.

$$t_b(x,y)=\max(\phi|V-S|,t(x,y)) \tag{3.6}$$

In equation 3.6, the difference adjustment factor of brightness and saturation is represented by ϕ , and the sky transmittance is represented by $t_b(x,y)$. At this time, the difference between brightness and saturation of the image is indicated by $|V-S|$. When the difference adjustment factor of brightness and saturation is large, the transmittance deviation is large, and the effective compensation of transmittance can be realized if the value is small. The regularization expression of the weighted L1 norm is shown in equation 3.7.

$$Q(x,y)=\{t_b(x)-t_b(y)\} \tag{3.7}$$

In equation 3.7, adjacent pixels in the transmittance figure are represented by x and y , and the weighting function is represented by $Q(x,y)$, to complete the adjustment of transmittance difference. The transmittance difference depth information between pixels changes with the depth of the scene, and the more obvious the reflection of the weighting function is. The weighting function needs to reflect the depth difference information, and it is very difficult to directly use the depth map to construct the weighting function. The research uses the square variance of gray values of two adjacent pixels to construct the weighting function, as shown in equation 3.8.

$$Q(x,y)=e^{-\frac{\|I(x)-I(y)\|^2}{2\delta^2}} \tag{3.8}$$

In equation 3.8, the standard deviation is represented by δ, and the difference of gray values between adjacent pixel points is expressed by $I(x)-I(y)$. Image edge gradient jump changes can be described by detection operators, and more details can be provided. In this study, a filter kernel high-order difference operator is introduced to realize discrete convolution. The high-order difference operator is shown in Figure 3.2.

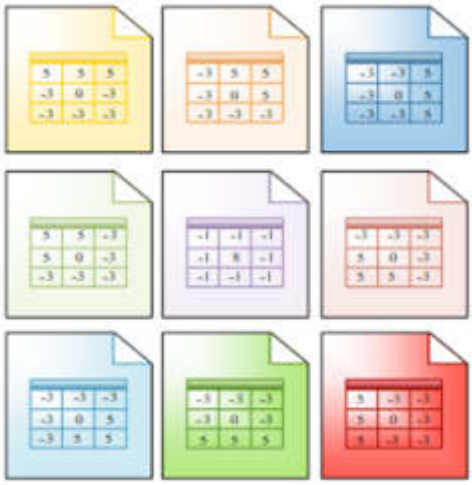


Fig. 3.2: High-order Difference Operator

The number of higher-order difference operators used in this study is 9. Discrete convolution is carried out in equation (8), and then the simplified expression is shown in equation 3.9.

$$\sum_{j\in\eta} \|Q_j \star (D_j \otimes t)\|_1 \tag{3.9}$$

In equation 3.9, the index set of the original fog image region is represented by η. The convolution operation is represented by $\otimes$. The set of higher-order difference operators is represented by D_j. Color attenuation priors focus on defogging effect and ignore problems such as color bias and edge blurring. The introduction of L1 norm can improve the fidelity of compensation transmittance of color attenuation priors. The minimization expression of L1 norm is shown in equation 3.10.

$$\theta\|t_b - t_z\|_2^2 + \sum_{j\in\eta} \|Q_j \star (D_j \otimes t_b)\|_1 \tag{3.10}$$

In equation 3.10, the regularization parameter is represented by θ. The transmittance after iteration is represented by t_z. The transmittance after compensation is represented by t_b. Since the DCP algorithm has atmospheric failure, the paper improves the algorithm by combining with clustering segmentation quadrangle number. Cluster analysis is an unsupervised learning method, which is broadly utilized in various engineering fields of data mining and statistics. In IDF, K-means is commonly used to cluster the Euclidean distance and complete the estimation of the transmission of the sky region [20]. The single clustering of RGB three-channel will lead to the inconsistency of gray color channels of pixels. The three-channel pixels are converted into single-channel gray maps, as shown in equation 3.11.

$$G(i,j) = avg_{c\in\{r,g,b\}} I^c(x) \tag{3.11}$$

In equation 3.11, the gray value of fog image is denoted by I , and the gray value of location $(i, j$ in a two-dimensional plane is denoted by $G(i, j)$. The clustering method is applied in image segmentation to improve the accurate calculation of atmospheric light.

3.2. IDF Algorithm Optimization and System Design Based on DCP. The DCP mechanism is constrained by various conditions, and its value is also affected. In this paper, a dark channel IDF algorithm is proposed by combining the feature pixel extraction idea of dark channel and convolutional network. The way

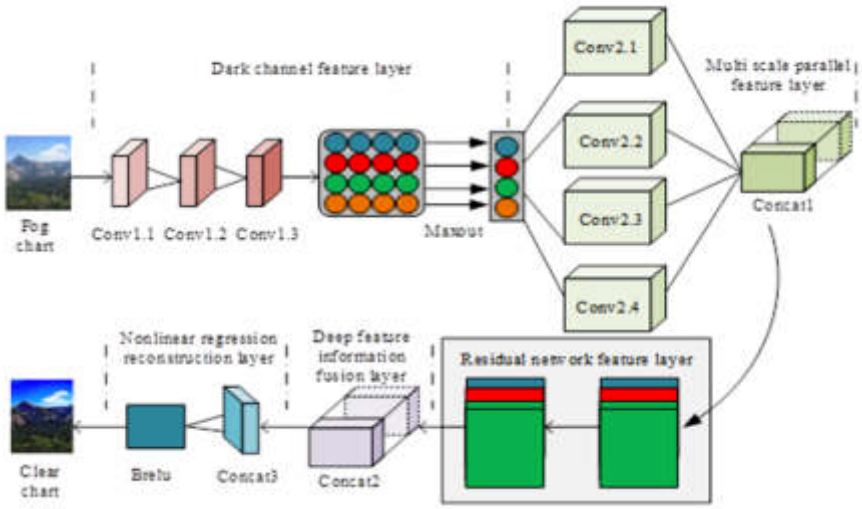


Fig. 3.3: The Overall Structure of DCNN Defogging Algorithm

of network independent feature extraction can solve the limitations of DCP algorithm, and help to improve the clarity of defogging [21, 22]. The training and test sets of the model utilize Reside data set. Then, feature extraction is carried out using the dark channel idea. The IDF model of the dark channel convolutional network (DCNN) is built through convolution components, etc. Parameter debugging is used to optimize the model, and the final model is used to complete the fog image processing. The overall structure of the DCNN defogging algorithm is displayed in Figure 3.3.

Dark channel feature layer is used to realize feature crude extraction and activated under Maxout function. The network input is the standard fog map with the size of 480×640. The output depth of the first two layers is 16. The filter window size is 5×5. the step size is 1 unit. The original input image is pre-extracted and mapped through the convolution kernel, and then the high-dimensional feature map is obtained. The filtering window size of the last layer is 3×3. The step size is one unit. The depth of the convolution kernel is 16. The DCP filtering is completed under the activation of Maxout function. The function of Maxout function is to group and map the convolution feature graph to obtain the key feature information of the fog graph V [23, 24]. The operation of Maxout function is shown in equation 3.12.

$$F_1^j = \max_{i\in[1,16],j\in[1,4]}\{\text{conv}(W_1^{(i,j)} \times I + B_1^{(i,j)})\} \tag{3.12}$$

In equation 3.12, the input fog map is represented by I. The amount of convolutional feature maps at the output end of the first three layers is denoted by i. The amount of output feature maps is represented by j. The filtering weight and bias of each feature map are denoted by W_i and B_i respectively. The convolution operation is expressed by *conv*. The output of the dark channel feature layer is indicated by F_1. In this study, four groups of convolution kernels with different sizes are used to extract deep feature information in parallel. Multi-scale convolution operation is shown in equation 3.13.

$$F_i = W_i \times F_1 + B_i \quad (i \in \{2,3,4,5\}) \tag{3.13}$$

In equation 3.13, the weights and bias of different convolution kernels are expressed by W_i and B_i, respectively. The output of the ith layer is expressed by F_i. Different feature maps are combined by parallel layers to obtain a feature map with a size of 32×480×640, which increases the number of feature maps. The convolution operation of each feature layer is shown in Figure 3.4.

Figure 3.4(a) shows the parallel operation of the multi-scale parallel convolutional layer. After extracting different features, the feature graph structure and information will be lost. In this study, the improved cavity

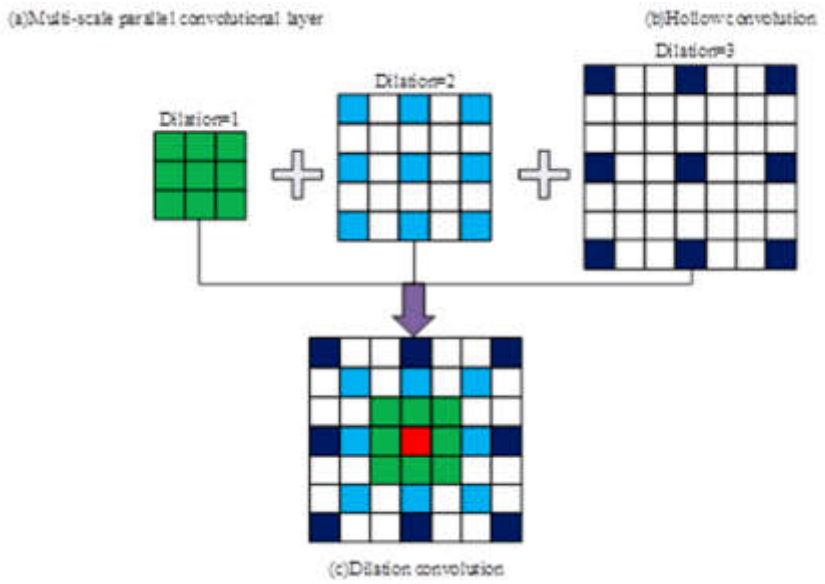


Fig. 3.4: Convolutional Operation of Each Feature Layer

convolution is utilized to the residual network to realize the detailed extraction of feature information. With the increase of the empty weight interval between the ordinary convolution and the sum, void convolution is formed, as shown in Figure 3.4(b). When the size of the convolution kernel of the filter window is 3×3 and the number of weight intervals is 1, the expansion rate is 2. The range perception is the same as that of the filter kernel of the filter window size 5×5, but the calculation is more convenient and fast. The training effect of the convolutional network does not increase with the increase of the depth of the network layer. When the number of layers of the network structure increases to a certain number, the training effect may become worse, causing network degradation. The residuals unit realizes the layered learning of the residuals between input and output through channel association. Hollow convolution can extend the range of visual field and increase the spatial hierarchy of features, but the weight of hollow convolution is discontinuous, resulting in the perceived visual field cannot contain all image features. Grid halo will occur in subsequent fusion, which will reduce the IDF effect. In this study, expansive convolution is applied to feature extraction of residuary units of different sizes. The principle of expansive convolution is shown in Figure 3.4(c). The inner convolution kernel is used to achieve the coherence of image feature information, and the structure hierarchy of feature space is completed through the outer convolution kernel, which reduces the degree of gradient dispersion and contributes to the propagation of detailed feature information. The number of units in the feature layer of the residual network is 6, and the components of each unit include the convolution module, batch normalization and activation functions. The amount of convolution cores of the first three residuals blocks is 4, the size is 4×3×3, and the size of the output feature graph is 4×480×640. The latter three residuals contain 12 convolutional blocks respectively, and the output feature graph size is 12×480×640, with a residual convolution step size of 1 unit.

The output features of convolutional layer of CNN include three indexes: channel number, graph height and width. Increasing the amount of network layers will reduce the feature extraction effect and affect the IDF effect and the integrity of feature information. In the depth feature information fusion layer, the height and width of the feature map are fixed, and the feature map of the convolutional kernel is splice by means of channel dimension extension. The fusion rule is shown in equation 3.14.

$$(c, h, w) \to (\alpha \cdot c, h, w) \tag{3.14}$$

In equation 3.14, the number of channels is represented by equation. The height of the feature graph is denoted by h. the width of the feature graph is indicated by w. And the number of the increased feature graph

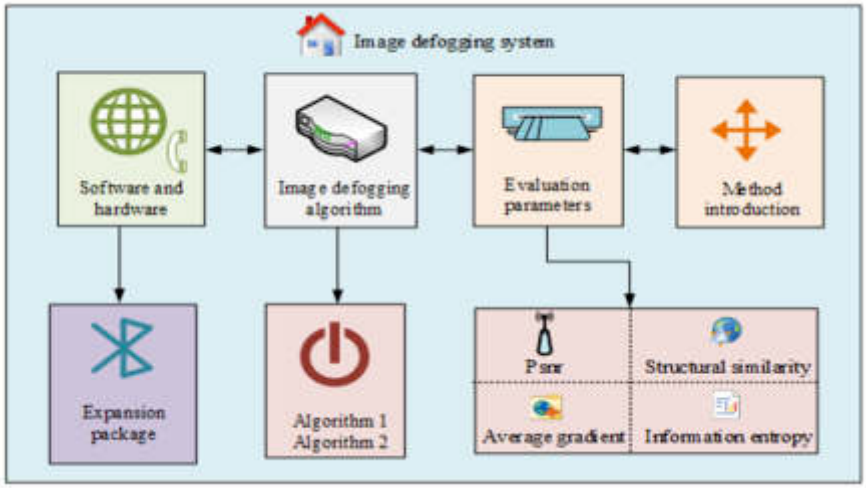


Fig. 3.5: Design Block Diagram of Landscape IDF System Optimized Based on DCP Algorithm

is represented by α. The depth feature information fusion layer realizes the refinement of the feature map, and obtains the feature map with the size of 48×480×640, which increases the amount of output feature maps and helps to transfer rich and effective details of the feature information. The nonlinear regression reconstruction layer is composed of independent convolution layers to realize the mapping between feature space and image space. The effect of network prediction is measured by the target loss function L_{MSE} , which is shown in equation 3.15.

$$L_{\mathrm{MSE}} = \frac{\sum_{i=1}^{N} \|F_{10}^{i} - I^{i}\|_2^2}{\mathrm{NUM}} \tag{3.15}$$

In equation 3.15, the clear image of group i and the predicted output image are expressed by I^i and F_{10}^i, respectively, and the number of sample training is labeled by *NUM*. The research constructs a defogging system through the above algorithms. The design block diagram of landscape IDF system optimized based on DCP algorithm is shown in Figure 3.5.

The basis of the system software design is the extension pack in the VS code editor, and the defogging system contains four functional areas. The first functional area is the system introduction and use area. Through the explanation of operation methods, points of attention and so on, the user's convenient use can be achieved. The second functional area is the objective performance evaluation area of the image, which mainly displays the parameters such as peak signal-to-noise ratio (SNR) and information entropy of the defogging algorithm to realize the evaluation of the defogging image. The third functional area is the selection area of IDF function, including two improved defogging algorithms, which can realize IDF and save the results through algorithm loading and use. The fourth functional area is the proposed system area, through which the system exits the system after IDF and saving [25, 26].

4. Effect Verification of Landscape IDF System Optimized Based on DCP Algorithm. This chapter is to evaluate the effect of the algorithm and model proposed in the second chapter. The first section of this chapter is to verify the effect of IDF algorithm estimated by the AS model. The second section is to verify the effect of IDF algorithm based on DCP. The third section is to verify the effect of landscape IDF system optimized based on DCP algorithm [27, 28, 29].

4.1. Effect Verification of IDF Algorithm Estimated by AS Model. To verify the effect of the IDF algorithm estimated by the AS model proposed in this study (algorithm Dq for short), He, Meng, Tarel, Berman and Lin algorithms were compared in the experiment. The He algorithm is an AS model estimation

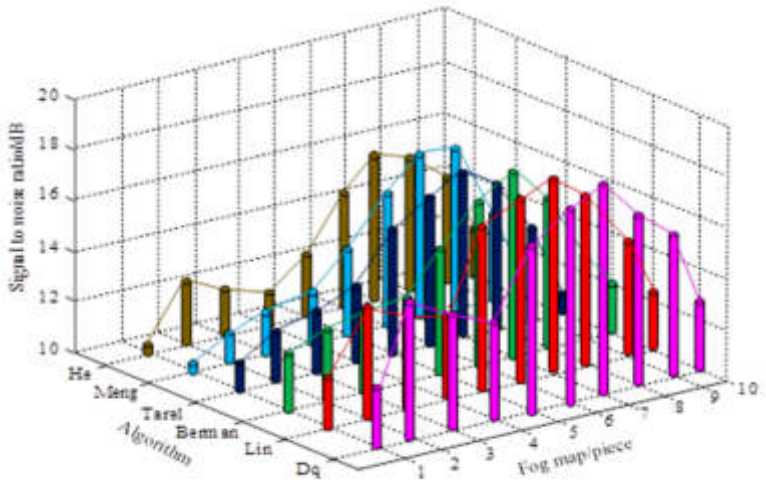


Fig. 4.1: SNR of Each Algorithm

algorithm based on scattering models proposed in 2020. It uses a set of filters applied to the observed image, multiplies the scattering terms in the image with the filters, and uses the backprojection method to invert the estimated values into an AS model. Meng algorithm is a deep learning-based AS model estimation algorithm proposed by Meng et al. in 2022. It uses CNN to encode images and uses backpropagation algorithms to invert the estimated values into AS models. The Tarel algorithm is an AS model estimation algorithm based on image segmentation proposed by Tarel in 2020. The Berman algorithm is a statistical model-based AS model estimation algorithm proposed in 2020. The Lin algorithm is an AS model estimation algorithm based on the least squares method proposed in 2022. It uses the least squares method to fit the observed images and predicts the AS model using a scattering model. In this experiment, a light source and a receiver (such as a camera or eye) will be used to verify the effect of different AS models on image defogging. The experiment will be conducted in an atmospheric environment with high relative humidity to simulate foggy conditions. It set parameters for the AS model, including simulating particle concentration, particle size, scattering angle, and speed of light for different foggy days. The particle concentration was 1010 particles per cubic centimeter, the particle size was 0.1 micrometers, the scattering angle was 30 degrees, and the speed of light was 3×108 meters per second. The SNR of each algorithm is shown in Figure 4.1.

In Figure 4.1, the highest SNR of He, Meng, Tarel, Berman and Linalgorithms was 15.1dB, 16.2dB,16.3dB, 17.3dB and 17.4dB, respectively. The SNR of the IDF algorithm estimated by the AS model was the highest, up to 19dB, which was an average improvement of about 15.4% in contrast to the other five algorithms, indicating that the image of the algorithm after defogging was clearer and retained more useful feature information. The average gradient of the defogging effect of each algorithm is shown in Figure 4.2.

In Figure 4.2, the average gradient of the IDF algorithm estimated by the AS model was the highest, up to 14.2, which was about 11.37% higher than the other five algorithms on average, indicating that the image under this algorithm was not easy to distort and was conducive to visual experience. The structural similarity and information entropy results of the defogging effect of each algorithm are shown in Figure 4.4.

Figure 4.3a expresses the structural similarity results of defogging effects of various algorithms. The structural similarity index of IDF algorithm estimated by the AS model proposed in this study was relatively high, which was about 9.3% higher than other algorithms on average, and the fluctuation was not very obvious, indicating that the IDF algorithm could retain more detailed structural information. Figure 4.3b shows the information entropy result of the defogging effect of each algorithm. The information entropy index of the IDF algorithm estimated by the AS model proposed in this study was the highest, which increased by about 3% on average, indicating that the image of this algorithm was the most authentic after defogging. A comprehensive

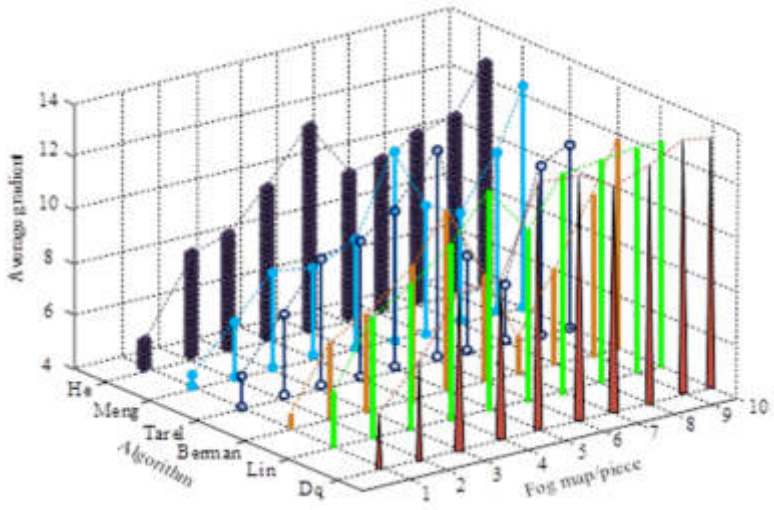
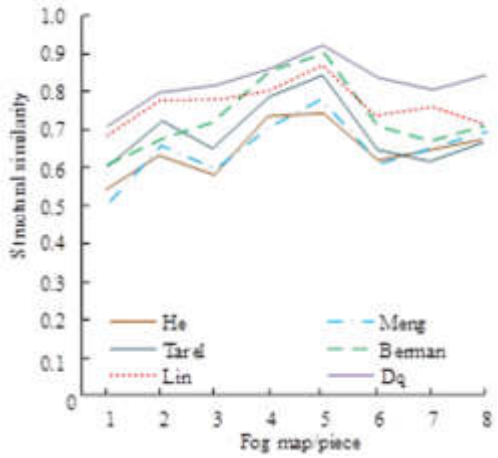
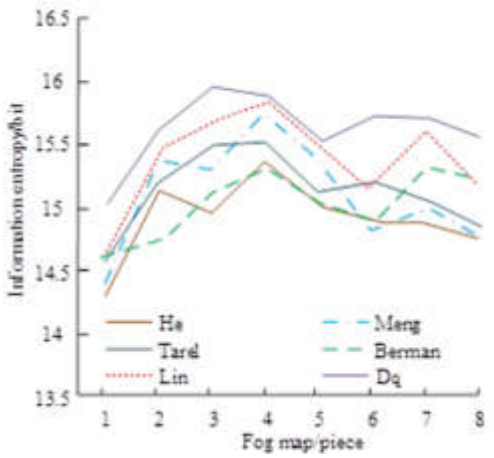


Fig. 4.2: The Average Gradient of the Defogging Effect of Each Algorithm



(a) Structural Similarity



(b) Information Entropy

Fig. 4.4: Structural Similarity Results of Defogging Effects of Various Algorithms

analysis showed that the IDF algorithm estimated by the AS model had a good defogging effect, which met the requirements of algorithm improvement.

4.2. Verification of IDF Algorithm Effect Based on DCP. The data set of the DCP-based IDF algorithm was Reside that contained abundant indoor and outdoor fog images. The composition of Reside date set is shown in Table 4.1.

Reside data set consisted of five sub-datasets, each of which had different functions and purposes. Indoor and outdoor data sets resided in training to achieve a simple and quick training process. Integrated target and mixed subjective test sets resided in testing and detection. The training results of the DCNN IDF algorithm are shown in Figure 4.5.

In Figure 4.5, the experiment adopted Gaussian distribution with mean of 0 and variance of 0.002 to realize

Table 4.1: Reside Data Set Composition

Type	Explain	Classification 1	Classification 2	Classification 3	Classification 4
ITS	Indoor training devices and equipment.	30000	40000	25000	15000
OTS	Outdoor training devices and equipment.	72000	65000	88000	98950
SOTS	Comprehensive test set for the target.	260	230	270	240
RTTS	A test set driven by real scenarios.	1332	2256	1123	1867
HSTS	Subjective mixed test set.	5	3	8	4

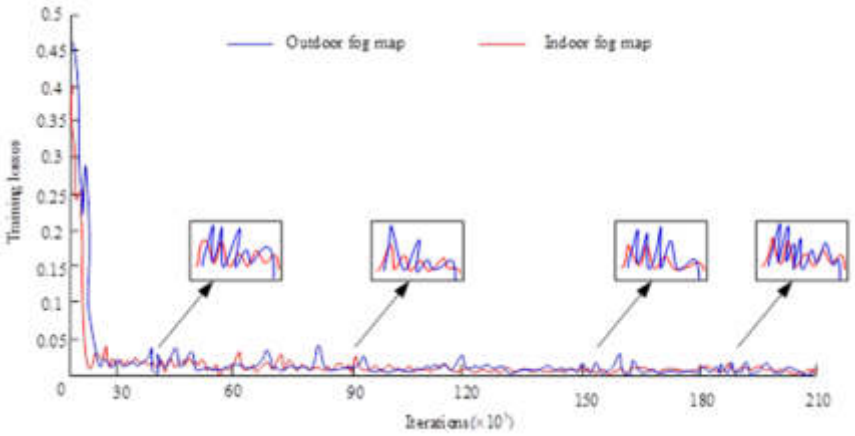


Fig. 4.5: The Training Results of the DCNN IDF Algorithm

weight initialization, and combined gradient descent algorithm for training. The loss reduction speed was fast in the first 30×103 training. When the number of iterations increased, the change of depth of field in outdoor scenes was more obvious, which was conducive to the improvement of defogging effect in real scenes. To verify the effect of IDF algorithm based on DCP, He, Cai, Ren and Li algorithms were compared in the experiment. The defogging effect data of each algorithm on 4 groups of indoor images are displayed in Table 4.2.

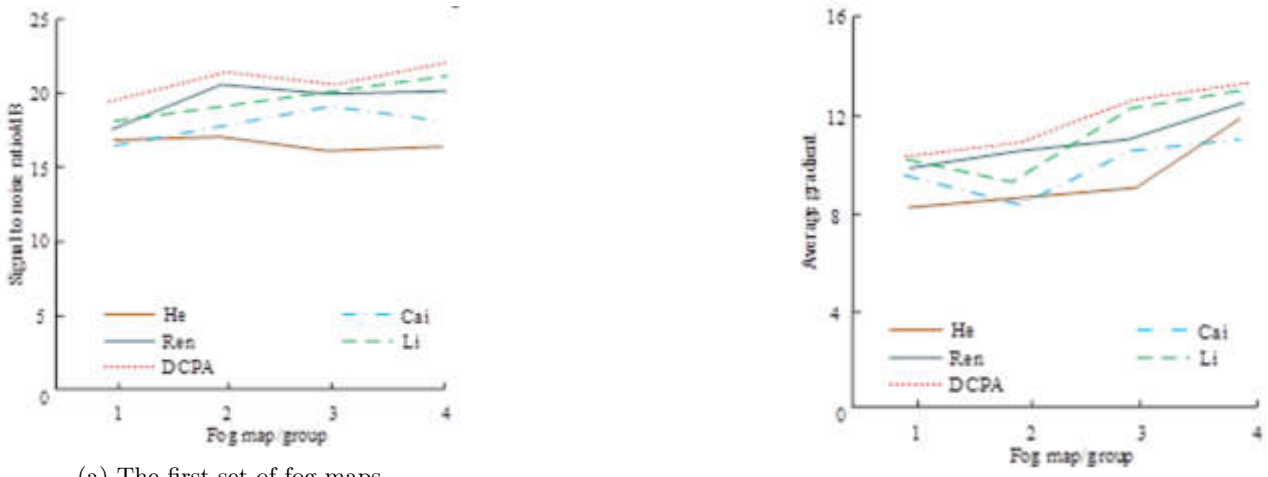
From Table 4.2, the SNR, average gradient, structural similarity and information entropy indexes of the IDF algorithm based on DCP were all higher than those of other algorithms. Among the defogging effects of the four groups of images, the SNR of the IDF algorithm based on DCP was above 20, the structural similarity was above 0.9, and the information entropy was above 15. It showed that the IDF algorithm based on DCP had better performance, and the IDF had smaller distortion and was clearer. Figure 4.7 shows the defogging effect data of 2 groups of outdoor images applied by each algorithm.

Figure 4.6a shows the defogging effect data of the first group of outdoor fog images. The algorithm based on DCP had the highest structural similarity and higher SNR and information entropy. Figure 4.6b shows the defogging effect data of the second group of outdoor fog images. Each index of the IDF with DCP was the highest, which meant it had better defogging effect, could retain more image details, and had stronger authenticity after defogging. The defogging effect data of each algorithm on 4 groups of real landscape fog images are shown in Figure 4.9.

In Figure 4.9, all indexes of the proposed DCP-based IDF algorithm were higher than those of the other four algorithms, among which the indexes of Ren and Li algorithms were not much different from those of the DCP-based IDF algorithm. However, the defogging effect of these two algorithms on complex images was unstable and poor. The analysis of experimental data showed that, by contrast, the IDF algorithm based on

Table 4.2: The Defogging Effect Data of Each Algorithm on Four Sets of Indoor Images

Indoor fog map	Objective indicators	He	Cai	Ren	Li	DCP
Set 1	SNR/dB	15.61	15.22	16.41	18.12	20.22
	Average gradient	9.42	8.41	9.73	9.61	10.61
	Structural similarity	0.76	0.84	0.86	0.88	0.92
	Information entropy/bit	15.02	15.14	15.53	15.08	16.38
Set 2	SNR/dB	15.58	18.23	17.97	18.25	21.65
	Average gradient	8.82	9.41	10.42	9.87	10.87
	Structural similarity	0.78	0.79	0.82	0.85	0.91
	Information entropy/bit	15.14	16.23	15.23	16.21	17.56
Set 3	SNR/dB	18.01	20.11	19.09	20.42	23.56
	Average gradient	8.82	9.52	11.02	10.61	11.54
	Structural similarity	0.83	0.82	0.88	0.86	0.92
	Information entropy/bit	13.25	14.26	14.52	15.29	16.23
Set 4	SNR/dB	17.23	18.25	20.01	20.78	22.98
	Average gradient	8.08	7.51	8.99	8.25	9.62
	Structural similarity	0.71	0.77	0.84	0.81	0.91
	Information entropy/bit	14.92	13.58	14.18	13.94	15.35



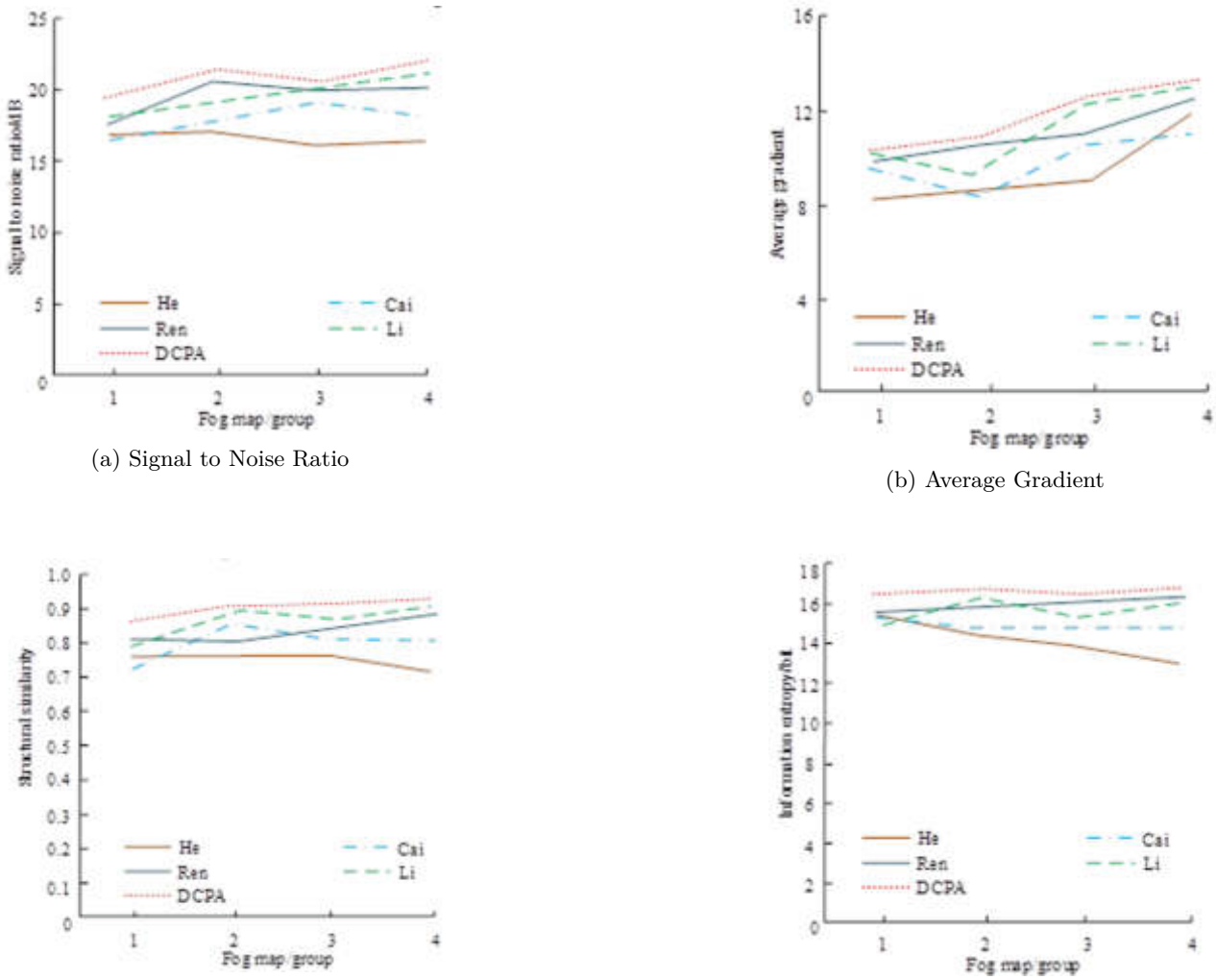
(a) The first set of fog maps

(b) The second set of fog maps

Fig. 4.7: The Defogging Effect Data of Each Algorithm on Two Sets of Real Scene Fog Images

DCP increased the SNR by about 9.5%, the average gradient by about 10.4%, the structural similarity by about 12%, and the information entropy by about 5.8%, indicating that the performance of the algorithm was stable and the IDF effect was good.

4.3. Effect Verification of Landscape IDF System Optimized Based on DCP Algorithm. Combined with the real fog environment, the experiment verified the landscape IDF system optimized based on DCP algorithm. The experimenters input the real landscape fog map into the defogging system and input objective parameters according to the actual situation. The system used Python 3.7 programming language and PyTorch 1.7.1 programming framework, and adopted CUDA 10.1 universal parallel computing architecture. When building a development environment group based on Python+Qt designer, the defogging algorithm was implemented and objective performance parameters were displayed through an interactive interface. The implementation of this system software was achieved by downloading an integrated Python interpreter and



(a) Signal to Noise Ratio

(b) Average Gradient

(c) Structural Similarity

(d) Information Entropy

Fig. 4.9: The Defogging Effect Data of Each Algorithm on Two Sets of Real Scene Fog Images

PYqtter integration package based on the VScode editor, and installing Pyqt5.0 using a pip pipeline. Real landscape fog maps could be divided into natural, architectural and historical landscapes. The test effect data of landscape IDF system optimized based on DCP algorithm are displayed in Table 4.3.

In Table 4.3 that the SNR and average gradient index were better than logarithmic transform adaptive defogging algorithm, indicating that it had less distortion and higher contrast when the sky area of the image was small. The DCNN defogging algorithm had better structural similarity and information entropy index, indicating that the images processed by it could contain more details, have clear hierarchy and better visual effect, and the fog images with fewer sky areas had better processing effect. In terms of running time, the logarithmic adaptive defogging algorithm had a complex structure, so the running time was longer, which reduced the efficiency of the algorithm. The DCNN algorithm had a less running time, which reduced the complexity of the defogging structure, by contrast, the running time was reduced by about 67%. The results showed that the logarithmic transformation adaptive defogging algorithm had good processing effects in natural landscapes, architectural landscapes, and historical landscapes, with good SNR and average gradient indicators,

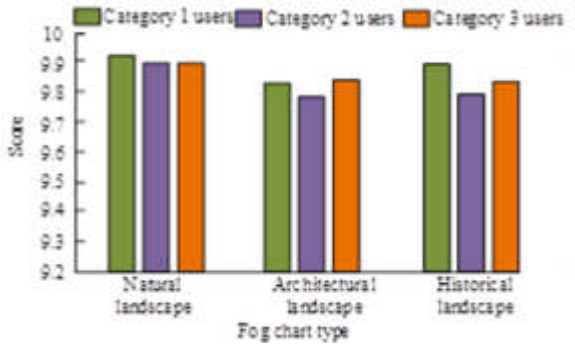
Table 4.3: Test Effect Data of the Defogging System

Realistic landscape fog map	Defogging algorithm	SNR/dB	Average gradient	Structural similarity	Information entropy/bit	Run time/s
Natural landscape	Logarithmic transformation adaptation	17.8	10.4	0.8	12.2	7.1
	DCNN	15.6	8.2	0.9	14.9	2.8
Architectural landscape	Logarithmic transformation adaptation	20.3	12.4	0.8	11.8	14.8
	DCNN	17.6	10.7	0.9	15.6	4.1
Historical landscape	Logarithmic transformation adaptation	18.8	10.9	0.8	12.5	7.9
	DCNN	16.8	9.2	0.9	15.9	2.9

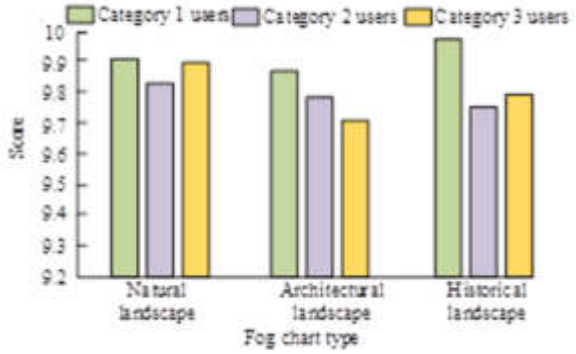
as well as high structural similarity and information entropy indicators, resulting in better visual effects. The DCNN defogging algorithm performed better in processing architectural and historical landscapes, with higher structural similarity and information entropy indicators, and performed better in processing fog images with fewer sky areas. In addition, the DCNN defogging algorithm had a shorter running time, which reduced the complexity of the defogging structure and was more suitable for real-time application scenarios. To further verify the use effect of the landscape IDF system optimized based on DCP algorithm, the operability, stability and defogging effect of the system were evaluated in combination with user ratings. Users contain three categories: the first was 10 artists, the second category was 10 defogging system designers, and the third category was 10 random system users. The operability evaluation was a maximum of 10 points, with higher scores indicating better performance. The stability evaluation had a maximum score of 10 points, and the higher the score, the better. The evaluation of defogging effect was a maximum of 10 points, and the higher the score, the better. The user rating results of the landscape IDF system optimized based on the DCP algorithm are shown in Figure 4.11.

Figure 4.10a is the operability score of the system marked by three types of users. In the case of natural landscape fog map processing, the average scores of the three types of users were 9.92 points, 9.89 points and 9.89 points, respectively. In the case of architectural landscape fog map processing, the average scores of the three types of users were 9.85 points, 9.78 points and 9.86 points, respectively. In the case of historical landscape fog map processing, the average scores of the three types of users were 9.91, 9.84 and 9.86 points, respectively. Figure 4.10b shows the three types of users scoring the stability of the system. In natural landscape fog map processing, the average scores of the three types of users were 9.91 points, 9.83 points and 9.89 points, respectively. In architectural landscape fog map processing, the average scores of the three types of users were 9.89 points, 9.79 points and 9.76 points, respectively. In historical landscape fog map processing, the average scores of the three types of users were 9.89 points, 9.79 points and 9.76 points, respectively. The average scores of the three types of users were 9.98, 9.78 and 9.79 points, respectively. Figure 4.10c shows the three types of users scoring the defogging effect of the system. In natural landscape fog map processing, the average scores of the three types of users were 9.71 points, 9.52 points and 9.75 points, respectively. In architectural landscape fog map processing, the average scores of the three types of users were 9.41 points, 9.18 points and 9.22 points, respectively. In historical landscape fog map processing, the average scores of the three types of users were 9.41 points, 9.18 points and 9.22 points, respectively. The average scores of the three types of users were 9.71, 9.49 and 9.86 points, respectively. By analyzing the experimental data, the average scores of operability, stability and defogging effect of the system were 9.87, 9.85 and 9.54 points, respectively. According to the experimental results, different categories of users gave different evaluations of the operability, stability, and defogging effect of the landscape IDF system optimized based on the DCP algorithm. However, considering the average scores of the three types of users, the average scores of the system were all above 9, indicating good performance and good user experience. In addition, the processing effect of the system on fog images varied under different algorithms, but the results all showed good defogging effects.

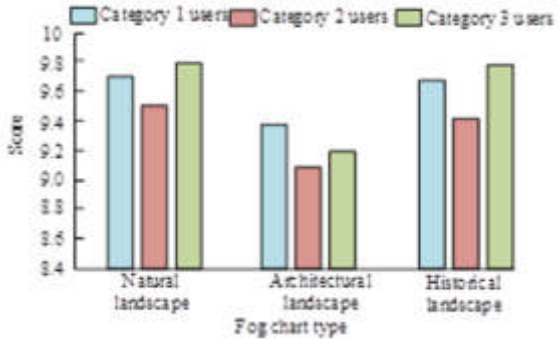
5. Conclusion. IDF is one of the important image processing techniques, and its application value is high. To raise the effect of landscape IDF, a landscape IDF system based on DCP algorithm was proposed.



(a) Operability



(b) Stability



(c) Defogging Effect

Fig. 4.11: User Rating Results of The Defogging System

Fog image processing was realized by combining the IDF algorithm estimated by AS model and the algorithm based on DCP, and the system design was realized by using the extension package in VS code editor. The experimental data showed that the IDF algorithm estimated by the AS model had the highest SNR, up to 19dB, which was about 15.4% higher than other algorithms on average, indicating that the image was clearer after defogging by this algorithm. The SNR, structural similarity and information entropy of the DCP-based IDF algorithm were above 20, above 0.9 and above 15, indicating that the effect of the DCP-based algorithm was better, and the distortion of the IDF was smaller and clearer. The SNR, average gradient, structural similarity and information entropy of the DCP-based IDF algorithm were increased by about 9.5%, 10.4%, 12% and 5.8%, respectively, indicating that the effectiveness of the algorithm was stable and the IDF effect was good. The DCNN IDF algorithm had less running time and reduced the complexity of the defogging structure, by contrast, it reduced the running time by about 67%. The average score of the system was above 9 points, indicating that the system had good operability, stability, defogging effect, and good user experience. In summary, the IDF system based on the DCP algorithm optimized for landscape images has been verified by experiments. The system performed well in terms of image quality, and its performance could meet the requirements of real-world applications. The DCP algorithm has been proven to be effective in removing fog from the images, and its performance outperformed other state-of-the-art defogging algorithms. The system can handle various types of real-world images, including natural, built-up, and historical landscapes, with good results. The system's high performance is due to the combination of multi-scale parallel feature layers, residual networks, and deep feature fusion. The system's fast performance also contributes to its ability to handle large-scale images. Moreover, the system is user-friendly and has good stability. The IDF algorithm based on DCP can be applied in fields such as photography, computer vision, and remote sensing, helping to improve image quality, fog detection

and semantic segmentation, enhance image super-resolution, and provide an efficient image processing solution. The limitation of this study is that the algorithm performs defogging on degraded images affected by fog during the day. However, when dealing with degraded images such as hail, rainy and snowy weather, and nighttime fog images, the proposed algorithm is not entirely applicable. Future research will focus on studying these different degraded images separately to further enhance the applicability of image processing algorithms.

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ENERGY SAVING AND EMISSION REDUCTION OPTIMIZATION OF ENTERPRISE HAZARDOUS WASTE RECYCLING MANAGEMENT SYSTEM BASED ON HYBRID GENETIC ALGORITHM

LI SHANG*

Abstract. This research proposes a new path planning model for hazardous waste recycling transportation to effectively manage the hazardous waste recycling transportation, improving the transportation efficiency, while considering the actual road conditions. The new model adopts the conservation algorithm and hybrid genetic algorithm, which makes the new model better meet the complex needs of hazardous waste recycling. The new approach enables optimal transportation path planning for hazardous waste recycling while ensuring safety and compliance. The results showed that the hybrid algorithm outperformed the other two algorithms in terms of path optimization, cost reduction, accuracy improvement and error reduction. The hybrid algorithm had the best path optimization effect, which can get the optimal path with the lowest cost and highest efficiency. The hybrid algorithm had the highest accuracy of 95.62%. It also had the lowest root mean square error and average percentage error, indicating that it had less error. Finally, the hybrid algorithm had the highest loss function value, which indicated that the model had the best stability and better performance. The new hybrid genetic algorithm performed better than the single traditional algorithm, which is more efficient for hazardous waste recycling.

Key words: Hazardous waste recycling; Transportation costs; Transportation efficiency; Genetic algorithm; Hybrid genetic algorithm

1. Introduction. Global climate change and environmental protection have become one of the most important challenges facing the world today. To mitigate the effects of climate change and reduce carbon emissions, more countries and enterprises have begun to take active measures. One of them is to formulate and implement dual-carbon strategy objectives [1]. Under the framework of dual-carbon strategy, the importance of corporate social responsibility is further emphasized. Enterprises need to actively participate in reducing carbon emissions and environmental protection, while striving to improve resource efficiency to minimize negative impacts on the environment [2]. Hazardous waste management is a key area that is directly related to the environmental impact and sustainability of a business. Hazardous wastes are harmful wastes generated by production and industrial activities, including chemicals, wastewater, exhaust gases and solid wastes [3]. If pollutants are not properly treated and recycled, hazardous wastes may cause serious pollution to the environment, posing a threat to public health. Therefore, effective hazardous waste management and recycling is crucial. Hybrid genetic algorithms are powerful optimization tools that have been successful in several fields, including path optimization problems [4]. In the recycling and utilization of hazardous waste in enterprises, the transport link is one of the main CO_2 emission sources. Therefore, optimizing the transportation path of hazardous waste recycling can not only improve the efficiency, but also significantly reduce carbon emissions, which is in line with the national strategic objectives. Hybrid genetic algorithm combines the global search ability of traditional genetic algorithm and the optimization features of other algorithms, which can effectively solve complex optimization problems. In hazardous waste recycling path optimization, the algorithm can be used to design optimal transport paths to reduce driving distance and time, thus directly reducing fuel consumption and CO_2 emissions. By combining the global search capability of the genetic algorithm with the fine tuning of local search techniques, the hybrid genetic algorithm can effectively solve path optimization problems in hazardous waste recycling and management systems, obtaining more efficient, environmentally friendly and economically feasible solutions. Based on this, this research aims to optimize the path planning of hazardous waste recycling to reduce the environmental risk, improve the resource recovery rate, and reduce the operation cost. The required data for the

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experiment are collected through actual visit surveys. Then, the concept of multi algorithm fusion is introduced to analyze the data, improving the efficiency of hazardous waste in the transportation process. Meanwhile, it can reduce the cost and carbon emissions generated during the transportation process. This research is divided into four parts. The first part is mainly to analyze the domestic and international research. The second part is to build the hazardous waste recycling model through multiple algorithms. The third part is to prove the feasibility of the algorithm through the data analysis. The fourth part is to summarize and analyze the whole research. At the same time, route planning for hazardous waste transport is particularly important in the quest to reduce carbon emissions and improve transport efficiency. Especially in urban environments, it is crucial to avoid travelling through densely populated or ecologically sensitive areas. When planning transport routes, consideration should be given to avoiding densely populated areas such as schools, hospitals and residential areas, as well as nature reserves, water sources and other important ecologically sensitive areas. Choosing suitable routes not only reduces the accidents, but also helps to minimize the potential impact on the lives of residents and the natural environment. Starting from reducing carbon emissions, reducing transportation costs, and improving transportation efficiency, the experimental data are collected through actual visits and surveys. The concept of integrating multiple algorithms is introduced to analyze data, improving the hazardous waste transportation efficiency while reducing the costs and carbon emissions generated during transportation.

2. Related works. In domestic and international research, many scholars have achieved rich research results in the hazardous waste recycling application and hybrid algorithms. Ziye Zhao et al. introduced a hybrid algorithm in customer satisfaction and profitability improvement, which could solve the order booking and production scheduling. Therefore, based on the traditional genetic algorithm, Taboo search was introduced to optimize the parameters. The research results indicated that the introduced hybrid genetic algorithm significantly improved the efficiency while increasing the total net profit [5]. Uysal, Furkan et al. improved the traditional genetic algorithm to solve multi project scheduling problems. Among them, the original problems were assumed to set some priority order and resources. The hybrid algorithm was applied to achieve the priority relationship of different problems in the project. The research results indicated that the hybrid algorithm improved the scheduling efficiency for multiple projects [6]. Su, Bentao et al. introduced a hybrid genetic algorithm in job scheduling to reduce resource constraints and fully utilize resources. Therefore, a new hybrid genetic algorithm was designed. The research results indicated that the performance of hybrid algorithms could be effectively improved [7]. Shun-chi Yu discovered that the genetic algorithm was developed as a heuristic algorithm on many traditional problems. For some time related sequences and window settings, it could solve multi-stage workshop scheduling problems. The research results indicated that the multiple hybrid algorithms could significantly outperform other single algorithms [8].

There have also been many studies analyzing path optimization problems. Haitao Chen believed that some solid waste recycling could be carried out using image recognition technology. Therefore, a target detection network algorithm model was designed to collect and analyze data on solid objects in buildings. The research results indicated that the detection algorithm had better results in waste recycling, improving recycling efficiency [9]. Wang, Jiaqian et al. introduced the artificial intelligence into robot path planning to effectively improve the planning efficiency. Therefore, a bio-geographical optimization method based on negative gradient difference was proposed, which had strong global search ability. The research results indicated that the accuracy and optimization efficiency could be effectively improved [10]. Umesh Pandey et al. conducted a three-level optimization design for path optimization. The new optimization route could increase some production capacity. The research results indicated that the production route could be effectively improved. The production efficiency could be improved through three-level optimization design [11]. Gao, Zhaohui et al. proposed that diversity of recycling types should be considered in logistics recycling. Therefore, improving the new crossover mutation operator on traditional recycling path optimization accelerated the computational speed of genetic algorithm. The research results indicated that the new optimization algorithm could reduce the cost recovery to a certain extent. The algorithm had good stability and convergence [12]. SS Sana et al. proposed two models to explore how to provide optimal green quality at a reasonable price in an increasingly environmentally conscious economy. Model 1 examined optimal green quality and selling price for manufacturers and retailers in a double helix supply chain. Model 2 focused on price competition for alternative products and considered corporate social responsibility. The results showed that the proposed models could help business managers

to develop effective strategies to achieve a win-win situation in terms of profit and environmental protection [13]. Ospina-Mateus, Holman et al. proposed a hybrid method combining the genetic algorithm and simulated annealing to analyze motorcyclists' accidents on Bogotá's roads. The method used data mining and machine learning techniques to analyze 34,232 accidents that occurred between 2013 and 2018. The results showed that the method performed well in predicting accident severity, improving the prediction accuracy by 20-21% [14]. To solve the operator mutation in genetic algorithms, Behroozi F et al. proposed a new method for operator selection. The new method uses teaching-optimized novel operators for algorithm improvement. The quality and convergence speed of the algorithm model was improved by intelligent replacement. The results showed that the new method improved the computational efficiency of the traditional genetic algorithm model [15]. Sana S S et al. proposed a mathematical model for job rotation to achieve the multi-objective optimization problem. The letter model could complete complex tasks in highly variable environments. The new non-dominated sequential genetic algorithm was applied in the letter model. The convergence was improved by changing and replacing schemes that are not very different from each other. The results showed that the letter method had better efficiency in combinatorial optimization [16].

In summary, many experts have optimized path planning and hybrid algorithms. But there is still room for improvement in this issue, such as reducing the path optimization cost and improving optimization efficiency. However, existing research mainly focuses on the efficiency and effectiveness of hybrid algorithms. There is still much room to explore the comprehensive improvement of cost reduction and transport efficiency. Especially in practical application scenarios such as hazardous waste recycling and multi-project scheduling, how to combine different algorithms to maximize the cost-effectiveness is an important in the current research. Therefore, on the basis of existing hybrid algorithms, conservation algorithms and large-scale neighborhood algorithms are introduced, aiming to enhance the computational efficiency and optimize the path planning process, and improve the overall transport efficiency while reducing the transport cost. In this way, this study hopes to fill the research gap in the existing literature on cost-effective optimization, providing a more effective solution to the hazardous waste recycling and multi-project scheduling. It is expected to improve the computational efficiency of the algorithm, thereby improving the transportation efficiency of path optimization and reducing transportation costs.

3. Materials and methods. This chapter mainly focuses on the optimization design of hazardous waste recycling path. A path optimization design algorithm model based on hybrid genetic algorithm is established. Firstly, the hazardous waste recycling is elaborated. The path optimization algorithm is improved by limiting conditions. Then, the algorithm is improved.

3.1. Optimization design of hazardous waste recycling paths for enterprises under the dual carbon strategy goal. The Path Optimization problem refers to how delivery vehicles choose the path for different quantities and types of goods delivered by distribution centers [17]. Under all delivery task conditions, the delivery path, delivery vehicles, and recycling sequence are selected to achieve minimum resource utilization and shortest path optimization. Figure 3.1 shows the constraint conditions for path optimization.

The recycling route shown in Figure 3.1 is generally constrained by time. When loading and unloading goods on a truck, the recycling route is affected by this specified action, resulting in an increase or decrease in time. The distance traveled by vehicles will to some extent constrain the truck's recycling route. New energy vehicles that typically carry out transportation operations cannot replenish energy in a timely manner for extended range like traditional vehicles. Therefore, the mileage and range of recycled cars are constrained by distance. Some customers may set a recycling time. Failure to complete the recycling task within the recycling time will result in losses for both parties. Therefore, the recycling time and effectiveness will greatly affect the optimization of the recycling path. In recycling, the path security has significant impacts on the path selection. For high-risk materials such as hazardous waste, they cannot be driven on campus, ring roads, and other routes. The loading capacity of the final vehicle transportation also limits the transportation of goods [18].

The optimization of hazardous waste recycling paths has always been a research focus for enterprises, mainly focusing on optimizing some recycling time, recycling costs, and reducing the impact of hazardous waste on society. Generally speaking, the current algorithms for optimizing the path of hazardous waste include genetic algorithm, conservation algorithm, and large-scale neighborhood search algorithm. Genetic algorithm is an algorithm that utilizes the genetic and evolutionary abilities of species in nature, as shown in Figure 3.2.

Fig. 3.1: Different constraints and limitation

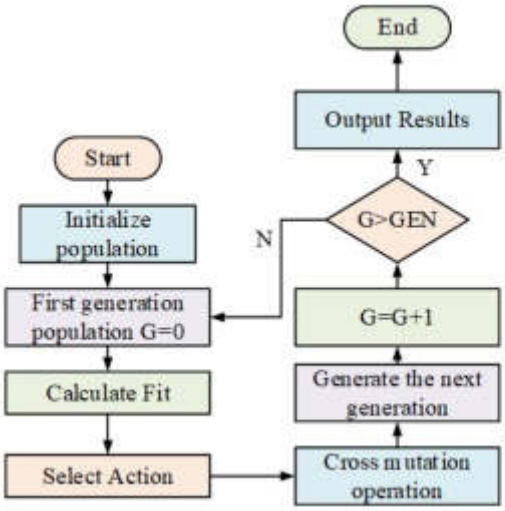

Fig. 3.2: Flow chart of genetic algorithm

In Figure 3.2, in the genetic algorithm, the algorithm first initializes the data to form a population. Then, the fitness of the first generation population is calculated to generate the next generation. Population categories are selected, crossed, and mutated to generate the next generation of new species populations. Finally, the iterated populations are determined to determine whether they meet the new species. If they do, the optimal algorithm solution is output. If not, the population fitness is recalculated. Finally, the optimal species population is obtained. Generally speaking, genetic algorithms will retain the genetic results from the previous

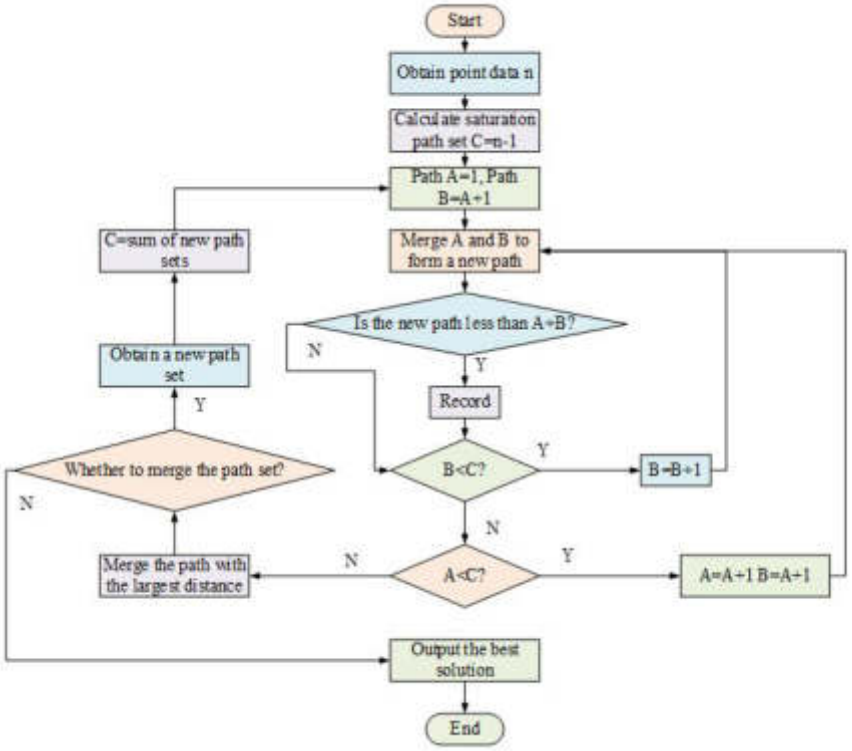

Fig. 3.3: Basic process of the saving algorithm

round until the next stage when optimizing the recycling path. However, genetic algorithms may have premature convergence. Therefore, a new saving algorithm is introduced into the recycling path for hazardous waste. The basic process of the saving algorithm is shown in Figure 3.3.

In Figure 3.3, the basic operation of the saving algorithm first confirms the point data, and then calculates the saturated recycling path. The calculated path A and path B are merged to obtain a new path. The new path size is determined to be less than A+B. If it is less than A+B, it is recorded. If not, the size of path B is directly determined to be less than the saturated path. If it is less than the path, the new path is determined by increasing the path size and merging with A again. If it meets the criteria, the size of A is determined, which is consistent with the judgment criteria for path B. If both path sizes are not less than the saturated path, the largest path in the record will be merged. Whether to merge the path set has been determined. If not merged, output the path. If there is a merge, obtain a new set of paths. At this point, the saturated path becomes a new set of paths, and then A and B paths are determined. The saving algorithm can integrate and judge any path of two paths. Therefore, the generated new path can be used as the initial solution algorithm for path optimization design in improving delivery efficiency and reducing transportation costs. Therefore, the entire problem remains at the same level, thereby reducing the premature convergence. Genetic algorithms and saving algorithms can optimize data for the early stage path selection of hazardous waste recycling path optimization problems. The large-scale neighborhood algorithm process is shown in Figure 3.4.

In Figure 3.4, large-scale neighborhood algorithms mainly perform algorithm operations through destruction and repair. The main computational process is similar to genetic algorithm. By inserting and solving the missing parts of the repair operator, the missing parts are supplemented and the optimal solution is obtained.

3.2. Path optimization model construction based on hybrid genetic algorithm. Although the hazardous waste recycling is a complex transportation organization optimization process, some transportation

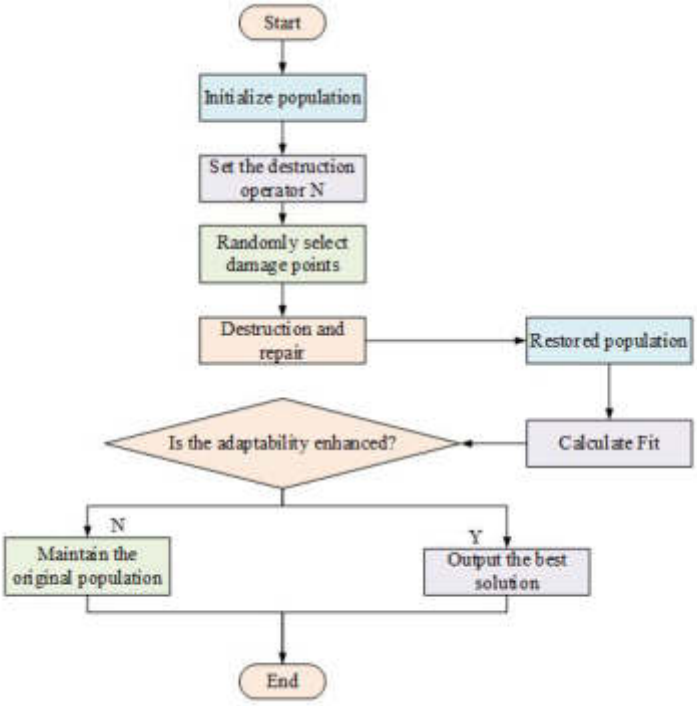

Fig. 3.4: Large scale neighborhood algorithm flow

units and transportation costs are also considered. When selecting routes and delivering vehicles for all products and hazardous waste, transportation efficiency is considered. Although carbon emissions and transportation costs are not reflected in path optimization, new carbon emissions taxes will be added to enterprises and transportation that exceed carbon emissions, which will increase transportation costs [19]. Section 2.1 has pointed out that the recycling path optimization for hazardous waste mainly considers several optimizations, including time window constraint optimization, vehicle travel distance optimization, vehicle carrying time optimization, service time optimization, etc. Therefore, the basic construction process of path optimization problems can be achieved by reducing costs and improving transportation efficiency. The transportation cost of hazardous waste includes vehicle cost, transportation cost, and time cost. The vehicle cost can is shown in equation (3.1).

$$f_1 = \sum_{k=1}^{n} c_1 z_k \tag{3.1}$$

In equation (3.1), n represents the number of recycled vehicles. f_1 represents the vehicle cost function. k represents the current recycling vehicle. c_1 represents the transportation cost of the vehicle. z_k represents vehicles involved in the hazardous waste recycling. The transportation cost of vehicles is shown in equation (3.2).

$$f_2 = \sum_{i=1}^{m} \sum_{j=1}^{m} \sum_{k=1}^{m} c_2 d_{ij} x_{ijk} \tag{3.2}$$

In equation (3.2), f_2 represents the transportation cost function of the recycling vehicle. c_2 represents the kilometer transportation cost of hazardous waste recycling vehicles. d_{ij} represents the distance from the hazardous waste recycling point i to j. x_{ijk} represents vehicle k from recycling station i to j. The time cost of

the vehicle is shown in equation (3.3) [20].

$$\begin{array}{l}[Et_a, Et_b] = [e_i + \lambda, l_i + \lambda] \\ f_3 = \sum_{k=1}^{n} \sum_{i=1}^{m} \left\{ \begin{array}{cc} \varepsilon_1 Et_a & t_i^k < Et_a \\ \varepsilon_1(Et_a - t_i^k) & Et_a < t_i^k < e_i \\ \varepsilon_2(t_i^k - Et_b) & l_i < t_i^k < Et_b \\ \varepsilon_2 Et_b & t_i^k > Et_b \end{array} \right\} \end{array} \tag{3.3}$$

In equation (3.3), ε represents the penalty factor of time. t_i represents the time when the hazardous waste vehicle is at the hazardous waste recycling point i. e_i represents the left time window of the unit i that generates the waste. l_i represents the right time window of the unit i that generates the waste. Et_a represents the relaxation time window of the a-th recycling vehicle. λ represents the relaxation degree in the time window. Et_b represents the relaxation time window of the b-th recycling vehicle. The total cost F is calculated through fixed vehicle costs, transportation costs, and time penalty costs. Equation (3.4) shows the maximum loading capacity of vehicles transporting hazardous waste.

$$\sum_{i=1}^{m} g_i y_{ik} \leq Q \tag{3.4}$$

In equation (3.4), Q represents the maximum loading weight of hazardous waste. g_i represents the demand for hazardous waste upon arrival at station i. y_{ik}represents that the hazardous waste station i is transported by vehicle k. Equation (3.5) shows the task volume completed by each individual hazardous waste vehicle.

$$\sum_{k=1}^{n} y_{ik} = 1 \tag{3.5}$$

In equation (3.5), when fixed vehicle transportation is carried out, the cost of completing the entire transportation is expressed as 1. The unit in a recycling path is shown in equation (**??**).

$$\sum_{i=0}^{m} x_{ijk} = y_{jk}, \sum_{j=0}^{m} x_{ijk} = y_{ik} \tag{3.6}$$

Equation (**??**) indicates that the recycling paths of different recycling sites are all the same path. Equation (3.7) represents the transportation expression of the recycling vehicle for the recycling unit [21].

$$\sum_{i=0}^{m} \sum_{k=1}^{n} y_{jk} = n \tag{3.7}$$

In equation (3.7), each station has an expression for vehicle transportation. Each vehicle departs from the origin company. The transportation delivered to the corresponding company is shown in equation (3.8).

$$\sum_{i=0}^{m} x_{i0k} = \sum_{j=0}^{m} x_{0jk} \tag{3.8}$$

In equation (3.8), the cost of each vehicle during transportation is the same. When the front and back paths of hazardous waste are connected to the same hazardous waste unit, the calculation is shown in equation (3.9).

$$\sum_{i=0}^{m} x_{ipk} - \sum_{j=0}^{m} x_{pjk} = 0, p \in \{1, 2, \cdots, m\}, k \in \{1, 2, \cdots, k\} \tag{3.9}$$

In equation (3.9), the unit of hazardous waste production is expressed by a path connected expression. Within the time interval of hazardous waste generation unit i, but it cannot exceed the specified time window, as shown in equation (3.10).

$$t_i \leq l_i \tag{3.10}$$

The parameter representative values in equation (3.10) are the same as those expressed in the equation. In path planning problems, the constraint variables y_{ik}, $z_k$and x_{ijk} are between 0-1. To better simulate the variables of recycling, both early and delayed delivery to the recycling site will affect user satisfaction. Therefore, to ensure customer satisfaction in research, it is necessary to ensure customer trust, which serves as a constraint for the study. In equation (3.11), it represents the arrival time change at transportation unit i.

$$t_j = \sum_{i=0}^{m}\sum_{k=1}^{n}(\max\{e_i, t_i\} + s_j + t_{ij}) \times x_{ijk} \tag{3.11}$$

In equation (3.11), t_j represents the arrival time at the transportation unit i. The time expression from the station recycling unit to the waste production unit i is shown in equation (3.12).

$$t_{ij} = \frac{d_{ij}}{v} \tag{3.12}$$

In equation (3.12), t_{ij} represents the time from the recycling unit vehicle to the waste production unit i and to the waste production unit j. Therefore, the minimum model for hazardous waste recycling is shown in equation (3.13) [22].

$$\min F = f_1 + f_2 + f_3 \tag{3.13}$$

In equation (3.13), $\min F$ represents the minimum cost function for hazardous waste recovery. Therefore, the path recycling problem of hazardous waste is a static data problem with a single target and a time window. Traditional genetic algorithms have limitations in processing both initial and output data. Therefore, on the basis of the genetic algorithm, a saving algorithm model is introduced to optimize the preliminary data processing. Then a large-scale neighborhood algorithm is used to strengthen the genetic algorithm design to obtain a hybrid genetic algorithm.

To process computer data, initial genetic algorithm encoding is used to process path optimization data. However, genetic algorithm has some drawbacks in processing, resulting in a large amount of redundant data in the calculation process. Therefore, to improve efficiency, decimal encoding is used for data processing in hybrid genetic algorithms. To improve computational efficiency, enhance the initial population speed, increase the speed of obtaining the initial population in the early stage, the saving algorithm is used for population initialization calculations. The specific steps are shown in Figure 3.5.

In Figure 3.5, the saturation calculation method is first used to calculate the results of hazardous waste recycling for each hazardous waste generating unit vehicle without considering cost. The calculated results are summarized. Then any two paths are merged. The calculated savings values are sorted in descending order. After sorting, a save pool sequence is performed to determine whether the merged paths meet the time window requirements until a new merged path is obtained. Afterwards, the path is updated and determined to meet the loading requirements until it is calculated to meet the requirements. Finally, any two paths in the path pool are merged and calculated to determine whether the new path passes through the hazardous waste generation unit. Finally, the order in which the recycling vehicles pass is obtained.

The fitness mainly involves the current target's recovery cost, vehicle transportation cost, and time cost. The best result with the lowest cost path is obtained. To optimize the fitness, a genetic operator is added for operation. The genetic operator mainly compares the probability of the unit with the fitness degree to obtain a path with better fitness. The large-scale neighborhood algorithm mainly involves operator destruction and re-repair of the gene waste units for the parent chromosome in genetic algorithms. It mainly solves the minimum value of the target. Under the basic completion of the target conditions, the objective function is increased to

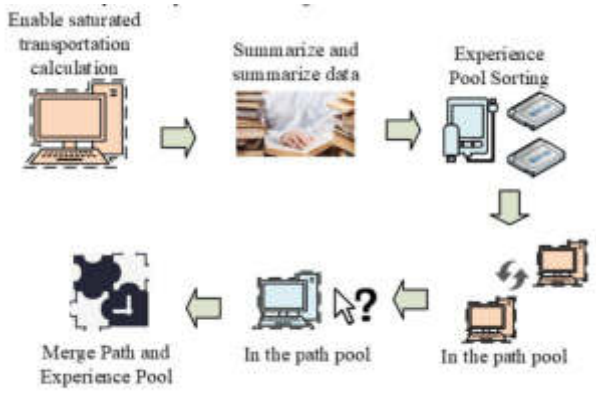

Fig. 3.5: Population optimization steps of the conservation algorithm

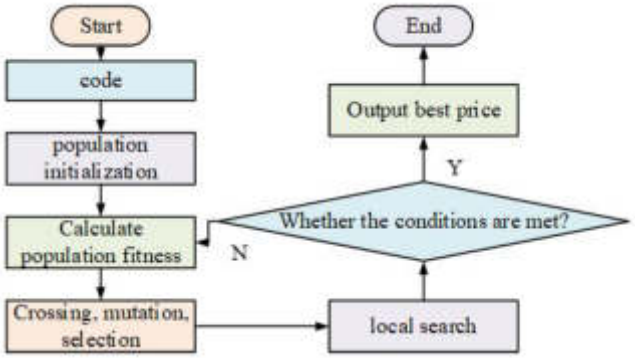

Fig. 3.6: Hybrid genetic algorithm process

reduce the adaptability of chromosomes. The convergence speed of the joint algorithm is enhanced to improve the search ability of the algorithm. The overall process of the hybrid algorithm is shown in Figure 3.6.

In Figure 3.6, the hybrid genetic algorithm first uses the saving algorithm to initialize the population. The genetic algorithm calculates the individual fitness of the population. After completing the selection, crossover and mutation operation, a large-scale neighborhood algorithm is used for local search calculation. Finally, it is determined whether the requirements of the path problem are met. If it is met, the optimal solution is output. If it is not met, the fitness is recalculated.

3.3. Materials. A hazardous waste recycling company in a city is selected as the starting point for hazardous waste recycling in the experiment. The detailed solid waste recycling data collected in the city on 18th May 2021 are analyzed and collected in a systematic data analysis. After carefully analyzing the collected data, the focus is placed on the hazardous waste category labeled HW08, which consists primarily of waste mineral oils and wastes containing mineral oils. Specifically, waste engine oil represented by 900-214-08 is a common type of vehicle waste, which is the main focus of research. Considering that the average household car needs to change about 4 litres of engine oil every 5,000 km, it can be assumed that this type of hazardous waste is relatively stable and widely distributed. This characteristic makes hazardous waste an ideal choice for detailed research and recycling.

4. Results and discussion. This chapter mainly analyzes the data of enterprise hazardous waste recycling management system based on the mixed algorithm. Some analysis data and optimization paths are compared.

Table 4.1: List of hazardous waste recycling

Hazardous waste varieties	Source of hazardous waste	Hazardous waste code	Detailed categories of hazardous waste	pollution
HW08 Waste mineral oil & waste containing mineral oil	General industry	900-214-08	Waste engine oil and transmission oil generated during equipment repair and disassembly	toxicity
				Flammable
		900-199-08	Mineral oil and sludge generated during the dismantling process of automobiles and other vehicles	toxicity
				Flammable
		900-200-08	Waste mineral oil and sludge generated during polishing and development processes	toxicity
				Flammable

Table 4.2: Comparison of parameters after path optimization of hybrid genetic algorithm

Algorithm type	vehicle number	Recycle Path	mileage(km)	Total mileage(km)	Total cost(yuan)	Timing(s)
Traditional genetic algorithm	1	0-3-7-10-11-6-2-1-0	139.7	358.2	1309.24	3.4478
	2	0-13-14-12-4-0	95.5			
	3	0-5-8-9-0	123			
Semi optimal genetic algorithm	1	0-3-7-10-11-6-2-1-0	154	340.9	1274.99	6.6751
	2	0-13-14-0	32.6			
	3	0-5-8-9-12-4-0	154.3			
Semi optimal genetic algorithm	1	0-5-7-8-11-9-12-4-0	199.8	364.4	1121.51	4.5842

The performance of the algorithm model used in the experiment is also compared with other algorithms to verify the performance.

3.1 Experimental analysis of path optimization problem based on hybrid algorithm

In the experiment, a hazardous waste recycling enterprise in a certain city is selected as the starting point for hazardous waste recycling. The pollution control platform established in the province is used to collect data and information on hazardous waste recycling from the enterprise. The current hazardous waste category is HW08. The recycling object data is solved. The specifications and categories of the recycling vehicles for this hazardous waste are the same, and the data remains roughly unchanged. Therefore, the production of hazardous waste recycling is consistent. For the convenience of data collection and calculation, hazardous waste products of this category are selected as the data analysis source. The list of hazardous waste recycling is shown in Table 4.1.

In Table 4.1, waste mineral oil such as HW08 is used as the recycling object for the current experiment. The hazardous waste generated mainly includes waste oil generated by equipment, transmission oil, and gear oil. The hazardous waste generated from 990-199-08 is mainly oil sludge and mineral oil produced during the dismantling of some cars. The waste generated with code 900-200-08 mainly consists of mineral oil and sludge generated during the polishing and ing. The main pollution of these wastes is toxicity, flammability, and explosiveness. Therefore, it needs to be recycled and treated. To compare the computational results of optimized algorithms for path optimization problems, traditional genetic algorithms, semi genetic algorithm optimization with only saving algorithm optimization, and hybrid genetic algorithm optimization are compared. The results are shown in Table 4.2.

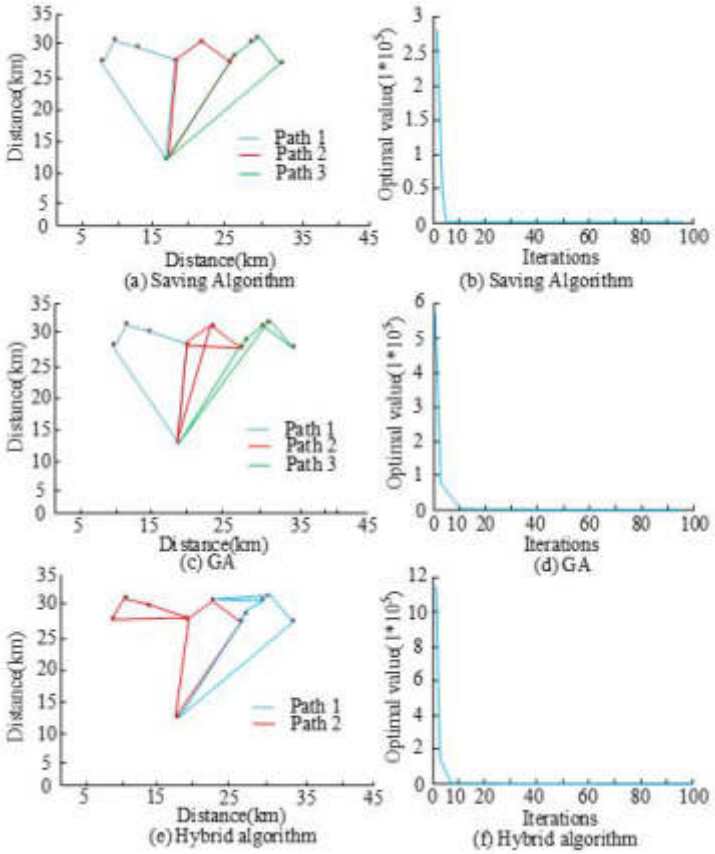

Fig. 4.1: Three algorithm paths and optimization

In Table 4.2, among the three algorithms, the hybrid algorithm increased the total mileage obtained from vehicle recycling after optimizing the path. Compared with genetic algorithm and semi optimized genetic algorithm, it increased by 6.2km and 23.5km, respectively. But the total cost of transportation decreased by 187.73 yuan and 153.48 yuan, respectively. The computational time of hybrid algorithms was relatively fast, because large-scale neighborhood algorithms were added in the later stages. The hybrid algorithm performs better than the other two algorithms in reducing costs in path optimization, CO_2 emissions can be calculated and compared under each scenario by simulating different transport routes. The path maps and optimization processes of the three algorithms are compared, as shown in Figure 4.1.

In Figure 4.1, only the hybrid genetic algorithm had fewer paths for the three algorithms, with only two paths. Meanwhile, the optimal solution value of the hybrid algorithm in solving path optimization problems was significantly higher than the other two algorithm models. From this, the hybrid algorithm could sort the existing paths reasonably to obtain the optimal solution of the path when designing path optimization, thereby making the current path the most cost-effective and efficient optimal path.

4.1. Performance analysis of the algorithm. To compare the feasibility of the hybrid algorithm, different algorithms are tested for performance. Genetic algorithm, conservation algorithm, and hybrid algorithm are selected for comparison. The testing system is Windows 10. The memory is 16GB. The CPU is i7-9800X. The test data is the current hazardous waste recycling dataset. Algorithm performance is tested and analyzed using different metrics such as Accuracy. Accuracy is one of the most intuitive performance metrics used to measure the correctness of the algorithm prediction. In algorithm performance evaluation, higher accuracy

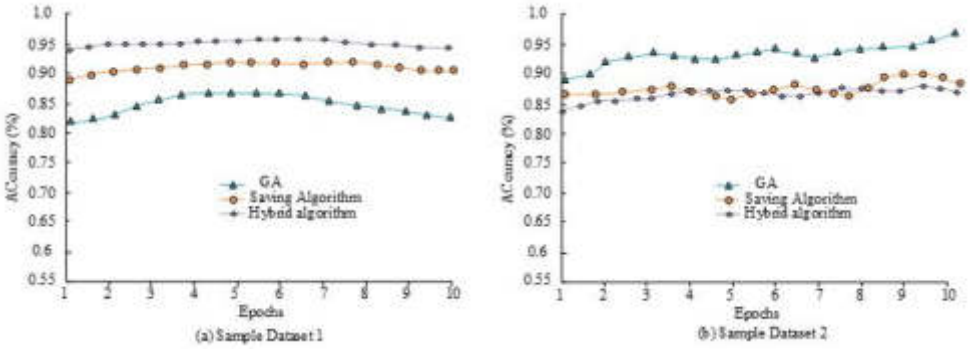

Fig. 4.2: Comparison of accuracy of three algorithms

indicates that the algorithm is more effective in prediction or classification problems. The Mean Percentage Error (MPE) measures the difference between predicted and actual values. It calculates the average prediction error and represents it as a percentage. This metric is particularly important for measuring the performance of the algorithm on continuous numerical prediction tasks. Root Mean Square Error (RMSE) measures the difference between predicted values and actual observations. RMSE gives more weight to large errors, making it a strict measure of algorithm prediction accuracy. Stability refers to the consistency of an algorithm across different datasets or across different subsets of a dataset. Even with slight changes in data, stable algorithms can still provide relatively consistent results. In practical applications, the stability of an algorithm is very important because it affects the reliability and robustness of the algorithm on new or slightly changed data. In practical applications, a single metric often fails to fully assess the performance of an algorithm. These indicator combinations can fully reflect the strengths and limitations of an algorithm from different perspectives, which improves the algorithm used in the study. The accuracy of three algorithms is compared. The accuracy is shown in Figure 4.2.

In Figure 4.2, when comparing the accuracy of the three algorithms, in dataset 1, the accuracy first increased with the increase of the sample size, and then stabilized. Finally, it decreased. From the graph, the hybrid algorithm had significantly higher accuracy than the other two algorithms. The highest accuracy value of the hybrid algorithm was 95.62%. The maximum accuracy of genetic algorithm was 85.67%, and the saving algorithm was 91.25%. From this, the accuracy of the hybrid algorithm was 9.95% higher than that of the genetic algorithm, and 4.37% higher than that of the conservation algorithm. In dataset 2, the accuracy improved with iteration, possibly because the dataset was more stable and did not exhibit bias. The actual operational errors of the three algorithms are compared, as shown in Figure‘4.3.

In Figure 4.3, the three algorithms exhibited different sample error sizes in the same sample. The hybrid algorithm had the lowest error value compared to the two algorithms. The lowest RMSE was 0.185%. Compared to the 0.284% of genetic algorithm, it was 0.099% lower. Compared to the 0.245% of saving algorithm, it was 0.060% lower. The minimum average percentage error was 0.174%. Compared to the 0.346% of genetic algorithm, it was 0.172% lower. Compared to the 0.286% of saving algorithm, it was 0.112% lower. The error of the hybrid algorithm was smaller. The loss functions of the three algorithms are compared to obtain a stability comparison chart, as shown in Figure 4.4.

In Figure 4.4, the loss functions of the three algorithms gradually decreased with the increase of iteration times and then tended to stabilize. The loss function value of the hybrid algorithm was relatively high among the three algorithms. The genetic algorithm had the lowest loss function value. Among the three algorithms, the hybrid algorithm had the best algorithm stability, performing better in path optimization problems.

5. Discussion. With the increasing global concern for environmental protection and climate change, the strategic goal of ”double carbon” has been proposed. In this context, the recycling and treatment of hazardous wastes generated during the production and operation of enterprises has become a key link in achieving this

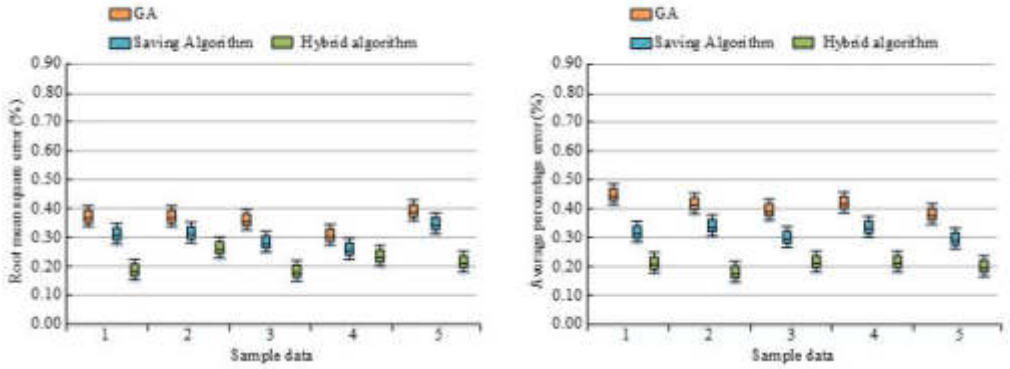

Fig. 4.3: Comparison of Errors among Three Algorithm

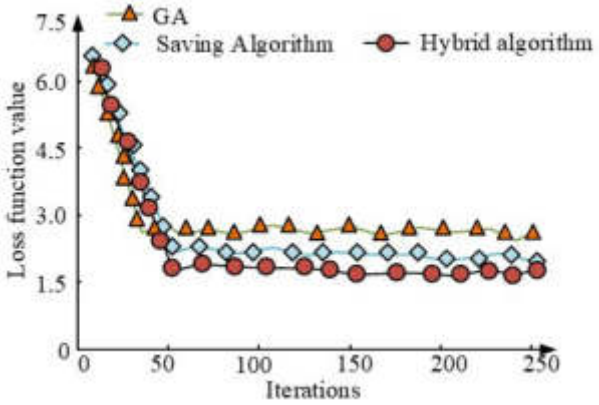

Fig. 4.4: Comparison of Loss Functions of Three Algorithms

strategic goal. Reasonable and effective management of hazardous waste recycling and treatment not only reduces environment pollution, but also promotes resource recycling, which is an important measure to achieve sustainable development. Therefore, in the selection of hazardous waste, the HW08 waste mineral oil is selected as the current experimental recycling object, because the selected hazardous waste is more common and produce more hazardous waste a. It can make the current study more universal, which is more favourable to research analysis. Meanwhile, when comparing path optimization of multiple algorithm models, compared with genetic algorithm and semi optimized genetic algorithm, the hybrid algorithm increased the total mileage after path optimization by 6.2km and 23.5km, respectively. It indicates that the hybrid algorithm can optimize the hazardous waste material path under the same conditions. It can achieve relatively good results, achieving better results in hazardous waste route management and transportation vehicle management. The paths of the three algorithms are only less than the paths of the hybrid genetic algorithm. There are only two paths. The optimal solution of the hybrid algorithm in solving the path optimization problem is significantly higher than that of the other two algorithms, indicating that the hybrid algorithm can reasonably sort the original paths to obtain the optimal solution in path optimization design. This can make the current path the most cost-effective, efficient, and optimal path. When comparing the path planning process of different hybrid algorithms, the optimal solution of the hybrid algorithm in solving the path optimization problem is significantly higher than that of the other two algorithmic models. The algorithm has fewer routes on the path optimization. This indicates that the hybrid algorithm can reduce the current driving situation of hazardous waste. Meanwhile,

due to the reduction of paths, better management and planning of vehicle carrying capacity are required for transportation vehicle planning and use. This is more conducive to improving the management level of hazardous waste. When comparing the accuracy of the three algorithm models, the accuracy of the algorithm improves with the increase in the number of samples and then stabilizes. Finally, it decreases. This indicates that the model achieves maximum accuracy after increasing the number of samples. Then it decreases to indicate that the optimization effect of the model begins to decrease. It may be that the changes in the sample data, such as vehicle information, so the accuracy of the algorithm is not a stable increase in the situation. At the same time, compared to the error of the current three models, the research uses the model with the smallest error value. This indicates that the model can better optimize most of the data in sample testing when planning paths. The algorithm performance is more stable and the effect is also the best. Meanwhile, the stability of three models is compared. The stability of the model used in the study is the best, and the loss function value is the lowest, which indicates that the hybrid model used in the current path optimization is able to maintain relatively good stability. It is more beneficial to the path optimization analysis.

In summary, the model used in the study can achieve better test results when planning and analyzing the transport path of hazardous waste. Meanwhile, the model used in the study has better algorithmic stability, which is more advantageous for planning and management different paths. By optimizing hazardous waste recycling routes, it can reduce the empty and repeated trips of transportation vehicles, and reduce the total mileage traveled. This not only reduces fuel consumption and corresponding CO_2 emissions, but also lowers transport costs, achieving a win-win situation in terms of economic benefits and environmental protection.

6. Conclusion. The research mainly discusses the hazardous waste recycling in the context of dual carbon to find the most suitable path for hazardous waste recycling. According to the traditional path algorithm analysis, the advantages of each algorithm are combined to form a new hybrid genetic algorithm. Finally, the hybrid algorithm is compared for path optimization problems. The algorithm performance of the hybrid algorithm is analyzed. The experimental results showed that the hybrid algorithm increased the transportation mileage by 6.2km and 23.5km respectively compared to genetic algorithm and semi optimized genetic algorithm. But the total cost of transportation decreased by 187.73 yuan and 153.48 yuan, respectively. Simultaneously, the hybrid algorithm obtained a larger optimal value in analyzing path optimization data. There were fewer paths for transportation vehicles, improving transportation efficiency. In the performance comparison, the accuracy of the hybrid algorithm was 9.95% higher than that of the genetic algorithm, and 4.37% higher than that of the conservation algorithm. The RMSE of the hybrid algorithm was 0.099% lower than that of the genetic algorithm, and 0.060% lower than that of the saving algorithm. The average percentage error was 0.172% lower than the genetic algorithm, and 0.112% lower than the saving algorithm. The hybrid algorithm had a lower loss function descent index and more stable algorithm performance. In summary, the hybrid algorithm has a better optimization effect and higher efficiency when dealing with hazardous waste path optimization problems. After comparing several traditional algorithms, the algorithm performance is also better. Research has achieved some results in optimizing the path of hazardous waste.

This study focuses on the conversion of new energy trucks by transport companies in the context of building an ecologically civilized society and the "dual-carbon" strategy, but it does not include carbon emissions in the costing. Future trends will require companies to measure carbon dioxide in the production process and achieve carbon neutrality through carbon sinks. Carbon emissions from vehicles will be costed. The improvements are as follows. The study needs to combine the simulation of the actual carbon trading market, quote the carbon market price of the target city for cost calculation, and incorporate the carbon market price into the cost calculation function. Thus, the optimal solution reflecting cost minimization under the requirement of "carbon neutrality" is obtained. However, there are still some shortcomings in the research, such as the relatively small dataset used in the experiment. Therefore, further research will be conducted on larger and more datasets in the future.

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DESIGN AND IMPLEMENTATION OF SAAS ONLINE EDUCATION MANAGEMENT SYSTEM FOR EXPANDING LMS SYSTEM

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Abstract. The development of the education industry benefits from the continuous progress and updates of internet technology, and the organic integration of the two can further promote the emergence of the LMS (Learning Management System) system. Based on the application characteristics of the LMS system and the characteristics of the Software as a Service online education management system, a Software as a Service online education management system based on the extended LMS system was constructed. The service mode of the system was analysed, and a solution to the problem of paper formation and an analysis of the automatic paper formation algorithm in the system were provided. In addition, further research was conducted on the scores of the credibility evaluation of the system's services under different attribute parameters. Through the correlation analysis between different attributes and the credibility evaluation scores of the Software as a Service system, it can be seen that among the selected attribute parameters, Response Time and Latency show a negative correlation with the credibility evaluation, while other parameters show a positive correlation. The Software as a Service system constructed in this article provides relevant technical solutions, which have great practical application value and have reference significance for other similar applications. It provides more support for the application and promotion of the Software as a Service (SaaS) online education management system.

Key words: Expand LMS; Software as a Service system; service mode; credibility evaluation; correlation analysis.

1. Introduction. At present, the main users of the Learning Management System are usually schools and related enterprises. The main functions of the LMS system include basic information management, course management, learning record tracking, learning effectiveness evaluation, and various learning assistance functions (discussion, chat, quizzes, surveys, statistics, collaboration, voting). During the teaching process, teachers can use the LMS system to achieve functions such as online classes, homework assignments, uploading classroom materials, and social interaction [1-2]. Enterprises can use the LMS system for employee training, employee registration, progress tracking, and more. The business model of the LMS system is to charge fees for schools or corporate institutions, while providing free services to students and teachers.

With the innovation and development of internet technology, traditional LMS systems are no longer in line with the rapid iterative development model that prioritizes user experience in the context of the internet. Nowadays, most domestic LMS systems still remain in the traditional C/S mode. Alemayehu Fikru K et al.'s research shows that there is a certain degree of gap between China and advanced SaaS based architecture models abroad [3]. Studying the universal architecture of a SaaS based LMS system from a technical perspective, in order to continuously improve and optimize the performance of online education management systems, is one of the important issues currently faced, including the analysis and resolution of key details and encountered problems. Among them, the front-end includes how to use the latest single page architecture front-end framework to cooperate with traditional Java back-end technology, build reusable front-end components through the directive feature in angular.js, build unit testing and end-to-end testing for the front-end, and automate the front-end through construction tools. The backend section mainly includes how to achieve communication and routing between the client and backend, how to build the company's own modular framework based on the characteristics of JVM and Tomcat, and how to achieve isolation and mutual communication between modules, the company's backend storage framework, and the implementation of cache mechanism [4-6]. In addition, by analysing the key technologies of LMS system application in SaaS online education management system, we can refer to the implementation process of the system and build a SaaS based LMS system that has a good user experience, is stable, and is easy for the team to develop quickly [7].

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Cloud computing and internet technology are also widely applied on LMS. In the field of LMS, currently the most advanced Blackboard company in foreign countries has adopted SaaS technology, serving LMS on the basis of AWS public cloud. Schools and educational institutions can pay as needed for the functions they need to activate, and there is no need to configure and install users' client and server sides. As long as users purchase LMS services, they can use the services anytime and anywhere [8-9].

At present, there is still a certain degree of lag in the domestic development status, and the development of LMS system is still insufficient. Technically, the traditional C/S architecture is still used, with limited scalability and the need for engineers to implement it on-site, resulting in poor user experience. In terms of functionality, it is also too simple, lacking a series of key functional points from the teacher creating the course to students completing their studies, achieving grades, and ending the course [10-11]. Customization and on-demand payment are also urgent issues for domestic LMS systems. Different schools and training institutions will have different ways of educational management, therefore, the demand for LMS is different. In traditional software systems, such systems can result in significant costs during implementation. With the increasing attention paid by the domestic education industry, the scale of users is increasing, and there are more and more course resources. The traditional LMS system in China is no longer able to meet the needs of users [12]. In order to provide users with more powerful functions and a better experience, there is an urgent need for a modern SaaS based online LMS system.

Based on the main problems faced above, this article introduces the solution of SaaS online education management system, and constructs a SaaS online education management system based on the extended LMS system. Based on the constructed system, the impact of service modes and different attribute changes on the credibility evaluation of its services was analysed, laying an important foundation for the application of the system in the education management industry.

2. LMS system and SaaS technology characteristics. Based on the development of the education industry and related technologies, the construction and experience optimization of an online design education knowledge service platform are achieved using a distributed SaaS model framework. Based on the analysis of typical users' needs in the online design education industry, relevant design goals and platform construction plan design process planning can be formulated for the design and improvement of the online design education knowledge service platform system [13-14].

The concept of user experience is explained from a qualitative perspective, which describes how a product is directly or indirectly associated with the outside world and the emotional cognition and subjective feelings that arise when it interacts with it. Simply put, when describing the user experience of a product, what needs to be asked is whether it is convenient and fast to use. Describing the determining factors of user experience in a structured manner can be divided into the following five elements: strategic layer, scope layer, structural layer, framework layer, and presentation layer [15-16]. The strategic layer determines the product design goals from the perspective of the school or enterprise, as well as the core demands from the user perspective; The scope determines the list of product requirements and the segmented needs of various types of users from which; The structural layer determines the information exchange structure framework of the product; The framework layer determines the roommate process and interactive page layout of the product; The presentation layer determines the visual style and style of the product. As shown in Figure 2.1, the design objectives of an online education management system based on user experience elements are presented.

2.1. LMS system. For common LMS systems, there are three main modes used: LAN mode, C/S mode, and B/S mode. The local area network (LAN) method was the earliest used, mainly running through LAN protocols. The advantage of this system is that it is easy to develop, but its security and stability are poor, so it has been basically phased out. The C/S mode is implemented jointly by the client software and the server, and the application software needs to be installed on the user's machine [17]. The C/S model is built on the basis of a local area network, which has certain limitations and is not conducive to expansion, and updates and upgrades are not flexible enough. The B/S mode, also known as the browser server mode, adopts popular internet technology and is more user-friendly, making installation, deployment, and version updates more convenient. With the rise of cloud computing in recent years, SaaS, as a way to implement cloud computing, has been welcomed by schools or enterprise level applications. SaaS allows users to rent software by purchasing services, and applications can be paid on demand based on customized functions. Users only need to log in to the

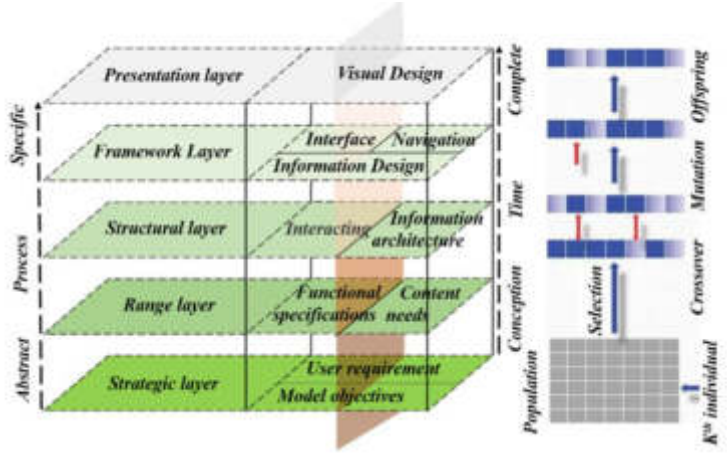

Fig. 2.1: Design Objectives of Online Education Management System Based on User Experience Elements

browser using the purchased account to enjoy customized services. Under the background of cloud computing, LMS systems are gradually evolving towards SaaS based services to provide a better user experience [18-19].

2.2. Advantages of SaaS technology in LMS systems. Both abroad and domestically, SaaS service software has gained great development opportunities. In addition to the precise judgment of customer needs by SaaS service providers, the most crucial aspect is the advantages of SaaS software itself. It appears at an appropriate time to adapt to the development of the times and people's consumption needs, in order to gain a clear advantage in competition with traditional software. This is also the reason why this article uses the SaaS model for online teaching system design [20].

1. Advantages on the user side
   Ready to use: For users, using SaaS software is a simple task. As long as you can connect to the internet, you can start using SaaS software, without the complex installation and configuration process of traditional software. The SaaS software was already installed on the network server of the software supplier before its launch, and the installation and configuration of the software are independent of the user. If there is a problem, you don't need to solve it yourself. You only need to provide feedback to the service provider to solve the problem, which is convenient and fast.
   No maintenance required: A software or product cannot be perfect, and there may be some issues during use. No matter what the problem is, the traditional software model leaves it to users to solve, which is both time-consuming and a waste of energy; The maintenance of SaaS software is the responsibility of the provider, and users do not need to consider these issues [21].
   Cost reduction: An important consideration factor for whether software is worth consuming is the price of the software. In the past, traditional software users bought just as they did, but if there were problems, they couldn't help it even after the shelf life; When SaaS software users need the software, they pay according to the time, and buy it as soon as they use it; If you feel it's not suitable, you can no longer pay for the rental.
   Congenital antivirus: The client of SaaS software is usually a browser or other tool software. Even if the client's system is infected with a virus, it only needs to reinstall tools and software such as the system and browser, without the need to install and restore application software one by one. Moreover, it is difficult for viruses on the client side to spread to the server, as the client and server mainly communicate through protocol-based data, making it difficult for viruses to penetrate. Users do not need to overly consider security and other issues [22].
2. Advantages of software vendors
   Saving sales costs: Software products produced under traditional software models require a series

of investment, development, sales, and marketing efforts. When users purchase a product, they often focus most on its usability and durability, whether the product can be applied in multiple aspects, and whether it can withstand the test of time. Based on these considerations, users may have difficulty making decisions when purchasing a product. But for software products under the SaaS service model, service providers only need to do a good job in market promotion. For product quality, users can first spend a small amount of money on product trials, and then decide whether to continue purchasing product services based on the level of experience.

Saving maintenance costs: Through previous analysis of SaaS mode services, it can be concluded that in traditional software service modes, when encountering major software problems, software service providers may need to dispatch specialized technical maintenance personnel for on-site software maintenance, which will greatly consume the service provider's maintenance costs. If multiple users encounter problems, the service provider will need to spend a lot of money on software maintenance [23-24]; But in the SaaS service mode, no matter how many users encounter problems at the same time, users only need to feedback the problem to the service provider. On the one hand, software maintenance is carried out on the servers purchased by the service provider themselves, and on the other hand, software maintenance technicians will be very familiar with their own servers and deployment environment, and can quickly locate the problem and solve the user's problem. Based on this advantage, software maintenance costs can be greatly reduced [25].

3. Design and Implementation of SaaS Online Education Management System Expanding LMS System. Taking online education models and platform learning and platform user experience as research objects, highlighting the professional attributes of design disciplines. In addition, it was emphasized that optimizing and researching the experience design of the platform, as well as building online platforms, should be the focus of design practice. In the context of the experience economy era, the quality of user experience evaluation in online education is no longer limited to the visual effects and functional richness of the product, but includes the comprehensive impact of other factors such as the entire process of service backend management, organizational operation, information access, acquisition and feedback, and student learning effects on users, Therefore, through comprehensive analysis of online design education and training scenarios and deep exploration of needs, a better platform user experience optimization has been achieved.

Based on the above introduction of typical trust models or frameworks in cloud computing environments, combined with the 3D cloud service credibility evaluation system, this article analyses the comprehensive evaluation indicators of service credibility in order to evaluate the comprehensive performance of the system used in the education field before proceeding with system design. Through relevant analysis, this article proposes a third-party based comprehensive evaluation reference model for the credibility of SaaS services, based on the constructed SaaS online education management system based on the LMS system. As shown in Figure 3.1, a third-party based comprehensive evaluation reference model for SaaS service credibility is provided. As shown in the figure, the system is based on the basic framework of cloud services and forms the basic part of the system through relevant data collection, processing, and feedback. In addition, further combining with the consumer needs of cloud services and achieving data feedback, promoting system updates and improvements, and reflecting the overall functionality of the system, ultimately forming a comprehensive evaluation reference model for SaaS service credibility.

3.1. Service Model of SaaS Online Education Management System. The core of SaaS software services is to transform traditional software industry sales products into sales services, treating software as a service rather than a sold product [26]. The basic theory of SaaS holds that the essence of software is services. From the perspective of users, what they are more concerned about is whether a software product is easy to operate and does not encounter significant problems. Even if a software product requires a large amount of money to purchase, as long as the functionality is convenient and there are no subsequent usage issues, most users are willing to purchase it. Users value the service of a product more than the price. SaaS software is able to gradually establish a foothold in the field of software services by meeting the needs of users [27].

From the perspective of modern economics, regardless of the business model, the establishment of the model requires a clear supply-demand relationship to support this business model, that is, whether the product's functions can meet the needs of users. The biggest difference between traditional software business models

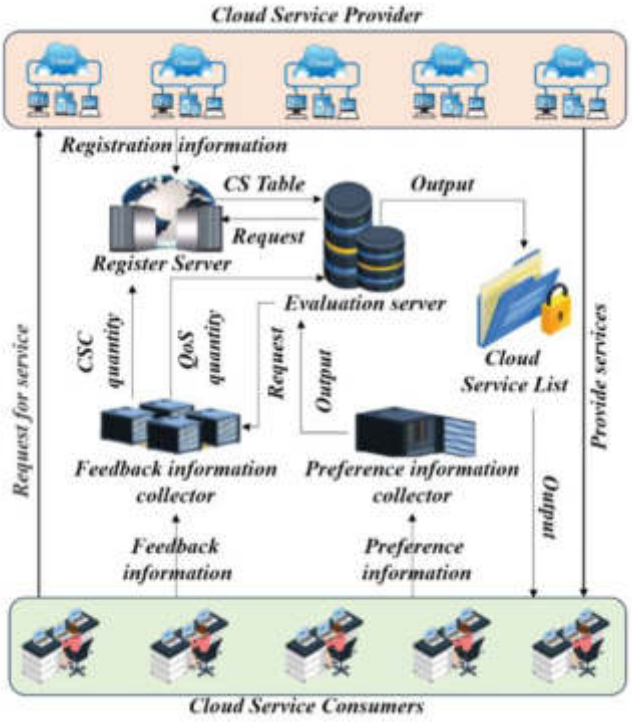

Fig. 3.1: Reference Model for Comprehensive Evaluation of SaaS Service Credibility Based on a Third Party

and SaaS software business models lies in their different definitions of software [28]. The traditional software business model regards software as a product, which is customized according to user needs based on market research. When user needs change, the existing functions of the software product may not necessarily meet user needs; The SaaS software business model views software as a service that sells services to users. Even if users' needs change, service providers can make changes to their services in a short period of time, in line with the supply-demand relationship in economics.

3.1.1. Analysis of Paper Formation Problems. In the education industry, the problem of generating test papers is one of the important issues that most online education management systems face. Similarly, for the SaaS online education management system that expands the LMS system, the paper generation problem is essentially a combinatorial optimization problem with multiple constraints, which can be defined as a combination of a set of constraint conditions and an objective function. In order to assess students' mastery of knowledge, each test question is mainly set with the following attributes: a) test question number; b) Question score; c) Question type; d) Difficulty coefficient; e) Knowledge points, the range of knowledge levels to which the test questions belong; f) Cognitive classification, reflecting the level of requirements for the teaching content of the question; g) Differentiation, reflecting the degree to which the question identifies and distinguishes the candidate's level of knowledge and ability; h) Estimated answer time.

In automatic test paper generation, for each test question, the above 8 indicators need to be determined. For each test paper, a matrix Sg determined by $8 \times m$ is shown in formula (3.1). Among them, m is the number of test questions included in the test paper.

$$Sg = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{18} \\ a_{21} & a_{22} & \ldots & a_{28} \\ \ldots & \ldots & \ldots & \ldots \\ a_{m1} & a_{m2} & \ldots & a_{m8} \end{bmatrix} \tag{3.1}$$

The objective matrix should meet the following constraints as much as possible: The total score of the test paper is approximately given by formula (3.2):

$$P = \sum_{i=1}^{m} a_{i2} \tag{3.2}$$

In the formula, P represents the total score of the test paper, and a_{i2} is the score of the *i-th* test question. In addition, for the difficulty constraints of the test paper, formula (3.3) needs to be met:

$$ND = \frac{\sum_{i=1}^{m} a_{i2}a_{i4}}{100} \tag{3.3}$$

In the above formula, ND is the difficulty of the test paper, and a_{i4} is the difficulty coefficient of the *i-th* test question. In the process of education management, not only the above two links need to be constrained, but also the knowledge points need to be constrained. The specific constraint conditions are given by formula (3.4):

$$\sum_{i=1}^{m} c_{1i} \times a_{i2} = z_h c_{1i} = \begin{cases} 1, IFa_{i5} = 0 \\ 0, IFa_{i5} \neq 0 \end{cases} \tag{3.4}$$

In the formula, a_{i5} is the knowledge point number of the *i-th* test question, and h_z is the score of the *h-th* knowledge point. For the constraints of cognitive classification, formula (3.5) can provide:

$$\sum_{i=1}^{m} c_{2i} \times a_{i2} = P_k c_{2i} = \begin{cases} 1, IFa_{i6} = k \\ 0, IFa_{i6} \neq k \end{cases} \tag{3.5}$$

For the above formula, a_{i6} is the cognitive classification number of the *i-th* question, and Pk is the score of the *k-th* cognitive classification. The constraint of question type also has an important impact on the analysis of paper formation problems. In this model, the constraint conditions of the question type can be described using formula (3.6):

$$\sum_{i=1}^{m} c_{3i} \times a_{i2} = q_d c_{3i} = \begin{cases} 1, IFa_{i3} = d \\ 0, IFa_{i3} \neq d \end{cases} \tag{3.6}$$

In addition, constraints on time and overall differentiation are important components of ensuring overall quality, as shown in formulas (3.7) and (3.8), which provide constraints on time and overall differentiation:

$$T = \sum_{i=1}^{m} a_{i8} (i = 1, 2, ..., m) \tag{3.7}$$

$$D = \frac{1}{P} \sum_{i=1}^{m} a_{i2}a_{i7} \tag{3.8}$$

In addition to the constraints of the above individual items, other indicators such as expected value, extraction frequency, etc. can also be specified. However, based on our experience, having too many indicators can increase the difficulty of paper formation and reduce the efficiency of paper formation.

3.1.2. Automatic test paper generation algorithm. Through the analysis of the paper generation problem in the SaaS online education management system, it can be seen that the efficiency of automatic paper generation and the good performance of generating test papers mainly depend on the design of the algorithm. Here, we will introduce an improved genetic algorithm based on segmented integer code coding. According to the adaptive crossover probability P_c, each question type segment is crossed separately. The crossover method is as follows: randomly select two crossover points within a certain question type segment, and then exchange

the middle segment between the two points to determine the non-duplication of each gene in the generated child. If duplicate genes appear, they are re crossed or replaced with randomly generated genes until all genes are different [29-30]. Adopting adaptive crossover probability not only performs well in the later stage of evolution, but also improves the crossover rate of individuals with excellent performance in the early stage of evolution, so that they do not stay in a state of approximate stagnation, reducing the possibility of evolution towards local optimal solutions. The adaptive crossover probability P_c is determined by formula (3.9):

$$P_{\mathrm{c1}} = \begin{cases} P_{\mathrm{c1}} - \frac{(P_{c1}-P_{c2})\times(f^{'}-f_{max})}{f_{max}-f_{avg}}, f^{'} \geq f_{max} \\ P_{\mathrm{c1}} f^{'} f_{max} \end{cases} \tag{3.9}$$

In the above equation, f 'is the larger fitness value between the two strings to be crossed; f_{max} and f_{avg} are the maximum fitness values of individuals in the previous generation population and the average fitness values of the population; P_{c1}=0.9, P_{c2}=0.6.

According to the adaptive mutation probability Pm, the mutation is performed separately in each question type segment. The mutation method is as follows: randomly select a mutation site within a certain question type segment, and then randomly generate a gene. If the gene is the same as the mutation site gene, the mutation is repeated until a different gene appears. By adopting adaptive mutation probability, mutation can perform well in both the early and late stages of evolution. The adaptive mutation probability Pm is determined by the following equation:

$$P_m = \begin{cases} P_{m1} - \frac{(P_{m1}-P_{m2})\times(f_{max}-f)}{f_{max}-f_{avg}}, f \geq f_{avg} \\ P_{m1} f^{'} f_{avg} \end{cases} \tag{3.10}$$

In the formula, fmax and f_{avg} are the maximum fitness values of individuals in the previous generation population and the average fitness values of the population; F is the fitness value of the individual to be mutated; P_{m1}=0.1, P_{m2}=0.001.

3.2. Construction of SaaS Online Education Management System Based on Extended LMS System. In the actual process of expanding the SaaS online education management system of the LMS system, a total of three ports were designed for the online design education knowledge service platform, as shown in Figure 3.2. The PC user webpage display environment is usually the port where students and teachers enter the knowledge service platform for related learning or teaching activities in home and office settings; The H5 mobile end is usually used in mobile scenarios, where students can access the platform anytime and anywhere for knowledge learning. Teachers can also view course and student information for knowledge teaching at any time. In addition, teaching scenarios also break the limitations of time and space; The backend management end is used for unified management of platform systems. As shown in the figure, the design of the online design education knowledge service platform includes three main parts. At the same time, it combines feedback data from students and teachers to achieve multi-dimensional data sharing. Through relevant data processing techniques, it breaks through the data barriers in common systems and provides necessary guarantees for the implementation of the system's performance.

In addition, based on the functional design of the online design education platform knowledge service platform system mentioned above, through the design analysis experiment of the information framework, the experimental plan for designing the information framework for three ports was obtained.

Based on the above analysis, in the construction process of expanding the SaaS online education management system of LMS system, the characteristics of simple form and easy modelling of linear models can be fully utilized. Given a sample set described by n attributes, namely n-dimensional eigenvectors $x\leq(x_1,x_2,...,x_n)$, and using n-dimensional eigenvectors $w\leq(w_1,w_2,...,w_n)$ to represent the weights corresponding to each attribute, the linear model of the sample set can be expressed in the form of a quantization matrix as formula (3.11):

$$f(\overrightarrow{w}, x, b) = \overrightarrow{w}^T \overrightarrow{x} + b \tag{3.11}$$

In the formula, $f\in R$, the value range is the entire real number field, and b is the non-zero intercept. After learning $\overrightarrow{w}$ and b, the model can be determined. Due to the intuitive expression of the importance of each attribute in prediction by $\overrightarrow{w}$, this linear model has good interpretability.

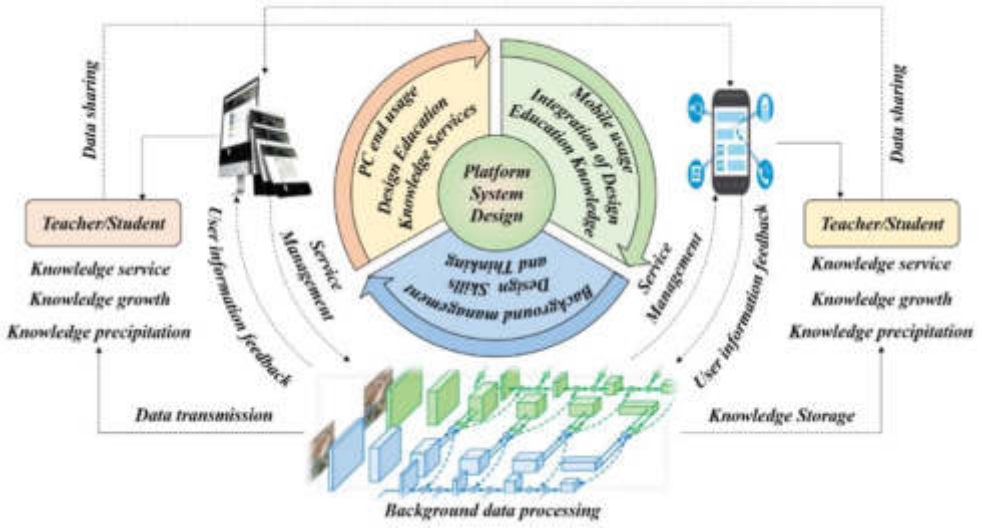

Fig. 3.2: Framework Construction of Online Design Education Knowledge Service Platform System

In order to use the linear model above to handle the binary classification problem, it is necessary to use the function shown in formula (3.11) to map $f \in R$ to (0,1), and obtain formula (3.12):

$$y(z) = \frac{1}{1 + e^{-z}} \tag{3.12}$$

If $y(z)$ is considered as the possibility of the sample being a positive example, then (1-y) is the possibility of its negative example. If y is considered as the class posterior probability $P(y = 1\,|x\,)$ and combined with formula (3.12), formula (3.13) can be obtained:

$$\ln \frac{p(y = 1\,|x\,)}{p(y = 0\,|x\,)} = \overrightarrow{w}\,\overrightarrow{x} + b \tag{3.13}$$

Due to $p(y = 1\,|x\,) + p(y = 0\,|x\,) = 1$, further formula (3.14) can be obtained:

$$\begin{cases} p(y = 1\,|x\,) = \frac{e^{\overrightarrow{w}^T \overrightarrow{x} + b}}{1 + e^{\overrightarrow{w}^T \overrightarrow{x} + b}} \\ p(y = 0\,|x\,) = \frac{1}{1 + e^{\overrightarrow{w}^T \overrightarrow{x} + b}} \end{cases} \tag{3.14}$$

When using the feature vectors $\overrightarrow{X} = (\overrightarrow{x^1}, \overrightarrow{x^2}, ..., \overrightarrow{x^m})$ of a set of m training samples and their corresponding classification target variable $\overrightarrow{Y} = (\overrightarrow{y^1}, \overrightarrow{y^2}, ..., \overrightarrow{y^m})$, we hope that the regression algorithm can achieve the maximum probability $L(\overrightarrow{w, b})$ on this set of training samples. At this point, the maximum likelihood method can be used to estimate the values of $\overrightarrow{w}$ and b, as described in formula (3.15):

$$\arg\max_{\overrightarrow{w}, b} L(\overrightarrow{w}, b) = \arg\max_{\overrightarrow{w}, b} \prod_{i=1}^{m} p(y^i \left| \overrightarrow{x^i} \right., \overrightarrow{w}, b) \tag{3.15}$$

It is not difficult to see from the above analysis that the regression analysis is used to study the relationship between a categorical dependent variable and a set of independent variables, namely characteristic variables. The binary evaluation results of the service credibility, including CSP reputation, of the SaaS online education management system based on the extended LMS system are truly applicable, as the dependent variables only have two values: 1 and 0 [31].

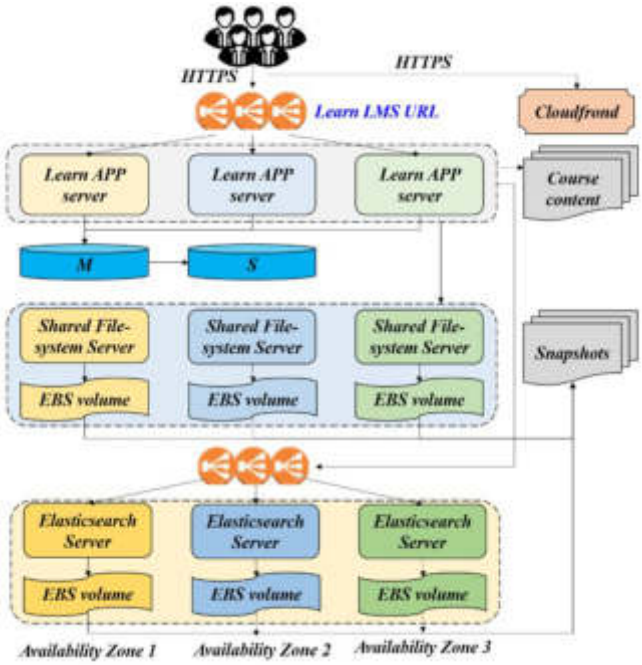

Fig. 3.3: SaaS Deployment Diagram of Learn System

Table 3.1: User Information Table

Field Name	Type	Field Constraint	Annotation
ID	bigint(20)	NOT NULL	Unique ID identification (primary key)
phone	varchar(12)	NOT NULL	Mobile phone number
nickname	varchar(128)	DEFAULT NULL	nickname
avatar	varchar(255)	DEFAULT NULL	Avatar
gender	tinyint(4)	DEFAULT NULL	Gender
age	int(11)	DEFAULT NULL	Age
birth	date	DEFAULT NULL	birthday
is_auth	tinyint(4)	NOT NULL	Is it certified
auth_type	tinyint(4)	DEFAULT NULL	Certification type
auth_time	datetime	DEFAULT NULL	Certification time
is_enabled	tinyint(4)	NOT NULL	Is it enabled
is_deleted	tinyint(4)	NOT NULL	Do you want to delete it

The deployment of SaaS systems is distributed across multiple AWS availability zones, and the overall architecture of the system is designed to withstand failures in one to two availability zones, and can run in any service interruption situation. Figure 3.3 summarizes the distribution of the logical components of this system in the availability zones of AWS, and the system is deployed using three or more availability zones.

3.3. Database Table Design. The system has designed multiple database tables based on functional requirements. This section mainly introduces the tables related to core functions based on the E-R diagram.

1. User Information Table
   The user information table records the information of registered users, including fields such as user ID, phone number, nickname, avatar, gender, age, etc. The user information table is shown in Table 3.1.
2. Teacher Information Form
   The teacher table records the information of the certified teacher, including teacher ID, avatar, mobile

Table 4.1: Correlation Analysis Between Attribute Changes and Model Evaluation Scores

Attribute	Attribute Description	Correlation
Response Time(RT)	Time it takes to send a request and receive a response	Negative correlation
Availability (Ava)	Successful calls/total calls	Positive correlation
Throughput (TP)	Total number of calls (or times) within a given period of time	Positive correlation
Success ability (Suc)	Number of response messages/number of request messages	Positive correlation
Compliance(Com)	Degree to which a WSDL document complies with the WSDL spec	Positive correlation
Latency (Lat)	Time the server takes to process a given request	Negative correlation
Reliability (Rel)	Ratio of error messages to total messages	Positive correlation
Best Practices (BP)	Degree to which web services comply with WS-I basic configuration files	Positive correlation
Documentation(Doc)	Proportion of document detection in WSDLs	Positive correlation

phone number, ID card number, hand-held ID card photo and other fields. Among them, is user user_id, institution organization_id is foreign key, and teacher information

3. Institutional Information Table
   The institution information table records the information of the institution, including the institution ID, institution name, organization type, institution contact phone number, institution introduction, and other fields, mainly displaying some important fields.
4. Course Information Table
   The course information table records the information of the course, including course ID, associated teacher, course name, cover background, limited number of trial sessions, limited number of registrations, and other fields. It mainly displays some important fields.
5. Course Registration Form
   The course registration form records the student ID and course ID when students register for course selection.
6. Course User Check in Record Form
   The course user check-in record table records the information of course user check-in records, where course check-in course_sign_in_id and user user_id are foreign keys.

4. Analysis of system credibility evaluation results. In the SaaS online education management system model based on the extended LMS system, research was conducted on the credibility evaluation score of the selected parameter attribute changes in the SaaS model. In order to further analyse the correlation between different attributes and the credibility scores of SaaS online education management system services in expanding the LMS system, as shown in Figure 4.1, four attributes, namely Availability, Reliability, Response Time, and Latency, were selected as examples to perform a regression analysis relationship between the attributes and the credibility evaluation scores of the system services. As shown in the figure, both Availability and Reliability show a positive correlation with the system service credibility evaluation score; The Response Time and Latency attributes show a negative correlation with the credibility score of SaaS system services.

This article summarizes and analyses the attributes related to the credibility evaluation of SaaS online education management system, as shown in Table 1. The correlation analysis between different attributes and the credibility evaluation score of SaaS online education management system is provided.

Due to the absence of missing values in the dataset, no corresponding processing is required. Based on the previous classification processing, the dataset is divided into a test set and a training set by 3:7. The comparison between the boxplot of the 7 datasets before partitioning and the boxplot of the training dataset after partitioning is shown in Figure 4.2. It can be seen that there are some obvious outliers in the RT and Lat attributes. In addition, it can also be seen that Ava, TP, and RelBP also have a few outliers. Considering that the WOE transformation used later can eliminate outliers to a certain extent, it will not be dealt with here.

In addition, in order to further compare the distribution of provinces in different geographical regions more intuitively, as shown in Figure 4.1, the distribution and division of provinces in each region are presented. From the figure, the determination of provinces involved in analysing the environmental performance and measurement of smart city power supply is a comprehensive consideration of their geographical location and

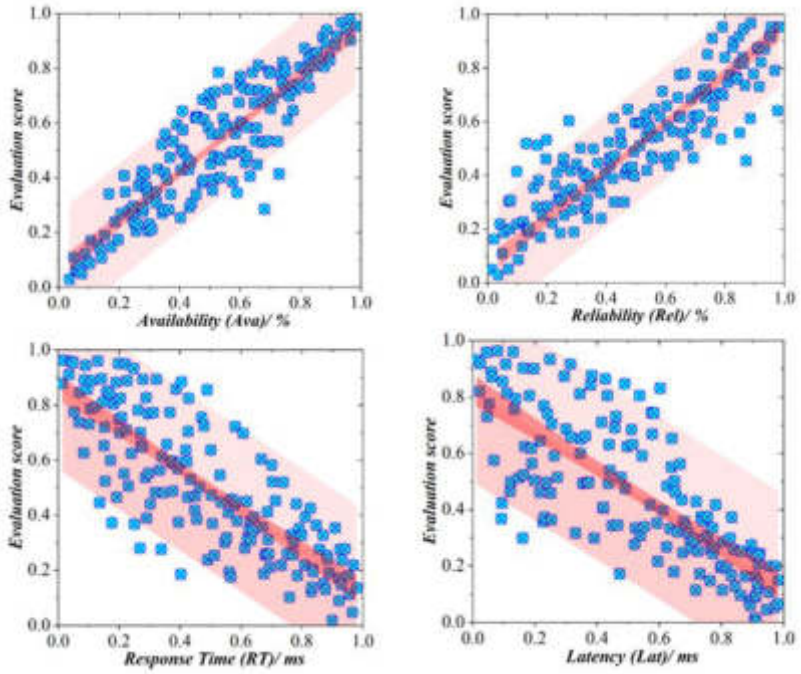

Fig. 4.1: Correlation Analysis Between Various Attributes and Evaluation Scores in SaaS Online Education Management System

economic development.

In fact, based on the above analysis results, it can be seen that the distribution of attributes *RT* and *Lat* is very close. Similarly, from Figure 4.3, it can be seen that the distribution of *Suc* and *Rel* is the closest. In addition, after dividing the dataset into test and training sets in a 3:7 ratio, the number of samples in the training set is 282, and the number of samples in the test set is 120. From the comparison of the box plot, it can be seen that the distribution pattern of the divided training set and the sample population before the partition is consistent, indicating that the partition of the dataset has a certain representativeness. For the convenience of the experiment, this section is mainly based on the training set data for analysis.

Based on the correlation analysis results of different attributes, four feature attributes were selected to generate histograms, as shown in Figure 4.3. From the figure, it can be seen that there are certain differences in the distribution of different attributes, which basically exhibit a normal distribution or F-distribution. For the attributes *Best Practices* and *Reliability*, their distribution is closer to a normal distribution.

5. Conclusions . Internet technology has laid the foundation for the development of online education management systems. Based on the characteristics of LMS systems, this article proposes a Software as a Service online education management system that extends LMS systems. It analyses and studies the self-service mode, discusses the credibility evaluation score of the system, and further studies the correlation between different attributes and credibility evaluation scores, as well as the comparison of attribute distribution histograms. The main conclusions are as follows:

1. Based on the basic characteristics of the LMS system, the Software as a Service online education management system, which expands the LMS system, can achieve more comprehensive functional service modules, further improve the service mode of the online education management system, and achieve innate defence functions with lower operation and maintenance costs, higher stability, and virus threat. This lays the foundation for the development of the online education management system and the comprehensive improvement of application performance.

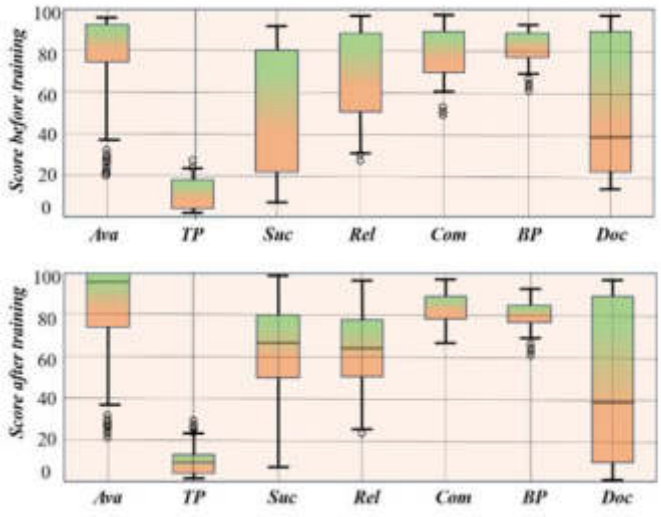

Fig. 4.2: Statistical Description of Regional Efficiency Scores at Different Stages

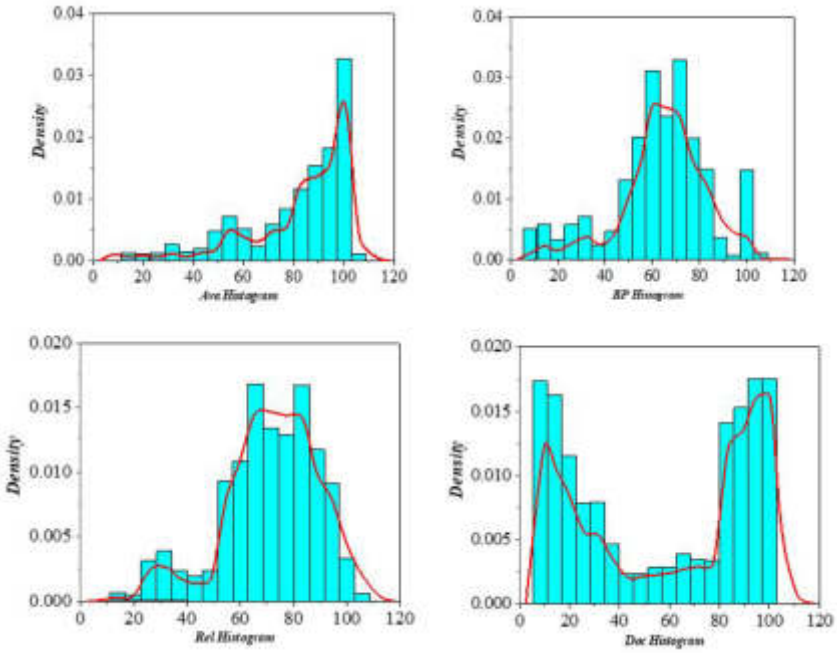

Fig. 4.3: Histogram Comparison of Four Feature Attributes in Training Set

2. In the Software as a Service online education management system constructed in this article, there are certain differences in the impact of different attribute parameters on the credibility evaluation score of the system. Among the 7 analysed attributes, Response Time and Latency show a negative correlation with credibility evaluation, while other attributes show a positive correlation; Histograms with different attributes mostly exhibit features of normal distribution and F-distribution; The proposed credibility evaluation method can also be applied to other types of online education management

systems, providing more research methods for evaluation and analysis of different systems.

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PARAMETRIC DESIGN OF OFFICE FURNITURE PARTITION SPACE INTEGRATED WITH THE INTERACTIVE EVOLUTION ALGORITHM OF FNT AND TREE STRUCTURE

SHIDONG CHEN*AND HUIYUAN GUAN †

Abstract. Office furniture and its spatial layout design are playing an increasingly important role in improving work efficiency and employee comfort. However, the technology still faces some challenges. For instance, accurately simulating and evaluating the behavior and feelings of people in the office environment is difficult due to the high complexity of furniture spacing space design. It is important to address these issues. The study aims to explore the key technology and practical application of the parametric design of office furniture partition space based on the interactive evolution algorithm of tree structure. This paper proposes an improved version of the flexible neural tree model and corresponding algorithm. It also presents a design method based on the interactive differential evolution algorithm to optimize the automatic balance effect between global exploration and local development in the average shortening of the difference vector based on individual distribution. The results showed that all indexes were larger than or equal to other algorithms on 46 datasets. According to the Wilcoxon signed-rank test, the *P*-value was all less than 0.05, which is a significant advantage. Median, mean, and quartiles indicated that the overall performance of the algorithm was higher than the others. Furthermore, similarity evaluation-based Flexible Neural Tree algorithm had no outliers in the selected dataset, which also indicates the stability of the performance. The research results will support innovation and development in the field of office furniture design. This will promote intelligence, efficiency, and personalization in the design process, and meet the diverse needs of modern office environments.

Key words: Flexible neural tree; Similarity assessment; Interactive evolution; Indoor space; Parameterization

1. Introduction. In recent years, computer-aided design technology has made parametric design a hot topic in the fields of architecture and interior design. This technology provides designers with unprecedented flexibility and innovation. Office space serves not only as a place for employees to work but also as an important location for promoting communication, cooperation, and innovation [1-2]. Parametric design enables designers to explore creativity within pre-defined parameter spaces. Traditional parametric design methods still face problems such as low efficiency and unstable results when dealing with complex office environments. Interactive evolutionary algorithm is a computational method that draws inspiration from biological evolution mechanisms, which can adaptively search for the optimal or near optimal solution in the design space [3-4]. The Flexible Neural Tree (FNT) structure can better describe the relationship between office furniture and its configuration, thereby achieving more efficient and accurate design search and optimization. Through this method, designers can not only quickly explore design solutions that meet specific needs, but also continuously explore and optimize creativity based on algorithm feedback [5-6]. Therefore, this study proposes a parameterized design method for office furniture partitions that combines tree structure Interactive Differential Evolution (IDE) algorithm. The aim of this study is to provide designers with an efficient and flexible design tool, enabling office furniture design to meet functional needs while demonstrating outstanding aesthetic value.

The research innovatively combines the FNT structure and the IDE algorithm based on similarity evaluation to realize the parametric design of office furniture spacing space. The FNT model is optimized by introducing the similarity distance between nodes and intertree similarity partial function, improving genetic diversity. At the same time, the improved FNT is applied to the IDE algorithm to replace the complex scoring mechanism to realize the automatic balance between global exploration and local development. Moreover, an IDE algorithm based on the backtracking strategy is proposed to solve the problem of Local Optimal State (LOS).

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The first part of the study presents the purpose and provides a literature review. The second part proposes a parametric design method of office furniture partition combined with IDE structure. The third part is algorithm performance testing and application analysis. The fourth part summarizes the method and experimental results and draws the research conclusion.

2. Related works. The principles of spatial layout design have been widely applied in modern engineering and daily life. Keshavarzi M et al. proposed three new layout methods through the interactive design system GenFloor and implemented them as part of the Dynamo software package. Experiments had shown that the GenFloor system performed well in residential floor plan planning tasks [7]. To optimize the layout of the sewer network, Hassan W H et al. proposed a Hybrid Genetic Algorithm (HGA), which solves the problem by generating feasible layouts of the network and determining the optimal design from them. Compared with previous methods, this model could achieve the optimal solution with the minimum number of generations [8]. Dong et al. proposed an automatic solution method for Ship Piping Route Design. The feasibility and effectiveness of this method were verified by combining A* algorithm and Genetic Algorithm (GA) [9]. Feng et al. proposed an effective B-spline parameterization method to improve the layout of stiffeners for the optimization of thin-walled shell structures in aerospace engineering. This method could produce design results with clear layout and no checkerboard effect [10]. To reduce the manual work of indoor floor plan design, He S et al. used a differentiable renderer as an optimizer to achieve design optimization by adjusting the parameters of grid primitives. The optimization process was constrained by input boundaries, overlap, and weight constraints to ensure parameterization of the design and reasonable spatial partitioning. The effectiveness of this method in floor plan design was verified through ablation and control experiments [11].

Tan et al. studied the existing research work of Evolutionary Transfer Optimization (ETO) in multitasking, complex, multi/multi-objective optimization, and machine learning applications in uncertain environments. At the same time, the article discussed the challenges faced in computational intelligence and explored the future research directions of ETO [12]. Zhang et al. proposed an Adaptive and Scalable Neural Structure Search method (AS-NSS), which utilizes the enhanced International Data Encryption Algorithm and a variable structure encoding strategy. The effectiveness and superiority of the AS-NSS method had been demonstrated [13]. Deng et al. proposed a population generation method based on target space, which generates new individuals in the target space and maps them to the decision variable space to synthesize new solutions. The algorithm outperformed traditional algorithms in large-scale decision variables and multi-objective problems [14]. Al Fugara et al. used an integrated model of support vector regression and GA to map groundwater spring potential for the Jerash and Agilent regions of Jordan. This study provided a new integrated model for the drawing of groundwater spring potential maps, with high accuracy and reliability [15]. Yi et al. proposed a new interval multi factor evolutionary algorithm to overcome the limitation of solving optimization tasks and simultaneously solve multi-objective optimization problems. This method had effectiveness and performance advantages in benchmark testing functions and robot path planning cases [16].

Although the studies mentioned above have yielded results, they still have limitations. Some methods rely too heavily on specific algorithms and are less universal. For instance, methods like GA, HGA, and neural structure search may incur high computational costs and long solution times when dealing with complex problems, particularly in scenarios with large-scale decision variables or multiple objectives. Applying parametric design to furniture spacing allows for the automatic generation of multiple layout schemes in a rule and parameter-driven manner, enabling rapid iteration and optimization when combined with IDE. This study focuses on the parametric design of office furniture spacing and explores the application of IDE structure. This research level and methodology is in sharp contrast to the research areas and methods of the literature, demonstrating unique innovations.

3. Parametric design of office furniture partition space based on tree structure IDE. The study first discusses the FNT structure based on similarity evaluation and applies it to the IDE algorithm to achieve parameterized design of furniture spacing space. The algorithm achieves automatic balance between global exploration and local development during the process of average shortening of the difference vector based on individual distribution.

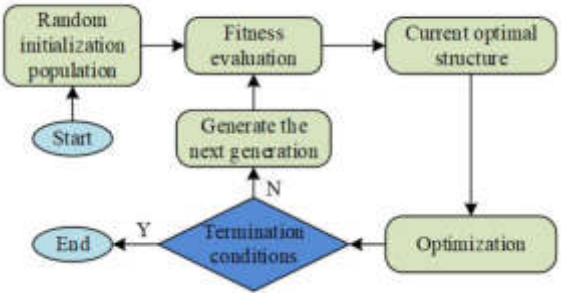

Fig. 3.1: The overall evolutionary framework of FNT

3.1. FNT structure based on similarity evaluation. Compared with conventional neural networks, FNT can find the optimal network structure by utilizing evolutionary algorithms. Hence, the modeling process of FNT optimization has two aspects: structure and parameter, as displayed in Figure 3.1.

In the FNT model, leaf nodes correspond to the input nodes of the neural network and are used to represent a certain feature in the dataset. Non leaf nodes (NLN) represent hidden layers in neural networks, representing an activation function. Therefore, two instruction sets are proposed for these 2 kinds: terminal and functional instruction sets, T and F. T has all the dataset features, while F owns the neurons' operating instructions, which together make up the set S for adjusting the tree structure, as shown in equation (3.1).

$$S = F \bigcup T = \{+_2, +_3, \cdots, +_n\} \bigcup \{x_1, x_2, \cdots, x_n\} \tag{3.1}$$

In equation (3.1), $+_n$ is the instruction function of a NLN with n parameters. $x_1, x_2, \cdots, x_n$, fitting to the feature meaning in the dataset, is the instruction of the leaf node. The output results of NLN of FNT need to be calculated based on FNT. $+_i$ is also represented as a flexible neural operator with i inputs. During creating FNT, an instruction is randomly selected from the F and T sets as a node. Besides, two optimized random parameters a_i and b_i are generated as parameters for the activation function. This commonly used function in the FNT model is equation (3.2).

$$f(a_i, b_i, x) = e^{-(\frac{x-a_i}{b_i})^2} \tag{3.2}$$

The input calculation of flexible neuron $+_i$ is equation (3.3).

$$net_n = \sum_{j=1}^{n} w_j \cdot x_j \tag{3.3}$$

In equation (3.3), leaf node $x_j (j = 1, 2, \cdots, n)$ is the input of NLN $+_n$. The output calculation of $+_n$ is equation (3.4).

$$out_n = f(a_i, b_i, net_n) = e^{-(\frac{net_n - a_i}{b_i})^2} \tag{3.4}$$

Figure 3.2 shows a classic FNT model that calculates recursively from left to right using a depth-first traversal method to obtain the overall output of FNT.

This study utilizes Particle Swarm Optimization (PSO) algorithm to optimize the parameters of FNT. In the FNT model, each node has three parameters, namely activation function parameters a_i, b_i, and the weights ω representing the strength of the connection with the parent node (PN). The range of values for these parameters is a real number between [0,1]. During the parameter optimization process, FNT nodes are traversed in the order of the root traversal. The parameters of each node are sequentially encoded and ultimately represented

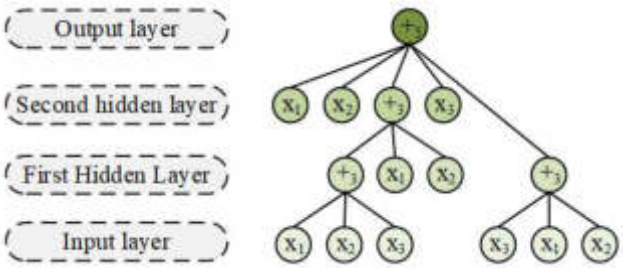

Fig. 3.2: Classic FNT model

as a particle vector in PSO. This study uses the standard PSO formula to update the velocity and position (V-P) of particles. The speed of particle updates is equation (3.5).

$$v_i(t+1) = \omega \times v_i(t) + c_1 r_1(pbest_i(t) - x_i(t)) + c_2 r_2(gbest(t) - x_i(t)) \tag{3.5}$$

The position of particle updates is equation (3.6).

$$x_i(t+1) = x_i(t) + v_i(t+1) \tag{3.6}$$

In equations (3.5) and (3.6), ω is the inertia weight, and c_1 and c_2 are the learning factors. r_1 and r_2 are two random numbers that obey a uniform distribution within the range of [0,1]. $v_i(t)$ and $x_i(t)$ are the V-C of the i-th particle in the t-th generation. $v_i(t+1)$ and $x_i(t+1)$ are the iteration results for the $t+1$-th generation. $pbest_i$ represents the historical optimal position of the particle i during the current iteration process. $gbest$ represents the optimal position in the global particle record.

The standard FNT dose not consider the similarity between tree structures during the evolution process, which may significantly reduce the genetic diversity of tree structure populations [17]. Therefore, this study proposes an enhanced version of the FNT model. The Similar Distance between Nodes (SDN) function is a distance function proposed based on FNT nodes. For any two random nodes a and b of FNT T_1 and T_2, both have $a \in \{x_1, x_2, \cdots, x_n, +_2, +_3, \cdots, +_N\}$ and $b \in \{x_1, x_2, \cdots, x_n, +_2, +_3, \cdots, +_N\}$. This study uses $\varphi(a, b)$ to represent the a-b distance of nodes, as shown in equation (3.7).

$$\varphi(a,b) = \begin{cases} a \oplus b, \ \ if \ \ a \in T, b \in T \\ n(b) \times std(b), \ \ if \ \ a \in T, b \in F \\ h^{\alpha} \times \sum \varphi(a_c, b_c), \ \ otherwise \end{cases} \tag{3.7}$$

In equation (3.7), the function $n(x)$ is utilized to calculate the quantity of leaf nodes of x. $std(y)$ is used to measure the high number of words in the root node. h represents the maximum height of numbers T_1 and T_2. a_c and b_c are sub-trees of a and b, respectively. α can reflect the impact caused by the height difference between nodes. When two nodes are the same height, α=0, otherwise α=1.

Considering the differences in the position of nodes in the tree structure, the differences brought by nodes closer to the root node may be more significant than those far away from the root node. Two factors need to be considered, namely the size and height of the tree [18-19].

As exhibited in Figure 3.3, this study introduces two ideas when testing the trees' distance and combines them with SDN. Firstly, nodes near the root node have higher weights when calculating distance. Secondly, regarding the similar distance between two trees, various heights should be greater than the same height. The representation of the Similarity Dist between Trees (SDT) function is as follows. Supposing there is a tree $T_1 = \{st_1(T_1), st_2(T_1), \cdots, st_m(T_1)\}$, where T_1 represents the root node and $st_1(T_2), st_2(T_2), \cdots, st_n(T_2)$ represents the presence of m sub-trees. In another tree $T_2 = \{st_1(T_2), st_2(T_2), \cdots, st_n(T_2)\}$, T_2 represents the

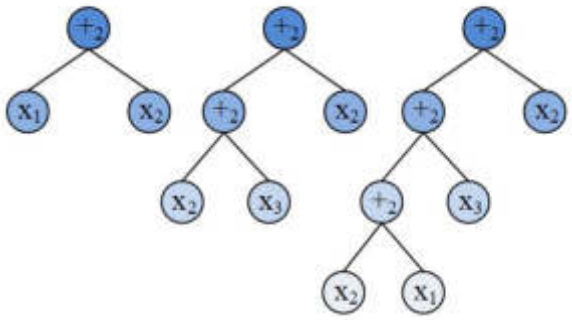

Fig. 3.3: Example of the impact of height difference between trees on distance calculation

root node. $st_1(T_2), st_2(T_2), \cdots, st_n(T_2)$ represents having n sub-trees. Therefore, the SDT between T_1 and T_2 is represented by equation (3.8).

$$siml(T_1, T_2) = \begin{cases} \varphi(T_1, T_2), & if\ T_1\ or\ T_2\ is\ a\ single\ node \\ C^{\Delta h} \times k \times \sum_{i=1}^{\min(m,n)} \varphi(s_i(T_1), s_i(T_2)), & otherwise \end{cases} \tag{3.8}$$

The calculation method for k in equation (3.8) is equation (3.9).

$$k = \frac{1}{1 + e^{-h}} \tag{3.9}$$

In equation (3.9), k is the weight of the node, and C is a constant.

The setting of fitness functions is crucial for the performance of evolutionary algorithms. Generally, a smaller fitness function value indicates better performance, while a larger AUC value indicates more accurate classification. Therefore, the non equilibrium fitness function proposed in the study is equation (3.10).

$$fitness(i) = 1 - AUC_i \tag{3.10}$$

In equation (3.10), i is the i-th individual in the population. AUC_i represents the classification performance when using the i to classify the dataset. This study proposes a Similarity Evaluation-based Flexible Neural Tree algorithm (SEFNT) by integrating SDN, SDT function, and imbalanced fitness function. The SEFNT algorithm first calculates the fitness values of all individuals in each generation of FNT population, and sorts them in ascending order according to the size of the fitness values. Then, individuals in adjacent positions are grouped in pairs. The structural similarity of each group of individuals is calculated and determined whether to delete them based on the preset similarity criteria. Finally, a new population is obtained after deleting similar individuals.

3.2. Parameterized design of furniture spacing space based on IDE. The IDE algorithm is an evolutionary algorithm that replaces the scoring mechanism. In the IDE, users only need to choose a more satisfactory individual between two individuals, without the need for complex comparative scoring processes. The IDE algorithm utilizes information on individual differences and indirect population distribution size to search for offspring of parent individuals around a base individual. The parent individual will only be replaced by the offspring if they exceed it in fitness. During the optimization process of the algorithm, the individual distribution gradually shrinks, and the difference vector shortens on average according to the individual distribution, thus achieving automatic balance between global exploration and local development. The standard IDE algorithm includes four steps: population initialization, crossover, mutation, and selection [20-22].

Firstly, here is a specific method for providing the initial population, which is represented by equation (3.11).

$$x_{j.i.0} = x_i^{\min} + (x_i^{\max} - x_i^{\min}) \times rand,\ \ \forall i \in 1, \cdots, D;\ \ \forall j \in 1, \cdots, N \tag{3.11}$$

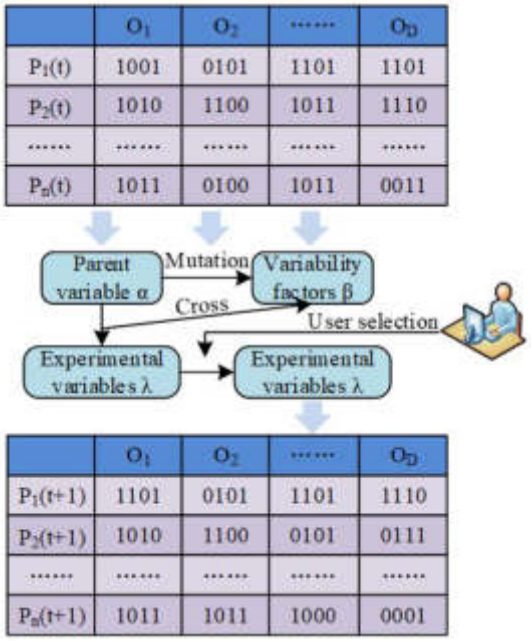

Fig. 3.4: The iterative process of IDE

In equation (3.11), $x_{j,i,0}$ is the gene in the i part of the chromosome of the j-th individual. $x_i^{\min}$ and $x_i^{\max}$ represent the lower and upper bound of the i-th component. $rand$ is a random number that follows a uniform distribution of [0,1]. In each iteration, a mutation vector is produced through mutation operations. The latter is vital in performing the differential evolution algorithms. The classic mutation operator $DE/rand/1$ is equation (3.12).

$$V_{j,t} = X_{r1,t} + F_j \times (X_{r2,t} - X_{r3,t}) \tag{3.12}$$

In equation (3.12), $X_{j,t}$ represents the j-th individual during the t-th iteration. $V_{j,t}$ is the related mutation factor. r_1, r_2 and r_3 are mutually exclusive integers chosen from array $[1, 2, 3, \cdots, N]$ at random and are not equal to j. F_j is the proportion factor. Then cross operation is performed to obtain the experimental vector. The crossover operator is calculated by equation (3.13).

$$U_{j,i,t} = \begin{cases} V_{j,i,t}, & if \ \ rand < CR \ and \ i = i_{rand} \\ X_{j,i,t}, & otherwise \end{cases} \tag{3.13}$$

In equation (3.13), $U_{j,i,t}$ is the i component of the experimental vector of the j individual during the t iteration. CR is the crossover rate. i_{rand} is a random number from $[1, 2, \cdots, D]$. After obtaining the test vector, a selection operator is used to choose the greater one from the PN and test vector to survive to the next generation. The operation is selected as shown in equation (3.14).

$$X_{j,t+1} = \begin{cases} U_{j,t}, & if \ f(U_{j,t}) < f(X_{j,t}) \\ X_{j,t}, & otherwise \end{cases} \tag{3.14}$$

Figure 3.4 is the IDE's iterative diagram.

As a heuristic algorithm, the differential evolution algorithm is essentially a greedy strategy. Selective pressure causes the population to gradually move towards the higher fitness region, which can cause the algorithm

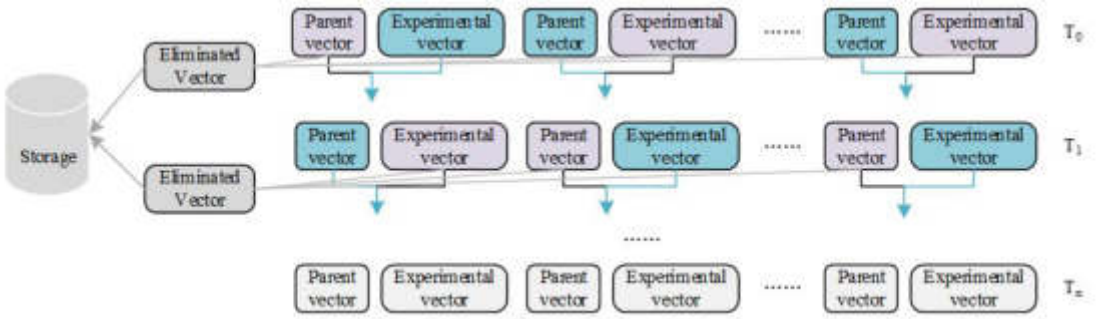

Fig. 3.5: The iterative process of IDE-BO

to converge prematurely to the local optimal solution. If the individuals in the population are too similar, the resulting difference vector may not be sufficient to lead the algorithm out of the local optimal region. To address this issue, this study introduces an IDE based on the backtracking strategy (BS-based) to address the LOS by gradually returning to the previous choice.

To address the shortcomings of greedy selection operators in LOS, the algorithm adopts a new BS-based selection operator. The first is to determine whether an individual has fallen into a LOS. When an individual slowly updates within a certain interval, it is in a stagnant state. It may have a certain rate of misjudgment but effective for determining if an individual has fallen into a LOS and can develop strategies to low down the misjudgment effect. The new operator utilizes backtracking and establishes a spatial warehouse in each iteration to store individuals that failed in the current round of competition and were discarded. When an individual is detected falling into a LOS, a series of vectors are continuously extracted from the storage space to survive to the next generation. To avoid calculating the fitness of random vectors and increase computational complexity, the PN is substituted with a discarded experimental vector. These vectors will not be passed on to the later generation, but individuals evolved built on them are more likely to aid individuals to overcome. Figure 3.5 is the process of IDE-BO.

4. Analysis of the parametric design effect of office furniture spacing space based on IDE-SEFNT algorithm. To verify the effectiveness of differential evolution algorithm and GA in indoor layout design, this study conducted simulation experiments. All eigenvalues are normalized to intervals (0.0, 1.0) during the experiment. To pre set parameters, with a number of individuals NP=12 for each iteration, a jump rate Jr=0.3, a scaling factor F=0.7, and a crossover probability CR=0.5. In the simulation experiment, it is assumed that the user cannot manually adjust the feature values, but can have a clear overall understanding of the layout design generated by the algorithm and accurately select the layout that suits their preferences. The target individual is set that the user is most satisfied with $O(o_1, o_2, \cdots, o_D)$. In the system, the distance between the individual and the satisfactory solution is considered as the fitness value. The experimental template and parameter values are shown in Figure 4.1.

This study selected 10 publicly available datasets from the UCI machine learning library as experimental data for performance testing of the SEFNT algorithm. The experiment divided the data into 10 equal parts, each containing two parts: the training and the test sets. The imbalanced rate (IR) is the sample ratio between the majority and minority class, indicating the imbalance degree. In the experiment, datasets with IR$<$9 and IR$\geq$9 were considered low-imbalanced and high-imbalanced datasets. Table 4.1 is the UCI dataset.

The experiment compares the SEFNT algorithm with ten other algorithms. These algorithms can be divided into 9 non equilibrium methods and 1 standard FNT method. Among them, the imbalanced method includes 4 oversampling algorithms, 3 cost sensitive algorithms, and 2 ensemble algorithms. Non equilibrium algorithms are all based on random forests as the basic classifier. The AUC and GM experimental results of different algorithms on low and high imbalanced datasets are shown in Figure 4.2.

In Figure 4.2, the maximum, minimum, median, mean, and quartile of AUC/GM results of the SEFNT

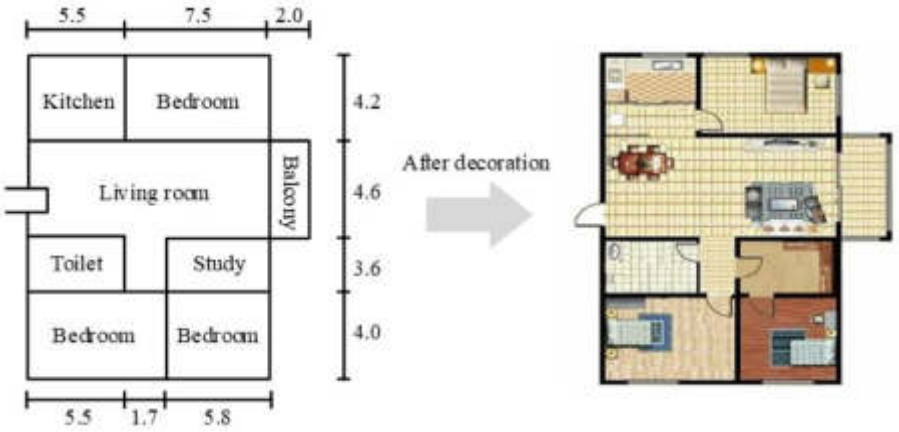

Fig. 4.1: Experimental template and parameter values

Table 4.1: UCI dataset

Dataset	Number of samples	Characteristic number	IR
Chesscking-Rook vs. King	28056	6	113.05
letter-recognition	20000	16	24.35
HTRU2	17898	9	67.44.
musk	6598	168	5.49
isolet	7797	617	24.99
waveform	5000	21	2.04
page-block0	5472	10	8.79
nursery	12960	8	2.00
parkinsons telemonitoring	5875	26	41.57
sat	6435	36	9.28

on 46 datasets are greater than or equal to those of other algorithms. The max and min values reflect the good performance of the SEFNT algorithm on certain datasets. The median, mean, and quartile indicate that the overall performance of the SEFNT algorithm is higher than other algorithms. In addition, SEFNT has no outliers in the selected dataset, which also indicates the performance stability. Compared with other algorithms, the SEFNT still performs well on five indicators and has no outliers. Compared to its performance on low imbalanced datasets, the SEFNT algorithm performs slightly better on high imbalanced datasets. Specifically, the box area in the figure is smaller, while the box area of other algorithms increases slightly. When the performance of other algorithms decreases, the SEFNT algorithm can maintain more stability and better performance on highly imbalanced datasets. Table 4.2 is the AUC results of the UCI dataset.

In Table 4.2, the SEFNT has AUC values greater than 0.85 on most datasets. On the Nursery dataset, the AUC of the EE is 0.1668, while the SEFNT's AUC is 0.6295. In addition, the SEFNT algorithm has an AUC value of up to 0.9960 on the Parkinsons Telemonitoring dataset. Table 4.3 is the GM results of the UCI dataset.

In Table 4.3, the SEFNT algorithm has a GM value greater than 0.85 on most datasets. On the Nursery dataset, the EE's GM value is 0.0622, while the SEFNT's GM is 0.6220. In addition, the SEFNT algorithm has a GM value of up to 0.9959 on the Parkinsons Telemonitoring dataset. Overall, the SEFNT has AUC and GM values greater than 0.85 on most datasets. These values indicate that the SEFNT algorithm not only maintains good classification performance, but also has more stable performance.

This study conducted simulation tests on this algorithm and other three. To accurately verify the convergence, the iterations in the simulation are set to 150. However, in real interactive environments, to avoid inaccurate results caused by user fatigue, the maximum number of iterations generally does not exceed 50. The

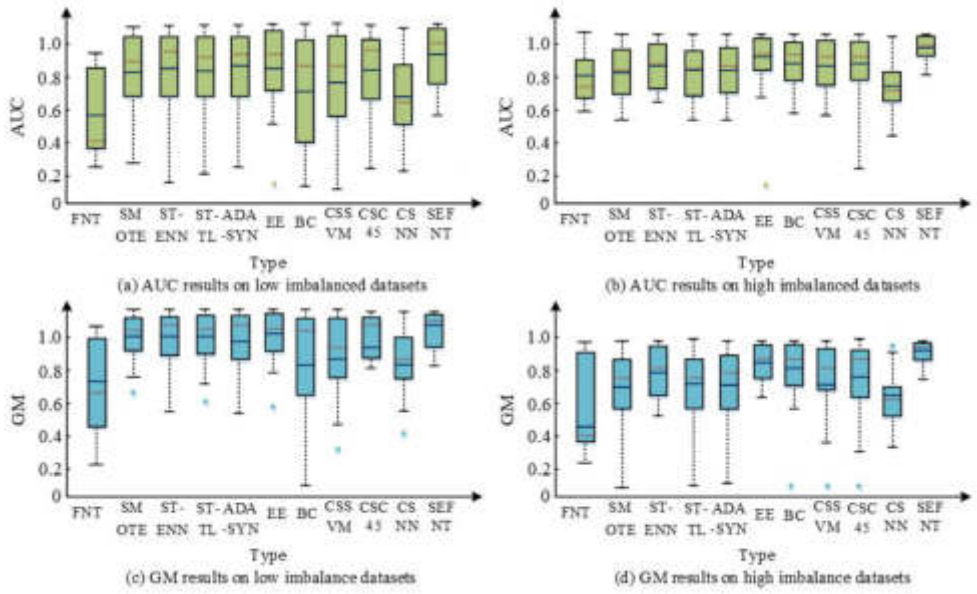

Fig. 4.2: AUC and GM test results

Table 4.2: AUC experimental results on the UCI dataset

Dataset Type	FNT	SMOTE	ST-ENN	ST-TL	ADASYN	EE	BC	CSSVM	CSC4.5	CSNN	SEFNT
Chesscking-Rockvs.King	0.5000	0.7632	0.8183	0.7857	0.7954	0.9758	0.9731	0.972	0.9858	0.6535	0.9849
HTRU2	0.7242	0.9340	0.9372	0.9327	0.9321	0.9427	0.9416	0.9431	0.9304	0.875	0.9445
Isolet	0.5000	0.8915	0.9122	0.8967	0.887	0.9752	0.9692	0.9697	0.9287	0.5000	0.9333
Letter-recognition	0.6513	0.9694	0.9705	0.9703	0.9704	0.9944	0.9931	0.9554	0.9808	0.5509	0.9428
Musk	0.5416	0.7604	0.7552	0.7584	0.7631	0.7853	0.7874	0.9252	0.9437	0.5526	0.829
Nursery	0.5000	-0.3023	0.2075	0.3008	0.2992	0.1668	0.2595	0.5871	0.5871	0.5160	0.6295
Page-block0	0.7348	0.9188	0.932	0.9221	0.9213	0.9397	0.9411	0.9219	0.9491	0.7036	0.8904
Parkinsons telemonitoring	0.5000	0.9785	0.9769	0.9799	0.982	0.9917	0.9867	0.9834	0.9920	0.4082	0.9960
Sat	0.5000	0.7587	0.8200	0.7574	0.7627	0.8571	0.8554	0.7275	0.7841	0.615	0.8543
Waveform	0.7529	0.8714	0.8871	0.8699	0.8713	0.9056	0.9010	0.8981	0.8502	0.8023	0.8943

Table 4.3: GM experimental results on the UCI dataset

Dataset Type	FNT	SMOTE	ST-ENN	ST-TL	ADASYN	EE	BC	CSSVM	CSC4.5	CSNN	SEFNT
Chesscking-Rockvs.King	0.0000	0.7279	0.8004	0.7578	0.7711	0.9757	0.973	0.9716	0.9858	0.6076	0.9848
HTRU2	0.6727	0.9327	0.9363	0.9313	0.9312	0.9423	0.9413	0.9423	0.9298	0.873	0.9441
Isolet	0.0000	0.885	0.9081	0.8909	0.8799	0.9753	0.9692	0.9690	0.9260	0.0000	0.9220
Letter-recognition	0.5566	0.9689	0.9700	0.9699	0.9699	0.9944	0.9931	0.9553	0.9806	0.4674	0.9422
Musk	0.3084	0.7582	0.7535	0.756	0.7578	0.7845	0.7862	0.9251	0.9431	0.3804	0.828
Nursery	0.0000	0.1138	0.1738	0.1070	0.1019	0.0622	0.0566	0.5548	0.4317	0.4582	0.6220
Page-block0	0.6916	0.9172	0.9315	0.9207	0.9199	0.9397	0.9049	0.9217	0.9487	0.6342	0.8901
Parkinsons telemonitoring	0.0000	0.9785	0.9768	0.9798	0.9819	0.9917	0.9866	0.9833	0.9919	0.2560	0.9959
Sat	0.0000	0.7317	0.8161	0.7299	0.7376	0.8569	0.8546	0.7064	0.7701	0.5174	0.8530
Waveform	0.7468	0.8708	0.8851	0.8692	0.8711	0.9040	0.9009	0.8957	0.8498	0.7805	0.8924

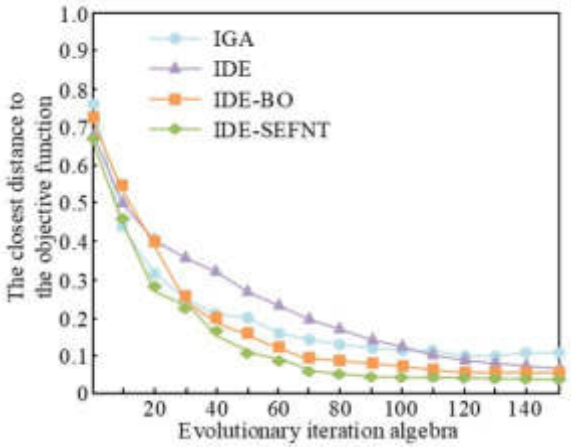

Fig. 4.3: Simulation experiment results

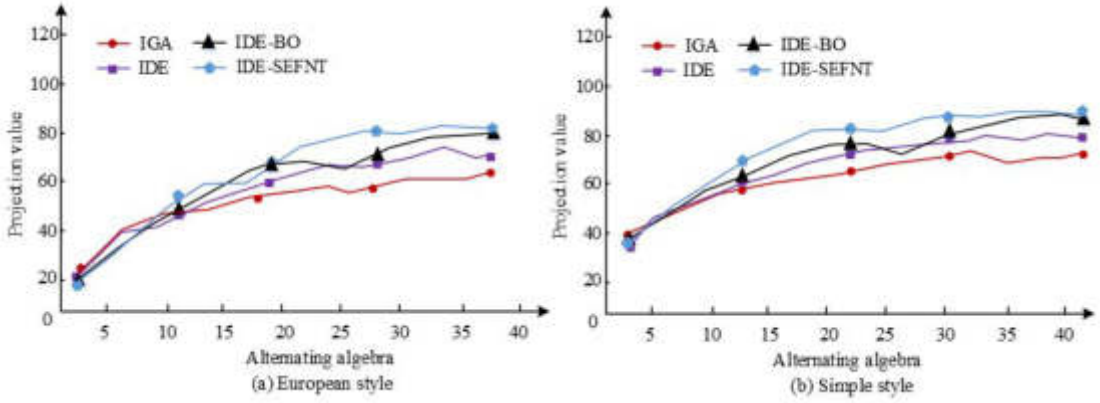

Fig. 4.4: Convergence test results

simulation evaluation results are shown in Figure 4.3.

In Figure 4.3, there is no obvious discrepancy among the four in the early iteration stage. In the later stage, IGA converges early. IDE and IDE-BO own better convergence effects. IDE-SEFNT is the best. When the iterations are 40, the convergence speed and accuracy of IDE-SEFNT are significantly greater than others.

In interactive algorithms, the subjective choices of users play a crucial role in the convergence of the system. Therefore, the convergence testing is used to test the user satisfaction and practicality of testing parameterized office furniture spacing space design schemes in the real world, and study the influence of user subjective choices. To ensure the diversity and representativeness of the results, the study selected 10 testers from different occupational backgrounds, age groups, and usage habits. These testers comprise office employees, designers, managers, and other individuals, to simulate the reactions of diverse user groups to the spacing design of office furniture. Due to the characteristics of the design and art industries, it is difficult to quantitatively describe convergence. Therefore, 10 testers were selected in the experiment and the maximum number of iterations was set to 40 to investigate their satisfaction with the individual. The convergence test results are shown in Figure 4.4 .

In Figure 4.4, at iteration number $t \in [0, 12]$, the four algorithms have no significant impact on the results. However, when t, the IDE algorithm exhibits more excellent convergence ability than IGA. The optimized IDE

Table 4.4: Wilcoxon sign rank test results

Index	Interval of t	Euclidean style				Simple style			
		IGA	IDE	IDE-BO	Ours	IGA	IDE	IDE-BO	Ours
P	[1,10]	0.873	1.000	0.872	0.825	0.378	0.470	0.471	0.764
	[11,30]	0.001	0.093	0.330	0.002	0.005	0.001	0.003	0.003
	[31,40]	0.003	0.003	0.003	0.001	0.004	0.004	0.166	0.002
	[1,40]	0.018	0.110	0.257	0.002	0.004	0.007	0.166	0.001

is easier to run from the LOS, thus achieving higher satisfaction. At the same time, the improved IDE algorithm dose not show a significant improvement in score at high iterations, but it can accelerate the convergence speed, which is beneficial for users to complete the evolution of the algorithm before low iterations and prevent user fatigue. The users' subjective requirements have a significant impact. Diverse style choices can also affect users' subjective judgments, thereby affecting the algorithm convergence. By comparing to "minimalist", the meaning of the term "European" is more complex, making it hard to make accurate judgments. Hence, the "minimalist" style owns more outstanding results.

To compare and study the performance differences between improved and traditional algorithms, Wilcoxon Signed Rank Test (WSRT) was used in the experiment, with a significance level set at 0.05. The WSRT results are shown in Table 4.

The experiment is divided into three stages based on the number of iterations: early stage, mid stage, and late stage. In Table 4, there was inconspicuous distinction in performance among the four algorithms in the previous stage. However, starting from the mid-term stage, the proposed IDE-SEFNT algorithm shows significant advantages, with all P-values less than 0.05 in the "minimalist" style. As the research progresses, the advantages of algorithms become more apparent. In summary, the IDE-SEFNT algorithm has achieved significant performance improvements compared to the other three algorithms.

5. Conclusion. This study has designed an improved version of the FNT algorithm and the IDE algorithm based on similarity evaluation. The structure and parameters of the neural tree were optimized by PSO, and BS was introduced to help the algorithm overcome the LOS. The results showed that the AUC and GM metrics of SEFNT were greater than or equal to the other algorithms on 46 datasets. Moreover, the SEFNT algorithm also showed some advantages in the AUC and GM values of 0.9960 and 0.9959 on the Parkinsons remote monitoring dataset, respectively. In terms of style selection, minimalist style showed superior performance than European style, so the research suggested more minimalist style in future applications. The results of the Wilcoxon signed-rank test also showed that the IDE-SEFNT algorithm has a significant performance advantage over the other algorithms. Especially in the "minimalist" style, the performance was more pronounced, with all P-values less than 0.05. Therefore, this research method has important influence on solving the problems existing in the traditional algorithm and furniture spacing space design and has wide practical applications. The management significance of the research lies in that it can help enterprises to improve work efficiency and employee satisfaction. By optimizing the partition space design of office furniture, the working environment is more comfortable, efficient and flexible, so as to improve the work efficiency and satisfaction of employees. The proposed methods may have performance limitations when dealing with highly complex or large-scale layout design issues. Additionally, user preferences and real-time feedback may not be fully integrated. To compensate for these shortcomings, future research can explore more effective combinations of optimization algorithms and parallel computing techniques to improve the performance and efficiency of algorithms in handling complex problems. In addition, further research can be conducted on how to effectively integrate user preferences and real-time feedback into algorithms to achieve more personalized and interactive layout design processes.

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INDOOR SPACE LAYOUT DESIGN BASED ON DIFFERENTIAL EVOLUTION ALGORITHM

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Abstract. To enhance the interactivity of spatial design, this study proposes an indoor spatial layout design method based on differential evolution algorithm, which combines backtracking strategy and reverse learning strategy to improve the interactive differential evolution algorithm. The experimental data demonstrated that the proposed method for indoor space layout design achieved an average user satisfaction of 81.7%, which increased by 16.8% compared with traditional interactive genetic algorithms. In addition, the improved human-computer interaction interface scored higher than 0.8 in terms of usability, reliability, customizability, and interactive feedback. This means that the improved interface can better meet user needs and provide a better user experience. This study shows that the indoor space layout design method ground on differential evolution algorithm and the improved human-computer interaction interface can significantly improve user satisfaction and user experience. This has brought more efficient and convenient solutions to the field of spatial design.

Key words: Differential Evolution Algorithm; Interior Design; Spatial Layout; Backtracking Strategy; Reverse Learning Methods

1. Introduction. With the acceleration of urbanization, the demand for indoor space layout design is becoming increasingly important. Reasonable indoor space layout design can not only improve space utilization, but also improve quality of life and work efficiency [1]. However, traditional design methods cannot meet the needs for personalization and efficiency, due to the complexity and diversity of indoor space layout design issues [2]. Modern indoor space layout design methods rely on computer technology and data analysis to design more objectively and scientifically [3]. By collecting and analyzing a large amount of data, designers can understand people's living habits, work needs, and space utilization, thus making reasonable and efficient designs. Computer technology can also simulate and predict the effects of different design schemes, helping designers make decisions [4]. The pursuit of personalization is constantly increasing, hoping to express their individuality and taste in indoor spaces. Modern design methods can be customized according to individual needs and preferences to meet personalized pursuits. Differential Evolution Algorithm (DEA), as a global optimization algorithm, has achieved significant results in many fields, with strong search capability and adaptability. Nevertheless, there is currently relatively little research on the application of DEA in indoor space layout design [5]. At present, traditional indoor space layout design methods are unable to meet the increasing personalized needs. Although modern design methods can provide more objective and scientific design, they lack a profound understanding of diverse needs. Therefore, it is necessary to design a technology that combines traditional and modern design methods to meet growing needs. Therefore, this study aims to explore indoor space layout design methods on the ground of DEA, providing a new solution to solve indoor space layout design problems. The study consists of four parts. The first is a review of relevant research. The second is designs the indoor Spatial Layout (SL) method. The third part is the application analysis of indoor space layout design on the ground of DEA. The fourth part is a summary of the entire study.

2. Related works. Spatial location layout refers to how to arrange and organize the positions and layout of various elements in the design and planning of buildings, indoor or outdoor spaces. Stephan et al. proposed a mixed integer program ground on orthogonal parking for parking lot space design, which maximized the number of parking spaces to effectively utilize urban space attributed to parking. Experimental data showed that the effectiveness of this method reached 77% [6]. The Boysen research team proposed a dynamic programming algorithm based on Multi-Objective (MO) optimization for the layout design of moving walkways, optimizing

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the position of two-way walkways. The results showed that the optimization efficiency of this method reached 85% [7]. Wang et al. used MO optimization methods to obtain a set of solutions for industrial park layout design. An extended risk map method was used for describing the risk distribution. The outcomes showcased that the effectiveness of this method was superior to that of non-dominated sorting genetic algorithm [8]. Related research proposed an improved search genetic algorithm for the layout design of multi-deck cabins in ship cabins. This algorithm considered the layout optimization of ship's multi-layer residential compartments as a combination optimization problem with multiple performance constraints. The energy method was combined to determine the deck layers of each compartment. The experiment showcased that this method was useful [9]. Fathy et al. proposed a simplified facade lighting design process for museum layout design. The current solar performance evaluation was used as an overall spatial indicator and considered spatial distribution relationships [10]. This study indicated that sustained solar autonomy and annual sunshine were the indicators that best meet the standards.

The DEA simulates the biological evolution process, searching for the optimal solution through continuous iteration and mutation. Lin et al. proposed a hybrid optimization algorithm for ship pipeline layout. A ship pipeline vector encoding method based on existing encoding methods and ship pipeline characteristics was proposed [11]. Then, the proposed vector encoding was used to implement the discrete mixed differential evolution and cuckoo search algorithms. The results indicated that the hybrid optimization algorithm could obtain optimization schemes with fewer elbows and more remaining area. Related research proposed an accelerated MO DEA for the layout of offshore power systems. The analytical wave tail model of the converter was used to optimize the device layout [12]. The experiment showcased that the optimized power system layout could increase the output energy by 37%. Pan et al. proposed a MO DEA on the ground of competition mechanism. The competition mechanism of shift density estimation strategy was used to design new mutation operations [13]. The dataset experiment showcased that this method was more excellent than six state-of-the-art MO optimization algorithms. DEA was used to optimize and identify the parameters of multi-layer T-S fuzzy models. Then it combined with adaptive fuzzy sliding surfaces to ensure the asymptotic stability of closed-loop systems. The simulation showcased that the performance indicators of this method were superior to both inverse fuzzy controllers and conventional adaptive fuzzy controllers [14]. A research team proposed a parameter optimization method for a swinging buoy type wave energy converter. The DEA and linear potential flow theory were used to analyze the impact of buoy volume on optimal power capture. The results indicated that this method improved the energy of the wave energy conversion system [15].

In summary, many researchers have conducted extensive design and research on layout design and DEA, but the applicability of these methods and systems still needs to be improved. Therefore, an indoor SL design method ground on DEA is proposed, aiming to enhance the interactivity and user experience of SL design.

3. Design of Indoor Space Layout Method. Indoor SL refers to how to arrange and organize the positions of various functional areas, furniture placement, and decorations in indoor design, to achieve comfortable, practical, and aesthetic effects [16]. This study combines backtracking strategy and reverse learning method to propose an indoor space layout design method ground on DEA, thereby achieving optimized indoor space layout and improving design efficiency. Meanwhile, a two-stage indoor layout method is proposed to meet diverse needs, which divides the positioning of functional space positions and the generation of wall constraints in the surrounding area into two stages. Finally, the study adopts a reverse learning strategy to accelerate the convergence speed of the algorithm and achieve better experimental results.

3.1. Indoor spatial layout constraints. The layout design of indoor space is to arrange the placement of furniture and decorations reasonably on the ground of the size, shape, and functional requirements of the space, to achieve aesthetic, comfortable, and practical effects [17]. This study summarizes four main constraints through investigation and sample analysis, with geometric constraint $Geometry$ shown in equation (3.1).

$$Geometry \rightarrow \{Fun, Dec, Pla, Spa\} \tag{3.1}$$

In equation (3.1), the room function is Fun. Decoration and placement are Dec and Pla respectively. The physical space size is Spa. Different functional rooms have different requirements depending on their purpose, such as the master bedroom and the secondary bedroom. The special functional room constraint $Spef$ is shown

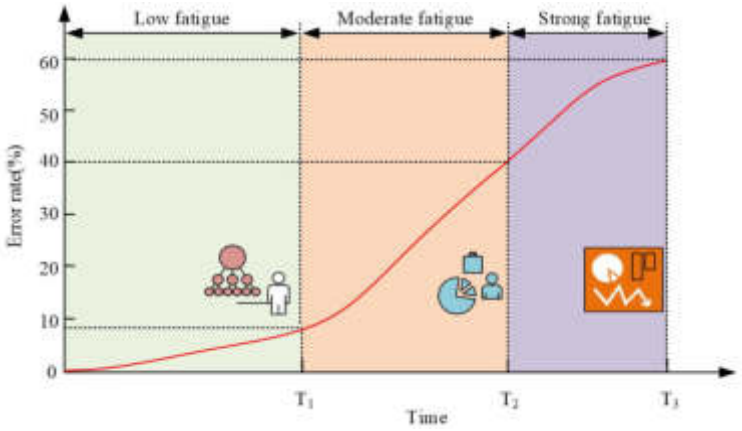

Fig. 3.1: Schematic diagram of user fatigue level

in equation (3.2).

$$Spef \rightarrow \{Lig, Toi, Air\} \tag{3.2}$$

In equation (3.2), the lighting of the special functional room is Lig. The bathroom and other ventilation conditions are Toi and Air, respectively. The spatial topology constraint Top is shown in equation (3.3).

$$Top \rightarrow \{Rel, Lim\} \tag{3.3}$$

In equation (3.3), the adjacency relationship of spatial objects is Rel. The space constraint is Lim. A rough layout, such as the bathroom adjacent to the kitchen, and the bedroom close to the door, can affect the functionality and living experience of the room. The feng shui factor constrain $Geomantic$ is shown in equation (3.4).

$$Geomantic \rightarrow \{Con, Env, Sea\} \tag{3.4}$$

In equation (3.4), the geographical condition is Con. The environmental factor is Env, and factors such as climate are Sea. A high-quality feng shui layout can leverage the functionality of rooms and furniture, providing a comfortable living space, and also having an indescribable impact on academic, career, and fortune. In traditional MO weighting methods, each objective function is weighted and summarized into a single objective value to solve a single objective optimization problem, for obtaining the optimal solution. The MO genetic algorithm can generate a set of preference free Pareto optimal solutions for decision-makers to choose ground on their preferences. However, selecting the appropriate solution from numerous feasible solutions increases the decision-making burden and reduces the effectiveness. To address these issues, Interactive Genetic Algorithm (IGA) replaces complex fitness functions with subjective choices by users. The evolutionary algorithm is used to gradually search for individuals that meet user requirements in complex environments, seeking better solutions. However, methods on the ground of the genetic algorithm and manual scoring may lead to user fatigue, which can affect usage persistence and result accuracy after multiple iterations [17, 18]. The study analyzes the accuracy of fatigue level assessment through comparative testing. The schematic diagram of user fatigue is shown in Figure 3.1.

As users invest more time and iterations, they quickly feel fatigued, leading to a significant decrease in the accuracy of evaluation scores. Therefore, in interactive algorithms, user fatigue is a key factor affecting the accuracy of the final solution. When fatigue cannot be avoided, one of the directions for algorithm improvement is how to accelerate algorithm convergence to find satisfactory solutions before users enter moderate and severe fatigue.

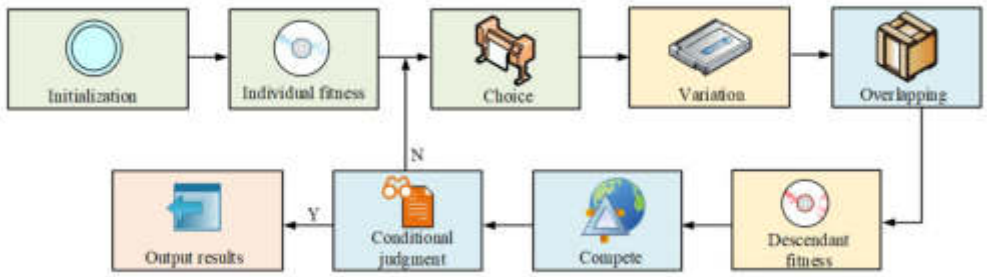

Fig. 3.2: IDE algorithm steps

3.2. Indoor Space Layout Method Based on DEA. Interactive Differential Evolution Algorithm (IDE) is an optimization algorithm compared to IGA. IDE adopts a selection operation to replace the scoring mechanism, where users only need to choose a more satisfactory individual in two individuals without the need for complex comparative scoring processes. This simplified operation method decreases the operation complexity and alleviates fatigue during the operation process [19]. In recent years, IDEs have been widely used in fields such as image retrieval, image enhancement, and image filtering. The IDE algorithm steps are shown in Figure 3.2

The steps of interactive DEA include crossover operation, evaluation of fitness, competition operation, termination condition judgment, result output, and iteration and other relevant steps. The algorithm initialization is shown in equation (3.5).

$$x_{j,i,0} = x_i^{\min} + (x_i^{\max} - x_i^{\min}) \times rand \tag{3.5}$$

In equation (3.5), the i-th gene of the chromosome for the j-th individual in the initial population serves as $x_{j,i,0}$. The lower bound of the i-th component serves as $x_i^{\min}$, and the higher bound of the i-th component serves as $x_i^{\max}$. The uniformly distributed random number is $rand$, with a value range of [0,1]. The mutation operation involves different mutation operators (MOP). The DE/rand/1 MOP is showcased in equation (3.6).

$$V_{j,i} = X_{r1,t} + F_j \times (X_{r2,t} - X_{r3,t}) \tag{3.6}$$

In equation (3.6), the j-th individual of the population in the t-th iteration is $X_{j,t}$. The corresponding mutation factor is $V_{j,t}$. The mutually exclusive positive numbers randomly selected from the array are $r1$, $r2$, and $r3$, respectively, and the scaling factor of the j-th individual is F_j. The DE/test/1 MOP is shown in equation (3.7).

$$V_{j,t} = F_j \times (X_{r1,t} - X_{r2,t}) + X_{best,t} \tag{3.7}$$

In equation (3.7), the optimal individual in the t generation is $X_{best,t}$. The DE/current to best/1 MOP is shown in equation (**??**).

$$V_{j,t} = X_{j,t} + F_j \times (X_{r1,t} - X_{r2,t}) + F_j \times (X_{best,t} - X_{j,t}) \tag{3.8}$$

In equation (3.8), the characteristic of the DE/current to best/1 MOP is to combine the information of the current individual and the optimal individual. The information of the best individual is introduced, which can accelerate the convergence speed of the algorithm. The DE/current to pbest/1 MOP is shown in equation (3.9).

$$V_{j,t} = X_{j,t} + F_j \times (X_{r1,t} - X_{r2,t}) + F_j \times (X_{pbest,t} - X_{j,t}) \tag{3.9}$$

In equation (3.9), the randomly chosen individual among the top ranked $p\%$ individuals is $X_{pbest,t}$. The advantage of the DE/current to pbest/1 MOP over other MOP is that it uses the information of the optimal

individuals in the population. In the crossover operation, the crossover operator is shown in equation (3.10).

$$U_{j,i,t} = \begin{cases} V_{j,i,t}, \ if \ rand < CR \ and \ i = i_{rand} \\ X_{j,i,t}, \qquad\qquad otherwise \end{cases} \tag{3.10}$$

In equation (3.10), during the t-th iteration, the i-th component of the experimental vector for the j-th individual is $U_{j,i,t}$. The crossover rate for the j-th individual is CR, and the random number is i_{rand}. In the selection operation, the selection operator is shown in equation (3.11).

$$X_{j,t+1} = \begin{cases} U_{j,t}, if \ f(U_{j,t}) < f(X_{j,t}) \\ X_{j,t}, \qquad\qquad otherwise \end{cases} \tag{3.11}$$

In equation (3.11), by selecting operators, genetic algorithms can optimize generation by generation, enabling individuals in the population to gradually tend towards better solutions. Although the DE algorithm is a global optimization algorithm, it may be hard for helping individuals break away the best solution in certain situations. To overcome this problem, the study adopts a backtracking strategy to improve the IDE. The IDE Backtracking Optimization (IDE-BO) algorithm first determines whether an individual has fallen into a local optimum, and then observes the slow update of individual data to determine. When an individual is considered stagnant, a new selection operator on the ground of backtracking strategy will be adopted. During each iteration, individuals who fail in competition are stored in a spatial warehouse. If an individual falls into a local optimum, continuous vectors are extracted from the storage space and randomly selected to survive to the next generation. When the individual still fails to leave the local optimum, the vector is further extracted from the storage space and a random vector is selected to survive to the next generation. It replaces the parent vector with discarded experimental vectors, which are not inherited by the next generation. Individuals evolved on the ground of these vectors are more inclined to aid in escaping local optima. The target feature vector and the most satisfactory target individual for the user are shown in equation (3.12).

$$\begin{cases} X = \{X_1, X_2, \ldots, X_n\} \\ O = \{o_1, o_2, \ldots, o_D\} \end{cases} \tag{3.12}$$

In equation (3.12), the target feature vector is X, which is the Euclidean distance between evolutionary individuals. The most satisfactory individual for users is O. The distance calculation between evolutionary individuals is showcased in equation (3.12).

$$f(x) = \sqrt{\sum_{i=0}^{n} (x_i - o_i)^2} \tag{3.13}$$

In equation (3.13), the distance between evolutionary individuals is $f(x)$. The i-th evolutionary individual is x_i, and the i-th target individual is o_i. The iterative process of improving the IDE algorithm with a backtracking strategy is shown in Figure 3.3.

3.3. The Application of Reverse Learning Strategy in IDE-BO Algorithm. In the actual market, the fixed number of rooms and the indoor layout design within a fixed area cannot meet the diverse needs of users [20]. Therefore, this study proposes a two-stage indoor layout method. The two-stage indoor layout method is an evolutionary method ground on interactive evolutionary algorithms, which eliminates a large number of rule constraints in the generation stage of indoor space and simulates the thinking mode of professional designers. This method is divided into two stages. The first is to locate the functional space position, and then is to generate wall constraints for the surrounding area. In the stage of positioning the functional space, the principle of prioritizing the positioning of the living room is adopted. Then, the positions of other functional areas are randomly generated by adjacent relationships with the living room or areas. In generating wall constraints, a constraint satisfaction based method is adopted, using the boundaries of the room extending outward from the origin as constraints for other rooms. On the ground of the principle of sequential design, each room is numbered according to its spatial location. Its size and shape are determined in sequence. The constraints

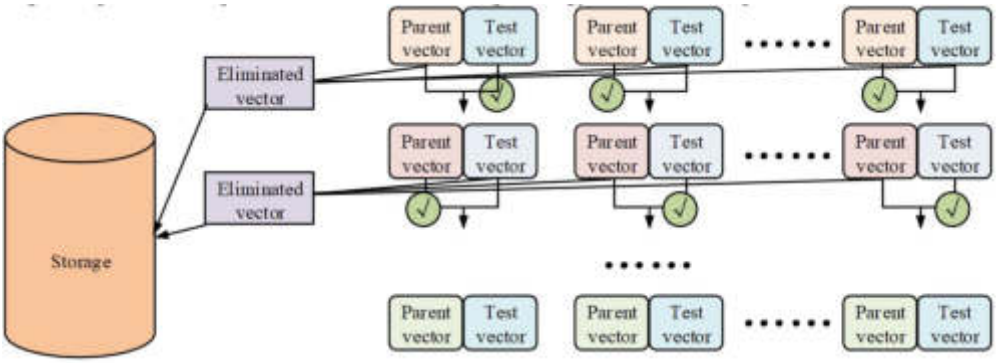

Fig. 3.3: The iterative process of improved IDE based on backtracking strategy

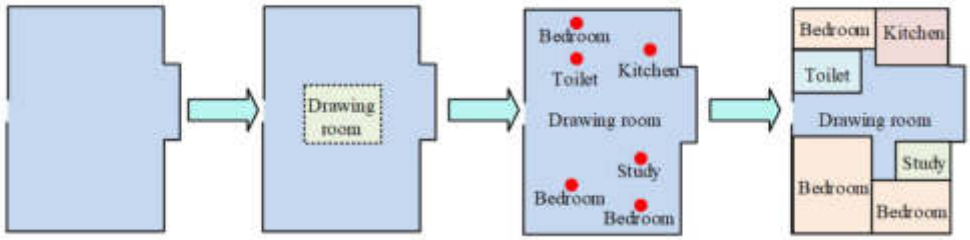

Fig. 3.4: The design process of the two-stage indoor layout method

generated earlier are then passed into the subsequent methods to provide constraints for determining the walls of subsequent rooms. The design process of the two-stage indoor layout method is shown in Figure 3.4

To better adapt to DEA, this study designs a new form of genetic coding. This encoding form adopts binary encoding ground on the character set [0,1] to represent functional region division and area parameters as chromosome bit strings. The coding form is designed on the ground of a two-dimensional coordinate axis, with the overall layout model located in the first quadrant. The smallest gene unit consists of two parts, X and Y, each in a 4-bit binary encoding form. It can represent all possible positions within the house model. The area type and number of rooms are independently composed of 3-bit and 4-bit binary codes, achieving code decoupling and merging. In the design, the positioning of the regional wall is based on a regular rectangle, which can be represented by the bottom left and top right coordinates on the coordinate axis. According to the process steps, the genetic coding of individual population consists of three parts, corresponding to determining the coordinates of the living room, determining the coordinates of the functional area, and generating the wall of the functional area. The new coding design eliminates hard constraints and introduces more randomness, which can adapt to the living needs of the vast majority of users in the market. The indoor layout design method has changed, no longer using fixed design methods, but determining the frame of the house and the number of rooms based on the number of people required for the residence. Users can choose the appropriate unit type according to their own needs. However, this method increases the complexity of evolutionary algorithms, resulting in an increase in the time required to generate the final satisfactory solution. In addition, users will enter a fatigue state after multiple iterations, and the evaluation error rate will also increase. To solve these problems, a reverse learning strategy can be utilized to accelerate the convergence speed and achieve better experimental results. Reverse points are the basic concept of reverse learning strategies. The one-dimensional reverse points are defined, as shown in equation (3.14).

$$\bar{x} = a + b - x \tag{3.14}$$

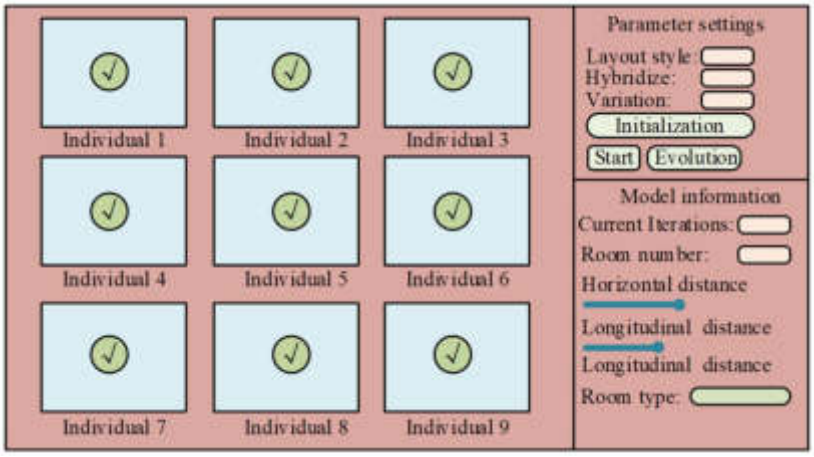

Fig. 3.5: Improved human-computer interaction interface design

In equation (3.14), the one-dimensional reverse point is $\bar{x}$, and the range of values for the real number x is [a, b]. The reverse point in N-dimensional space is shown in equation (3.15).

$$\begin{cases} \bar{X} = (\bar{x}_1, \bar{x}_2, \ldots, \bar{x}_n) \\ \bar{x}_i = a_i + b_i - x_i \end{cases} \tag{3.15}$$

In equation (3.15), the reverse point in the N-dimensional space is $\bar{X}$, and its i-th coordinate is $\bar{x}_i$. Reverse optimization method is an optimization algorithm ground on the concept of reverse points, which iteratively finds the reverse points of the objective function for achieving the optimization goal. The reverse learning strategy in IDE algorithms is usually divided into two stages: the reverse strategy in population initialization and the evolutionary population jump. Among them, the fitness comparison is presented through the human-computer interaction interface. The user inputs the evaluation results. The initialization parameters include the original population and reverse original population, individual dimensions, and variable value ranges. After introducing the reverse learning strategy, new independent individuals are introduced in each iteration. The goal of user evaluation has also changed from two to three. In this study, the reverse learning strategy is applied to the population initialization and the end stage of the new species generation. The improved human-computer interaction page of indoor layout design adopts a selection mechanism, where users can evaluate the offspring or their reverse individuals in pairs and select the solution that suits their own preferences by checking the box. The improved human-computer interaction interface design is shown in Figure 3.5.

4. Application Analysis of Indoor Space Layout Design Based on DEA . This chapter is an application analysis of indoor space layout design ground on DEA. Different evaluation indicators and analysis methods are used in the experiment to evaluate the effectiveness of relevant methods. This is to validate the effectiveness and applicability of the research method.

4.1. Application Analysis of Indoor Space Layout Method Based on DEA . The experiment randomly generates 500 sample models. The indoor space layout design styles are divided into 6 types: modern, classical, rural, industrial, Nordic, and Mediterranean, labeled 1-6. Subsequently, the study selects 10 testers to evaluate the satisfaction and feasibility of interactive SL design methods. The evaluation results of the interactive SL design method are shown in Figure 4.1

In Figure 4.1, the evaluation results showed a satisfaction rate of 95% and a feasibility rate of 94%. This indicates that most testers have a positive attitude towards the interactive SL design method. It performs well in meeting their needs and feasibility. Interactive SL design methods may provide an intuitive interface and real-time feedback, enabling testers to better understand and explore different layout choices. This participation

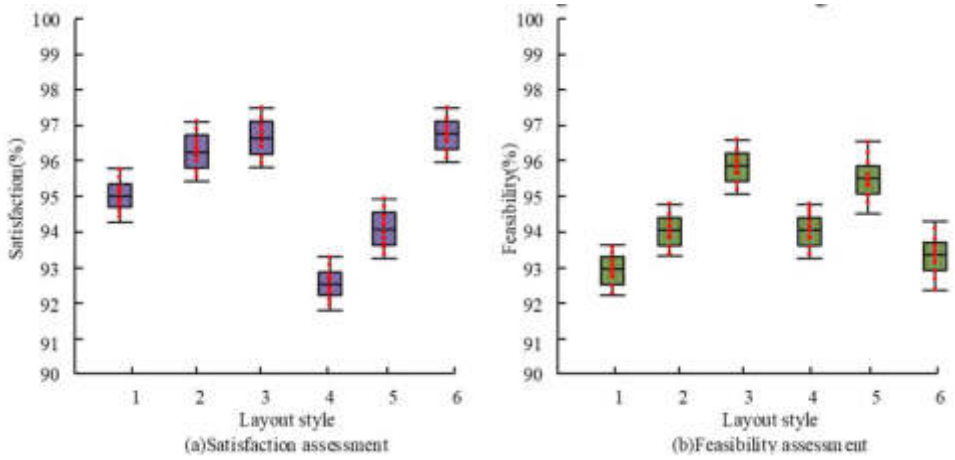

Fig. 4.1: Evaluation results of interactive spatial layout design methods

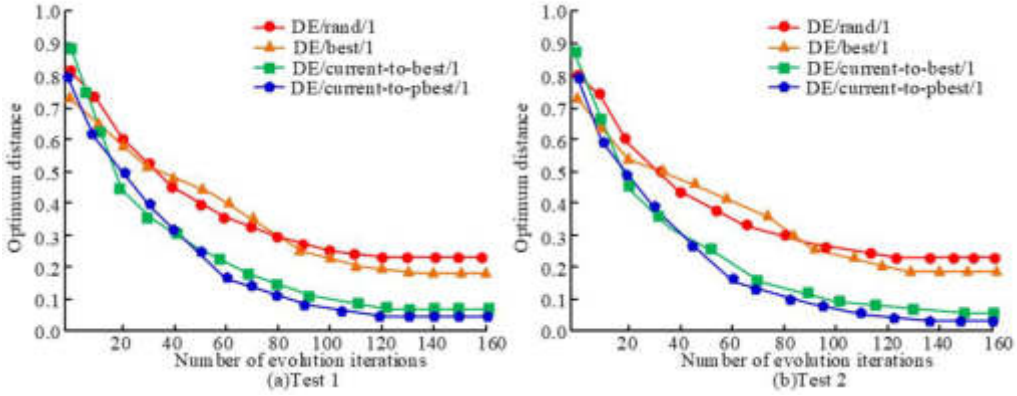

Fig. 4.2: Comparison results of different MOP

may increase the satisfaction of testers with the layout design process and increase their acceptance of the final design solution. This method provides effective tools and functions during the design process, enabling testers to conduct layout design in actual environments and ensuring the feasibility of the design scheme. The comparison results of various MOP in the IDE algorithm are shown in Figure 4.2.

Figure 4.2 showed that the two MOP, DE/current to pbest/1 and DE/current to best/1 had the most excellent performance because they possessed more excellent performance in terms of convergence. Next were DE/rand/1 and DE/test/1. This means that DE/current to pbest/1 and DE/current to best/1 MOP are more suitable for individual selection in IDE algorithms, which can more effectively help users make judgments in an extremely short time and reduce errors. To reduce the possible errors caused by selecting time sorting, this research chose DE/current to best/1 as the MOP, which is simpler and has equally excellent performance. The experiment uses the target vector as a reference to analyze the convergence of different algorithms when searching for target values. The convergence of different algorithms is shown in Figure 4.3.

From the changes in the average convergence curve shown in Figure 3.3, there were no significant differences among the three algorithms (IGA, IDE, and IDE-BO) during the initial stage of the experiment. However, in the later stage, the IDE and IDE-BO algorithms showed better convergence performance, while the IGA showed slight shortcomings. Especially when the number of iterations reached 60, the IDE-BO algorithm showed

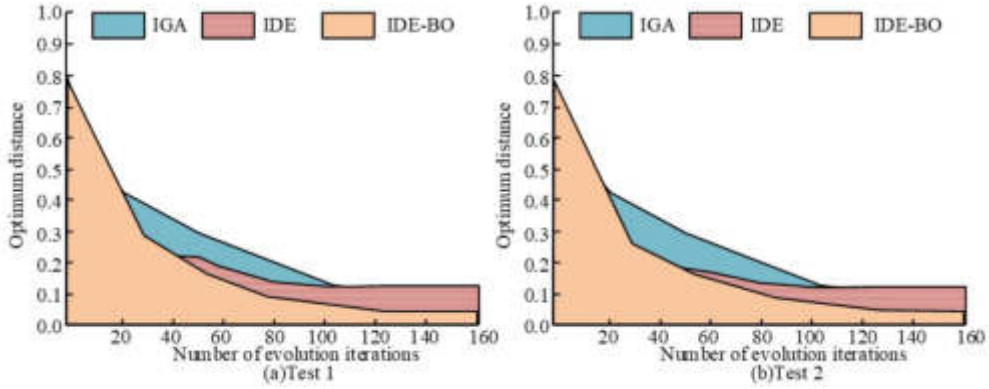

Fig. 4.3: Convergence of various algorithms

Table 4.1: The quantity of iterations required for reaching convergence

Test group number	IGA	IDE	IDE-BO	Maximum value	Minimum value
1	92	136	122	136	92
2	85	120	118	120	85
3	96	145	120	145	96
4	99	163	121	163	99
5	89	126	129	129	89
6	92	131	122	131	92
7	96	136	131	136	96
8	87	130	128	130	87
9	91	139	119	139	91
10	89	124	119	124	89
Average value	91.6	135	122.9	/	/

obvious advantages, with faster convergence speed and higher convergence accuracy. The optimal distances between IGA, IDE, and IDE-BO algorithms and the objective function were 0.09, 0.13, and 0.04, respectively. In real human-computer interaction environments, to avoid the impact of user fatigue on the results, the lowest quantity of iterations is usually set to 50. The iterations required for reaching convergence is shown in Table 4.1.

Table 4.1 showed that the IDE BO algorithm achieved convergence with an average of t=122.9 iterations in 10 simulation experiments. The IDE algorithm required approximately 135 iterations. Although the convergence speed of the IGA was significantly faster than IDE-BO, the IGA was trapped in local optima. To compare the relevant differences in IDE-BO and other competitors, Wilcoxon sign rank test is conducted. The significance is lower than 0.05, indicating that IDE-BO algorithm has a significant convergence advantage compared with IDE algorithm.

4.2. Analysis of the Application Effect of Reverse Learning Strategy in IDE Algorithm. To test practicality in practical applications, convergence testing is conducted and the impact of user subjective selection on convergence is investigated. In this experiment, 10 testers are selected to use the system and the highest quantity of iterations is set to 45 to investigate their satisfaction with the individual. In each iteration, the tester selects the most suitable individual in the group according to own preferences, with a score of 0 to 100. Then the average score is calculated from the 10 testers. A high score in both indicators indicates good convergence ability. If the final solution score reaches 75 or above, it can be considered that the system has generated the most satisfactory solution for the user. The user satisfaction test results of different methods are shown in Figure 4.4

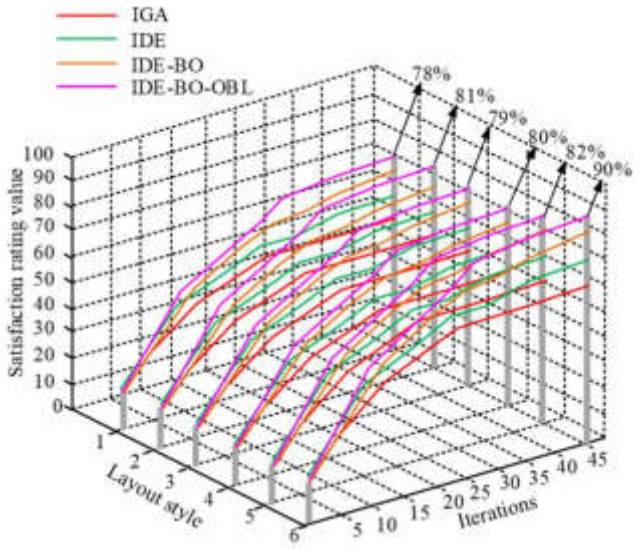

Fig. 4.4: User satisfaction test results of different methods

Table 4.2: Wilcoxon sign rank test results

Layout style	Algorithm	t=[1,10]	t=[11,30]	t=[31,40]	t=[1,40]
Modern	IGA	0.836	0.001	0.003	0.017
	IDE	0.468	0.092	0.003	0.111
	IDE-BO	0.397	0.330	0.003	0.256
Classical	IGA	0.581	0.002	0.004	0.015
	IDE	0.603	0.089	0.005	0.116
	IDE-BO	0.945	0.333	0.004	0.255
Rural	IGA	0.361	0.001	0.002	0.017
	IDE	0.902	0.084	0.004	0.111
	IDE-BO	0.788	0.323	0.006	0.212
Industrial	IGA	0.816	0.002	0.003	0.016
	IDE	0.665	0.089	0.002	0.112
	IDE-BO	0.679	0.346	0.001	0.245
Nordic	IGA	0.977	0.003	0.003	0.015
	IDE	0.646	0.078	0.002	0.156
	IDE-BO	0.975	0.379	0.004	0.215
Mediterranean	IGA	0.854	0.003	0.001	0.016
	IDE	0.768	0.089	0.002	0.136
	IDE-BO	0.664	0.336	0.004	0.189

In Figure 4.4, IDE-BO-OBL represents the IDB-BO algorithm incorporating a reverse learning strategy. This indicated that the IDE-BO-OBL algorithm had the highest user satisfaction, with an average satisfaction rate of 81.7%. It was 16.8% higher than the IGA. To further compare the relevant differences in IDE-BO-OBL and traditional evolutionary algorithms, the study conducts the Wilcoxon sign rank test. The relevant outcomes are showcased in Table 4.2.

Table 4.2 showed that the differences among the four algorithms were not significant at the beginning of the algorithm. However, in the middle to late stages, the advantages of the IDE-BO-OBL algorithm were clearly reflected. This indicates that the IDE-BO-OBL algorithm has significantly improved compared with IGA. To

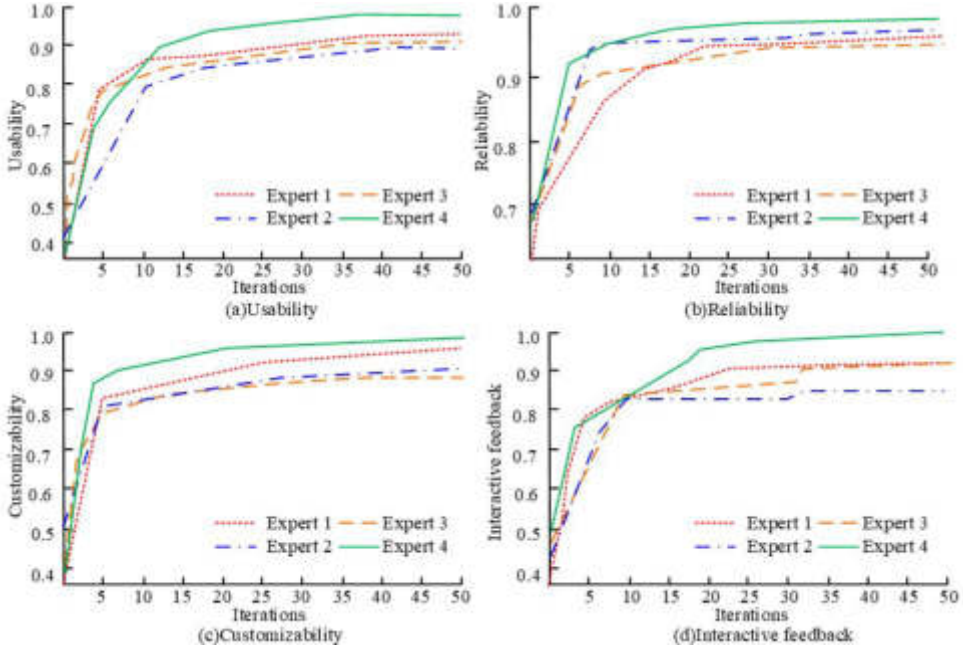

Fig. 4.5: Improved human-computer interaction interface evaluation results

evaluate the effectiveness of the improved human-computer interaction interface, four experts were selected in the experiment to evaluate its usability, reliability, customizability, and interaction feedback. The evaluation results of the improved human-computer interaction interface are shown in Figure 4.5.

Figure 4.5 demonstrated that the improved human-computer interaction interface had usability, reliability, customizability, and interaction feedback scores higher than 0.8. The improved human-computer interaction interface has significantly improved in multiple aspects, meeting the user needs and providing a better user experience.

5. Conclusion. In traditional IGAs, there may be some ineffective design solutions due to the limitations of the algorithm itself and the subjective preferences of the designer. To overcome these problems, this study focuses on indoor space layout design, and combines backtracking strategy and reverse learning strategy to optimize the interactive DEA. An improved human-computer interaction interface was proposed. Experimental data showed that the improved DEA achieved an average user satisfaction of 81.7% in indoor space layout design, which was 16.8% higher than the traditional IGA. In addition, the improved human-computer interaction interface scored higher than 0.8 in terms of usability, reliability, customizability, and interactive feedback, indicating that the improved method had a good user experience. The experiment showcased that the improved method achieved significant improvements in user satisfaction and human-computer interaction interface ratings, providing an efficient, reliable, and user-friendly solution for indoor space layout design. The limitation of this study is that it only considers the SL and does not involve other factors such as material selection and color matching. Future research can consider spatial factors such as material selection, color matching, and furniture layout to improve the comfort, aesthetics, and functionality of the space.

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DECISION-MAKING SUPPORT PLATFORM AND SECURITY DESIGN FOR RURAL LEISURE TOUR INDUSTRY BASED ON SEA METHOD AND SVR MODEL

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Abstract. An accurate short-term passenger flow forecast of rural tourism can avoid accidents as much as possible. However, the short-term passenger flow of rural leisure tourism shows nonlinear, seasonal, random, and other complex characteristics. Meanwhile, the traditional forecasting methods are often difficult to achieve accurate forecasting. Therefore, this study now used the nonlinear mapping function in the support vector regression to convert the passenger traffic training sample into a high-dimensional feature space and established a linear decision function. Then the influence of periodicity on the prediction effect through seasonal index adjustment was reduced. Finally, event triggering combined with core embedding technology for tamper-proof detection was adopted to improve the security of the platform. The results showed that the minimum absolute error of prediction with improved SVM model was 0.27% compared with traditional model and autoregressive integrated moving average model. After the introduction of the Internet search factor, the traffic prediction result was more accurate, which was 0.0425 smaller than that without the introduction of the Internet search factor. When the concurrency was less than 100 times/s, the average response time difference before and after adding the core embedded program was small, indicating that the security of page tampering technology was high. This research method can effectively predict the passenger flow of rural leisure tourism industry and ensure the safety of the platform.

Key words: SVR model; SEA method; Leisure tour industry; Page anti-tampering technology; Countryside

1. Introduction. In response to the national call, the rural leisure tour industry has gradually developed in various places, operating numerous farmhouses and attracting urban residents to spend leisure and entertainment in rural farmhouses [11]. According to statistics, the rural leisure tourism industry receives nearly 800 million visitors annually, creating considerable revenue for the countryside. However, the rural leisure tourism industry has the characteristics of loose geographical distribution, uneven development across the country, and low information level. These may lead to greater difficulties in the management mode transformation [4]. The forecast of passenger flow plays an important role in the leisure tourism industry. On the one hand, the forecast value can assist managers to make reasonable scheduling of resources and improve industrial benefits [13]. On the other hand, it can assist the early warning work in the peak period of tourism. The security of the platform is the key to the normal operation of the decision support platform of rural leisure tourism industry [10]. The content of the platform has a wide audience. Meanwhile, the decision is based on the final display to the user in the form of a web page [12]. The content of the page will affect the interests of all parties. Meanwhile, the immutable content of the web page will be the most basic requirement for the security of the platform [5]. This study combines the current situation and demand of the industry, integrates local real-time passenger flow information, network public opinion information, and other data, and builds a relevant decision support platform. Users' preferences and needs can be understood through in-depth analysis of users' behavior path, stay time, conversion rate and other data on websites or apps. The user experience and page design are optimized, the budget and financial plan of the scenic spot are scientifically formulated, and the tourist resources of the scenic spot are optimized. In view of the advantages of Support Vector Regression (SVR) in time-series data processing, a short-term passenger flow prediction model is constructed to improve the management level of scenic spots, optimize the allocation of tourism resources by understanding tourists' needs, and ensure tourists' safety. The innovation of this research is as follows: (1) SVR is used as the basic model to build a short-term passenger flow prediction model. Different from the traditional model, the network related search factor is introduced. Meanwhile, the compensation effect of the prediction model is improved by optimizing the Sea-

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sonal Exponential Adjustment (SEA) weight. (2) The short-term passenger flow prediction model is used as the core module of the decision support platform. Meanwhile, data analysis technology is used to model the aggregated data. (3) The event-triggered combination and core embedding technology are used to achieve the tamper-proof performance of the platform to ensure the safe use of the platform. The contributions of this study are as follows: (1) According to the nonlinear characteristics of passenger flow data, the SVR model is introduced. Meanwhile, the influencing factors of SVR are selected through Grey correlation analysis, which overcomes the shortcomings of the classical time-series prediction model. (2) In view of the obvious seasonal characteristics of annual holiday passenger flow, an adaptive SEA-SVR model based on seasonal adjustment is proposed to directly process the seasonality of the original time-series data, shortening the forecasting time and improving the forecasting accuracy. (3) A decision-making support platform is established for the rural leisure tourism industry, the allocation of tourism resources is optimized, and the management level of scenic spots is improved.

2. Related Works. A new type of tourism is the countryside leisure tour. It has become a choice for many people to relax on weekends due to its location in the suburbs and proximity. While the rural leisure tour industry is developing rapidly, its rough management mode has hindered its development. Therefore, optimizing the management mode and effectively using computer technology becomes the direction for optimizing the rural leisure tourism industry. Zheng et al. conducted a relevant data survey to understand the focal actor characteristics and identify the core actors among them in the rural tourism actor network translation through interviews and other forms. The results showed that leisure services, etc. affected the actors [15]. Liu conducted a specific study through practical case studies to grasp the development of leisure agriculture. From the analysis results, the utilization of idle home base was not high and there were more deficiencies in rural tourism, which limited the spatial expansion of leisure tourism [9]. Ding et al. conducted a sampling survey to understand the characteristics of Sichuan farmhouse sewage and analyze its physical and chemical characteristics. The results showed that their effluent discharge was increasing year by year, which negatively affected water resources and should be noticed. Chase L et al. conducted a study on the problems faced by agritourism and proposed a conceptual framework that contains different stratification. The framework made agritourism easier to understand and facilitated the development of agritourism [2].

Hasanipanah et al. chose the improved SVR model to predict air overpressure due to it in my blasting. The improved SVR model was found to have better prediction through comparative analysis [1]. The SVR model was used by Zhang et al. to predict the relevant reaction time of the driver based on Electroencephalogram (EEG) to understand the driver's reaction under unexpected events [14]. The results showed that the correlation between different EEG characteristic parameters. Meanwhile, simple reaction time were different, and the prediction accuracy of SVR model was higher compared with other models [3]. Hu et al. constructed a human face grain yield prediction problem based on Grey correlation analysis using SVR model and optimized the model using adaptive boosting algorithm. The results showed that the model could obtain better prediction results [6]. Lin et al. faced the short-term PV power prediction problem and proposed a hybrid model based on the SVR model. The model could make more accurate predictions under ideal weather conditions through experimental analysis [8].

In summary, the existing methods can well solve the single-factor forecasting. However, these methods have high requirements for the accuracy of historical data and problems such as high time and cost, difficult to determine impact factors, etc. It is difficult to achieve complex and nonlinear short-term passenger flow without considering various interference factors affecting tourism demand. Meanwhile, more references and suggestions cannot be brought to tourism decision-makers. Therefore, the paper starts from the computer technology-assisted aspect and constructs a relevant decision support platform to forecast the short-term passenger flow. Since the SVR model has certain advantages in time-series data processing, the model is used as a prediction model for short-term passenger flow analysis.

3. Rural leisure and tourism industry decision-making support platform and safety design.

3.1. Construction of industry short-term passenger flow forecast model. In recent years, the leisure tour industry in China's countryside develops rapidly, and the form of the industry is undergoing major changes. Due to factors such as loose geographical distribution and low Informa ionization, it has

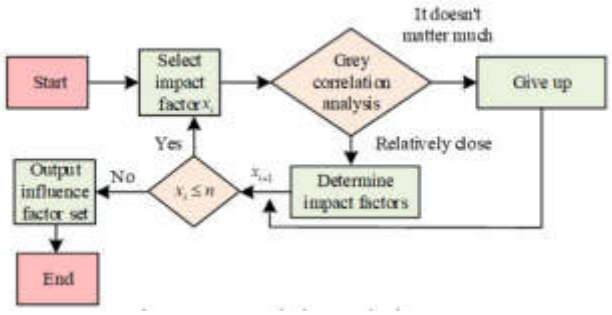

Fig. 3.1: Grey correlation analysis process

added difficulties to the management of the rural leisure tour industry. Meanwhile, it is difficult to have a comprehensive understanding of the leisure tour development in each region. The forecast of tourist flow mainly includes the traditional time-series method, econometric model, and the current artificial intelligence forecasting methods. However, it is difficult for time-series method and econometric model to realize complex nonlinear short-term passenger flow prediction. Meanwhile, the learning process of artificial neural network is usually slow, and the adaptability to emergencies is poor. SVR provides a new theoretical guidance for nonlinear time-series prediction because of its good generalization ability to deal with small samples and nonlinear data.

To address this situation, the study integrates information such as real-time passenger flow information of the rural leisure tour industry through data analysis technology. Meanwhile, a short-term passenger flow prediction model is constructed through the SVR model to make the passenger flow prediction values more targeted [7]. The prediction model influencing factors are first analyzed before constructing the model. According to the actual situation, the study initially determines three influencing factors, which are the amount of web-related keyword searches, the passenger flow data of yesterday, and various indicators of the weather on the day of travel, and put them as the to-be-entered items of the prediction model.

The passenger flow data of yesterday can provide managers with information such as passenger flow and passenger flow trend. These data help understand the needs of tourists and improve service levels. Meanwhile, the waste of vehicles and human resources can be minimized through reasonable scheduling and operational arrangements to achieve cost savings. Nowadays, people can easily obtain a lot of travel-related information through the Internet to customize their itinerary. Therefore, it is necessary to include the search volume of related keywords in the model. Weather indicators on the day of travel affect whether people decide to travel.

Grey correlation is a method to determine which factor has the greatest impact on the final results. The correlation is a measure of how much they change over time or from object to object for the factors between two systems. The basic idea is to judge whether the connection is close according to the similarity of the shape of the set of sequence curves. The closer the curves are, the greater the correlation between the corresponding sequences, and the smaller the correlation is. The Grey correlation analysis method is selected to make secondary selection of these influencing factors to determine the final influencing factors of the model. The related process is shown in Figure 3.1.

In Figure3.11, the impact factor to be considered is first determined. Meanwhile, a correlation degree calculation is performed to calculate the correlation between the impact factor and the output sequence. Based on the results of this calculation, the influence factor is selected twice to obtain the final influence factor of the model. There are certain differences in magnitudes among the data, which can affect the analysis results. Therefore, these data need to be pre-processed. The Z-score function can compare and analyze the values between different data sets. The principle is to subtract the mean from the original data and divide by the standard deviation. The result is the Z-score value. The Z-score function is used to standardize the data. Therefore, there is comparability between different data sets to better data analysis and mining. The impact

factor is normalized and de-scaled by the function, and the relevant calculation formula is shown in Eq. (3.1).

$$x^* = \frac{x - \upsilon}{\sigma} \tag{3.1}$$

In Eq. (3.1), x and x^* represent the original series and the de-quantized series, respectively. The mean of x is expressed as υ. The standard deviation of x is expressed as σ. The human comfort index is calculated by quantitative analysis to take into account all weather indicators. The formula for calculating the human comfort index is given in Eq. (3.2).

$$ssd = (1.818 * t + 18.18)(0.88 + 0.0002 * f') + \frac{t' - 32}{45 - t'} - 3.2 * v + 18.2 \tag{3.2}$$

In Eq. (3.2), the human comfort index is set as ssd, the average temperature is expressed as t', the relative humidity is set as f', and the wind speed is expressed as v, respectively. The nonlinear mapping function is set as $\phi(x)$. The overhead feature space is set asF. x_i represent the model influence factors. i denotes the ordinal number. The sample data are defined as (x_i, y_i), $i = 1, 2, \cdots, n.y_i$ denotes the target output value. The SVR model uses $\phi(x)$, which can map x_i into F. The relevant regression problem in this space is solved to overcome the nonlinear regression problem in the original space. In this case, the SVR model function is shown in Eq. (3.3).

$$f(x) = w^T \phi(x) + b, \phi : R^n \to F, w \in F \tag{3.3}$$

In Eq. (3), $f(\cdot)$denotes the function, w and b denote the variables, andR denotes the function. Because SVR adopts the principle of minimizing structural risk, it is necessary to find the corresponding function to solve the related function regression problem, and the related calculation formula is shown in Eq. (3.4).

$$R_{SVR}(C) = R_{emp} + \frac{1}{2}\left|\left|\omega^2\right|\right| = \frac{1}{n}\sum_{i=1}^{n}|y_i - f(x_i)| + \frac{1}{2}\left|\left|\omega^2\right|\right| \tag{3.4}$$

In Eq. (3.4), the structural risk function is expressed as $R_{SVR}(\cdot)$. The penalty function is set as C, which is a constant. The larger the value of C is, the smaller the allowable correlation error will be, and the corresponding generalization ability will be worse, which means the complexity of the model is higher. The empirical risk function is expressed as $R_{emp}(\cdot)$. $\frac{1}{2}\omega^2$ denotes the Euclidean norm. $C\frac{1}{n}\sum_{i=1}^{n}|y_i - f(x_i)|$ denotes the training set error. The relevant expression in $|y_i - f(x_i)|$ is shown in Eq. (3.5).

$$\left|y_i - f\left(x_i\right)\right| = \begin{cases} 0, |y_i - f\left(x_i\right)| \le \varepsilon \\ |y_i - f\left(x_i\right)| - \varepsilon, \text{ else} \end{cases} \tag{3.5}$$

In Eq. (3.5), ε denotes the insensitive loss function, and more stable estimation results can be obtained by introducing ε. The function regression problem is represented by minimizing the cost generalization function, and its related expression is shown in Eq. (3.6).

$$min\frac{1}{2}\left|\left|\omega^2\right|\right| + C\sum_{i=1}^{n}\left(\xi_i + \xi_i^*\right) \tag{3.6}$$

In Eq. (3.6), ξ_i and ξ_i^* denote the relaxation variables, which are introduced to make the solution of Eq. (3.7) exist.

$$\begin{cases} y_i - w^T\phi(x) - b \le \varepsilon + \xi_i^*, i = 1, 2, \cdots, n \\ -y_i + w^T\phi(x) + b \le \varepsilon + \xi_i, i = 1, 2, \cdots, n \\ \xi_i, \xi_i^* \ge 0, i = 1, 2, \cdots, n \end{cases} \tag{3.7}$$

In solving the functional regression optimization problem, the Lagrange multiplier is introduced and the optimality condition (Karush-Kuhn-Tucher, KKT) is used to obtain the regression function as shown in Eq. (3.8).

$$f(x) = \sum_{i=1}^{n}\left(\alpha_i - \alpha_i^*\right)K(x_i, x) + b \tag{3.8}$$

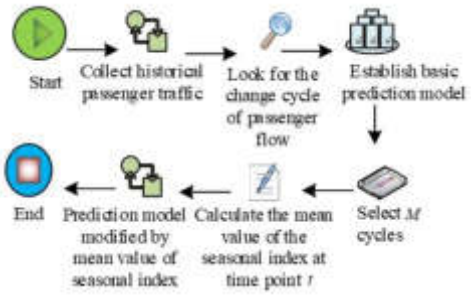

Fig. 3.2: Process of the SEA method

In Eq. (3.8), α_i and α_i^* denote Lagrange multipliers, $\alpha_i \in [0, C]$. The kernel function $K(x_i, x) = \phi(x_i)\phi(x)$ can satisfy the Mercer condition. The Gaussian radial basis kernel function is chosen for use in the prediction model, and the relevant mathematical expression is shown in Eq. (3.9).

$$f(x, \alpha_i, \alpha_i^*) = \sum_{i=1}^{n} (\alpha_i - \alpha_i^*) exp \frac{\left(-|x_i - x|^2\right)}{\sigma^2} + b \tag{3.9}$$

In Eq. (3.9), exp represents the multiplicative power operation function of e. $K(x_i, x) = exp\frac{\left(-|x_i - x|^2\right)}{\sigma^2}$ and x are the optimal support vectors obtained from the model search. In the passenger flow forecasting, the cyclical variation affects the forecasting results. Therefore, the study chooses SEA to reduce this effect, and its related process is shown in Figure 3.2.

In Figure 3.2, firstly, the historical statistics of passenger flow are collected. The period of passenger flow change is set as T, which is searched for. The basic prediction model is constructed, and M cycles are selected to calculate the seasonal index, and the relevant calculation formula is shown in Eq. (3.10).

$$C_{s,t} = \frac{a_{s,t}}{a'_{s,t}} \tag{3.10}$$

In Eq. (3.10), the selected historical periods are denoted as $s, s = 1, 2, \cdots, M$. The specific time points of the prediction are denoted as $t, t = 1, 2, \cdots, T$. The sample true value is set as $a_{s,t}$. The sample prediction result is $a'_{s,t}$ after prediction by the original model. The mean value of the seasonal index at the time points of t is calculated. The prediction model is modified by this mean value. The relevant calculation formula is shown in Eq. (3.11).

$$\begin{cases} AJ_t = \frac{1}{M} \sum_{s=1}^{M} C_{s,t} \\ F_t(x_t) = \varphi(x_t) * AJ_t \end{cases} \tag{3.11}$$

In Eq. (3.11), the forecast model adjusted by setting the SEA method is $F_t(x_t)$. $\varphi(x_t)$ denotes the original model. The average seasonal adjustment index at the time point oft is AJ_t, which is also the compensation coefficient. The forecasting model after introducing the seasonal adjustment index is shown in Eq. (3.12).

$$f(x_{n+t}) = (\sum_{s=1}^{M} (\alpha_i - \alpha_i^*) K(x_i, x_{n+t}) + b) * AJ_t \tag{3.12}$$

The formula at AJ_t can be interpreted as meaning that the seasonal index for each of the past M years contributes to the coefficient for the current compensation coefficient. The problem can be transformed so that each of the given M models affect the solution of AJ. These models form an integrated model. The optimal collaborative model, the best AJ, is obtained by assigning to each model the corresponding weight w'_i. In

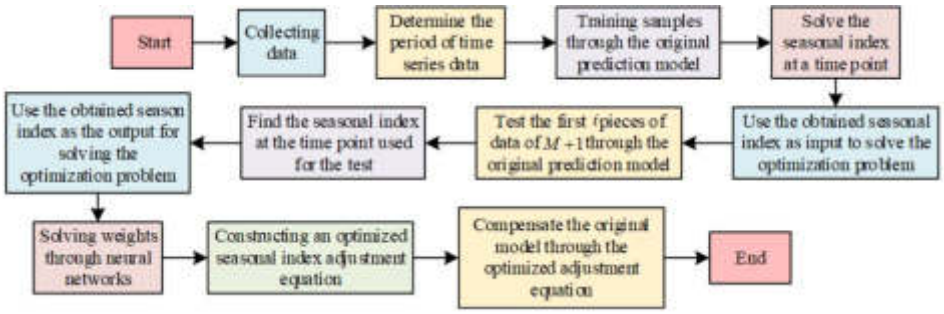

Fig. 3.3: Specific process for improving the SEA method

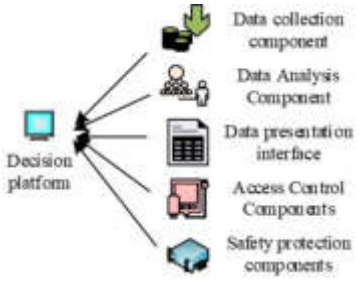

Fig. 3.4: Main functional components of the platform

solving the weights of each model, the solution can be performed by a neural network. Therefore, the specific flow of the improved SEA method is shown in Figure 3.3.

In Figure 3.3, data collection is performed to determine the time-series data for T, and the data need to have M period history data. A training sample is taken from $\varphi(x_t)$ and the results obtained are used as input to solve the optimization problem by solving AJ for each time point according to the formula of AJ_t. The mathematical expression of the output vector λ is shown in Eq. (3.13).

$$\lambda = \frac{a_{m+1,t}}{a'_{m+1,t}} \tag{3.13}$$

In Eq. (3.13), $t = 1, 2, \cdots, m$. m denoted the number of historical data periods. The weights are solved by using neural network. The number of hidden nodes is set to 1 and the weights from hidden nodes to output nodes are automatically adjusted to 1. The optimized seasonal index is set to AJ_t^* and the correlation equation of this index is constructed as shown in Eq. (3.14). $\varphi(x_t)$ is compensated by this equation.

$$AJ_t^* = \sum_{s=1}^{M} w_i' C_{s,t} \tag{3.14}$$

3.2. Page anti-tampering technology and construction of related decision support platform. After completing the establishment of the short-term passenger flow prediction model, a rural leisure tour industry decision support platform is constructed. Visitors can see personalized leisure tour content recommendations, which are conducive to their choice of places to visit. Operators can receive comprehensive marketing analysis guidance data given by the platform and keep abreast of other operators' dynamics in this platform. Among them, the platform's main functional components are shown in Figure 3.4.

In Figure 3.4, the platform mainly includes data collection component, data analysis component, data display interface, access control component, and security protection component. The data collection component

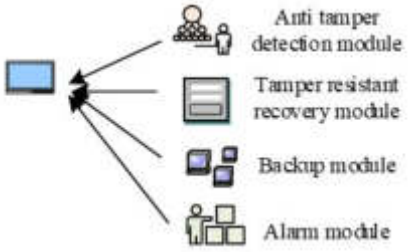

Fig. 3.5: Modules of the tamper-proof system

collects data such as real-time traffic information and the trajectory of visitors browsing the platform. The data analysis component makes use of data mining technology and relevant mathematical modeling to conduct directional analysis on the aggregated data. These data involve prediction of tourist flow, recommendation of popular products, development evaluation of leisure tourism merchants, etc. Then valuable information can be extracted, which can provide data support for the decision-making platform. The security protection component is distributed among the modules of the platform. For the platform pages, the anti-tampering technology of the pages makes them tamper-proof and protects the platform from network tampering attacks. Access control component is the core of the platform. This paper studies how to control system data access by designing role-based access control security access control component. The main method is to divide tourists, merchants, and regulators into three roles. Roles have different permissions based on regions. That is, roles in a region can access only the content of the current region and its subordinate regions. When the user accesses the data, the identity of the role (tourist, merchant or regulator) needs to be verified, and the relevant data can be obtained when the verification is passed. Meanwhile, the anti-tampering system has several modules, as shown in Figure 3.5.

In Figure 3.5, the anti-tampering system has four modules including anti-tampering detection module and backup module. The event triggering mechanism is combined with the core embedding technology in the anti-tamper detection module. The core technology is the notify feature in Linux in the event triggering mechanism through which the server-side files are monitored and illegal tampering is detected. Meanwhile, recovery is performed while tampering is detected with the aid of the resync file synchronization tool. Meanwhile, the core embedding technology will be based on Tomcat's filter technology for specific implementation, intercepting and verifying all Web requests. The location where the tampering occurred can be recovered in time and the backup files can be encrypted in the anti-tampering recovery module. The backup module backs up Web server-side files and has a disaster recovery role. In the alarm module, when the anti-tampering detection module finds an attack event, this alarm module sends an email to the administrator in time, etc. From the functions of different modules, the core of the anti-tampering system is the anti-tampering detection module, in which the core issue is the page tampering detection technology. In the core embedding technology to check the integrity of outgoing pages, the study selects Hashed Message Authentication Code (HMAC) encryption. Meanwhile, time-seeded random numbers are chosen for the selection of "challenge" numbers. HMAC is a message authentication code that uses a password hashing function, combined with an encryption key, to generate a message authentication code after a special calculation. It can be used to ensure data integrity and can be used to authenticate a message. The mathematical expression of the encryption algorithm is shown in Eq. (3.15).

$$HMAC(K', M) = H\left(K' \oplus opad \,||H\left(K' \oplus ipad|\,|M\right)\right) \tag{3.15}$$

In Eq. (3.15), HMAC denotes the encryption algorithm, H denotes the chosen Hash algorithm, and the Message-Digest 5 (MD5) algorithm of the Hash algorithm is chosen in the study. The authentication password is denoted as K'. The block size processed in H is denoted as B. B is the processed block size, not the output Hash value. opad and ipad denote the repetition of 0x5a and 0x36, respectively. B is the repeated several times. The algorithm is applied to the page verification, and the related flow is shown in Figure 3.6.

In Figure 3.6, the system is first initialized, the file Hash value is calculated, and the calculation result is

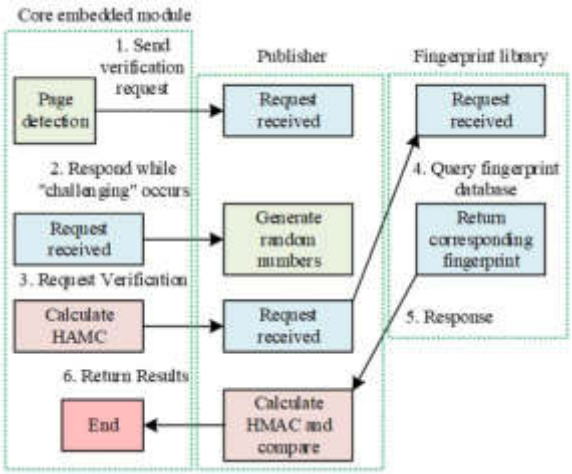

Fig. 3.6: Page verification process

backed up. Before the system is released to the public, the files to be released to the Web server need to be backed up. These files will be operated by MD5. Meanwhile, the corresponding file fingerprint information will be obtained and stored in the database for future verification work. One of the files has a unique location in the database. When the file is changed on the publishing server and the data is updated on the web server, the backup file is updated and the file hash value is recalculated. Meanwhile, the relevant fingerprint database is updated so that the relevant files are synchronized to ensure the normal operation of the system verification process. In the verification request, the filter is used as the client and the publishing server is used as the server based on the HMAC encryption idea. The filter sends a network verification request to the publishing server. The current system time is treated as a random number seed and a random number is generated and returned to the client as the answer upon receiving the request. The random number is the "challenge" number. The random number and the MD5 value of the Web page to be authenticated are encrypted with the HMAC-MD5 algorithm to obtain a message digest.

The page is verified and the message digest is sent to the server side. When the server side receives the message digest, it performs the HMAC-MD5 algorithm encryption on the basis of random numbers and fingerprint library keys. Meanwhile, the results obtained are compared with the message digest sent by the client. When the two are consistent, it directly informs the filter of this client. After this client releases the web page, the external request can get the relevant Web resources. On the contrary, it sends emails and other messages to the administrator to inform him/her and calls the data backup module to recover the tampered contents. For the page verification process, it is transient in nature, and the process is executed according to the authentication rules specified in advance. It is unforgeable in nature, and the random seed is selected according to the current time character of the publishing server. The random number generated from the seed is used as the "challenge number", which cannot be known by the third party in advance. The random number generated by the seed is used as the "challenge number", which cannot be known by the third party in advance to ensure the security of the page verification.

4. Application analysis of decision support platform for rural leisure tourism industry.

4.1. Performance analysis of the improved SVR model. The ARIMA model mainly focuses on the regression of the data itself and the extrapolation of the time trend, which is a kind of time series. The main purpose of ARIMA is to predict the future value of the deformation series. The improved SVR model used in the study was analyzed. The Autoregressive Integrated Moving Average Model (ARIMA), an SVR model, was used as a comparison model to study the forecast results of the three models in this dataset for 2019, as shown in Figure 4.1.

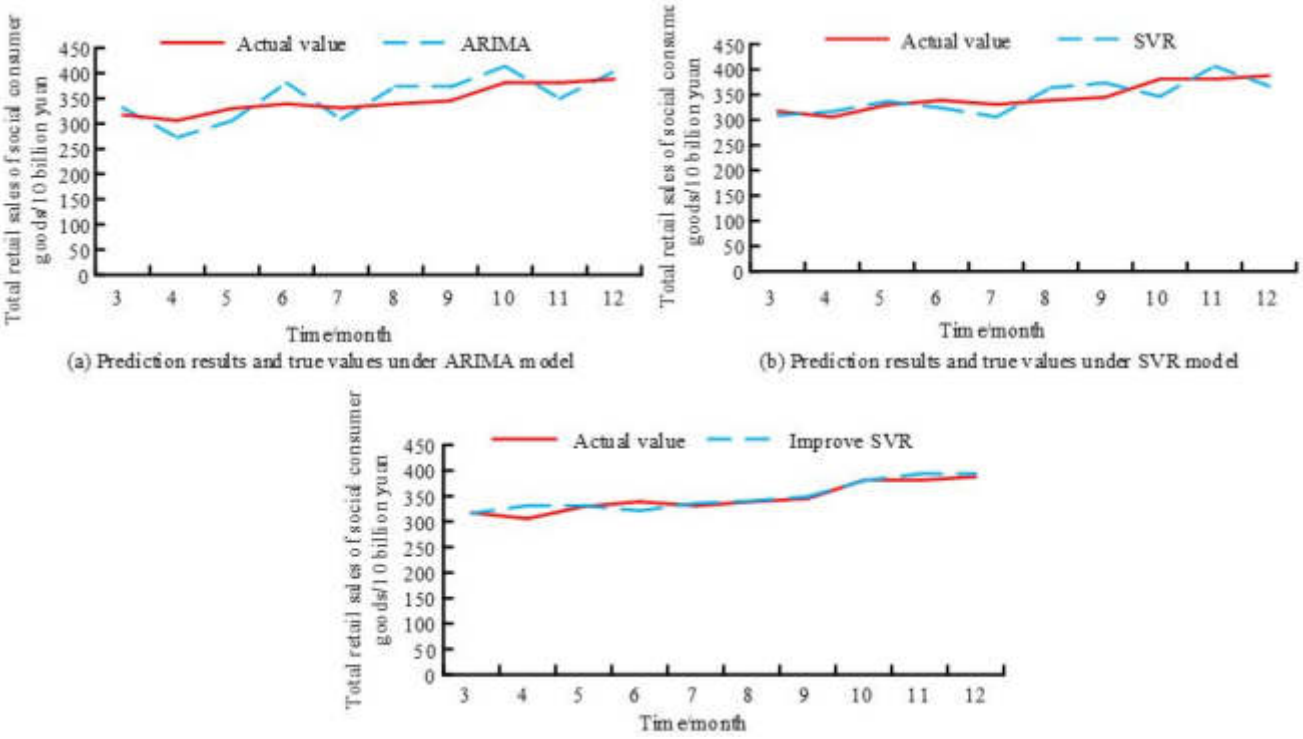

Fig. 4.1: Prediction results of three models

In Figure 4.1(a), the prediction results of different months have different degrees of difference from the actual value, and the predicted value fluctuates above and below the actual value. In Figure 7(b), the change of the prediction results is similar to that in Figure 7(a), and the magnitude of fluctuation decreases. The prediction results in Figure 7(c) also fluctuate above and below the actual value, but the magnitude of fluctuation is relatively minimal. In Figure 4.1(a), in March, the prediction result of ARIMA model is 33.128 billion yuan, which is 14.02 billion yuan more than the actual value, and the actual value is 317.26 billion yuan. In May, the prediction result of the ARIMA model is 305.30 billion yuan, which is 33.31 billion yuan less than the actual value. In Figure 4.1(b), in October, the predicted value of SVR model is $346.29 billion, which is $34.75 billion less than the actual value. In August, the predicted value of SVR model is 363.64. In Figure 4.1(c), in March, the predicted value of improved SVR model is $316.28 billion, which is $0.98 billion less than the actual value and $7.05 billion more than the SVR model. The prediction effect of the improved SVR model is known based on the difference between the predicted and actual values of the three models. Absolute error refers to the difference between the measured value and the true value of a measurement. The smaller the value, the more accurate the prediction. The absolute errors of the predictions of the three models were obtained to further analyze the prediction differences of these three models as shown in Figure 8.

In Figure 4.2(a), the absolute error of prediction of the ARIMA model fluctuates up and down within 6.00% to 13.00%. In March, the corresponding absolute error of prediction is 4.42%, which is 6.47% smaller than that of April, while the absolute error of model prediction is 10.89% in mid-April. In May, the corresponding absolute error of prediction is 12.30%, which is the maximum absolute error of prediction of the ARIMA model. In May, the corresponding absolute error of prediction is 12.30%, which is the maximum absolute error of prediction of ARIMA model, and 6.29% larger than the minimum absolute error of prediction of the model. In Figure 4.2(b), the maximum absolute error of prediction of the SVR model is 9.12%, corresponding to the month of October, which is 3.73% larger than that of December. In May, the minimum absolute error of prediction of the model is 2.20%, while the absolute error of prediction corresponding to June is 4.37%. In Figure 4.2(c), the minimum

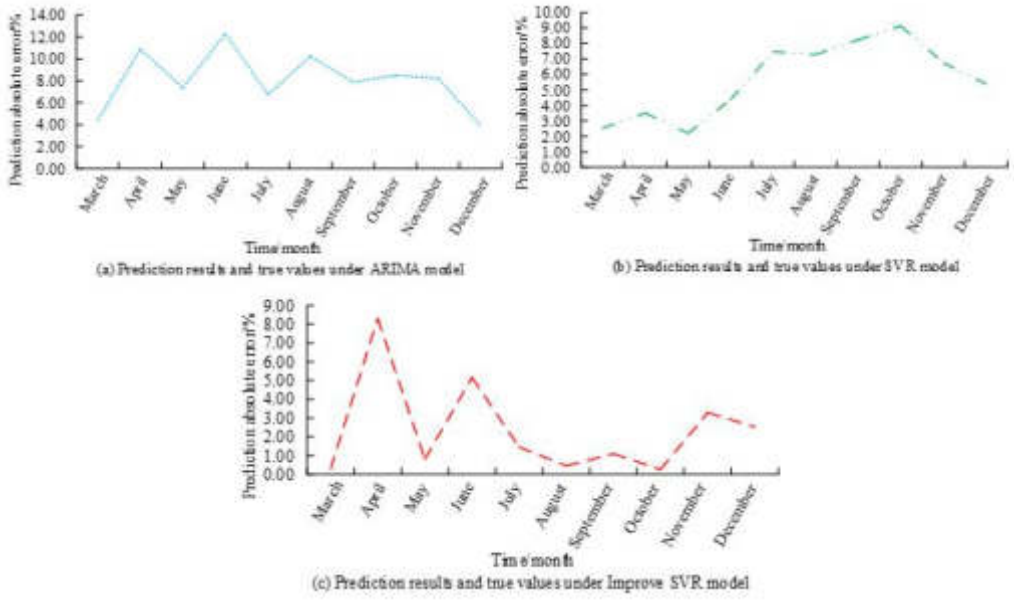

Fig. 4.2: Prediction absolute error of three models

absolute error of prediction of the improved SVR model is 0.27%, which is smaller than the minimum absolute error of the other two models. In June, the corresponding absolute error of prediction is 5.16%, which is 4.06% larger than that of September, while the corresponding absolute error of prediction in November is 3.29%. In April, the corresponding absolute error of prediction is the largest, which is 8.30%. This is smaller than that of the other models. The maximum absolute error of prediction is smaller than that of the other models. This shows that the improved SVR model has better performance among these three models.

4.2. 2 Analysis of the effect of application in decision support platform based on the improved SVR model. In this study, the traffic data were provided by the Jiuzhaigou tourism official website (http://www.jiuzhaigou.com/). The daily traffic data of 2013-2016 were selected, a total of 9.56 million people. Historical weather indicators were queried through historical meteorological website (http://mlishi.tiianqicom/), including the highest temperature, lowest temperature, wind speed, air, and relative humidity, etc. The human comfort index was to calculate the index value according to the indexes of the day. Then the index was used to classify and determine the comfort level. The related keyword search volume was provided by Baidu Search Index (http://index.baiducom/). The keywords "Jiuzhaigou Valley", "Jiuzhaigou ticket" and "Jiuzhaigou tourism" were selected in this study. The daily keyword search volume was calculated as the input factor. Then the desensitization of sensitive information, such as partial hiding or replacement of personal identity information such as name, ID number and phone number, was studied. Therefore, it could ensure that the real identity of users was not exposed in the anonymization process. Meanwhile, a strict access control mechanism was established to prevent data from being obtained by unauthorized personnel.

The constructed compensated prediction model was analyzed and simulation experiments were conducted. The OSX EI Capitan system was selected to obtain the 2017-2020 passenger flow data from an official tourism website. Therefore, queries on each index of relevant historical weather were conducted through the historical weather network. Meanwhile, the keyword search volume of Jiuzhaigou was queried through the Baidu search index. The time-series were plotted from January 2016 to October 2019 in Figure 4.3.

Figure 4.3(a) shows the daily passenger flow statistics, Figure 4.3(b) shows the daily human comfort index statistics, and Figure 4.3(c) shows the daily search volume statistics for the keyword "jiuzhaigou". The data in these three subplots show a certain periodicity, especially in Figure 4.3(b), where the periodicity of the data is

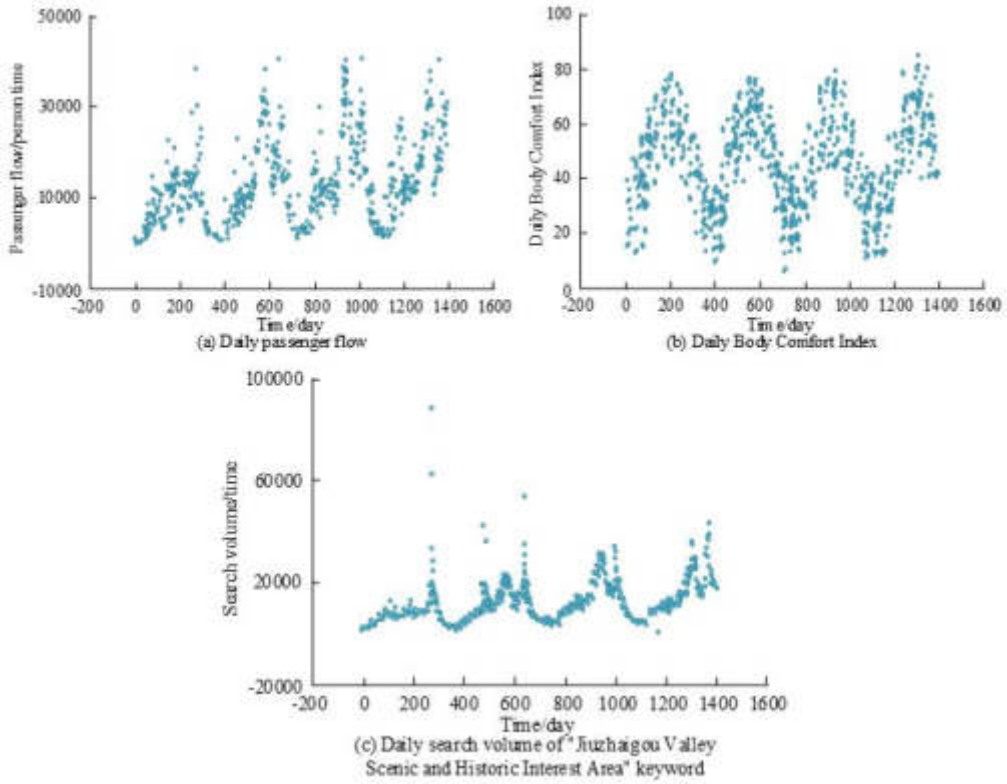

Fig. 4.3: Relevant time-series diagram

more obvious. In Figure 4.3(a), when the time is on the 264th day, visitors are 39,457, which is 39,408 more than that on the 400th day, which is 49. When the time is on the 389th day, visitors are 114. When the time is on the 1000th day, visitors are 32,927. In Figure 4.3(b), the situation of peak human comfort index occurs near the 200th, 600th, 1000th, and 1400th days. The time interval of the peak appears tends to decrease as time goes on. In Figure 4.3(c), except for the keyword "jiuzhaigou", which is searched for more than 60,000 times, the keyword is searched for less than 40,000 times at other times. The collected data are calculated and processed. The SVR model is selected to predict the daily passenger flow. Meanwhile, the "jiuzhaigou" Baidu search factor is used as an input factor to analyze its impact on the model prediction, as shown in Figure 4.4.

In Fig. 4.4(a), the corresponding traffic values are different at different times. The overall difference between the model prediction and the actual sample value is smaller after adding the web search factor. On day 5, passengers are 6597, which are 49 more than passengers at the same time without the web search factor. On day 7, passengers are 7335, which are 668 more than passengers at the same time without the web search factor, and 357 less than the actual value. In Figure 4.4(b), R denotes the correlation coefficient and MSE denotes the mean square error. After adding the network search factor, the MSE value of the training output is 0.0845, which is 0.0153 smaller than that without the network search factor. The R-value is 0.9284, which is slightly larger than that without the network search factor. The inclusion of network search factor can improve the prediction effect, which affects the passenger flow. The keyword "jiuzhaigou" was added to the input factor. The SVR model was improved to make the prediction. The SVR, ARIMA, and seasonal SVR models were used for comparison.

In Figure 4.5(a), based on the graph, the improved SVR model used in the study is located in a fold that is closer to the actual sample data. At day 6, the improved SVR model predicts 6668 passengers, which is 1665 passengers less than the SVR model considering the season and 102 passengers less than the actual value.

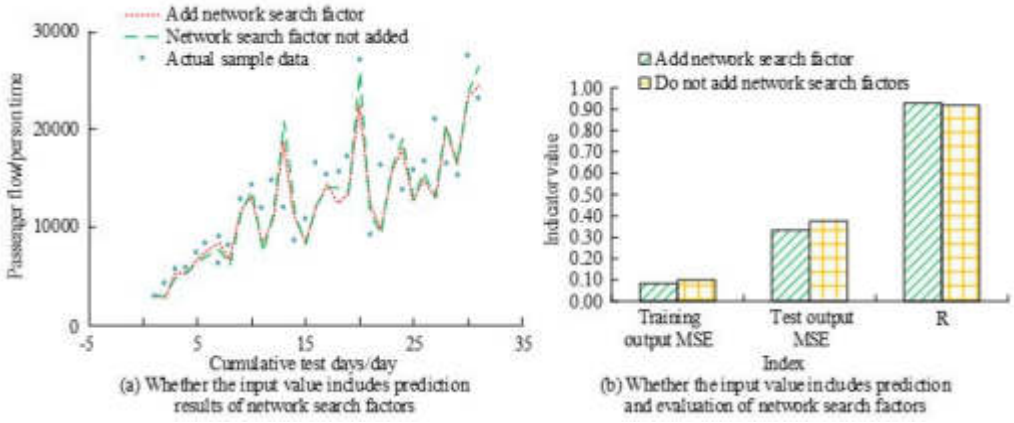

Fig. 4.4: Relevant prediction results

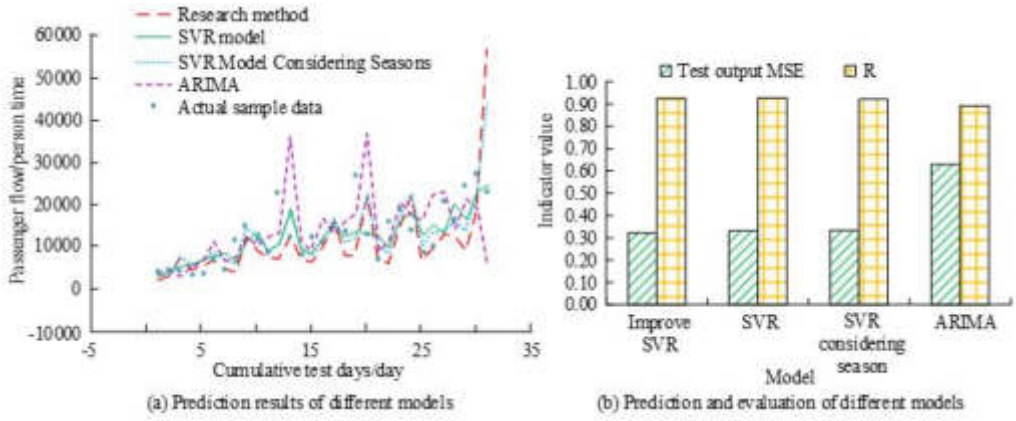

Fig. 4.5: Prediction results of different models

At day 21, its predicted passenger flow is the same as the actual value. In Figure 4.5(b), the tested output MAE value of the ARIMA model is 0.6299 at the maximum, which is 0.3075 larger than that of the improved SVR. This corresponds to a minimum MAE value of 0.3224. The improved SVR model has a higher R-value of 0.9254, which is slightly smaller than the SVR but larger than the other two algorithms. This shows that the improved SVR model has better performance. The performance of the anti-tampering scheme is analyzed, and the related results are shown in Figure 4.6.

From Figure 4.6, adding core embedded programs to the server affects the performance of the server. When the concurrency is less than 100 times/s, the average response time difference before and after the program is added is very little. The concurrency is greater than 100 times/s, and the time difference between these two increases continuously as the concurrency increases. When the concurrency is 150 times/s, the response time under adding the core embedded program is 15.11s, which is 3.83s more than when it is not added.

5. Conclusion. A decision support platform was constructed for the leisure tour industry in the countryside to grasp the development of the leisure tour industry in various parts of the countryside, understand the local passenger flow. The improved SEA method was used, the SVR model was improved, and a related passenger flow prediction model was constructed. An anti-tampering system was established to combine the event triggering mechanism with the core embedding technology for anti-tampering detection. The HMAC en-

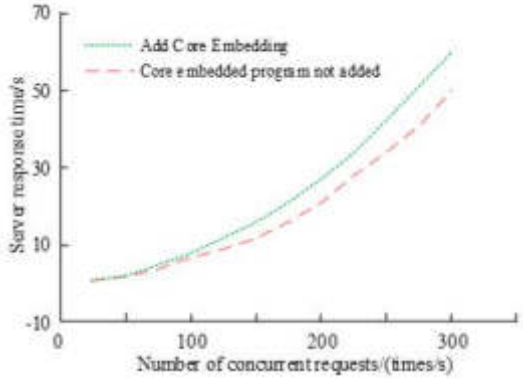

Fig. 4.6: Performance Analysis of Tamper Proof Schemes

cryption algorithm was used for page verification to prevent the page from being tampered. The results showed that the improved SVR model had better performance compared with SVR and ARIMA. The difference of the improved SVR model with the actual value was smaller. In March, the prediction value was $31.628 billion, which was $0.98 billion less than the actual value and $7.05 billion more than the SVR model. The absolute error of prediction was smaller. The minimum absolute error of prediction was 0.27%, which was smaller than the other two models. Adding the network search factor improved the accuracy of passenger flow prediction. After adding the network search factor, the MSE value of the training output was 0.0845, which was 0.0153 smaller than that without the network search factor. The R value was 0.9284, which was slightly larger than that when the network search factor was not added. In the analysis of the application of the improved SVR model, its prediction performance was better than that of the other models. At day 6, the improved SVR model predicted 6668 passengers, which was 1665 passengers less than the SVR model considering the season and 102 passengers less than the actual value. The minimum MAE value of this model's test output was 0.3224, which was 0.3075 smaller than the ARIMA model. The core embedded program affects the performance of the server in the performance analysis of the anti-tampering scheme. The concurrency was greater than 100 times/s, and its response time increased. This shows that the application of the research method is good. Since the time of page verification is not short, the verification technique can be improved later to improve the verification efficiency.

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A MULTI-LEVEL DEEP NEURAL NETWORK-BASED TOURISM SUPPLY CHAIN RISK MANAGEMENT STUDY

LIPING XU*

Abstract. With the rapid advancement of the tourism, the capital demand of tourism enterprises has gradually risen, but the confusion of market management has increased the difficulty of risk assessment of tourism enterprises by financial institutions, which has led to difficulties in financing tourism enterprises and seriously hindered their development. On this basis, this research first analyses the risk structure of the tourism supply chain (TSC) from the financial aspect and establishes a relevant risk assessment system. After confirming the assessment indexes, the data is dativized and normalized, and finally a multi-level deep neural network (DNN) is used to construct a TSC risk prediction model to calculate the transformed indexes and assess the risk degree of the enterprise according to the results. The experimental results indicate that the model has the best performance when the H-Net hidden layer is 3 layers and the L-Net hidden layer is 4 layers, and its accuracy reaches 93.35%, sensitivity reaches 84.13%, convergence starts at 25 iterations, the final loss value is only 0.8, and the predicted and the real value error is within 2.5%. Therefore, the multi-level DNN model constructed in this experiment has certain application value in TSC risk management.

Key words: Multilevel Deep Neural Networks; Tourism; Risk Management; Finance

1. Introduction. As people's living standards improve, the domestic tourism market is developing more and more rapidly, and the rapid development of the tourism market also demonstrates the country's growing economic strength [9]. Although the domestic tourism industry is currently thriving, small and medium-sized tourism enterprises still have some obstacles for development, mainly the lack of capital due to financing difficulties, which makes it difficult for enterprises to develop on a large scale. The difficulty of financing is mainly due to the complexity of the SME management system which makes it difficult for financial institutions to predict the risk level of the business and therefore prevents them from investing in it [11]. The TSC is the main investment of financial institutions. Although many studies have been explored on this issue, it is still difficult to cope with the complexity of the tourism industry. The field of deep learning is developing rapidly, replacing traditional mathematical and statistical methods as an important form of computing, and has led to many industries entering the age of intelligence [1]. DNNs, an important algorithm in the field of deep learning, can synthesize a wide range of input features and characterize the results. However, the current application of deep learning technology in the tourism industry is relatively rare. To address the above issues, this study proposes to construct a multi-level DNN model based on improving the risk assessment index of tourism enterprises to predict and assess the risk level of enterprises.

2. Related Works. With the development of information technology, DNN, a core technology for deep learning models, is widely used in various fields. lee et al. designed a heterogeneous floating point computing architecture using DNN. The architecture uses bfloat16DNN to train the processor to optimize the exponential computation and to improve energy efficiency and reduce memory consumption. The resulting computational architecture achieves an energy efficiency of 13.7 TFLOPS/W when processing data [6]. Wang C et al. developed a DNN-based optimized read voltage value strategy for expressing the relationship between voltage distribution and read voltage threshold. The strategy first analyses the channel coding rate for error probability, then uses cross iterative search to optimize the read voltage threshold, and finally uses DNN to optimize it. The results of this simulation experiment indicate that the optimization strategy using DNN improves the stability of the programming and slows down the read time delay [15]. Manoharan V et al. proposed a hybrid DNN-SHO algorithm for the performance measurement of an ECDM process for zirconia. The process starts with input parameters such as electrolytic concentration, duty cycle and voltage, followed by measurements of the output

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parameters, i.e., material removal rate, overcutting and tool wear rate, and finally performance determination based on the measured results. The research results indicate that the final material removal rate is 0.371 mg/min, the overcut is 162.2 μm and the tool wear rate is 0.26 mg/min. This determination is fully consistent with the experimental values and therefore the DNN-SHO algorithm is feasible [10]. A DNN accelerator was proposed by Jia et al. to solve the dynamic timing margin problem for PE arrays. First, a two-dimensional PE array with 16 clock domains is created, the clock period is dynamically adjusted according to the running instructions and operations, and finally a global clock bus is used for data transfer. The measurement results show that the performance conversion rate of the dynamic timing margin data stream under this DNN accelerator is improved by 34% and the effective operating frequency is increased by 19%, so this DNN accelerator can effectively solve the dynamic timing margin problem of PE arrays [3]. Kwon et al. define the concept of flexibility of DNN accelerators and propose flexion as a quantitative metric. Different accelerator flexions were tested and the experimental results showed that the Eyeriss-like accelerator was 2.2 times more flexible than the NVDLA-based accelerator, which is in line with the actual value, so the proposed quantitative metric has some application value [5]. Kariyappa et al. proposed drift regularization and multiplication in order to solve the situation of unstable DNN weight values caused by noise sources of PCM devices. noise training two techniques. The proposed techniques were used for image classification and language modelling experiments and performance evaluation, and the experimental results indicated that the proposed techniques raise the accuracy of DNN models by 12% [4]. Sun et al. proposed a DNN-based PDF security detector for epidemic documents in order to protect the security of PDF documents. Experiments on security detection of PDF files using this detector showed that the accuracy of the determination was 99.3% [14]. Ravindran R et al. applied DNNs to the field of self-driving cars. The technique of fusing sensors and DNNs to achieve multi-target detection and tracking of self-driving cars is proposed to optimize the perception model of self-driving cars [13].

As mentioned above, DNN, as a key technology of deep learning, has been well utilized in different fields, and many scholars have optimized and developed the performance of DNN. However, not many studies have applied DNN to the tourism industry, especially to the risk assessment of the TSC. With the gradual increase in the value of the tourism market, the use of deep learning algorithms to establish risk assessment models for the supply chain is an inevitable development trend, so this study discusses and analyses the application of DNN in the risk assessment management of the TSC.

3. Research on the application of multi-level DNNs in TSC risk assessment.

3.1. Construction of a TSC risk assessment system incorporating financial risk forecasting.

With the rapid development of the global tourism industry, TSC is faced with increasing risks, which mainly include market demand fluctuation, supply chain disruption, information asymmetry and policy and legal changes. These risks not only threaten the operational efficiency of tourism enterprises, but also affect the profitability and sustainable development of enterprises. Although a variety of risk management tools and strategies have been proposed, these methods often rely on traditional statistical analysis and empirical judgment, which are difficult to deal with large-scale and high-dimensional data, resulting in inaccurate risk assessment and lagging response. In this context, this study aims to address two main issues. The first is how to accurately and quickly assess multiple risk factors in TSC, especially in a dynamic and changing market environment. The second is how to come up with an effective risk management framework that can respond in real time and adapt to changing risks. To this end, a risk assessment model based on Multi-level DNN is proposed, which utilizes deep learning technology to comprehensively analyze and process large amounts of data to discover potential risk patterns and associations, thereby improving the accuracy and efficiency of risk prediction.

The amount of capital invested needs to be determined by the value of the enterprise, however, the industry currently lacks a valuation system that can objectively reflect the market value of the enterprise [8]. In addition, as the TSC is relatively new, financial institutions are unable to objectively assess the transaction risk of tourism companies. This study aims to develop an objective and valid assessment system for risk prediction in the TSC [2].

Figure 3.1 shows the pyramid risk structure of the TSC. As shown in Figure 3.1, supply chain risks can be analyzed by viewing them as a pyramid structure [12]. The bottom level is the irresistible risk, which is the least likely to occur and the least damaging, and includes mainly policy risk and black swan risk. The middle level of risk is transaction risk, which determines whether the TSC can run smoothly and requires a

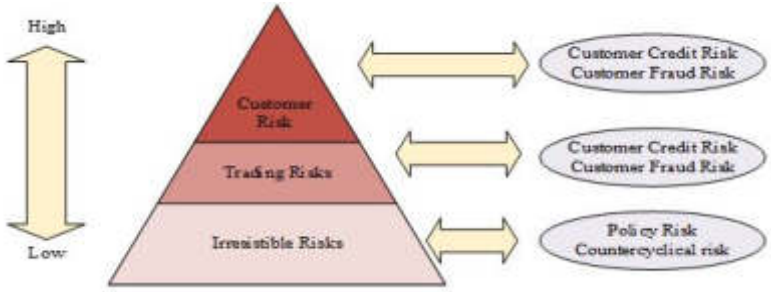

Fig. 3.1: The Pyramid Risk Structure of the Travel Supply Chain

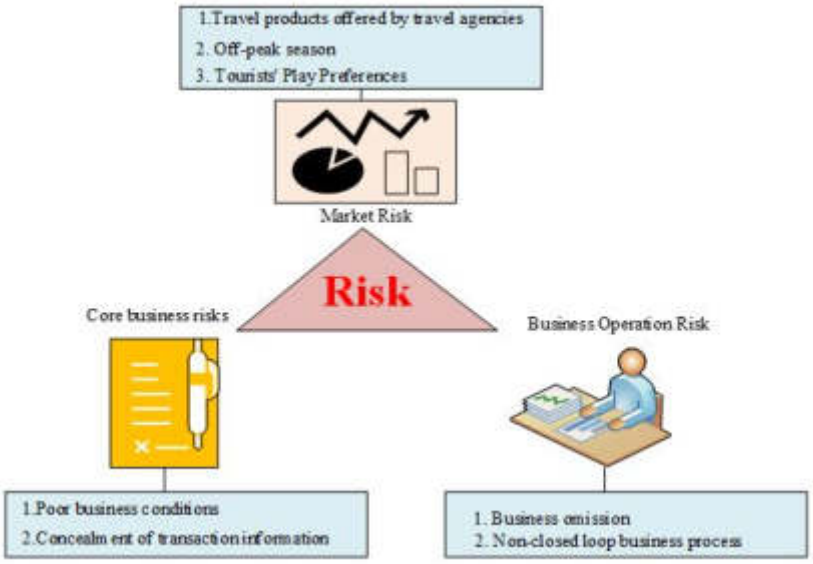

Fig. 3.2: Types of risk occurrence in the TSC

quantifiable model to dynamically predict the level of risk when assessing transaction risk. This risk is mainly tourism operational risk, for example. At the highest level is customer risk, where customer level risk is mainly assessed using financial institutions' intelligent risk control models, which are generally static and qualitative in nature. The probability of occurrence of this type of risk is the highest and is the most damaging.

The information flow of TSC mainly includes three aspects: market information flow, enterprise core information flow and operation information flow. The market information flow covers the dynamic changes of the tourism market, the uncertainty of tourism preference and other factors, which is helpful to accurately predict the market risk. Core businesses act as information hubs in TSC, holding visitor billing and transaction data. The integrity and transparency of information directly affect the trust of financial institutions and the financial stability of the entire supply chain. Operational information flow involves the monitoring of capital flow and financial information, which requires real-time, closed-loop management to ensure the effectiveness of risk control. Effective information flow management not only reduces the probability of risk occurring, but also protects the health of the entire TSC by responding quickly when it does occur. After analyzing the risk structure of the supply chain, different types of risk can be distinguished according to the characteristics of their occurrence.

Figure 3.2 shows the types of risk occurring in the TSC. As shown in Figure 3.2, the types of risk are

Table 3.1: Supply chain risk assessment index system for tourism enterprises

Primary indicators	Secondary indicators	Third level indicators
Corporate profitability	Return on Net Assets	Net income divided by owner's equity
	Operating Margin	Net income divided by operating income
Corporate debt repayment ability	Gearing ratio	Total liabilities divided by total assets
	Current Ratio	Total current assets divided by total current liabilities by total current liabilities
Business Operation Capability	Accounts Receivable Turnover Ratio	Ratio of operating revenues to average accounts receivable balance
Business Growth Capability	Total operating revenue	Growth for the period divided by total operating income for the previous period by total operating income for the previous period
	Total Assets	Increase in total assets for the period divided by total assets for the previous period
Corporate Capital Strength	Operating income	Net cash flow from operating activities and operating income
	Loan recovery rate	Loans recovered during the period
Corporate Cash Flow	Other receivables divided by assets as a percentage	Other receivables divided by total assets

mainly divided into three categories, firstly, market risk, market risk is mainly due to the off-peak season, the uncertainty of tourists' touring preferences and other factors, so it leads to the inability of financial institutions to make accurate predictions on the tourism market. The second is core enterprise credit risk. The core enterprises in the tourism industry hold most of the information on visitor billing transactions in the industry, which could easily lead to the disruption of most of the financial supply chain in the industry in the event of a breach of trust by the core enterprises. Finally, the business operation risk, because the tourism industry needs to monitor the flow of funds and other financial information in real time, and closed-loop management, so the tourism industry's financial business operation process must be interlocked, up and down to take over, one of the problems will lead to the failure of risk management. TSC risk assessment indicator validation refers to the process of determining which indicators effectively reflect the level of risk in the TSC. These indicators are a key element in assessing the various potential risks faced by tourism enterprises, including market risk, operational risk and customer risk. The selection of evaluation indicators is based on the following criteria. The first indicator should be directly related to TSC's operations and risks. The second indicator should be quantifiable and can be clearly expressed through data. The third indicator should be sensitive to changes in the supply chain and can reflect changes in risk in a timely manner. Fourth, in the process of data collection, indicators should be easily obtained to ensure the real-time and accuracy of risk assessment. On this basis, a risk assessment system can be constructed based on the risk characteristics of the TSC.

Table 3.1 shows the supply chain risk assessment index system of tourism enterprises. From Table 1, we can get the risk assessment indicators are mainly the profitability, debt servicing ability, operation ability, growth ability, capital strength and cash flow of the enterprise. Among them, profitability is the enterprise's ability to obtain profits in a certain period of time, mainly including operating profit margin, cost profit margin, etc. Debt servicing capacity is the ability and willingness of an enterprise to repay its bank debts, and is mainly an analysis of the enterprise's debt ratio. Operational capability reflects the business level of the enterprise, mainly through the capital turnover rate to determine the profitability of the enterprise. Growth capacity is the development prospect of the enterprise after the loan, which is mainly judged by the revenue growth rate and other indicators. Capital strength is the enterprise's strength in recovering capital, mainly assessed through indicators such as payment recovery rate. Cash flow reflects the cash flow of an enterprise, with positive cash flow representing an enterprise in profit mode and negative cash flow in loss mode.

As risk assessment in the financial sector is currently operated by computer, there is also a need to digitize and normalize the indicators in the TSC risk assessment system, allowing them to be converted into computer language. Set a three-level feature table with i primary features, a score of for primary features and a weight of $R_{11}, R_{12}, ...R_{1i}$ for primary features. The table has level 2 features, the score of level 2 features is and the weight of level 2 features is j $R_{21}, R_{22}, ...R_{2i}k$ level 3 features in the . There are table, the score of level 3

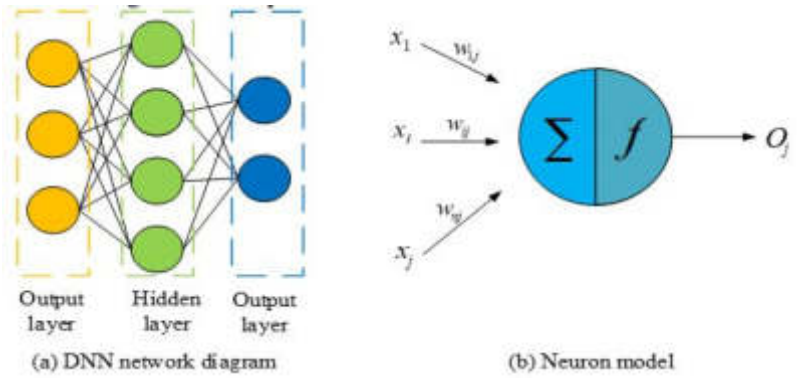

Fig. 3.3: Typical DNN diagram

features is and the weight of level 3 features is. $S_{31}, S_{32}, ...S_{3i}S_{2x}$ The formula for calculating the score of the x second level feature is shown in equation (3.1).

$$S_{2x} = \sum_{a=1}^{i} R_{1a} * S_{1a} \tag{3.1}$$

S_{2x} The of Eq. (3.1) is obtained by weighting the sum of the tertiary features under the secondary features. Similarly, the weighted sum of the secondary features under the primary features gives the fraction of the primary features S_{1x}, which is expressed in Eq. (3.2).

$$S_{1x} = \sum_{a=1}^{j} R_{2a} * S_{2a} \tag{3.2}$$

Equations (3.1) and (3.2) can convert the evaluation indicators into numerical form, but given the differences in units and value ranges of different indicators, normalization is also required before the DNN can perform operations on the data. To improve the speed of the operation, all data can be mapped to the interval range of [0-1] before the input values are pre-processed to obtain the expression for data normalization as in equation (3.3).

$$a` = \frac{a - a_{min}}{amin_{max}} \tag{3.3}$$

In equation (3.3), a is the original data value, a‘ is the data normalized value, a_{max} is the data maximum value and a_{min} is the data minimum value. In summary, after analyzing the financial risk structure and types of the TSC, a risk assessment system incorporating financial risk prediction is established. Based on this, this research proposes to construct a multi-level DNN-based TSC risk prediction model to identify and calculate the digitalized and normalized assessment indicators.

3.2. Construction of a multi-level DNN-based risk prediction model for the TSC. A DNN is a multi-layered structured neural network. Multi-level DNNs are designed to give machines the ability to learn and to analyses and recognize non-traditional data such as sounds, images etc [7]. The network's mode of operation is to first extract the non-linear relationship between the input data and the output result, then input the new data and derive the new output result from the resulting relational equation.

Figure 3.3 shows a typical DNN, where Figure 3.3(a) shows a DNN network structure with three layers: input, output and hidden layers, and neurons in one layer of the grid connect to neurons in the next layer. Figure 3.3(b) shows the neuron model, where the neuron is the basic structure of the DNN. When the input value of the neuron is greater than its threshold value, the neuron is activated and the output value is obtained through the activation function, which is then used as the input value of the next layer. In Figure 3.3(b),$x_1, x_2, ...x_n$ is

the input value of the neuron, w_{ij} is the weight, $\sum$ is the weighting operation, O_j is the output, and f is the activation function. The presence of the activation function enhances the non-linear processing capability of the DNN and is generally located at the output position of the neuron. Three types of functions are commonly used, namely Sigmoid, Tanh and ReLU. The Sigmoid function is presented in equation (3.4).

$$f(x) = \frac{1}{1+e^{-x}} \tag{3.4}$$

The Tanh function is presented in equation (3.5).

$$f(x) = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \tag{3.5}$$

The real numbers in Eq. (3.5) take values in the range [-1,1] and are generally used to exaggerate the effect of features. The calculation for the ReLU function is Eq. (6).

$$f(x) = max(0,x) \tag{3.6}$$

Eq. (3.6) shows that the ReLU function is essentially a maximising function. Combining the analysis of equation (3.4), equation (3.5) and equation (3.6), it can be obtained that the interval range of both Sigmoid and Tanh functions are relatively small and will tend to saturate at the end values leading to a slower training speed, while the ReLU activation function has the ability of computational simplicity and resistance to gradient disappearance, so it is utilized as the activation function for this experiment. Based on this, the formula for calculating the output of this neuron can be obtained as in equation (3.7).

$$O_j = f\left(\sum_{i=0}^{\sum_{i=0}} nx_i w_i - \theta\right) \tag{3.7}$$

In Eq. (3.7),θ is the neural network parameter, whose expression is Eq. (3.8).

$$\theta = \left\{W^{(1)}, ..., W^{(n-1)}, b^{(1)}, b^{(n-1)}\right\} \tag{3.8}$$

In equation (3.8),$W^{(n)}$ is the weight vector and $b^{(n)}$ is the bias vector. During the computation of a neural network, the complex mapping of neurons in different layers is achieved by one-way propagation from the input space to the output space. The process by which the neural network normalises the feature vectors at the output layer and outputs the predicted values is known as the feed-forward process. Substituting the sample set Φ into the neural network for feedforward operation, the expression of the sample set Φ is shown in equation (3.9).

$$\Phi = \{(x_1, y_1), (x_2, y_2), ... (x_n, y_n)\} \tag{3.9}$$

In equation (3.9), y_n is the actual value of the output and the predicted value of $y_n{}^*$ is passed on as shown in equation (3.10).

$$y_n^* = z^{(1)} \to O^{(1)} \to \bullet\bullet\bullet \to z^{(n)} \to O^{(n)} \tag{3.10}$$

In equation (3.10),z is the calculation result of the weighting operation. The parameter update of the neural node is calculated using the gradient descent algorithm, taking the first neuron in the neural network as an example, its parameter matrix is set as, $c^{(1)}$, and this update is shown in equation (3.11).

$$\begin{cases} C^{(1)} = C^{(1)} - \alpha \frac{\partial(C,c)}{\partial C^{(1)}} \\ c^{(1)} = c^{(1)} - \alpha \frac{\partial(C,c)}{\partial c^{(1)}} \end{cases} \tag{3.11}$$

In equation (3.11), α is the learning rate of the negative feedback operation process of the neural network. The above process allows the parameters in the neural network to be updated iteratively, and finally it gets the

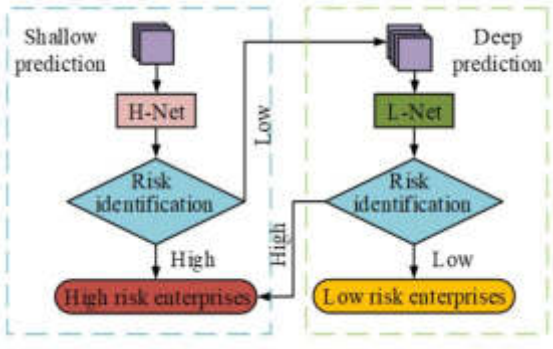

Fig. 3.4: Structure diagram of multi-level DNN system

optimal values of the parameters. After completing the optimization of the neural network parameter values, this research used multi-level DNNs to construct a supply chain risk prediction model for tourism enterprises. The model is divided into two network layers, H-Net and L-Net, to predict supply chain risk hierarchically. The input values of H-Net are the secondary characteristics of the enterprises TSC, and the input values of L-Net are the tertiary characteristics of the enterprises TSC, and the output values of both network layers are the risk assessment values of enterprises TSC. Firstly, the model will generate an initial score table based on the tertiary characteristics table by the system before prediction, and then weight and sum the table data to get the secondary characteristics score table, then the system will input the secondary characteristics score table into H-Net and calculate the supply chain risk score of this enterprise. If the risk score is lower than 60, the enterprise is a high-risk enterprise, and if the risk score is higher than 60, the enterprise is a low-risk enterprise. Finally, the three-level characteristic score table of the low-risk enterprise obtained from H-Net is input into L-Net for further evaluation, and if the score is lower than 60, the enterprise is a high-risk enterprise, otherwise vice versa. In the model development stage, through in-depth analysis of historical data, the study observed that when the enterprise risk score is below 60, the default rate of these enterprises is significantly higher than that of enterprises with a score above 60. In addition, compared with industry standards and similar studies, it is found that this threshold can effectively distinguish high - and low-risk enterprises. It can be seen that using 60 points as the dividing point to distinguish between high and low risks can maximize the prediction accuracy and sensitivity of the model and ensure the accuracy and practicality of the assessment.

In the risk assessment process, especially when using L-Net deep network for detailed risk analysis, this study constructs a score table based on three levels of characteristics, which is used to quantify and evaluate the performance of enterprises on different risk dimensions. Tertiary features refer to the detailed data points extracted from the daily operations and financial reports of an enterprise as detailed expansion features of primary and secondary features. Tertiary features are used to assess the specific risk status of an enterprise. The score table is created by quantifying and standardizing the above three levels of characteristics, each of which is assigned a score and weight. Scores are typically based on industry standards or historical performance data, determined by comparing a company's actual performance to the industry average. The weights are assigned according to the importance of the feature in the overall risk assessment. The main impact of the score table is to provide a quantitative, easy-to-understand way to assess the level of risk in a business. By scoring the three levels of characteristics together, risk managers can quickly identify those risk areas that may require further attention, while also having a clear view of the overall risk profile of the organization. In addition, the score table can also be used to monitor changes in the level of enterprise risk and provide support for enterprise risk management and decision-making.

Figure 3.4 shows the structure of the multi-layered DNN system. H-Net is designed as a shallow predictive network that is primarily responsible for processing and evaluating secondary features, i.e. features received directly from the data input layer. The primary purpose of this network layer is to quickly screen and initially assess possible risks, providing a preliminary risk assessment result in order to quickly identify high-risk entities

or situations. Due to its relatively simple structure, H-Net can initially process large amounts of data while maintaining speed, and screen out potentially high-risk cases for further analysis. Compared to H-Net, L-Net is a deeper network specifically designed to handle more complex data analysis tasks. It receives output from H-Net and mainly deals with tertiary features for more in-depth risk analysis. The purpose of L-Net is to provide a more refined risk assessment by deeply analyzing detailed operational data of an enterprise, assessing subtle risk changes, and predicting long-term risk trends. The analysis results of this layer are more accurate and suitable for further verification and analysis of low or uncertain risks after screening.

From the above, the DNN input values used in this experiment are the secondary and tertiary structures of the enterprise supply chain, and the number of neurons in the input layer of the H-Net layer and L-Net layer is 6 and 20. respectively. And the number of neurons in the output layer of both networks is 1. The number of hidden layers needs to be calculated and solved by the formula method, and the expression is as in equation (3.12).

$$p = \sqrt{n+q} + a \tag{3.12}$$

In equation (3.12), p is the quantity of neurons in the hidden layer, n is the quantity of neurons in the input layer, and a is the mediation parameter, which takes values in the range of [1-10]. To sum up, this research first carries out the assessment index confirmation of the TSC risk of enterprises, then data and normalization of the index, then constructs a multi-level DNN model to calculate the characteristics of the processed index, and finally judges the TSC risk degree of the enterprise according to the calculation results.

The development process of multi-level DNN model based on TSC risk prediction is as follows. The first is data preparation and preprocessing. Various types of data are collected, including market data, supply chain transaction records, and policy changes. The data is cleaned to remove missing values and outliers, and then normalized to fit the input requirements of the neural network. The second is the model architecture design. A neural network with two levels, H-Net and L-Net, is designed. H-Net handles the primary risk assessment, while L-Net further analyzes businesses that are initially identified as high-risk. Each network layer consists of input layer, several hidden layers and output layers, and the specific number of layers and neurons is obtained based on experimental optimization. The next step is feature selection and network training. In the feature selection phase, methods based on information gain and correlation analysis were used to determine which features were most important for risk prediction. The selected features are fed directly into the neural network. The back-propagation algorithm was used for the training of the network, and Adam was chosen by the optimizer because it can effectively adjust the learning rate to suit the needs of our model after many iterations. Finally, the model is evaluated and verified. To evaluate the performance of the model, metrics such as accuracy, recall, and F1 scores were used. In addition, the prediction results of the model were compared with other machine learning algorithms to prove its superiority.

4. 4 Analysis of the results of multi-level DNN-based TSC risk prediction management.

4.1. Experimental analysis of multilevel DNNs for ablation. The experiment was run on a workstation, and the experimental data used real transaction data of a core enterprise in the tourism industry within the last five years, of which 80% was used as the training set and the remaining 20% as the test set. The evaluation metrics were first datatized and normalized according to equations (1), (2) and (3) to normalize the values of all data to the range of [0-1], then the network structure was built through the API in TensorFlow, then the neural network function was used to initialize the network parameters and build TFRecord to transfer the data into the neural network, and finally the optimization of loss function, activation function and other neural network parameters, call the session.run function for training, and output the results.

Figure 4.1 shows a schematic diagram of the bench configuration and the experimental flow. Where Figure 4.1(a) shows the bench configuration parameters and Figure 4.1(b) is the experimental flow chart. The purpose of using Multi-level DNN in this study is to use neural networks of different levels to process and analyze complex data relationships, so that the model can learn nonlinear features in the data more deeply, so as to improve the accuracy of risk prediction. The ablation experiments were set up to verify the specific contribution of each hidden layer to the performance of the model and to ensure that the optimization of the model was effective. In the ablation experiment, different layers from the input layer to the hidden layer are removed one

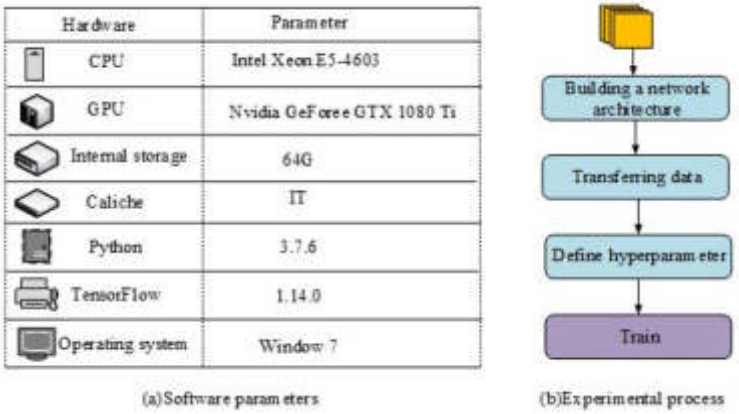

Fig. 4.1: Workbench configuration and experimental process

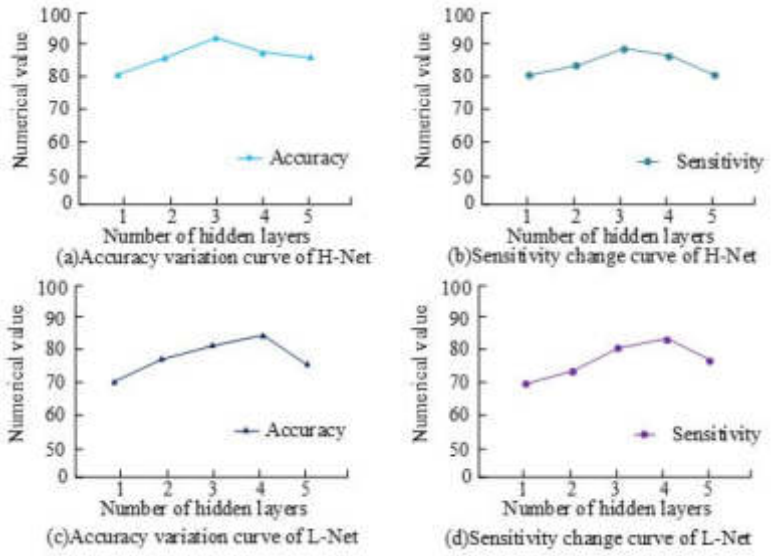

Fig. 4.2: Hidden layer ablation experiment

by one, and the importance of these layers in the overall network is assessed by comparing the performance of the model after removing specific layers. In this way, the study was able to clearly identify the network layers that contributed the most to the prediction results, thus providing a basis for further optimization of the model structure. Since the features of the DNN affect the output results, it is necessary to first determine the influence of the quantity of neural network layers on the H-Net and L-Net.

Figure 4.2 shows the multi-level DNN hidden layer ablation experiment. Among them, Figure 4.2(a) and Figure 4.2(b) show the curve of model accuracy and sensitivity with the number of H-Net hidden layers, respectively. When the quantity of hidden layers is at 3, the accuracy of the model prediction results reaches a maximum of 91.24% and the sensitivity is as high as 87.89%. The analysis of Fig. 4.2(a) and Fig. 4.2(b) shows that when hidden layers is greater than 3, the accuracy and sensitivity of the prediction results decrease gradually as the H-Net hidden layers increases. Figure 4.2(c) and Figure 4.2(d) denote the curve of model accuracy and sensitivity with the quantity of L-Net hidden layers, respectively. When the hidden layers are

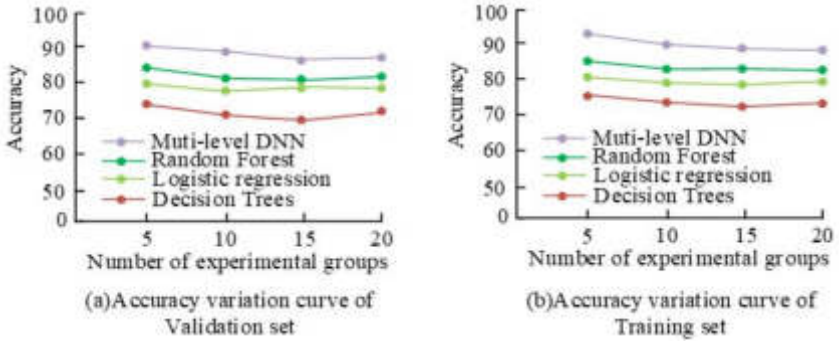

Fig. 4.3: Comparison of Model Accuracy under Four Algorithms

4, the model accuracy and sensitivity get the highest value of 84.79% and 82.12%, respectively. To sum up, within a certain range, raising the number of hidden layers can improve the data fitting ability of the model. The multi-level DNN performs best when the H-Net hidden layer is 3 and the L-Net hidden layer is 4.

4.2. Performance analysis and application of multi-level DNN models in TSC risk prediction. To further demonstrate the effectiveness of Multi-level DNNS, the study compared Multi-level DNNS to several other common machine learning algorithms, including logistic regression, decision trees, and random forests. These particular algorithms were chosen because they each exhibit unique performance characteristics when dealing with classification problems. Logistic regression is often used for baseline comparison because of its concise model and strong explanatory results. Decision trees are easy to understand because they can generate decision rules. As an ensemble learning method, random forest can improve the stability and accuracy of prediction. By comparing with these algorithms, this study can comprehensively evaluate the practicability and effectiveness of multi-level deep neural network in the risk prediction of tourism enterprise supply chain. The models under all three algorithms and the multilevel DNN model are applied to the supply chain risk prediction of tourism companies and the results of the training and test sets are compared to analyses their accuracy and sensitivity.

Figure 4.3 shows a comparison of the accuracy of the models under the four algorithms. Where Figure 4.3(a) and Figure 4.3(b) shows the accuracy results obtained for the test set and the training set, respectively. From Figure 4.3, the results of the training set under all four models are slightly higher than the results of the corresponding test set, which indicates that the classification of the dataset is effective. In addition, the accuracy of the proposed multilevel DNN algorithm is higher than that of the other algorithms, with the highest accuracy result of 93.35% in the training set. The model under the multi-level DNN algorithm has a certain accuracy in predicting the risk of the TSC.

Figure 4.4 shows a comparison of the sensitivity of the models under the four algorithms. Among them, Figure 4.4(a) and Figure 4.4(b) are the sensitivity results obtained from the test set and the training set, respectively. From Figure 4.4, it can obtain that the sensitivity results of the training set under all four models are slightly higher than the corresponding test set results, and the sensitivity of the model under the multi-level DNN algorithm is higher than the other algorithms, with the highest sensitivity of 84.13% in the training set. The sensitivity represents the response time of the model when performing data processing, which indicates that the model built with multi-level DNN can enter the data computing mode faster and reduce the time cost. In summary, it can be concluded that the model under multi-level DNN algorithm has higher application value.

Figure 4.5 shows the iteration curves under the four algorithms, where Figure 4.5(a) shows the iteration curve obtained from the test set and Figure 4.5(b) shows the iteration curve obtained from the training set. From Figure 4.5, the iterative stabilization rate of the test set is slightly lower than that of the training set. The multilevel DNN algorithm in the training set starts to converge after 25 iterations, while the random forest starts to converge at 48 iterations, the logistic regression starts to converge at 28 iterations and the decision tree starts to converge at 49 iterations, so the multilevel DNN algorithm has a better optimization finding ability

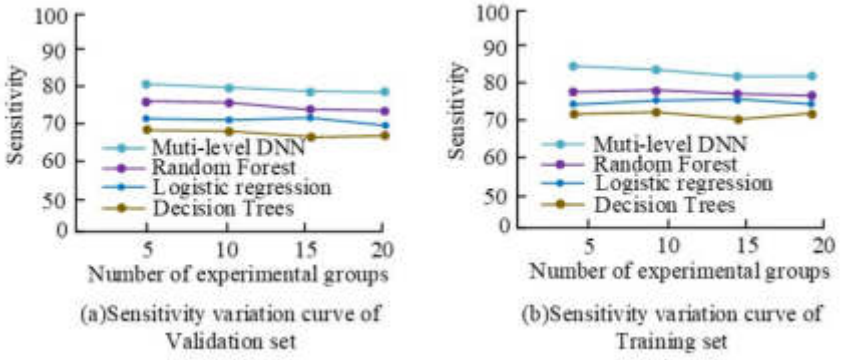

Fig. 4.4: Comparison of Model Sensitivity under Four Algorithms

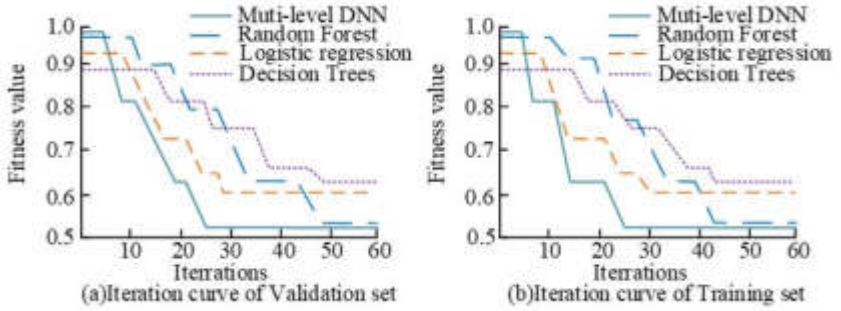

Fig. 4.5: Iteration curves under four algorithms

and eventually reaches an optimal fitness value of 0.52.

Figure 4.6 shows the iteration curves under the four algorithms, where Figure 4.6(a) shows the loss curve obtained from the test set and Figure 4.6(b) shows the loss curve obtained from the training set. From Figure 4.6, the loss values of the four algorithms gradually decrease and stabilize with more iterations, and the overall loss values of the training set are lower than those of the test set. The loss value of the multi-level DNN algorithm in the training set is 0.8 when it reaches stability during the iterations, that of the random forest is 1.1, that of the logistic regression is 1.8, and that of the decision tree is 1.9. Therefore, the multi-level DNN algorithm has a lower loss rate during the operation and has better application value.

Figure 4.7 shows the risk assessment trend of the tourism enterprise over a five-year period. The predicted value is the risk assessment score obtained through the multi-level DNN algorithm model, the traditional predicted value is the risk assessment score obtained using the traditional weighted summation algorithm, and the true value is the real risk value of the enterprise. From Figure 11, it can get that the results obtained by the multi-level DNN model are closer to the true value, and the prediction error is less than 2.5%, which indicates that the DNN can better evaluate and predict the TSC risk of enterprises. In summary, the model constructed using multi-level DNN proposed in this research can objectively and accurately manage the risk prediction of the TSC of enterprises.

5. Discussion. The multi-level deep neural network model proposed in this study has demonstrated significant predictive ability in tourism supply chain risk management, but its implementation strategies and potential challenges in real world scenarios need to be further explored to transform this model into an effective tool in practical applications. The following is the specific analysis of the model in practical application. The first is the problem of system integration. In order to deploy this risk management model in the travel industry,

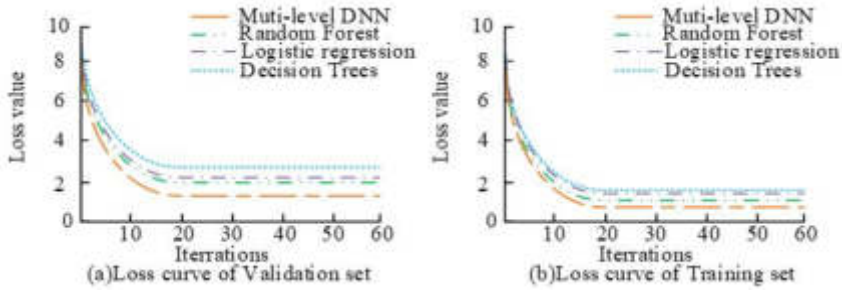

Fig. 4.6: Loss curves under four algorithms

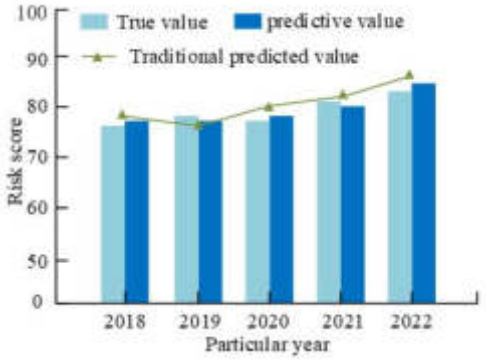

Fig. 4.7: Score chart of enterprise evaluation within five years

it first needs to be integrated into the existing supply chain management system. This step may require working closely with the IT department to develop appropriate interfaces to ensure real-time data updates and a smooth flow of information. The second is user training and support. Implementing new risk management tools requires not only technology integration, but also training of enterprise managers and operators, a process that includes a detailed explanation of how the model works, how it operates, and its application in risk identification and response. The next step is the real-time processing and analysis of the data. The efficient operation of the model depends on high quality and real-time data. In practical applications, it is necessary to ensure that the system can process information from different data sources, such as market dynamics, customer feedback, and internal operational data, and can quickly turn this data into risk predictions and alerts. Finally, risk response mechanism and continuous monitoring and optimization. Another key application of the model is the establishment of automated risk response mechanisms. Based on the model's predictions, the system should automatically trigger appropriate preventive or mitigation actions, such as adjusting supply chain configuration, optimizing inventory management, or reallocating resources to mitigate potential negative impacts. Continuous monitoring and periodic performance evaluations are necessary after the model is deployed. This not only ensures that the model accurately reflects the actual state of the supply chain, but also allows the model to be adjusted and optimized based on the latest business and market conditions. In summary, through the above measures, the risk management model can not only improve the enterprise's ability to predict potential risks, but also enhance the enterprise's adaptability and response speed in the face of market changes. This will greatly enhance the overall resilience and competitiveness of the tourism supply chain, bringing real business value to enterprises.

6. Conclusion. As the country's economic strength increases, the domestic tourism industry is booming. Many tourism businesses need a large amount of capital to be incorporated in order to keep up with the pace

of development. However, because financial institutions currently lack a way to assess the risk of tourism enterprises, many of them experience difficulties in financing. In this study, after improving the risk assessment system of the TSC, a multi-level DNN was used to construct a risk prognosis model to predict the risk of tourism enterprises with the assessment index. The above results indicate that the number of hidden layers of H-Net and L-Net of DNN affects the data fitting ability of the model, and the model has the best sensitivity and accuracy performance when the hidden layers of H-Net are 3 and the hidden layers of L-Net are 4. Based on this, the performance of the model constructed using multi-level DNN was compared with that of models under other algorithms, and it can be obtained that the model constructed using multi-level DNN has the highest accuracy of 93.35% and sensitivity of 84.13%, and starts to converge at 25 iterations, and the final stability loss value is only 0.8, which is better than the models under other algorithms. Applying this model to the risk prediction of the business and comparing it with the real risk value of the business over a five-year period, it was finally obtained that the predicted value obtained by the model was within 2.5% of the real value. In summary, the model constructed by this experiment using multi-level DNN outperforms models under other commonly used algorithms, with higher accuracy and sensitivity, and has some practicality in the field of TSC risk prediction. However, as this experiment only verified the risk level of one relevant enterprise, the generality of the model has not been well proven, and a large amount of enterprise data can be collected for its subsequent Validation.

7. Future Work. Although this study has achieved encouraging results in the risk prediction of tourism supply chain, there are still the following deficiencies. Future research will focus on the following aspects to promote the further improvement of the model and the deepening of practical application.

First, increased data diversity and coverage. In order to enhance the generalization of the model, future work will explore a wider range of data sources, including different regions, different sizes of tourism companies, and longer time horizons. This will help the model capture a wider variety of risk factors and market dynamics.

Second, the impact of data quality on model performance is analyzed. Considering that data quality and integrity can have a significant impact on prediction results, future research will strengthen data cleaning and preprocessing efforts and explore new methods to reduce the impact of missing data and mislabeling.

The third model refinement and algorithm optimization. Based on the preliminary results of this study, further refinement of the model structure and optimization algorithm will be an important research direction. In particular, exploring new techniques in deep learning, such as transfer learning and reinforcement learning, may provide new solutions for dealing with complex risk assessment problems.

Fourth, practical application and deployment. In view of the theoretical success of this research model, it is an important step in the future to apply the model to the actual tourism supply chain management system. Feedback from the actual deployment will be used to further validate and refine the model to ensure its validity and applicability in the real world.

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A NOVEL WIND POWER PREDICTION SCHEME BY COUPLING THE BP NEURAL NETWORK MODEL WITH THE FIREWORKS ALGORITHM

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Abstract. Wind power has unpredictable, intermittent traits due to meteorological conditions and environmental factors. Large-scale grid integration of wind energy will undoubtedly challenge system stability. This study developed a fireworks algorithm-backpropagation (FWA-BP) neural network model to forecast wind power using wind speed, direction, and power as model inputs. Optimization of the BP network weights and thresholds occurred through the fireworks algorithm. Compared to a standard BP network, the FWA-BP model yielded improved prediction accuracy seen through a lower mean squared error. This implies that the approach introduced in this paper significantly enhances global search capabilities, prediction accuracy, and speed. It contributes to enhancing the reliability of the power system, optimizing resource allocation, and improving wind power scheduling, with substantial potential and economic significance.

Key words: Backpropagation neural network; Power prediction; Wind speed; Wind power; Wind direction; Fireworks algorithm

1. Introduction. In recent years, more research has started to focus on wind energy due to its renewability, cost-effectiveness and environmental friendliness.This renewable energy option stands out for its ease of development and lack of pollution [1, 2, 3, 4]. However, the irregular and fluctuating output of wind power that is correlated with changing weather patterns and environmental variables poses integration challenges when connecting substantial wind energy capacities to the electric grid system. This integration presents difficulties in balancing electricity supply and demand, ensuring system stability, and effectively managing grid operations [5, 6, 7, 8]. Accurate forecasting of wind power output becomes essential for efficient resource distribution and wind power dispatch. For instance, some studies propose new frameworks and utilize optimization algorithms to enhance the short-term wind power generation forecasting accuracy. There are also those employing hybrid optimization algorithms to optimize neural networks for improved prediction accuracy. Furthermore, research in the field of deep learning introduces novel transfer models. Enhanced forecasting capabilities serve to strengthen the power system's resilience while also raising the ability to integrate more renewable wind energy production. Additionally, it assists in optimizing wind farm maintenance schedules and alleviates the need for extensive energy storage, thereby resulting in significant economic advantages [9, 10, 11, 12, 13, 14].

Ongoing research in the field seeks to enhance our understanding of wind power dynamics and improve forecasting methodologies. Advanced forecasting techniques, such as machine learning algorithms and predictive modelling, are being explored to address the challenges associated with the variability of wind power. These endeavors aim to further unlock the potential of wind energy, making it an even more reliable and integral component of the global energy landscape. In recent decades, scholars researching wind power generation have proposed a plethora of methods for forecasting wind power output in wind farms. Prior research has proposed using Adaboost-PSO-ELM model to address uncertainties and fluctuations in wind power prediction. This integrative approach aims to improve generalization capabilities beyond existing models. Validation on

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turbine data from Turkey demonstrated the Adaboost-PSO-ELM model provides more accurate and robust wind power forecasting [15]. In related work examining the inherent variability of wind energy, the parametric sine function superposition recurrent neural network is introduced in the prediction process for iterative tuning. This algorithm can effectively extract multiple features from intermittent wind power data, such as time series data of wind speed, wind direction, atmospheric pressure, and more. This capability has been confirmed through its robust predictive performance [16] .A recent study proposed a Differential Evolution-Backpropagation (DE-BP) algorithm for wind forecasting to address backpropagation limitations including local optima and slow speeds. Validation results show the DE-BP approach boosts accuracy around 5% over traditional BP models for power prediction. Additionally, prediction time decreased 23.1% compared to genetic algorithm-BP alternatives [17].There is also research proposing an improved BP neural network prediction method, namely an iterative genetic optimization BP neural network power prediction model, with the input being the power from one hour ahead and other influencing factors. Tests have proven that this model can effectively meet the power system's relevant short-term power prediction requirements for wind farms [18].

This study employs a Backpropagation (BP) neural network by integrating historical data on real power production, wind speed, and direction. While BP networks have shown promise in wind power forecasting, their performance relies heavily on model parameter initialization and optimization. Additionally, few studies explore the integration of advanced optimization algorithms like fireworks algorithms to improve model training. To address these gaps, this study puts forward a fireworks-enhanced backpropagation (FWA-BP) approach. Following simulations with actual data from a specific wind farm using Matlab, the results show that the Fireworks Algorithm optimization led to a notable decrease in errors when applying the backpropagation neural network model for wind power prediction. This enhancement leads to increased accuracy and speed in forecasting, addressing the limitations of a standalone BP neural network and ultimately achieving superior performance.

2. Wind Power Prediction Model. Wind power generation has numerous advantages that other renewable energy sources lack, but its drawbacks are also quite evident. The ongoing rise in installed wind power capacity exacerbates the technical constraints associated with wind power. Wind power production varies significantly between high and low wind speeds. These sudden changes can exert a notable influence on the primary power grid, and if they surpass the grid's capacity thresholds, they may result in a grid failure. Therefore, accurate prediction of wind power output is of utmost importance.

2.1. Analysis and Management of Wind Power Influencing Factors. We will analyze this from five aspects.

1. The correlation between wind energy output and wind velocity. The equation for the wind turbine's harnessed wind power is:

$$W = \frac{1}{2}\rho V^3 \pi r^2 C_p \tag{2.1}$$

In this equation, ρ represents air density, V is the wind speed, r is the rotor's swept area radius, and C_p is the wind turbine power coefficient [19].

Wind power generation varies markedly from traditional sources, mainly owing to its dependence on wind speed as a vital element. In Figure 2.1, the graphic depicts the non-linear relationship between wind energy generation and wind velocity.

In real-world wind farm power production, the link between wind velocity and turbine output is nonlinear. This can be characterized by the following segmented function:

$$W(v_w) = \begin{cases} 0, & v_w \le v_i \\ (X + Y v_w + Z v_w^2) p_u, & v_i < v_w \le v_u \\ W_u, & v_u < v_w \le v_o \\ 0, & v_o < v_w \end{cases} \tag{2.2}$$

In the equation, v_i, v_o, and v_u represent the starting, shutdown, and designated wind velocities, in that order. Meanwhile, p_u signifies the rated power output, X, Y,and Z are parameters outlining the wind energy curve.

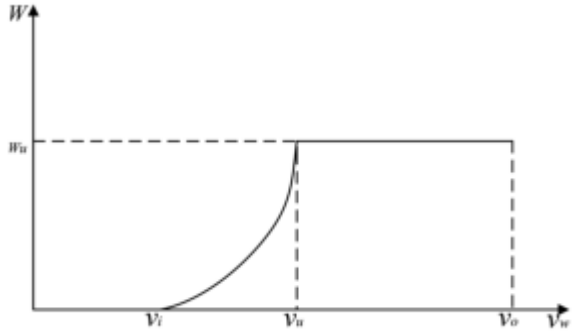

Fig. 2.1: Wind Power Output Characteristics Curve.

The parameters of wind turbine power characteristic curve obtained from observed data are as follows:

$$X = \frac{1}{(v_i - v_u)^2}\left[v_i(v_i + v_u) - 4(v_i \times v_u)(\frac{v_i + v_u}{2v_u})^3\right] \tag{2.3}$$

$$Y = \frac{1}{(v_i - v_u)^2}\left[4(v_i + v_u)(\frac{v_i + v_u}{2v_u})^3 - (3v_i + v_u)\right] \tag{2.4}$$

$$Z = \frac{1}{(v_i - v_u)^2}\left[2 - 4(\frac{v_i + v_u}{2v_u})\right] \tag{2.5}$$

The quation 2.2 shows that in different intervals, the wind power and speed of wind farm show a variety of functional relationships.

Additionally, use V_m to represent the measured value, and the normalized wind speed V_n is::

$$V_n = \frac{V_m - V_{\min}}{V_{\max} - V_{\min}} \tag{2.6}$$

2. The correlation between wind direction and wind power. Wind turbines use a yaw mechanism, guided by wind direction and speed, to capture more wind energy. The yaw mechanism typically has a time delay, so wind turbines cannot immediately align with the wind, resulting in varying power output at the same wind speed. Indeed, wind direction has a vital role in influencing wind turbine power output.

Wind direction is normalized as:

$$\theta_n = \frac{\theta_m - \theta_{\min}}{\theta_{\max} - \theta_{\min}} \tag{2.7}$$

Where θ_n represents the normalized wind direction angle, θ_m is the measured wind direction angle, $\theta_{\min}$ and $\theta_{\max}$ correspond to the minimum and maximum wind direction angles, respectively.

3. The correlation between air pressure and wind power. Wind power output exhibits correlation with atmospheric pressure; therefore, atmospheric pressure data should be incorporated when formulating wind power output forecasting models.

Pressure is normalized as:

$$P_n = \frac{P_m - P_{\min}}{P_{\max} - P_{\min}} \tag{2.8}$$

where P_n represents the normalized atmospheric pressure, P_m is the measured atmospheric pressure, $P_{\min}$ and $P_{\max}$ correspond to the minimum and maximum atmospheric pressures, respectively.

At the same time, pressure is related to temperature and atmospheric density, and the formula for calculation is as stated below:

$$\rho = \rho_0 \frac{T_0}{T} \frac{P}{P_0} \tag{2.9}$$

Where ρ_0, T_0, P_0 and represent standard air density, temperature, and atmospheric pressure, and represent local temperature and pressure.

4. The relationship between temperature and wind power. When the temperature is too low, the turbine blades may freeze and not function properly, leading to a decrease in wind power output. Conversely, when the temperature is too high, certain components of the wind turbines may not withstand the high temperatures, which can also affect wind power output. Additionally, temperature is related to pressure and air density.

Temperature is normalized as:

$$T_n = \frac{T_m - T_{\min}}{T_{\max} - T_{\min}} \tag{2.10}$$

5. The correlation between humidity and wind power. The relative humidity of the air and air density are inversely related. Relative humidity affects density, as indicated by equation 2.9, which shows that density affects temperature and atmospheric pressure. Therefore, local air humidity also influences wind power output.

Humidity is normalized as:

$$S_n = \frac{S_m - S_{\min}}{S_{\max} - S_{\min}} \tag{2.11}$$

Where S_n represents the normalized humidity, S_m is the measured humidity, $S_{\min}$ and $S_{\max}$ correspond to the mini-mum and maximum humidity, respectively.

2.2. BP Neural Network Predicting Wind Power. The three-layer structure of BP neural network is shown in Figure 2.2, n, m, and l represent the number of nodes in each layer [20]. The input variables $x_i (i = 1, 2, ..., n)$ enter the input layer. They are organized into a matrix, where rows represent the number of samples, and columns represent the feature dimensions of each sample. Each row corresponds to a sample, containing three types of features. The hidden layer outputs are denoted $h_j (j = 1, 2, ..., l)$, and the final outputs from the network are $y_k (k = 1, 2, ..., m)$. The transfer function mapping from input to hidden layer is $\varphi(x)$, the input-hidden weight matrix is ω_{ij}, and the hidden-output matrix is ω_{ik}. Matrices a_j and b_k provide thresholds for the hidden and output layers.

The input to the j-th hidden node is calculated as:

$$n_{ij} = \sum_{i=1}^{n} \omega_{ij} x_i - a_j \tag{2.12}$$

The hidden node j takes input:

$$hj = \phi(n_{ij}) = \phi\left(\sum_{i=1}^{n} \omega_{ij} x_i - a_j\right) \tag{2.13}$$

For output node k, the input is:

$$n_{jk} = \sum_{j=1}^{l} \omega_{jk} h_j - b_k \tag{2.14}$$

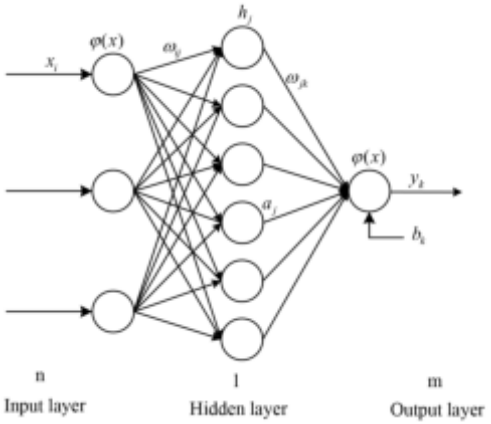

Fig. 2.2: Structure diagram of the BP neural network model.

Node k in the output layer produces output:

$$e_k = \phi\left(n_{jk}\right) = \phi\left(\sum_{j=1}^{l} \omega_{jk} h_j - b_k\right) \tag{2.15}$$

The parameters of influencing factors such as wind speed and wind direction serve as input features in the network model, acting as neurons in the input layer. Specifically, each neuron in the input layer corresponds to an input feature parameter, as follows:

1. Wind speed v serves as an input feature, corresponding to a neuron in the input layer. This neuron receives the raw wind speed data v as input.

2. Wind direction θ serves as another input feature, also corresponding to a neuron in the input layer. This neuron receives the raw wind direction data θ as input.

The values of these two input nodes are multiplied by weights associated with the respective connections and then passed to the hidden layer. The hidden layer and subsequent layers furtherand subsequent layers process this information, ultimately outputting the predicted wind power. Through multiple iterations of training, the model automatically adjusts the weight coefficients The model automatically adjusts the weight coefficients through multiple iterations of training to achieve the optimal fitting effect between input feature parameters and output values.

The BP neural network demonstrates a robust capability for non-linear mapping and can approximate non-linear functions through the utilization of two iterative processes: signal forward propagation and error backpropagation. This allows the network to satisfy specific conditions for error reduction in its output [21, 22].

2.3. The BP Neural Network Model's Drawbacks. This model also has some limitations, mainly in the following aspects:

1. The convergence rate during network can be relatively slow, primarily due to the influence of two key factors: the learning rate and the activation function's derivative. The choice of the learning rate directly impacts the magnitude of network parameter updates, while the activation function's derivative adjusts weights during the backpropagation process, further affecting convergence performance. As the network aims to address complex nonlinear problems, the "zigzag phenomenon" often occurs in the objective function, impeding the convergence speed [23].

2. Entering local optimal solutions is a common susceptibility in certain scenarios. In a BP neural network, when the error function equals 0, indicating no gradient, the weights and thresholds cannot be updated. If we assume that the nonlinear problem being solved is a standard convex function, there would be a unique extremum, and its local optimum would be the global optimum. Through the network, optimal solutions can

(a) High-quality fireworks exploding. (b) Low-quality fireworks exploding.

Fig. 3.2: The process of fireworks exploding with varying quality.

be identified, and the most effective converging weights and thresholds can be determined. However, in most cases, nonlinear problems have multiple extremum points within different intervals of their functions. In such cases, once the BP neural network reaches a local optimum, it stops updating, making it unable to continue towards finding the global optimum [24].

3. Selecting the optimal network architecture can be difficult, as the needs vary depending on the problem. While BP neural networks have proven effective in diverse applications, carefully configuring the structure based on the unique characteristics of each challenge is important. Overall architectural choices must be informed by both the general best practices of the method and the distinctive qualities of the particular predictive task.

3. Wind Power Prediction Model. By self-explosion to generate sparks and subsequently exploring the surrounding area, the Fireworks Algorithm possesses additional advantages due to this search mechanism. In comparison to traditional genetic algorithms and particle swarm optimization, it can better uncover hidden information in deep layers, offers higher randomness, and demonstrates greater versatility. In the fireworks algorithm, the initial fireworks and exploded fireworks positions are considered as a set of candidate solutions. The solutions are evaluated using an objective function that determines their quality. A fitness function then works to retain the higher performing solutions. This process is iteratively repeated. Eventually, the obtained firework positions converge towards the optimal solution, with the best output result achieved in the final iteration. High-quality fireworks typically generate a large number of sparks when the explosion radius is relatively small, while low-quality fireworks, due to a larger explosion radius, produce more scattered sparks. Figure 3.1 provides a simple comparison of the number of sparks and explosion range between high-quality and low-quality fireworks.

The Fireworks Algorithm demonstrates features related to the diversity of the population, notably observed in the variety of fireworks, explosion amplitudes, and the quantity of sparks. Additionally, it reflects diversity in Gaussian mutation and displacement operations. Diversity broadens the scope of global search, preventing it from getting stuck in local optima while not adversely affecting the algorithm's convergence capability. Some studies have elucidated its unique advantages, such as its search mechanism and efficiency in multi-objective optimization. Other research has focused on improvements to the Fireworks Algorithm and the selection of parameters for its applications [25, 26, 27, 28]. Considering its application in predicting wind power generation using BP neural networks, the Fireworks Algorithm can address many shortcomings of traditional BP neural network predictions.

3.1. Data Processing. The simulation analysis was conducted using data from a wind turbine in Turkey. The experimental data consists of wind speed, wind direction, and wind power output data at regular intervals. Divide the dataset into two segments, one designated for model training and the other for testing. Normalize the input vector to the range [0,1] using the provided formula [29]:

$$x^* = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \tag{3.1}$$

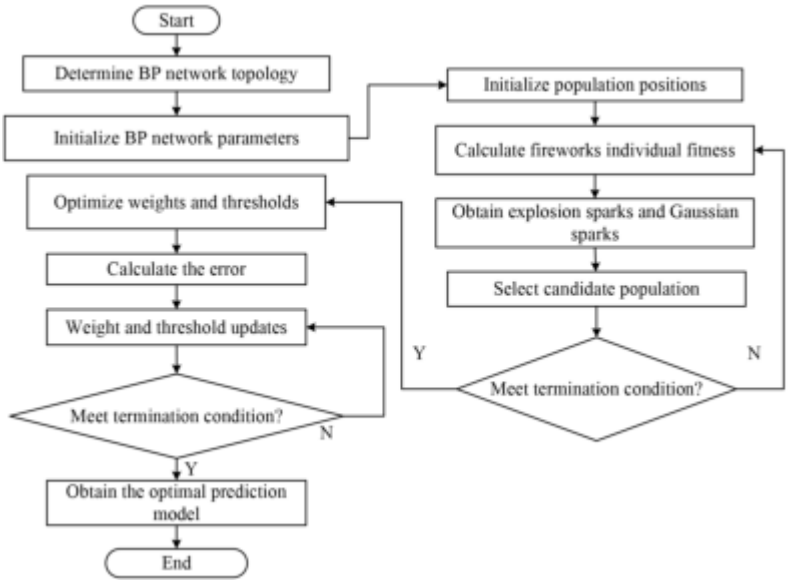

Fig. 3.3: Flow of Wind Power Prediction Using FWA-BP Neural Network.

Here, x is the actual data value, while $x_{\max}$ and $x_{\min}$ refer to the maximum and minimum values in the input vector. x^* is the normalized result.

3.2. The construction of the wind power forecasting model for FWA-BP. Use actual power, wind speed and direction as inputs to the neural network. Employ the fireworks algorithm to search optimal network weights and thresholds.

Here are the specific steps:

Step 1: Establish a BP neural network;

Step 2: Initialize firework population positions and define upper and lower limits for number of explosions;

Step 3: Calculate the fitness values for every individual in the fireworks population by utilizing the formulas to determine the count of fireworks generated in each explosion, represented as N_i and the explosion radius L_i.

$$N_i = c \times \frac{k_{\max} - f(x_i) + \beta}{\sum_{i=1}^{N}(k_{\max} - f(x_i) + \beta)} \tag{3.2}$$

$$L_i = d \times \frac{f(x_i) - k_{\min} + \beta}{\sum_{i=1}^{N} f(x_i) - k_{\min} + \beta} \tag{3.3}$$

where $k_{\max} = \max(f(x_i))$ $(i = 1, 2, \ldots, N)$ and $k_{\min} = \min(f(x_i))$ $(i = 1, 2, \ldots, N)$ represent the worst and best fitness values among all firework individuals in the current population, respectively. The function $f(x)$ represents the fitness value of an individual x. In this paper, the fitness function value corresponds to the mean squared error. c restricts total sparks, d is the explosion radius upper bound. β prevents division by zero;

Step 4: Perform the explosion difference operation to generate sparks for the fireworks individuals, as well as Gaussian-mutated sparks after Gaussian mutation. The formulas for calculating the position offsets are as follow:

$$ex_{ik} = x_{ik} + h \tag{3.4}$$

$$cx_{ik} = x_{ik} \times r \tag{3.5}$$

$$h = A_i \times rand(1, -1) \tag{3.6}$$

where A_i is the explosion radius for firework i. h gives position offset, ex_{ik} is a spark from the i-th firework's subsequent explosion. x_{ik} is firework i's k-th dimension value. cx_{ik} Gaussian-mutates x_{ik} based on distribution $r \sim N(1, 1)$;

Step 5: The subsequent generation of fireworks population comprises candidate fireworks. From the populations of fireworks, explosion sparks, and sparks produced through Gaussian mutation, select the one with the lowest fitness value. Additionally, $N - 1$ fireworks are selected through fitness-proportional selection;

Step 6: Determine if the termination condition has been reached. If so, move to the next step. Otherwise, return to the previous step and repeat the process;

Step 7: Retrieve optimal weights and thresholds, perform error checking, repeatedly validate and optimize the model, and thresholds to make wind power predictions using the model;

Step 8: Optimize the updating of network connection weights and thresholds using the Fireworks Algorithm. The following formulas provide the expressions for weight threshold optimization, based on which (2.12) - (2.15) are updated:

$$\omega_{ij} = \omega_{ij} + \eta H_j \left(1 - H_j\right) x_i \sum_{k=1}^{n} \omega_{jk} e_k \tag{3.7}$$

$$\omega_{jk} = \omega_{jk} + \eta H_j e_k \tag{3.8}$$

$$a_j = a_j + \eta H_j (1 - H_j) x_i \sum_{k=1}^{n} \omega_{jk} e_k \tag{3.9}$$

$$b_k = b_k + \eta e_k \tag{3.10}$$

where η represents the learning rate;

Step 9: Evaluate whether the termination condition has been fulfilled. If so, end the current iteration. otherwise, if the specified error performance criteria are not met, and the iteration limit has not been reached, continue with step 8.

Figure 3.2 illustrates the computational process for wind power forecasting using the optimized FWA-BP network.

4. Case Study Analysis. To assess prediction accuracy, this paper simulated wind farm power output over a period. The dataset contained wind speed, direction and power, serving as input for both BP and FWA-BP models. The first 150 data rows were utilized for training, while rows 151-185 were used for testing.

Based on an empirical formula for the number of hidden layers:

$$l = \sqrt{n + m} + \alpha \tag{4.1}$$

where n and m represent the number of nodes in the input and output layers, respectively, and α is a constant ranging between 1 and 10.

We used the MATLAB neural network toolbox to design, train and test the BP neural network. The version of MATLAB used was R2018a, and the related modules of the neural network toolbox used were version 11.1. The computer configuration we used for the simulation was an AMD Ryzen 7 5800H with Radeon Graphics, 3.20 GHz, and 16 GB of memory. The graphics card was an RTX 3060, running on the Windows 11 operating system. Based on the empirical formula in equation 4.1, the range for the number of hidden layer neurons was calculated to be 3 to 12. After approximately 10 simulation trials and adjustments, the number of neurons was finalized at 6.

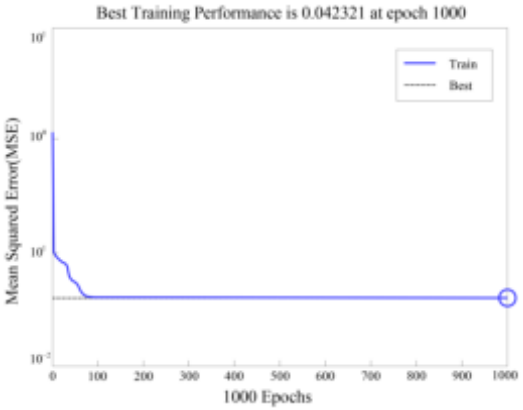

Fig. 4.1: BP neural network training error curve.

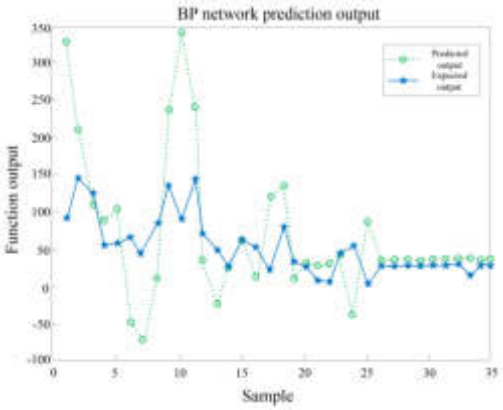

Fig. 4.2: BP neural network test data prediction results.

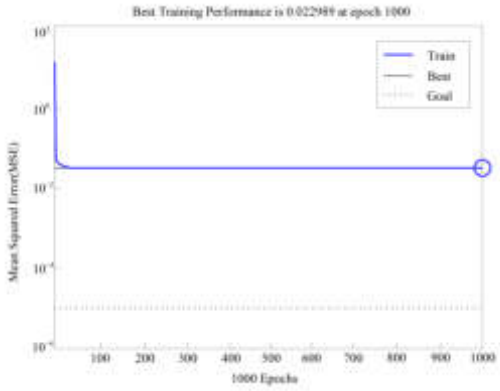

Fig. 4.3: FWA-BP neural network training error curve.

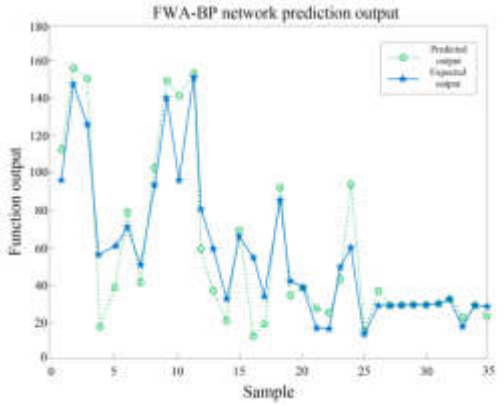

Fig. 4.4: FWA-BP algorithm test data prediction results.

Figure 4.1 and 4.2 show the training mean squared error, prediction speed, and comparison between predicted and actual outputs by using the BP neural network for prediction.

Figure 4.1 shows the BP neural network's mean squared error reached 0.042321 after 100 training iterations, with no further decrease. This is 0.042221 off the target value.Figure 4.2 shows the predicted and actual wind power results, with the dashed line representing the predicted values and the solid line depicting the observed/real values. While most of the predicted points closely match the actual values, there are slight discrepancies. Notably, about 11 prediction points show significant deviations. This is due to the inherent limitation of the BP neural network structure. As a simple three-layer feedforward network, its ability to simulate nonlinear mappings is limited, resulting in poor approximation performance for complex real-world systems. Additionally, factors such as the number of training epochs and the setting of the learning rate contribute to the inability of the BP network to achieve lower training loss and testing error. Therefore, the next step involves improving the BP network using the fireworks algorithm for prediction. For this, the following parameters were set: population size $N = 30$, explosion radius and spark number adjustment constants ($d = 5$, $c = 30$), upper and lower limits for the number of fireworks explosions ($L_m = 2$, $B_m = 0.8$), Gaussian-mutated sparks $G = 5$, and a maximum iteration count $T = 1000$.

Figure 4.3 shows the learning error curve for the FWA-BP algorithm during the training process. After

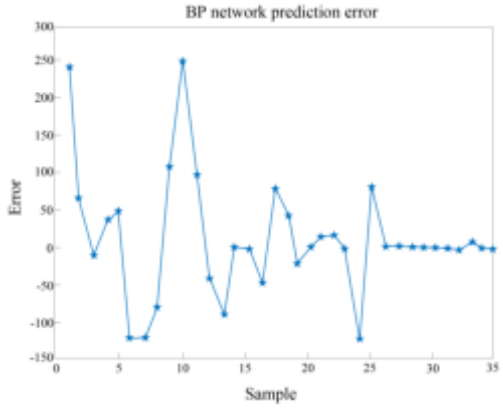

Fig. 4.5: BP neural network prediction error.

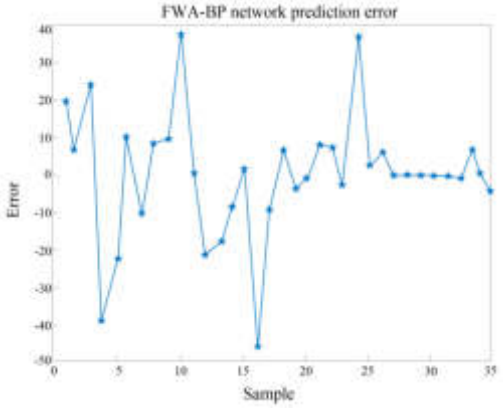

Fig. 4.6: FWA-BP algorithm prediction error.

approximately 50 training iterations, the mean squared error had already reached 0.22989, which is twice as fast as the BP algorithm and represents a reduction of 0.187569 in the mean squared error. In Figure 4.4, the dashed and solid lines closely match, indicating that the predicted and actual results are in close agreement. Only about 4 prediction points show significant errors. This is because the Fireworks Algorithm accomplishes a global randomized optimization search for the network's topology, number of nodes, and connection weights. It finds a better network structure, allowing for a more scientific and rational determination of training parameters, such as the learning rate, number of training epochs, and other hyperparameters. Additionally, it optimizes the weights ω and thresholds α in the BP neural network. A comparison shows that the FWA-BP algorithm notably enhanced predictive accuracy and meaningfully decreased errors.

Figure 4.5 illustrates the prediction errors for the BP network. The vertical axis spans -150 to 250, a 370 unit difference between the maximum and minimum prediction errors. This suggests that the BP algorithm exhibits significant fluctuations in prediction errors. Figure 4.6 illustrates the prediction errors for the FWA-BP network. Similarly, the error range falls within -50 to 40, which is 24% smaller than the BP network. The upper and lower error limits for the FWA-BP model is 110, a reduction of 260 compared to the BP network's prediction errors. This shows that the FWA-BP algorithm significantly outperforms the BP neural network in terms of fitting.

Figures 4.7 and 4.8 depict the linear regression fitting results for both algorithms. In Figure 4.7, the solid line and dashed line have substantial differences, with many data points lying far from the line. In contrast, in Figure 4.8, the solid line is notably closer to the dashed line, and most data points are clustered around it. This shows that FWA-BP algorithm has better fitting performance and verifies the superiority of FWA-BP algorithm.

5. Conclusion. Predicting wind energy production is crucial for properly allocating resources and scheduling wind power. More accurate predictions improve power system dependability and deliver major economic benefits. Since backpropagation (BP) neural networks for power forecasting can get trapped in local optima and are slow to converge, this study optimized them with a fireworks algorithm for estimating wind farm output. Historical data from an actual wind farm was leveraged to test predictions from both regular and optimized BP networks. Key findings show that the fireworks-enhanced BP neural network algorithm for wind power forecasting, reduces the error by 0.187569 compared to a standalone BP neural network, enhances training convergence speed, and provides predictions that are closer to the actual power output. This demonstrates a significant improvement in performance after optimizing the BP network. Moreover, the algorithm exhibits improved stability and reduced volatility.

While this study furnishes robust tools and methods for wind power forecasting, substantial potential remains for further research. Further investigation into improving the model's interpretability would be valuable for better understanding prediction results. Additionally, accounting for uncertainties can help provide more

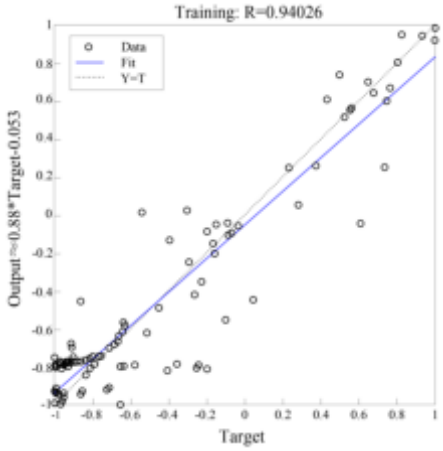

Fig. 4.7: BP algorithm's linear regression fitting performance.

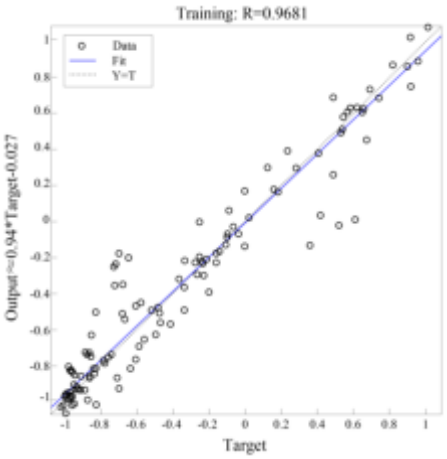

Fig. 4.8: FWA-BP algorithm's linear regression fitting results.

accurate estimations of the certainty in wind power output projections. It is crucial to apply the research outcomes to the administration and operation of actual wind farms to validate the algorithm's usefulness in real-world production settings and address any practical challenges.

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RESEARCH ON AUTOMATIC UNATTENDED BILL COLLECTION, PASTE AND VERIFICTION INTEGRATED ROBOT EQUIPMENT AND CONTROL PLATFORM BASED ON DEEP CONVOLUTIONAL NEURAL NETWORK

CHAO WANG*, XI CHEN, AND YING WANG

Abstract. A new solution for fully automated and unmanned ticket pasting verification based on deep convolutional neural networks is designed to address the issues of low efficiency, error-proneness, and wastage of manpower in the supplier service hall. The technology makes full use of machine vision and image processing, AI precise positioning correction algorithm and other methods to build an automatic unattended bill collection, paste and verification platform. Through the technologies of high-speed identification of invoice information, 3D vision-guidance planning, control of the path of robotic arm , detection of invoice pasting and repeating based on ultrasonic sensors, and tidal temporary storage of paper invoices, and so on, the automatic high-speed identification and inspection of bills in the supplier service hall are realized, and the efficiency and accuracy of bill processing in the supplier hall are improved. Experiments show that this research method reinforces ability of identification calibration and order correlation, and improves the efficiency of Invoice filing.

Key words: integrated robot,AI,3D vision,Automatic ticket collection and paste, Tidal operations,Document recognition.

1. Introduction and examples. OCR short for Optical Character Recognition , the main role of OCR technology is to convert the text in the image into an editable text format, allowing for subsequent text processing and analysis. It can convert scanned paper documents or pictures into an editable text format. NLP short for Natural Language Processing , the main role of NLP techniques is to transform natural language into a form that computers can recognize. It enables parsing and understanding of textual content, facilitating more advanced natural language processing tasks. The basic principle of NLP technology lies in converting natural language into a computer-recognizable form, such as logical expressions or vector space models. AI Vision techniques, also known as computer vision, are a branch of computer science that training computers to replicate the human visual system. This allows digital devices, such as face detectors and QR code scanners, to recognize and process objects in images and videos just like humans do.

With the rapid advancement of artificial intelligence technology, AI visual inspection technology is progressively emerging as a novel "game-changing tool" across diverse industries. The general trend is that AI machines are replacing human work in all directions. AI machines have advantages such as automation technology, high efficiency, high precision, and non-contact capabilities. They are widely used in various fields including industrial production, agriculture, animal husbandry, medicine, smart cities, and the military. Overseas AI machine vision testing has entered a period of significant growth. Currently, the share of AI machine vision testing in China remains relatively low. However, with a substantial increase in demand, AI machine vision testing is exhibiting an accelerated growth trend.

2. Problem formulation. Some business processes, such as the collection, verification, and creation of certificates for paper documents utilized in power grid engineering projects both domestically and internationally, can be effectively executed through information systems. However, manual tasks involving the separation, flipping, certificate creation, ticket issuance, and physical document filing are still in the preliminary research phase.

In recent years, in China, OCR and NLP technology have been commonly used for the identification and verification of various types of paper documents with unstructured information. The OCR intelligent conversion of electronic text has undergone several generations of technological upgrades, making it a mature technology. Based on this, there are related products available that have intelligent acquisition for paper

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documents and bill verification functions. However, these products only offer functions such as acquisition and checking, which cannot automatically complete the full process operations required for verifying various bills and other documents, matching and pairing them, creating certificates, pasting them into books, conducting multi-link consistency verification, and performing automatic archiving. The main pain point of this business is not only the manual searching and checking, but also the technical challenges such as correlating bills with orders, verifying invoices, printing vouchers, and automating sticker. The related research on this technology is still lacking in our country. Many experts and scholars in our country are still puzzled by practical problems such as pasting in large quantities, correcting errors, and preventing loss of bills.

3. Related work. In order to efficiently address the business pain points, such as a large number of invoice vouchers and repetitive manual labor in the company's supplier service hall, the company is focusing on various aspects of its invoicing process, which includes invoice collection, separation, verification, settlement, and certification. The company is also exploring and researching complex machine learning algorithms to innovate advanced technologies. As a result of these efforts, they have independently developed a fully automatic intelligent ticket collection and labeling machine that enables fully automated operations for receipt handling, division, inspection, review, posting, and archiving.

3.1. Visual positioning guidance. This paper presents a path planning and control method for manipulators based on 2.5D vision guidance. By utilizing a combination of 2D visual analysis and laser measurement technology, multiple invoices can be efficiently collected with just one key press, achieving an accuracy rate close to 100% in fast identification and automatic matching. The proposed system integrates advanced vision technology with image processing, artificial intelligence, and pattern recognition techniques. We apply three techniques, CCD, OCR and NLP, to achieve visual localization and recognition. CCD(Charged Coupled Device) is a technology that uses image sensor to capture and process images in real time to realize target positioning. OCR (Optical Character Recognition) is a software technology that can automatically identify the text into the computer. That is, the printed characters in the paper document is converted into a black-and-white dot matrix image file by optical means and the converted into text format by recognition software. NLP (Natural Language Processing) refers to the technology of interacting with machines using the natural language used by human communication. Natural language can be read and understood by computer through processing .The CCD intelligence is effectively employed to gather multiple invoice images, integrating AI perception analysis and self-evolution learning of big data. This comprehensive approach ensures the delivery of accurate invoice data through the utilization of AI visual intelligence and OCR+NLP review double insurance. Consequently, it enables an initial review of invoices with a remarkably high accuracy rate nearing 100% [1, 2, 3].

The real world is three-dimensional, and the image projected on the camera lens (CCD/CMOS) is two-dimensional, the ultimate purpose of visual processing is to extract the relevant three-dimensional world information from the perceived two-dimensional image [4, 5]. To put it simply, optical processing is carried out on the surrounding environment of the robot. First, the camera is used to collect image information, compress the collected information, and then feed it back to a learning subsystem composed of neural network and statistical methods. Finally, the learning subsystem will connect the collected image information with the actual position of the robot to accomplish autonomous navigation and positioning function [6, 7, 8].

3.1.1. Camera calibration algorithm.

Calibration parameters. The objective of camera calibration is to rectify lens distortion, establish a linear correlation between image position and spatial coordinates, and convert camera coordinates into pixel coordinates. 2D-3D mapping parameters: Camera calibration entails employing the direct linear transformation method along with a calibration board for point calibration in order to compute the camera parameters (including correction for camera distortion).

$$Z\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & C_x \\ 0 & f_x & C_x \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = KP \tag{3.1}$$

In the above formula, K is the Intrinsics of the camera.

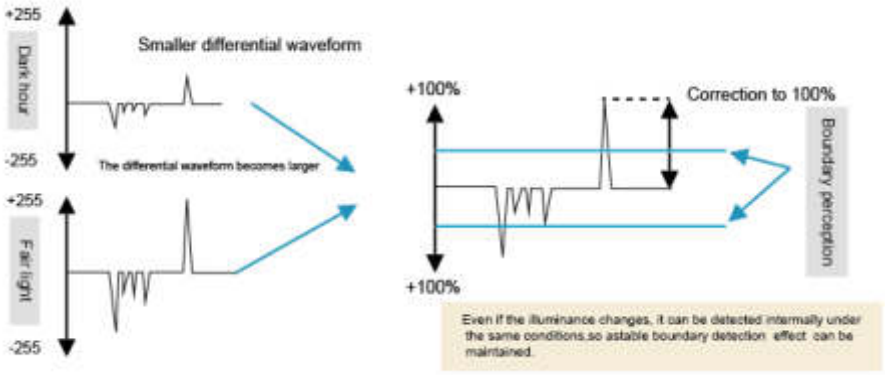

Fig. 3.1: Subpixel processing graph

Calibrating external parameters. The purpose of external parameters is to establish the correspondence between the camera coordinate system and the external world coordinate system (manipulator coordinate system / 3D space) and convert the coordinates of image elements into world coordinates. In this study, we utilize P's coordinates in the camera coordinate system (i.e., with the camera as the origin). Therefore, it is necessary to initially transform Pw from the world coordinate system to P in the camera coordinate system. The pose of the camera can be described by a rotation matrix R and a translation vector t, thus:

$$ZP_{uv} = K(RP_w + t) = KTP_W \tag{3.2}$$

where R and t represent the external parameters of the camera.

3.1.2. Machine vision and image processing. First of all, perform preprocessing which includes hashing, noise reduction, filtering, binarization, and edge detection. The second step involves extracting features by mapping the feature space to parameter space. The third step focuses on image segmentation and template recognition. In the fourth step, adopt the edge grabbing algorithm: it utilizes the Canny edge detection algorithm to apply Gaussian filtering on the image for noise elimination. Then, it calculates the gradient of each pixel to determine the direction of brightness change and finally detects edges through non-maximum suppression and double threshold processing. The fifth step involves utilizing two perpendicular edges to calculate the intersection points, while also determining the coordinate deviation and angle offset in relation to the template [9].

(1) Gaussian filtering (noise reduction). Gaussian blur is an image blurring filter that applies a normal distribution to calculate the transformation of each pixel in the image.

$$G(u,v) = \frac{1}{2\pi\sigma} * e^{\frac{-(u^2+v^2)}{2\sigma^2}} \tag{3.3}$$

In two dimensions, the contour line which surfaces generated by this formula is concentric circles that are normally distributed from the center. The convolution matrix, which a non-zero distribution and consisted of pixels is subsequently transformed using the original image, whereby each pixel's value is determined through a weighted average of its neighboring pixels' values. Notably, the original pixel's value carries the highest weight due to its largest Gaussian distribution value, while weights decrease for neighboring pixels as they move farther away from the original pixel. This method effectively preserves edge effects better than other equalizing blur filters and thus represents an optimal approach for enhancing image quality in various applications.

(2) Boundary detection (grabbing algorithm: using Canny edge detection algorithm). First of all, the information is differentiated. This is shown in Figure 3.1.

Then the information is subpixel processed, the following is shown in Figure 3.2.

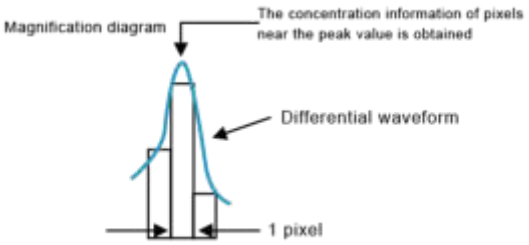

Fig. 3.2: Subpixel processing graph

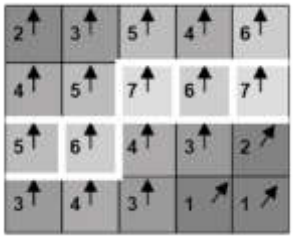

Fig. 3.3: Gradient scan image

(3) Compute image gradient. Employ the Sobel operator to compute the initial derivatives (inflection points) in both horizontal and vertical orientations for the smoothed image, subsequently determining the gradient magnitude and direction of the boundary based on the derived gradient map.

$$\begin{aligned} &Edge\_\ Gradient(G) - \sqrt{{G_x}^2 + {G_y}^2} \\ &Angle(0) = \tan\frac{G_x}{G_y} \end{aligned} \tag{3.4}$$

(4) Suppress non-maximum values. After obtaining the magnitude and direction of the gradient, scan the entire image, exclude points on the boundary, examine the first pixel point, and verify if it is indeed the point with the highest gradient in that same direction. Retain only the largest gradient value [10]. This process is illustrated in Figure 3.3.

(5) Threshold value confirmation. When the gradient of the image surpasses the maximum value, it is deemed as the authentic boundary. If it falls below the minimum value, it is disregarded. If it lies within these two values, its linkage to a confirmed true boundary point is verified. If connected, it is retained, otherwise, omitted. This process is exemplified in Figure 3.4.

(6) Calculate offsets and angles. Configure the edge position mode across multiple components and ascertain the X or Y coordinates of the specimen. The verification procedure is depicted in Figure 3.5.

3.1.3. Height measurement algorithm. When the laser pulse ranging method is in operation, the laser transmitting tube is initially oriented towards the target to emit a focused laser pulse. Upon reflection from the target surface, the laser scatters omnidirectionally. Subsequently, a portion of this scattered light returns to the sensor receiver and is efficiently captured by an advanced optical system before being projected onto an avalanche photodiode for further analysis. An avalanche photodiode is an optical sensor with an amplification function inside, so it detects extremely weak light signals and converts them into corresponding electrical signals.

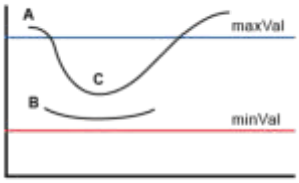

Fig. 3.4: Threshold confirmation image

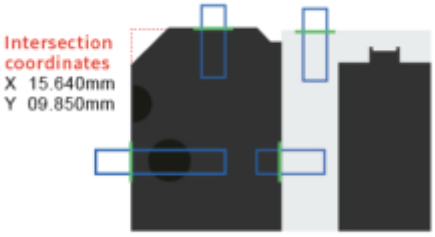

Fig. 3.5: Calculus diagram

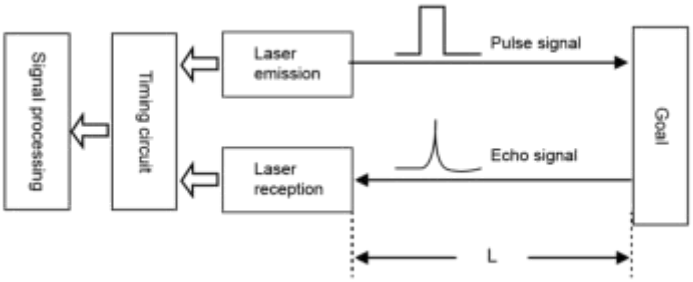

Fig. 3.6: Flow chart of laser pulse ranging

By measuring the time it takes the light pulse to travel to and from the point to be measured, multiplying by the speed of light and dividing by 2, the distance to the target to be measured is calculated by the following formula:

$$d = ct/2$$

where d: Measure the distance between points A and B, c: the speed of light, t: The duration of the light pulse's travel between points A and B once. This is shown in Figure 3.6.

After measurement and calculation, the distance d is obtained. This is shown in Figure 3.7.

When the specified distance is detected, the robot transitions into a precise positioning lock mode, decelerates gradually, and ultimately halts. The travel distance can be computed $d = \int(time * speed)$.This is shown in Figure 3.8.

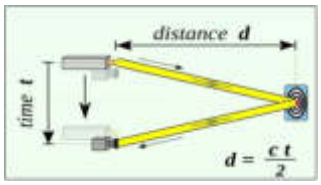

Fig. 3.7: Schematic diagram of laser pulse ranging method

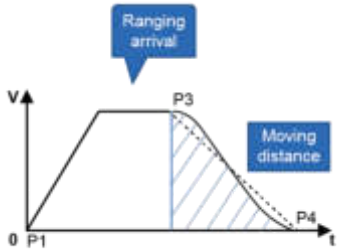

Fig. 3.8: Diagram of the z-direction localization algorithm

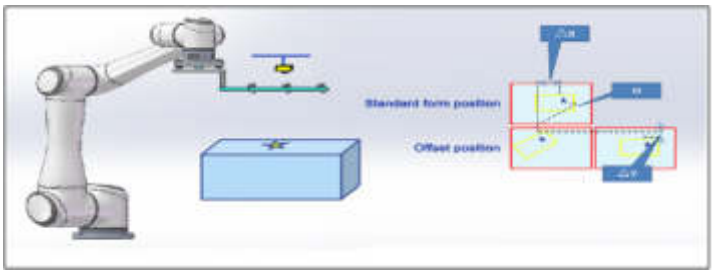

Fig. 3.9: Diagram of the robot correction algorithm

3.1.4. Robot correction algorithm. When invoices are separated, vouchers are printed, and multiple sheets are pasted, there may be a slight horizontal offset between the actual single ticket's position and the target coordinate. The manipulator needs to real-time correct the deviation $\Delta X, \Delta Y$, and offset Angleθ based on the difference between the actual bill's pose and target coordinate in order to ensure accurate positioning [11]. This is shown in Figure 3.9.

Computing center of rotation offset: compensation value Offset

$$X = \cos(\theta) * (x - \text{rx0} - \sin(\theta) * (y - \text{ry0}) + \text{rx0} + \Delta x$$

$$\text{Offset}Y = cos(\theta) * (Y - \ RY0) - sin(\theta) * (x - \text{rx0}) + \ \text{ry0} + \Delta Y$$

Finally, Offset$X$, Offset$Y$, Offsetθ is calculated.($\Delta X, \Delta Y$, are the horizontal deviation, rx0 and ry0 are the vertices of the manipulator, x and y are the coordinates of the current actual bill, and x0 and y0 are the coordinates of the target vertices.)

In this study, the manipulator effectively rectifies real-time deviation displacement and precisely aligns the target coordinates to ensure precise adherence of invoices and vouchers [12, 13, 14].

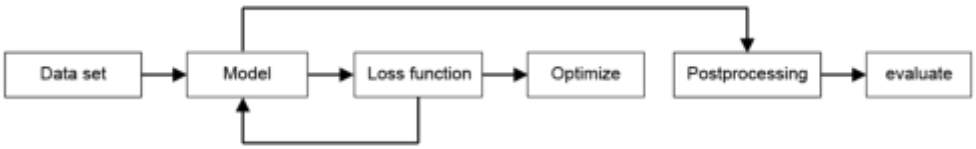

Fig. 3.10: Flowchart of text detection and recognition algorithms

3.2. Text recognition of bills. The text recognition of bills includes three parts: text detection, text recognition and information extraction. In the text detection part, the influence of different feature extraction networks on network performance improvement is analyzed based on the DBNet network. The core of DBNET is segmentation-based text detection, that is, each text block is semantically segmented, and then the segmentation probability map is simply binarized, and finally the detection results are converted into box or poly format. In the text recognition part, text recognition is studied using the network structure of CRNN(Convolutional Recurrent Neural Network) and CTC.For information extraction, a method based on text pattern and keyword matching is employed to obtain keyword key-value pairs [15, 16, 17].

The flow of text detection and recognition algorithms can typically be categorized into the following steps, as illustrated in Figure 3.10:

1) Data set. To gather a substantial amount of text data, which is then labeled to identify any undesirable content. his dataset serves is the foundation for algorithm training.

2) Model. Model is a commonly used feature extraction method. Each word or phrase within the text can be considered a feature. By extracting these features, this allows the transformation of the text into a digital format, which suitables for computer processing.

3) Loss function and Optimize. The extracted features and labeled datas are fed into a machine learning model, which undergoes training using a loss function. Throughout this process, adjustments can be made to enhance the algorithm's performance by modifying its parameters and structure.

4) Postprocessing and evaluate. After the training completed , the model is applied to real text detection tasks. When the new textual input, the algorithm will predict, assesses, and filter based on its learned model.

The text on the paper invoice presents the characteristics of dense and multi-scale. In the selection of the text detection network, the integrity of the detection text area should be taken into account as much as possible, and the adhesion between different texts should be avoided as far as possible. Therefore, this research chooses DBNet as the research object of this project. DBNet is a text detection network based on pixel segmentation [18]. It uses FPN to integrate multi-scale features, optimizes the training process through differentiable binarization to simplify post-processing, and reduces text sticking by shrinking text boxes. The DBNet network structure is shown in the following figure 3.11.

The DBNet text detection model can be divided into three parts. The first part is the backbone network, which has a feature extraction function. After inputting the image to be processed into the backbone network, multi-scale features are obtained through down-sampling operations. Section two, the FPN feature fusion structure is used to perform up-sampling and fusion operations from deep layers to shallow layers on these features. Concatenation (con-cat) is applied on the fused features to obtain feature maps. Both concatenation and addition require that the feature maps have the same resolution for processing [19]. The difference is that con-cat increases the number of channels by superimposing features while the single feature remains unchanged. Adding the corresponding elements of the feature, and the number of channels also remains unchanged. The third part of the network is responsible for obtaining the output content. After acquiring the feature graph, it further predicts the probability graph and threshold graph, and obtains an approximate binary graph through differentiable binarization. Finally, post-processing is performed to obtain the final text enveloping curve.

After the DBNet network detects the text on the ticket image, it is displayed as four-point mark boxes to

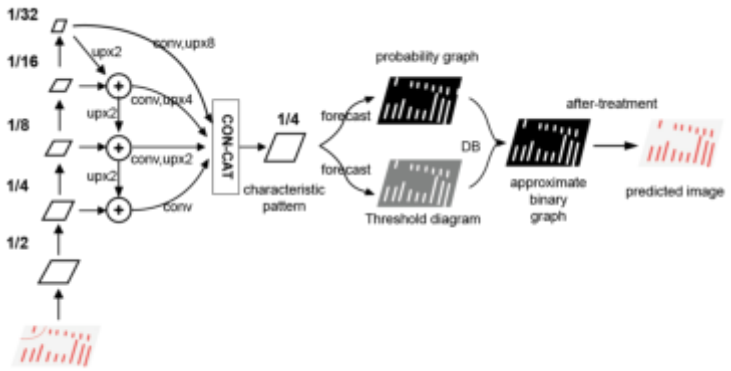

Fig. 3.11: DBNet network structure diagram

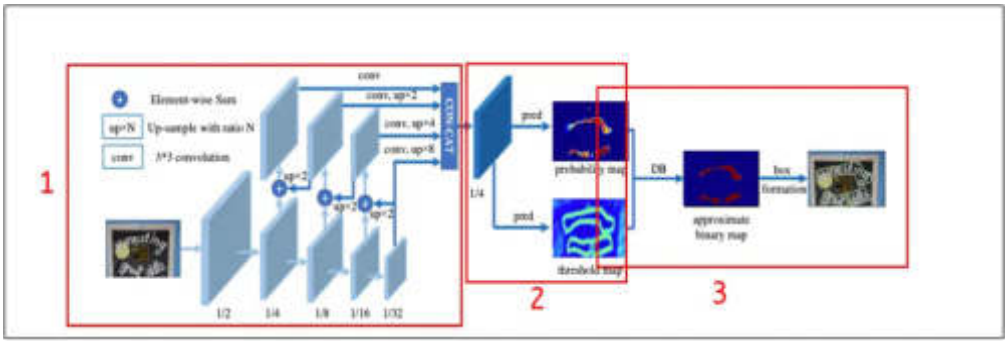

Fig. 3.12: The CRNN identifies the network logic graph

indicate its position. Then, the text content within these mark boxes is recognized. The CRNN recognition network used in this project consists of three main parts, as illustrated in Figure 3.12.

The first module: the red box on the left uses an FPN architecture consisting of a bottom-up convolution operation and a top-down upsampling operation to obtain multi-scale features. The lower part of the figure is a 3x3 convolution operation. According to the convolution formula, the feature maps of 1/2, 1/4, 1/8, 1/16, and 1/32 of the original image size are obtained respectively. Then, the upsampling x2 is performed from top to down, and then fused with the feature map of the same size generated from bottom to up. After fusion, 3x3 convolution was used to eliminate the aliasing effect of upsampling. Finally, the output of each layer is upsampled and unified into a feature map of 1/4 size.

The second module: the 1/4 size feature map is transformed through a series of convolution and transpose convolution mechanisms to the probability map P and threshold map T, which can refer to the FCN network structure . And the purpose is to generate the feature map P and T with the same size as the original map.

The third module: the DB method is used to obtain the approximate binary map through the feature map P and T.

For the recognition of the text content on the ticket, it is important to note that the extracted text lines from text detection may vary. CRNN, as the current mainstream text recognition network, transforms the problem of recognizing text into a sequence recognition problem. Its advantage lies in its ability to detect texts of any length. Additionally, CTC in transcription layer can reduce the cost of marking text content and fulfill the requirements for bill text recognition.

The text image size of the input CRNN network is variable. In this project, the constructed CRNN

network requires maintaining the feature size of the input loop layer at (channel , height , width)=[512,1,24], so preprocessing of the image is necessary before performing convolution operations. Taking the ResNet series feature extraction network as an example, it requires carrying out double of five times down-sampling operations in the network. The feature map size after the last subsampling operation is 1/32 of the original image. Therefore, it is necessary for the image height to be fixed as a multiple of 32. The preprocessing strategy adopted in this project involves first calculating the aspect ratio of text recognition images in the dataset. According to the statistics, the average aspect ratio of images used for text recognition in the dataset is approximately 1/3. Subsequently, the image is resized to a height of 32, and any portion with a width less than 100 is padded with zeros. If the width exceeds 100, it is scaled down to 100. The image size remains fixed at [3,32,100] after preprocessing.The image was down-sampled by convolutional neural network, and the input image was changed from gray image (single channel) to color image (512 channels). The height is 1/32 of the original, so it's 1, which is important; Through this step, we get 24 feature quantities, so the width is 24. In summary, we finally get the feature map of size [512,1,24]. During prediction for a single instance, only the width needs to be adjusted to a multiple of 32. However, when predicting multiple invoice pictures in batches, each batch's longest picture sets the width standard for that particular batch.

The pre-processed images are fed into the convolutional network to generate the feature sequence $(X_1, X_2, ..., X_{t-1}, X_t)$, which is then passed through the loop layer. In RNN-based sequence data processing, both LSTM and BiLSTM structures can be used to model the information of the context. Longer distance dependencies are better captured using LSTM models, but cannot encode information from backward to forward. BILSTM can better capture bidirectional semantic dependencies in the case of finer classification granularity, such as the five classification tasks of strong positive, weak positive, neutral, weak negative and strong negative, that is, when attention needs to be paid to the interaction between sentiment words, degree words and negative words. However, the all-in-one machine is mainly used for the identification and processing of invoices, and the semantics and its emotional color not need be judged, so LSTM is chosen. In natural language processing tasks, a bidirectional language model is used, that is, two unidirectional LSTMS are considered to accomplish it.

After the recurrent layer and argmax operation processing, the largest of character category of each frame in the sequence is output as the result of this frame. Because the sequence characteristics of adjacent are similar, there are duplicate adjacent characters in the output string.For example, for the ticket text string 'CNY 18.6', possible output strings include 'CNY 188.6600', 'CNY 118...6600', 'CNY 1888.60', etc. At this time, the final recognition result cannot be obtained through the string with repeated characters. The role of CTC is to predict the sequence label with the highest probability combined with each frame of the sequence.

For invoice recognition tasks, after obtaining text content through text detection and recognition, it is necessary to further extract the corresponding relationship between keywords and text. This relationship can be expressed as key-value pairs through certain processing methods. Such tasks fall under Natural Language Processing (NLP) problems. The text on invoices usually appears in pairs, starting with a descriptive word followed by its corresponding specific value [20].

3.3. Tidal temporary storage, give full play to the ability of multithreading parallel work. This study proposes a method that utilizes tide temporary storage technology to achieve cache operation for large-volume paper invoice submission. Under the business scenario of submitting a large number of paper invoices, the double-thread parallel operation of document submission and ticket pasting can be realized, while applying the working principle of tide temporary storage to implement peak cutting and valley filling. The diagram illustrating tidal temporary storage technique is shown in Figure 3.13.

1. The tide points are automatically monitored and managed, with ticket collection at the front desk and background verification work being conducted simultaneously.
2. When the temporary storage capacity exceeds the upper limit, it will stop the ticket collection task, when the attached work of the background is completed and the working-storage section is below the tide point level, and resume the ticket collection work.
3. The batch operation is primarily associated with the task to prevent temporary gridlock. When the order certificate is not generated, switch to temporary priority and continue requesting certification.
4. After completing the information binding of the order, please check if the ticket data matches the order

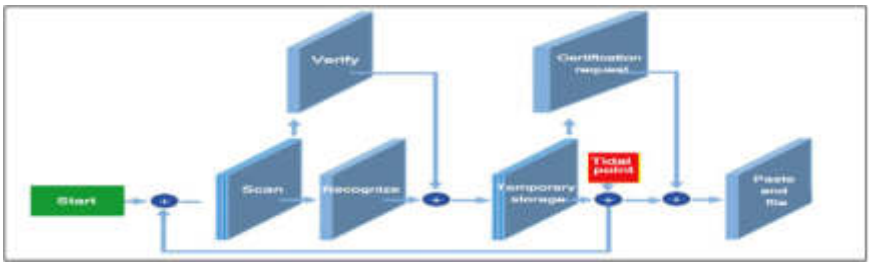

Fig. 3.13: Logic diagram of tidal temporary storage technology

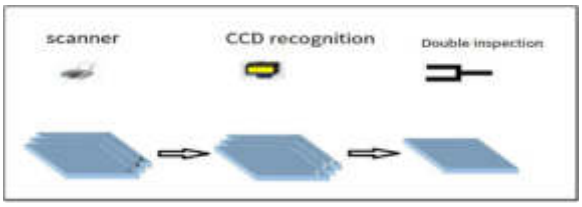

Fig. 3.14: Logic diagram of tidal temporary storage technology

information. Then, initiate the temporary storage task and concurrently submit a certificate request.

5. When the invoice is stored in the temporary storage process, it will switch to ticketing mode after receiving successful information about the previous temporary order certificate. The timing of this switch is controlled by the tidal point.
6. The dynamic distribution of tidal points is determined by the temporary occupancy level and time-weighted comprehensive evaluation, and it is adjusted based on previous statistical results.

3.4. The duplicate and adhesion of invoice detection. This study proposes a research method that utilizes AI intelligent detection to accurately identify and locate multiple invoices by detecting their adhesion. The design includes a double-sheet feed detection mechanism, which employs high-performance ultrasonic sensors to test the paper's weight (ranging from 27-413g/m2) and thickness (0.08mm-0.2mm). If multiple invoices are detected, the operation will be halted. Figure 3.14 illustrates the schematic diagram of detection of the duplicate and adhesion of invoice.

1. The application of antistatic and brushing techniques greatly reduces adhesion occurrences, thereby improving equipment stability.
2. The visual positioning CCD utilizes template matching, edge detection, and analysis of edge shapes to identify the presence of border adhesion. Once such adhesion is detected, an alarm is triggered and the operation is halted.
3. The first step in invoice entry is scanning. The primary function of the scanning operation is to separate a stack of invoices into individual ones. However, if there is adhesion between the invoices, it may cause a paper jam and trigger an alarm, leading to the suspension of further operations.
4. Positioning CCD as the function for correcting invoices, while also performing a secondary verification of invoice information. If the serial number on the invoice and the scanning position of the serial number are opposite, While CCD detection cannot scan the identification information in reverse order, an alarm will be triggered indicating either adhesive or missing tickets. In both cases, business operations will be suspended.
5. Place two detection sensors on the robot arm to detect when an invoice is removed. When a duplication phenomenon is detected, an alarm will be triggered and operations will be suspended.

The application of automatic unattended all-in-one machine solves the problem of manual operation in the

Table 4.1: Analysis of application results for an integrated robot capable of automatically handling bill receipts, stickers, and inspections without human intervention.

Verification item	result	unit
Visual localization	<0.5	mm
Recognition speed	<60	ms
Recognition accuracy	>99.93	%
Efficiency of automatic receipt and Posting of documents	2043	copies

Table 4.2: Analysis of application results for an integrated robot capable of automatically handling bill receipts, stickers, and inspections without human intervention.

Measurement position	Visual positioning deviation	Recognition speed	Recognition accuracy
1#	0.435mm	58ms	>99.93 %
2#	0.461mm	55ms	>99.93 %
3#	0.398mm	57ms	>99.93 %
4#	0.457mm	57ms	>99.93 %
5#	0.493mm	49ms	>99.93 %
6#	0.480mm	56ms	>99.93 %
7#	0.311mm	58ms	>99.93 %
8#	0.274mm	47ms	>99.93 %
9#	0.472mm	55ms	>99.93 %
10#	0.489mm	58ms	>99.93 %
11#	0.463mm	56ms	>99.93 %
12#	0.466mm	52ms	>99.93 %

financial process. The application scenarios of the automatic unattended invoice verification machine are as follows:

1. Supplier service platform: For the platform, whether it is delivering the supplier's invoice to the customer or paying the supplier through the invoice, it will receive a large number of invoices that need to be sorted, identified and archived. The application of all-in-one computer can reduce the four links of invoice review, entry, verification and filing, which greatly saves manpower and material resources;
2. Financial management of electric power enterprises: the realization of functions such as intelligent receipt of paper documents, bill verification, pasting into books and automatic archiving can help group enterprises optimize the process of invoice tax declaration, verification, archiving, inventory management and other operations, more efficient docking with ERP management system, and optimize enterprise resource management data;
3. Duplicate check of electronic invoices: due to the duplication of invoices, financial personnel must be extra careful when dealing with electronic invoices, for fear of repeated reimbursement. All-in-one machine can greatly solve this problem.

4. Results and discussion. Based on the AI vision of an automated unattended bill collection and inspection integrated robot system and control platform, we investigate the application of visual positioning guidance, bill text recognition, temporary storage during peak periods, re-tensioning, and adhesion detection in the process of bill collection and inspection. Through the conducted experiment, it was observed that the visual positioning deviation is below 0.5mm, the bill recognition speed is less than 60ms, and the recognition accuracy exceeds 99.93%. Additionally, the daily average efficiency of automatic receipt and pathing of documents surpasses 2000. As depicted in Table 4.1 and Table 4.2, successful implementation of intelligent automatic processing for invoice documents within the settlement hall has been achieved, leading to a significant enhancement in on-site work efficiency (refer to Figure 4.1).

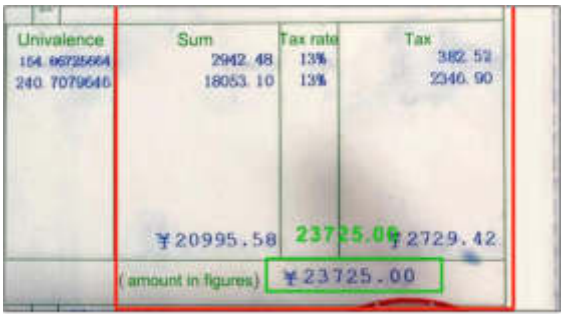

Fig. 4.1: Invoice information extraction results

1. Through the utilization of visual analysis technology, this study efficiently gathers multiple invoices with a single click, swiftly identifies and automatically matches them, resulting in an accuracy rate that is nearly 100%. The system employs advanced vision technology, integrating cutting-edge image processing techniques with state-of-the-art artificial intelligence algorithms and pattern recognition methodologies.
2. Collect multiple invoice images intelligently through CCD, combine AI visual analysis with self-evolution learning of big data, deliver accurate invoice data in the form of intelligent and manual double insurance, and achieve nearly 100% accuracy in the first review of invoices.
3. In this study, the DBNet model leverages ResNet18 as the feature extraction architecture for precise detection of text regions on the ticket. Moreover, to ensure accurate identification of textual content, the CRNN and CTC models employ MobileNetV3 as their feature extraction framework.
4. This study proposes a method that utilizes tidal temporary storage technology to achieve mass paper invoice delivery buffer operation. In the business scenario of mass paper invoice submission, the delivery operation and sticker operation are carried out in parallel as dual-thread processes. The order of document delivery and subsequent sticker application is executed simultaneously, employing the working principle of temporary storage to facilitate peak scene application.
5. This study proposes an AI-based research method for the intelligent detection of invoice adhesion, with the aim of accurately identifying and locating multiple positions where invoices are affixed. The proposed method incorporates a dual others-into-paper detection design, employing high-performance ultrasonic sensors capable of detecting paper weights ranging from 27-413 g/m2. Once more than one sheet of paper is found, the operation will be halted.

5. Conclusion. Through the utilization of an all-in-one machine for bill receipt, pasting, and verification, the functionalities of invoice verification and voucher management are effectively realized. This innovative solution offers the power company a sophisticated, user-friendly, and integrated platform for "verification and automatic certificate creation," thereby facilitating intelligent automated processing of invoice vouchers within the settlement hall. Create a fully automatic intelligent invoice voucher integrated machine to solve the operational problems of a large number of manual receipt, sticker of contract hall. It promoted the upgrading and transformation of the special work of supplier settlement, improved the satisfaction of the business environment, and truly promoted the construction of intelligent robots for invoice production from the theoretical system to the application and practice.

6. Limitations and further work. Notwithstanding, there exist certain limitations in this paper. Firstly, the ambit of bill recognition solely concentrates on the compilation, identification and authentication of specific invoices for power enterprise suppliers, however, it does not encompass receipts such as train tickets. Secondly, the AI vision-based automatic unattended ticket collection and inspection integrated robot equipment and control platform is currently primarily designed to cater to the specific business characteristics of the power industry. However, further adaptations are required to suit diverse business application scenarios such as in telecommunications and government enterprises. Future research can also be carried out from the following

aspects:(1) Combining the latest industrial and information technology to further enhance the accuracy and efficiency of automating certificate making and ticket sticking. (2)With the aim of establishing a modern smart supply chain, exploring additional robots to replace complex and repetitive manual tasks, developing various intelligent and automated industrial robots, promoting customization for multiple scenarios in smart supply chains, applying automated robots, and enhancing the overall operational intelligence and automation level of supply chain scenes have become crucial steps for power enterprises to optimize their business environment.

In our second set of experiments, we took $c = d = 100$ and carried out trials analogous to those in the first set above. No preconditioning was used in these experiments, both because we wanted to compare the methods without preconditioning and because the fast Poisson preconditioning used in the first set of experiments is not cost effective for these large values of c and d. We first allowed each method to run for 600 iterations, starting with zero as the initial approximate solution, after which the limit of residual norm reduction had been reached.

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AN EXPLAINABLE AI MODEL IN HEART DISEASE CLASSIFICATION USING GREY WOLF OPTIMIZATION

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Abstract. Heart disease is one of the world's leading causes of death. It is estimated that around one-third of all deaths are caused by heart disease in the entire world. Recently many research works have focused on using machine learning models to detect and warn patients about the occurrence of heart disease at the early stage. However, machine learning models provide promising results, and the performance of the classification is affected by various reasons which include imbalanced training, and missing values. There are three main contributions of this research work. Firstly, missing values are addressed by employing a grouping of instances. Secondly, a dual filter based feature selection is introduced to pick the most effective features and lastly, we make of Grey Wolf Optimization for optimizing the hyperparameters of the machine learning models. Together, these contributions aim to improve the robustness and efficiency of machine learning applications by addressing missing data, optimizing feature selection, and fine-tuning model parameters. The accuracy of 98.41% indicates the superiority of the proposed classification which is more than 17.15% than the existing machine learning models. On the other hand, we use Explainable AI (XAI) methods to make our proposed model interpretable.

Key words: Heart Disease classification, Grey wolf optimization, Explainable AI, feature selection.

1. Introduction. Heart Disease is caused by abnormal disorders that affect the functioning of the heart and the bloodstream. Traditionally, doctors examine a patient with heart-oriented diseases by checking blood pressure, glucose level, BMI, and other attributes [1]. Several medical devices such as Electrocardiogram (ECG), X-rays, and CT scans are used to measure the above-mentioned attributes. The process of detecting heart disease is affected miserably due to a few reasons which include lack of expectations, wrong diagnosis, and delayed diagnosis. Due to these reasons, machine learning approaches are slowly adopted in the hospital domains. The information from machine learning models can be converted into live charts, and time series data, which can be used by the hospital to make timely decisions and assist the healthcare professionals in taking proper actions [2].

Classification is one of the categories of machine learning models that can detect patterns in hidden observations [3]. The World Health Organization has listed that around 17.1 million people die from heart disease every year which is the highest when compared with other diseases [4]. In recent years, many health professionals have been involved in creating massive heart disease data which can create new opportunities for machine learning classifiers to detect patterns and warn patients in their early stages.

Despite several observations of the success of the machine learning models in the healthcare industry, gaining optimal efficiency of the machine learning models is still a challenging task because of several reasons which include an imbalanced dataset, finding optimal hyperparameters, reducing the dimensions of the feature

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space, and so on. This research focuses on addressing the above-mentioned issues and contributing an optimal classifier that can be used for heart disease classification [5].

Normally, the medical-related datasets are imbalanced, however, this causes the machine learning model training very less efficient as the model learns too much about one class and very little about the other class (s) [6] [7]. The dataset used in this research paper is also an imbalanced dataset, where we make use of the Synthetic Minority Over-sampling TEchnique (SMOTE) to generate multiple synthetic instances of minority class to form a balanced dataset [8].

A machine learning model performance is largely dependent on its hyperparameters, for example, the Support Vector Machines (SVM) have the hyperparameters C, Kernel, Gamma, and so on [9]. These hyperparameter values have to be chosen very carefully. There are many methods such as Genetic algorithms [10] [11], Grid Search [12], and so on to find the best combination of hyperparameters. In this paper, Grey Wolf Optimization is used to pick the correct combinations of hyperparameters that produce the maximum performance.

Another important problem a machine learning classifier faces is the dimension of the data, If the number of dimension is very high, the classifier experience more difficulty in finding the pattern [13]. All the features are not required to be fed into the training process [14]. Many research works prove that selecting an optimal number of features will increase the performance of the classification. In this work, we adopt an average of ranks calculated by two feature selection methods.

The contributions of the paper are as follows:

1. Resolve the missing values by grouping instances.
2. Select the best features representing the target variable by using the average of ranks obtained by two popular filter-based feature selections, Correlation and Mutual Information.
3. Using Grey Wolf Optimization for finding the optimal hyperparameters for the machine learning models.

As machine learning models seem to be powerful in decision-making, trusting the result produced by the machine learning models is not fully practical. Hence, a new field called Explainable AI (XAI) has emerged which allows any user of the classifier to understand how the logic is created and how the classifier yields the specific output for the given input combinations. In other words, an XAI-based classifier enables humans to understand the behavior by exhibiting the explanations that increase the trust in the outputs. XAI-based models are capable of producing explanations that can say what is happening in an ML model.

The use of XAI is increasing especially in the field of medical domain. Due to the explainability, the trust in using the ML models increases and thus the decisions produced by the classifier are less doubtful.

As mentioned by [15], there are many reasons to use the XAI concepts in the machine learning based classification models which are listed below

- What is the problem in training a model and why the problem has occured.
- what input features are responsible in calculating the final class?
- How does the layers affect the end result?

Shapley Additive exPlanations (SHAP) is a popular XAI technique that makes use of the Shapley values to make the models more understandable. The concept of SHAP is used in multiplayer games where a group of players plays together in winning a game, In the end, the rewards are not distributed equally to all the players, but the rewards are distributed based on the contribution of each player in the game. This contribution is calculated by the SHAP algorithm. The same logic can be used in the classification, where a collection of features is involved in the classification task, at the end, a measure has to be made which calculates the weightage of each feature towards the end classification. The SHAP should satisfy multiple conditions [16] which are listed below.

- The weightage must be shared among all the features involved.
- If two features made the same contribution, the weight assigned to both features should be the same.
- the features which did not contribute towards the target class should get zero weightage.

One of the important challenges in machine learning classifiers is the process of picking the correct hyper parameters. The optimal combination gives the perfect performance. In many research works, nature-inspired models such as grey wolf optimization. This algorithm originated from the behavioral patterns noticed in the grey wolf packs. Grey wolf optimization offers a promising solution for hyperparameter tuning which helps the

models to perform at their best.

Grey wolves live in packs that comprise an alpha wolf, beta wolf, delta wolf, and omega wolf. This hierarchical structure is the backbone of the GWO. The first and the best solution in decision-making is the alpha wolf, the second best and the third best solutions in hunting and surrounding the prey are the beta and delta wolf respectively. The last one in the hierarchy is the omega wolf which follows the order of the other wolves.

Each machine learning classifier requires a specific combination of settings known as hyperparameters which drastically influence the model's performance. For example, in neural networks, the learning rate, and number of layers are the main hyper parameters that can be customized to increase the performance. However, the search for the best combination of hyperparameters is often challenging. The traditional methods like the grid search lack in high dimensional spaces. The GWO provides flexibility in this regard.

The goal of explainable AI (XAI) is to enable AI systems to provide human-understandable explanations for their choices. Consider it a form of AI transparency, which is crucial in deep learning since the models can appear to be these intricate black boxes. By giving us a glimpse inside these models, the methods of XAI help us understand how they make decisions. In addition to increasing public confidence in AI, this openness makes it easier to identify biases, comprehend how the model functions, and even enhance its output.

XAI is now a turning point for deep learning optimisation. It's similar to using a map to find your way around a maze of intricate neural networks. Through the use of interesting techniques such as saliency maps and attention mechanisms, XAI helps us understand which features of the information being provided are most relevant to the model's results. This knowledge enables us to fine-tune and enhance the network, increasing its effectiveness and lowering its error rate. Furthermore, by identifying any irregularities in the training data, XAI enables us to correct biases and mistakes and build deeper learning models that are more accurate and dependable.

This paper is organized into 5 sections. The next section overviews the different existing related research works about heart disease classification. The full explanation of the proposed approach is discussed in section 3. The evaluation of the results and the explainability is exhibited in section 4. Finally, the conclusion and future work are presented in section 5.

2. Literature Review. Three datasets called Cleveland, Hungarian, and CH are used in a work by [17]. The authors performed four types of experiments to compare their research work with the existing models. The first type involves the use of raw datasets and measures the performance of the classification. In the second type, the authors have used a popular filter-based feature selection known as chi-square to obtain a subset of relevant features. The principal component analysis (PCA) is implemented in the reduced dataset in the third type and finally, the same PCA is implemented in the original dataset. The Irrelevant features, duplicate features, features without proper explanation, and features with lots of missing values are skipped from consideration. The Random Forest (RF) Classifier got the maximum accuracy of 98.7% for the Cleveland dataset 99% for the Hungarian dataset and 99.4% for the CH dataset.

A research work done by [18] uses Decision Trees (DT) to classify heart disease. In their work, they extracted the IF THEN rules which can be used to improve the clinical diagnosis. The dataset used in the research work is an electronic health record-based dataset, it contains 1190 instances. The feature selection is also used to improve the performance of the classification. To resolve the issue of overfitting, pruning is done to reduce the complexity of the parameters which helps to minimize the classification errors. The authors reported an accuracy of 87%.

The ensemble model is used to achieve a promising accuracy in heart disease classification. A machine learning model identifies the patterns in the dataset to predict the target variable. Some classifiers yield satisfactory performance whereas some models predict with limited performance. Hence ensemble method [19] is used to improve the accuracy of the classifier. In this method, the weak classifier performance is increased by methods such as bagging, boosting, and so on. Feature selection is also applied to improve the accuracy of the prediction. The results show that the accuracy of the existing models was improved by 7%.

The Electrocardiography (ECG) data are used by [20] to identify the presence of heart disease. The authors have used many machine learning classifiers such as Naive Bayes, Random Forest, and Logistic Regression. The dataset used in the experiment has 302 instances. The accuracy of 92% was obtained by the authors.

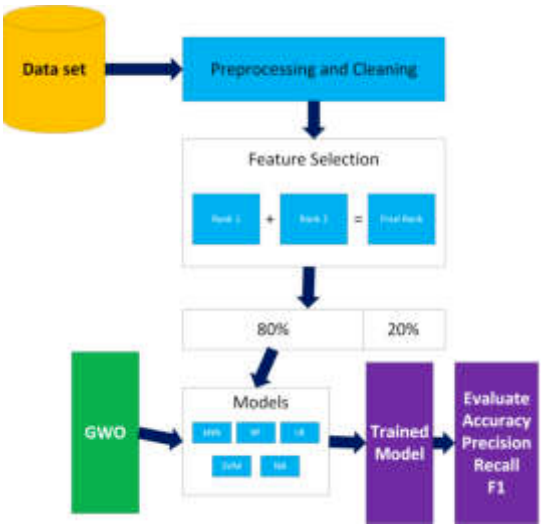

Fig. 3.1: The Methodology of the proposed classifier

The hybrid models are also used to detect the presence of heart disease like the one used in [21]. The irregular patterns are identified for the detection purpose. The paper tackles many of the common machine learning issues such as missing values, and imbalance datasets using proper preprocessing methods. Feature selection is done with the help of an extra classifier. The dataset that was used by the authors was Cleveland. The performance of the proposed model is compared and validated against multiple existing models and the proposed hybrid model produces an accuracy of 96.66%.

The imbalance problem is a major problem in the classifiers deployed in the healthcare industry. One of the solutions to solve the imbalance is undersampling, where the instances are dropped to create a balanced dataset. A work [22] mixes instance selection and under-sampling to improve the performance of the classification. Their proposed model produces an increased accuracy of 3.78% when compared with the existing methods.

A research work by [23] proposed a data mining technique called as Gini index decision tree where the the neural networks can increase the performance in the heart disease dataset. The authors have used the Cleveland dataset and found that the classifier accuracy is increased when the decision tree is used. The data is divided into supervised and unsupervised groups to equal the width, entropy, and frequency.

A hybrid method was projected by [24] which uses PSO and k means clustering for heart disease classification in Shimla, India. The clustering was made in the dataset for the construction of the model based on C4.5, neural networks, and linear regression. The number of the wrong classification and the accuracy were measured.

Different methods are used in the feature selection such as the incremental feature selection method which can increase the accuracy by reducing the false classification. The use of these methods has significantly increased the accuracy up to 93% [25].

Much research is involved in building a hybrid classification model that relies on multiple classifiers. A research work [26] uses a hybrid classifier and rough set concepts in heart disease classification for an accuracy of 92.55%. A twin SVM model has been used for effective decision-making in heart disease classification [27]. This model creates a dual non-parallel hyperplane to increase performance up to 86.75%.

3. The Proposed Heart Disease Classifier. In this section, we broadly explain the working of the proposed classifier. As mentioned in the section 1, we address some important problems such as missing values, balancing the dataset, feature selection, and hyperparameter tuning. Each of these is explained in the following subsections. Figure 3.1 exhibits the methodology of the proposed classifier models.

3.1. Missing Values resolving. A dataset is said to have a missing value when the data is absent for at least one feature in any of the instances. Missing values causes problems in the training stage and hence it is

resolved by various methods such as Deletion, Imputation, usage of ML models, and so on.

Imputation is one of the most trusted methods for handling missing values. In many cases, the statistical measure is calculated such as mean, median, min, and max, and assigned to the missing values. The problem with this method is, the actual distribution is disrupted. For example, they consider a dataset that has features called gender and height. Assume that height has many missing values, instead of taking the mean of height and assigning it to the missing values, we can group the dataset into two groups, one for males and another for females, and calculate the mean separately and assign the respective weight accordingly. In the heart disease dataset, we group the instances in the dataset according to gender and do the mean imputation respectively.

3.2. Balancing the dataset. The classifier learns all the patterns in the data during the training stage. If the number of instances for all the classes is equal, the classifier will have equal chances of learning all the patterns in all the classes equally. However, practically, it is not possible to obtain a perfectly balanced dataset. If the number of instances in any one class is higher than the other classes, then the classifier will learn more about the majority class and learn very little about the minority class.

The dataset that is used in the research work has 274456 instances in the negative class and 27261 instances in the positive class, which means the positive class has only 9.035% of the data. So to increase the instances of the minority class, we use the SMOTE technique and create a balanced dataset.

3.3. Feature Selection. The processed Heart Disease dataset contains 17 attributes, using all the 17 attributes will prevent the classifier from learning the complete pattern. Hence the correct subset of features should be selected from the original dataset so that the dimension of the input space gets reduced also the classifier easily learns about the relationship between input features and the target variable. In this paper, we use the two feature selection methods known as Correlation and Mutual Information which can pick the top 10 relevant features.

Correlation is a statistical measure that reveals the association between two variables, signifying their relationship from -1 to +1. A positive value suggest a direct relationship, while negative values indicate an inverse one. In feature selection, correlation aids in pinpointing redundant or closely linked features. Excessive correlation between features may cause problems, so opting for features with weaker correlation can potentially improve both the model's performance and simplicity.

A statistical metric called mutual information quantifies the degree of information that one variable tells about another, thereby establishing the relationship between the two. It measures how dependent one variable is on the others, regardless of the kind of link. When it comes to feature selection, mutual information evaluates each feature's relevance by calculating the degree to which one feature's information can be used to predict another. High mutual information features with the target variable are usually used for modelling since they are thought to be more informative.

$$r = \frac{\sum(X_i - \bar{X}_i)(Y_i - \bar{Y}_i)}{\sqrt{(X_i - \bar{X}_i)^2(Y_i - \bar{Y}_i)^2}} \tag{3.1}$$

$$MI(X,Y) = \sum_{x \in X} \sum_{y \in Y} p(x,y) \log \left(\frac{p(x,y)}{p(x)p(y)} \right) \tag{3.2}$$

In the process of selecting features, we first rank features based on the equation 3.1 and 3.2, then the average rank is found based on the two features as per the formula mentioned in 3.3.

$$Rank_i = \frac{Rank_{Corr_i} + Rank_{MI_i}}{2} \tag{3.3}$$

3.4. Hyperparameter Tuning. The parameters that can be changed are called a hyperparameter of a machine learning model. Choosing the best combination of hyperparameters can increase the performance of the classification. Grey Wolf Optimization (GWO) [28] is an algorithm that is inspired by how the gray wolf hunts its prey using the social hierarchy.

According to GWO, there are four levels of hierarchy Alpha, Beta, Delta, and Omega. The alpha wolf is the supreme commander of the wolf army. This wolf is responsible for making the most important decisions such as where to hunt. The second level in the hierarchy is the beta wolf where these wolves pass the decisions of the alpha wolf to other wolves and sometimes help the alpha wolf in making decisions. The next level of wolves is known as the delta wolf which takes care of the injured wolves and assists in the hunting process. The last level in the hierarchy is the omega wolf which eats the prey at the end. Omega wolves should be moved forward towards the prey and encircle it so that the prey becomes very easy to hunt. When a prey is found, the equations 3.4 and 3.5 are used to update the location of the wolf whenever a prey is found.

$$D = |\tilde{C}.\tilde{X}_p(t) - \tilde{X}(t)| \tag{3.4}$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{\mathrm{A}}.\vec{D} \tag{3.5}$$

$$\vec{\mathrm{A}} = 2\vec{a}.\vec{r_1} - \vec{a} \tag{3.6}$$

$$\vec{C} = 2.\vec{r_2} \tag{3.7}$$

$$D_\alpha = |C_1 * X_\alpha - X| \tag{3.8}$$

$$D_\beta = |C_2 * X_\beta - X| \tag{3.9}$$

$$D_\delta = |C_3 * X_\delta - X| \tag{3.10}$$

$$X_1 = X_\alpha - A_1 D_\alpha \tag{3.11}$$

$$X_2 = X_\beta - A_2 D_\beta \tag{3.12}$$

$$X_3 = X_\delta - A_3 D_\delta \tag{3.13}$$

$$X(t+1) = \frac{X_1 + X_2 + X_3}{3} \tag{3.14}$$

In the GWO equations 3.6 and 3.7, t represents the current iteration, and r_1, and r_2 are random vectors between 0 to 1. The equations 3.8, 3.9, 3.10, 3.11, 3.12, 3.13, and 3.14 are used to update the wolf positions until the global solutions are found. These equations are used to find the best hyperparameter based on the fitness function which calculates the accuracy at each combination of hyperparameter values.

The working of GWO is displayed in algorithm 2. The algorithm outlines how hyperparameter tuning is done using Grey Wolf Optimizer. The parameters of machine learning model is initialized and the fitness function is found for three best solutions: X_α, X_β, and X_ω. Until the maximum number of iterations is reached, each search agent position is updated on the defined equations. The values of a, A and C is also updated subsequently on the current search state. The fitness function is also gets reevaluated to obtain the three best solutions. The X_α gives the best possible combinations of hyperparameters at the end of all iterations. The algorithm allows to explore over the hyperparameter space efficiently and provide the best solution.

Algorithm 2 Hyperparameter tuning

procedure GWO(n)
    Initialize the value of a,A,c
    find the values of fitness function and obtain three best solutions.
    Let X_α be the first best solution.
    Let X_β be the second best solution.
    Let X_ω be the third best solution.
    for i=1 to maxIterations **do**
        for each Search Agent s **do**
            update the position of s based on 3.4 and 3.5.
        end for
        Update the values of a, A and C based on the present search state
        find the values of fitness function and obtain three best solutions for the oresent search state.
        Let X_α be the first best solution.
        Let X_β be the second best solution.
        Let X_ω be the third best solution.
    end for
    return X_α
end procedure

Table 4.1: Test bed details

Dataset	heart disease dataset downloaded at - [29]
Hardware Configuration	16GB RAM, i9 Processor, NVIDIA RTX 3060
Software Configuration	Windows 11, Python (with sklearn lib)
Experimental Design	80 (training)-20(testing) Split.
Evaluation Metrics	Four Standard metrics, accuracy, precision, recall and F1
Hyperparameters	Tuned using GWO (explained in Table 4.2)
Models	SVM, NB, kNN, LR and RF

Table 4.2: Hyper parameters used in the experiment

ML Model	Hyper Parameters
LR	penalty = 'l2'
kNN	n_neighbors= 3 weights= 'uniform'
SVM	C=0.366 kernel ='rbf'
RF	criterion= 'gini' max_depth= 5 min_samples_split= 3 n_estimators= 120
DT	criterion= 'entropy' max_depth= 5 min_samples_split= 3

4. Results and Discussion. To validate our proposed classifier, we use the heart disease dataset provided by from Behavioral Risk Factor Surveillance System (BRFSS) [29]. The processed dataset is available publically in kaggle [30]. We split the dataset into 80% for training and 20% for testing. The table 4.3 exhibits the feature information. The test bed details of the experiment is shown in table 4.1

Table 4.3: Feature Descriptions

Feature Name	Min	Max	Mean
Heart Disease	0	1	0.0856
BMI	12.02	94.85	28.325
Smoking	0	1	0.4125
Alcohol Drinking	0	1	0.0681
Stroke	0	1	0.0377
Physical Health	0	30	3.3717
Mental Health	0	30	3.8984
Diff Walking	0	30	3.8984
Sex	0	1	0.5247
Age Category	0	12	6.5145
Race	0	5	0.6851
Diabetic	0	3	0.42
Physical Activity	0	1	0.7754
Gen Health	0	1	1.405
Sleep Time	1	24	7.0971
Asthma	0	1	0.1341
Kidney Disease	0	1	0.1341
Skin Cancer	0	1	0.0932

Table 4.4: Accuracy values of the baseline and the proposed model

ML Model	Baseline	Proposed
SVM	0.84	0.98
NB	0.72	0.95
kNN	0.79	0.88
LR	0.91	0.78
RF	0.67	0.92

The machine learning models used to evaluate the proposed approach are listed below.

- Support Vector Machines (SVM).
- Naive Bayes.
- k Nearest Neighbours.
- Random Forest.
- Logistic Regression.

The hyperparameters for the machine learning models is shown in table 4.2.

The parameters used in the classification are explained in the upcoming subsections.

4.1. Accuracy. Accuracy is the most popular method to measure the correctness of the classification. It determines the correctly predicted samples among all the samples in the testing set. Accuracy is a metric used to measure the overall classification accuracy of the model on the entire dataset. The accuracy is calculated as mentioned in eq 4.1. The accuracy values are mentioned in the fig 4.1 and the table 4.4.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{4.1}$$

4.2. Precision. The percentage of correctly classified instances is known as precision. The formula for the precision is mentioned in eq 4.2. The table 4.5 and fig 4.2 displays the precision values of the baseline and

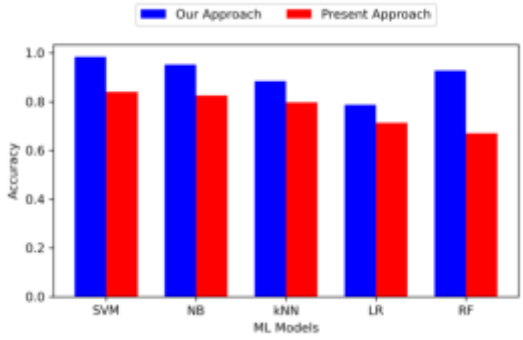

Fig. 4.1: Accuracy Comparision

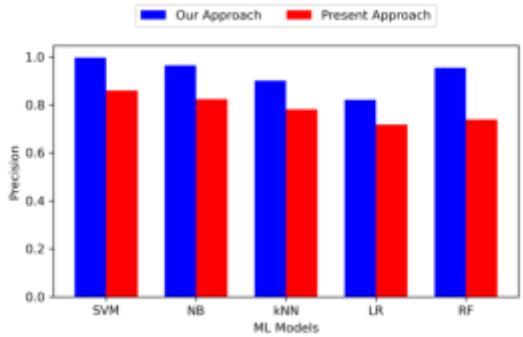

Fig. 4.2: Precision Comparision

Table 4.5: Precision values of the baseline and the proposed model

ML Model	**Baseline**	**Proposed**
SVM	0.85	0.99
NB	0.82	0.96
kNN	0.78	0.9
LR	0.71	0.82
RF	0.73	0.95

the proposed classifier.

$$Precision = \frac{TP}{TP + FP} \tag{4.2}$$

4.3. Recall. Another metric to measure the performance of a classifier is recall. Out of all positive classified instances, how much did the classified classify as positive? This is also called as hit rate of the classifier. Equation 4.3 shows how the recall is calculated. The table 4.6 and fig 4.3 displays the recall values of the baseline and the proposed classifier.

$$Recall = \frac{TP}{TP + FP} \tag{4.3}$$

Table 4.6: Recall values of the baseline and the proposed model

ML Model	Baseline	Proposed
SVM	0.9	0.98
NB	0.91	0.96
kNN	0.9	0.92
LR	0.83	0.86
RF	0.76	0.94

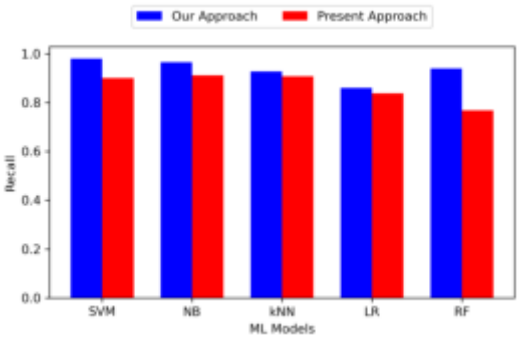

Fig. 4.3: Recall Comparision

Table 4.7: F1 scores of the baseline and the proposed model

ML Model	Baseline	Proposed
SVM	0.87	0.98
NB	0.86	0.96
kNN	0.83	0.91
LR	0.77	0.84
RF	0.75	0.94

4.4. F1 Score. F1 is the combination of Precision and Recall. The equation 4.4 displays the formula for the F1. The table 4.7 and fig 4.4 displays the F1 values of the baseline and the proposed classifier.

$$F1 = \frac{TP}{TP + FN} \tag{4.4}$$

The terms used in the equations are explained as follows

- True Positive (TP): If the classifier classifies a heart disease as heart disease.
- True Negative (TN): If the classifier classifies a normal patient as a normal patient.
- False Positive (FP): If the classifier classifies a normal patient as heart disease.
- False Negative (FN): If the classifier classifies a heart disease as a normal patient.

4.5. Model Explainable. Explainable Artificial Intelligence is one of the important research fields in recent years. An explanation is made so that the end user can understand how the machine learning classifications are made, i.e., it tries to convert the black box classification model into the interpretable model so that the decisions made by the classifiers are understandable by all.

Model explainations can be done in two ways, one is using the model as a whole and the other way is to explain only one instance. We demonstrate both the explainable methods in this section. Figure 4.5 exhibits

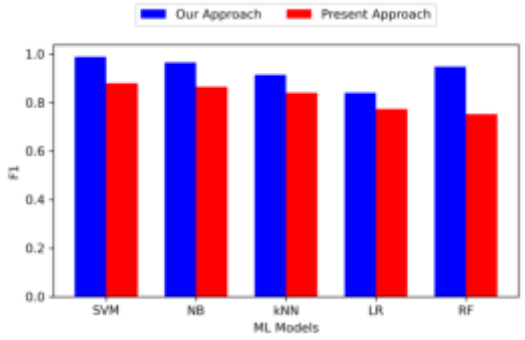

Fig. 4.4: F1 Comparision

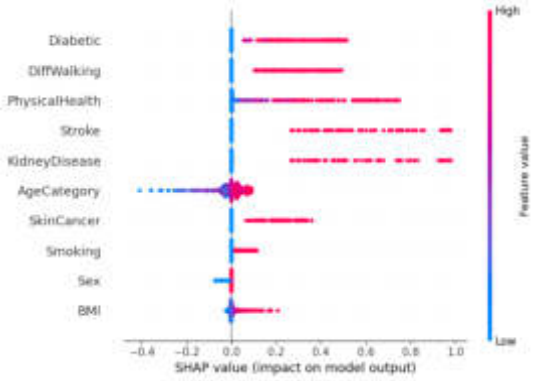

Fig. 4.5: SHAP Summary Values

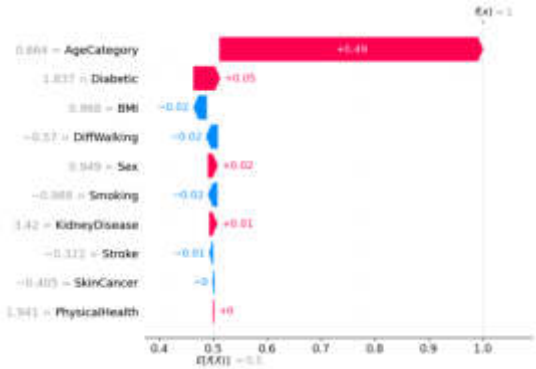

Fig. 4.6: SHAP values of RF

the summary of all features used in the classification. Figure 4.6, 4.7, 4.8 shows the SHAP values for RF, kNN, and NB respectively.

The random forest classifier is an ensemble model of multiple decision trees. The accuracy of the random forest using the proposed approach is 92.75% whereas without using our approach, the accuracy is just 67%.

The number of neighbors considered for kNN is 13. The accuracy of the kNN with and without using the

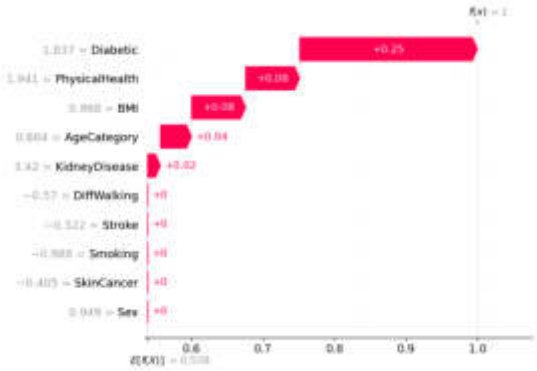

Fig. 4.7: SHAP values of kNN

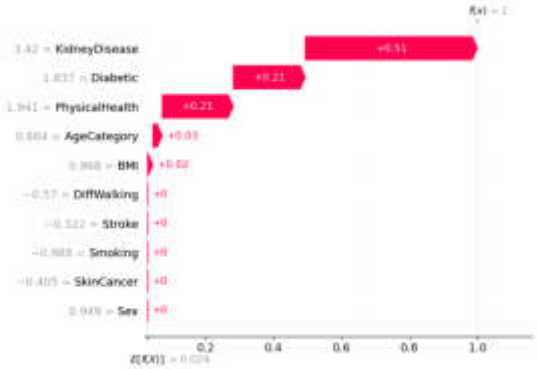

Fig. 4.8: SHAP values of NB

proposed approach is 88.5% and 79.68% respectively.

The NB is a probability-based classifier. NB produces the second-highest accuracy in our experiment next to SVM. The accuracy using our approach is 95.24%. When the baseline NB model was implemented in the same dataset, an accuracy value of 82.56% was observed.

5. Conclusion. In this research paper, we proposed a classification approach that makes use of average ranking of correlation and mutual information. Hence the complete features may not produce an optimal classification performance, we have selected 10 top features and performed the classification to detect whether a patient is having a heart disease or not. Along with the feature selection, we used SMOTE to balance the dataset and also GWO was used to pick the hyperparameters for the classification. The maximum accuracy of the proposed approach was produced by the support vector machine which is 98.41%. We have archived a 17.15% increase in accuracy.

In future work, we aim to develop a web app that can be used by all people, also we will implement the classification into other medical domain datasets.

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APPROXIMATE COMPUTING BASED LOW-POWER FPGA DESIGN FOR BIG DATA ANALYTICS IN CLOUD ENVIRONMENTS

MURALI DOVA *AND ANURADHA M SANDI †

Abstract. As cloud computing continues to evolve, the demand for scalable and energy-efficient infrastructure to handle extensive applications becomes paramount. Traditional transistor scaling and microprocessor design methods no longer suffice to meet the growing scale of cloud usage. This research explores the potential of approximate computing (AC) as an innovative solution to these challenges, particularly in high-demand computational settings. AC, known for its ability to make controlled accuracy trade-offs, is identified as a key strategy for improving both the performance and energy efficiency of cloud infrastructure, with a focus on low-power Field-Programmable Gate Array (FPGA) designs. This paper introduces novel methodologies that harness the strengths of AC, emphasizing its application in neural-based and machine-learning techniques for energy-efficient solutions. By targeting the performance of AC, especially in varied application domains and complex data mining scenarios, we propose two groundbreaking approaches that significantly enhance computational speed and reduce energy consumption. Our empirical analysis demonstrates notable improvements over existing techniques, highlighting the effectiveness of AC in optimizing cloud infrastructure. The proposed model on FPGA through cloud computing attains substantial elevation rates by 89 % and energy reduction by 122 %, which had been good outcomes. This study not only confirms the benefits of integrating AC with low-power FPGA designs for cloud environments but also sets a new benchmark for future research in achieving more sustainable and efficient cloud computing via VLSI FGPA design analysis solutions.

Key words: Low-power FPGA design, approximate computing, benchmark applications, and energy efficiency

1. Introduction.

The role of cloud computing infrastructure has emerged as a transformative force, reshaping the way computational resources are provisioned and utilized across diverse domains. This paradigm shift has been driven by the need for scalable, flexible, and cost-effective solutions to accommodate the exponential growth of data and the increasing complexity of applications. Cloud computing offers a dynamic environment where organizations can access a vast pool of virtualized resources, enabling them to scale up or down as demands fluctuate, all while reducing the burdens of managing and maintaining physical hardware.However, the efficacy of cloud computing infrastructure, while remarkable, is not without its challenges. One of the foremost challenges lies in the ever-increasing computational demands that stem from a myriad of applications, spanning from data analytics and machine learning to real-time communication and complex simulations. Traditionally, transistor scaling and microprocessor design have been the cornerstones of performance improvements. Yet, as Moore's Law faces diminishing returns and the power consumption of processors continues to rise, these approaches are reaching their limits in delivering the required computational power to match the scale of cloud usage.

This inherent disparity between computational demand and conventional performance improvement methods necessitates a departure from established norms. It is here that the concept of approximate computing (AC) emerges as a compelling and unconventional approach. At its core, approximate computing posits that in certain applications, a certain level of accuracy can be relaxed without significantly compromising the overall quality of results. By judiciously introducing controlled inaccuracies at specific points in computations, it becomes possible to unlock remarkable gains in terms of both performance and energy efficiency.The allure of AC lies in its alignment with the ethos of cloud computing - optimizing resource utilization and minimizing energy consumption. As cloud infrastructure aims to cater to diverse workloads from various clients, the ability to

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strike a balance between accuracy and efficiency becomes paramount. For instance, in scenarios where milliseconds matter less than throughput or where exhaustive accuracy is not required, AC becomes a potent tool for enhancing the overall efficiency of cloud-based applications.Moreover, AC's applicability is further accentuated when coupled with low-power computing architectures like Field-Programmable Gate Arrays (FPGAs). FPGAs provide an ideal platform for AC experiments, as their programmable nature allows for customized hardware configurations that can leverage approximate computations effectively. The synergy between AC and FPGAs holds the promise of enabling efficient and highly customizable computing solutions tailored to the specific needs of cloud-based services.

Approximate Computing (AC) emerges as a transformative solution for cloud computing, enabling scalable, energy-efficient, and adaptable infrastructure by intentionally incorporating inaccuracies to enhance performance without critically impacting result quality. This approach not only aligns with sustainability and cost-efficiency goals but also fosters the development of custom, low-power computing solutions like FPGAs, addressing the limitations of traditional computing and advancing the fields of data science and AI.

In light of these dynamics, this paper embarks on exploring the potential of AC in the context of cloud computing infrastructure. Through a combination of theoretical insights and practical implementations, this research aims to elucidate how the integration of approximate computing strategies can reshape the efficiency landscape of cloud-based applications. By investigating innovative methodologies that harness AC's power while mitigating its limitations, this study endeavors to provide a nuanced understanding of the symbiotic relationship between approximate computing and cloud infrastructure, fostering a new era of optimized computational resource utilizationFuture hardware will be unreliable if it is dependent on inexact computations in the context of big data and data analytics, or high scale RMS applications. Software that takes use of future hardware is needed at the same time. There will be changes to the underlying abstractions we've been living with for a long time. While computer prices have decreased by half in the past two years, it is necessary to go beyond Gordon E. Moore's law, which claims that "the number of transistors on a microchip doubles about every two years." This law falls short when it comes to meeting current and future demands as well as scaling up. Approximate computing (AC) and the investigation of low-power FPGA circuits are the solutions to the problem. Semiconductor companies encounter difficulties in developing software with a dependable hardware layer of 10nm. Soft errors are becoming more prevalent as a result of variables such as a decrease in processor lifespan and an increase in variability (SER). Resilient models of computing rather than deterministic hardware models will be essential in the future. In the presence of imprecise software and hardware components, approximate computing offers the opportunity to design acceptable systems. Future calculations will be greatly impacted by two key considerations: cost and energy. The importance of a quality-performance tradeoff cannot be overstated. As a result, the system's performance can be enhanced by sacrificing accuracy.

Literature shows that there have been some recent efforts to implement AC. In addition, they contain a probabilistic transformation compiler from MIT and an AC-based runtime from MSR, SAGE, etc., Blink DB is the database that incorporates the AC from MIT, as well as several processor designs using ANNs from MSR and other institutions. Rice provides probabilistic CMOS, whereas Purdue provides AC components, to name a few. Neuronal approximation computing phenomena were the subject of this research, since it has become a useful tool in the present era of data science and artificial intelligence (AI). RMS applications can be accelerated by neural transformation of algorithms. The proposed hardware design in this study aims to diversify approximation computing methodologies for diverse benchmark applications, leading to the development of low-power FPGA devices that can fully leverage AC. . To name only a few: Jmeint (3D gaming), Inverseektj (robotics), JPEG encoder, Sobel (image processing), Black-Scholes (financial analysis), and K-Means (signal processing) (machine learning). Classifier topology, approximation topology, test and training data, as well as the field or domain are all diverse in the datasets. Several benchmark applications of domain heterogeneity and different mining algorithms are used in this work to leverage the invocation performance of approximation computing. The proposed solutions outperform current best practices in terms of speed and energy efficiency, according to an empirical investigation. Our article makes several distinct contributions to the field, encompassing the following key advancements:

- We introduce two novel architectural frameworks aimed at enhancing the utilization of approximate computing (AC) by integrating multiple classifiers and employing diverse approximation techniques.

These architectures offer innovative avenues to harness the potential of AC for optimizing computational processes.

- Our work encompasses the design of a hardware architecture that facilitates the integration of multiple approximation methods within a CPU-based environment. This architecture is thoughtfully crafted to accommodate the execution of diverse approximations, thereby contributing to the effective implementation of AC strategies.
- To validate the effectiveness of our proposed methodologies, we construct a functional prototype that enables us to rigorously evaluate their performance. Through meticulous experimentation and analysis, we present comprehensive comparative results against established state-of-the-art techniques, thus offering insights into the tangible benefits of our novel approaches.

The rest of the paper is arranged in this manner. Accordingly, Section 2 focuses on the most recent developments in approximate computation. Design materials and procedures that increase energy efficiency with acceptable precision are discussed in Section 3. Results from studies involving eight different benchmarks are presented in Section 4. Section 5 wraps up the report and suggests further research avenues.

2. Related Work. This section reviews literature on approximate computing and also the possible designs based on them. Venkataramani, S. et al. [1] focused on problems with technology scaling in future to meet the needs of computing. They investigated the utility of AC and the need for using it with innovative methods. Zhang et al. [2] proposed an AC framework and its advantages for Artificial Neural Networks (ANNs) with an optimization procedure for energy efficiency. However, there are many challenges of AC as explored by Agrawal et al. [3]. Apart from challenges with respect to proper usage, AC also provides many opportunities in terms of scalability and energy efficiency in large scale computing paradigms. Shafique et al. [4] on the other hand studied cross-layer AC. They explored logic and architecture layer to fill gaps for optimization. Divya et al. [5] proposed approximate computing based system with statistical guarantees in managing quality trade-offs. Li et al. [6] considered AC as a low power technique and proposed approximate circuits to exploit AC approaches. They used AC-aware scheduling for reaping its benefits. They intend to propose methods for control-intensive and data-intensive use cases. Different techniques of approximate computing can be found in Mittal, S. [7] . They include precision and scaling, loop perforation, load value approximation, memorization, data sampling and voltage scaling to mention few. Xu et al. [8] proposed AC method to achieve quality trade-off control which is similar to the work in Moreau, T., Sampson, A., &Ceze, L. [9] opined that AC techniques make mobile systems more efficient. As mobile computing devices have low resources, AC is found suitable for them. Wang et al. [10] presented an FPGA architecture where AC plays crucial role in energy saving. In pattern recognition that is machine learning based, AC is found to improve performance. Boikos and Bouganis [11] explored low-power robotics with the SLAM algorithm on FPGA design. Jafari et al. [12] proposed an embedded deep convolutional neural network (CNN) for scalability and low power consumption. Mametjanov et al. [13] proposed a methodology for auto tuning FPGA design to achieve better performance and power reduction. It was based on machine learning technique to identify parameters for tuning. In future, they intended to apply it for larger designs. Licciardo et al. [14] used a novel radix-3 partitioning method for better floating point operations. Wirthlin, M. [15] explored high-reliability systems made up of FPGA designs that exploit programmability. Ortega-Zamorano et al. [16] used backpropagation method on FPGA design for efficiency of microcontrollers. The algorithm belongs to machine learning with neural networks. It could reduce memory usage and also power consumption.Lei Zhang.[17] studied the FPGA designs based on te usage of ANN models. A three layer ANN is used to achieve desired results in performance in terms of memory usage and power consumption. Zhang et al. [18] proposed a scheme based on FPGA. It is named as Quasi-Centralized Direct Model Predictive Control (QC-DMPC) which controls dc-link voltage. Lu et al. [19] explored the execution of deep learning algorithms on FPGA designs faster. With FPGA design the complexity of the algorithms is reduced besides improving energy saving. Arram et al. [20] proposed methodology for improving FPGA designs that exploit configurability and thus accelerate short read alignment. Wang et al. [21] proposed an FPGA based real-time high quality stereo vision system which is found to be scalable and energy efficient for image processing applications Esmaeilzadeh, H et.al[22] NeuroPIM unveils an innovative processing-in-memory architecture that utilizes a neural network as a versatile accelerator, designed based on the insight that neural networks can approximate certain or entire program outputs in real-world applications.

This architecture melds the versatility of general-purpose processors with the high performance of specialized accelerators, demonstrating up to 41% faster performance than processor-based neural network accelerators and up to eight times the speed of standard general-purpose processors Kalangi, R. R [23]. The deployment of compute-intensive applications in fields such as Artificial Intelligence (AI) and Digital Signal Processing (DSP) presents a significant challenge, compelling the computing systems community to investigate novel design methodologies Saikumar, K. et.al [24]. Approximate Computing has emerged as a promising solution, offering a way to adjust the quality of results during system design to enhance energy efficiency or performance Durga, B. K et.al [25].

3. Materials and Methods. We proposed two architectures to exploit AC based on iterative training approach. It results in a hardware design that supports neural approach for approximate computing in CPU setting (In future we intend to improve it for GPU).

3.1. Baseline Architecture. In presence of multiple approximations there are many opportunities that can lead to efficiency without losing accuracy. However, it is challenging to have optimal invocations provided heterogeneity of RMS applications for which AC is applied. When there is huge training data in such applications, classifier predicts the data that is safe for AC in the current iteration and other data to subsequent iterations. The clustering of "safe to approximate" samples lead to probability of invoking approximators. Given an RMS application, we use iterative training and discover safe to approximate samples. The iterations are tracked to monitor such discovery in each iteration.

The baseline architecture for training has pairs of approximators and classifiers. They divide input space into two clusters namely safe to approximate cluster and unsafe to approximate cluster. The first pair uses original data as input. The pair contains approximator 1 and classifier 1. The training process is iterative nature which results in identification of data samples that are safe to approximate and data which is not converged goes to the next iteration. Ultimately the final unsafe to approximate data only enters into CPU for exact computing process. Based on the prediction of classifier 1, it determines whether the input data can be approximated or not. If yes, the data is given to approximator 1 else it is given to classifier 2. This way, the moves on to all classifier and approximator pairs. The data rejected by all classifiers is finally executed by CPU with precise computations. In the baseline approach, it is time consuming process to speed up with approximate computing invocations.

3.2. Extended Architecture. This architecture is meticulously crafted to cater to the dynamic demands of modern applications, particularly those characterized by their error-tolerant nature, such as Recognition, Mining, and Search (RMS) applications.At its core, the architecture is engineered to accommodate diverse approximation methods, enabling the processing unit to seamlessly switch between different techniques based on the specific task and its associated requirements. This adaptability ensures that the processing unit can effectively exploit the benefits of approximation while maintaining a high degree of performance efficiency. By employing a modular and flexible design approach, the architecture empowers applications to achieve a finely tuned balance between computational accuracy and performance gains.

Furthermore, the proposed hardware architecture is geared towards optimizing energy utilization and computational throughput. It achieves this through strategic resource allocation and dynamic selection of approximation techniques, thereby capitalizing on the inherent trade-offs between accuracy and efficiency. This holistic approach not only enhances the overall performance of RMS applications but also aligns with the growing emphasis on energy-efficient computing solutions.More efficient architecture is designed to leverage performance. It overcomes limitations of the baseline model. Confidence is said to be suitable approximator. Thus multinomial classifier provides input samples to suitable approximator and finally divides input space into n+1 partitions. The second data allocation method is parallel in nature. In this case, all inputs samples are assigned to all approximators in parallel. Approximators compete in the process and produce fit input samples as many as possible. Due to randomness in the training samples, each approximator may produce bias in distribution. In other words, each approximator may exhibit different local minima. Every approximator in this approach tests input sample and produces an approximation error. Based on the lowest approximation error, a babel is assigned to the sample. With all the labels generate, the multinomial classifier gets trained and produces a knowledge model used for testing data further.

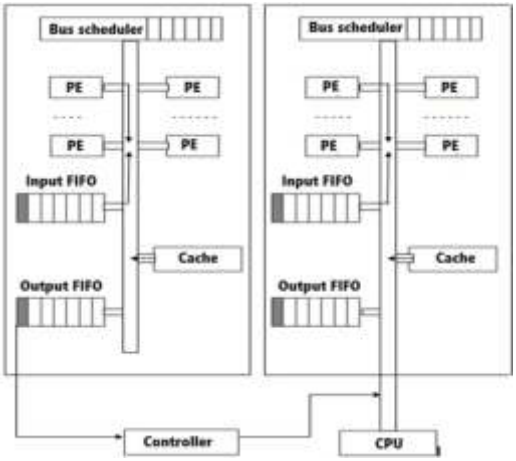

Fig. 3.1: Proposed hardware architecture for processing unit

The original data is subjected to multi-class classifier that produces safe to approximate data to different approximators. In the process the two data allocation models are employed empirically and the resultant data samples are given to appropriate approximator. The data samples that are not suitable for any approximator are given to CPU for exact computations. The extended model aims to improve approximator invocation performance as much as possible. The architecture's unique selling point lies in its capacity to seamlessly integrate with low-power FPGA designs, a synergy that underscores its adaptability and suitability for contemporary computing paradigms. By uniting the capabilities of FPGA technology with the advantages of approximate computing, the architecture opens up avenues for improved energy efficiency, reduced power consumption, and elevated performance across a diverse range of applications.

The above figure 3.1 clearly explains about proposed architecture of design. This FPGA design can give accurate scalable computation in adverse at data available scenarios.

3.3. Proposed Hardware Design. FPGAs can facilitate the verification of various VLSI design functionalities before fabrication by allowing implemented designs to be imported into the FPGA for testing. This analysis enhances hardware scalability and reduces manufacturing costs. Identifying any bugs in the design during the simulation stage can mitigate issues early on, saving on manufacturing expenses. In this manner improve the scalability of FPGA and its design process.As the extended architecture has multiple approximations, a neural processing unit (NPU) based hardware is designed in CPU setting (not targeted for GPU). The hardware design facilitates switch for various approximators and improves parallelism. As shown in Figure 3.1, the hardware architecture has identical tiles (computing resources). In each tile, there are many processing elements (PEs). An internal bus connects cache and input/output FIFOs. PE is meant for computing outcome of one neuron at a given time. This is as part of the neural network while performing inference task. Data scheduling between input FIFOs and PEs is carried out by bus scheduler. The bus scheduler also performs scheduling of weights associated with neural network between cache and specific PE. The structure of PE used in the hardware architecture has its own modus operandi in terms of functionality. It is graphically illustrated in Figure 3.2.

The PE has different components such as weight buffer fetch unit, W register, I register MAC and Sigmoid. The Fetch unit is meant for reading weights from the address (specific) associated with the weight buffer and sends the same to the W register which is shown in Figure 3.2. Input FIFO sends data to the I register where it is stored. When values arrive at registers, arithmetic computations are carried out. An activation unit such as Sigmoid will activate the result. Finally, the result is sent to the output buffer.so, FIFO instead of parallel in parallel out and other parallel procedures for providing delay for arithmetic computations were proposed. Based on the availability of resources and neural networks, classifiers and approximators are dynamically allocated. A

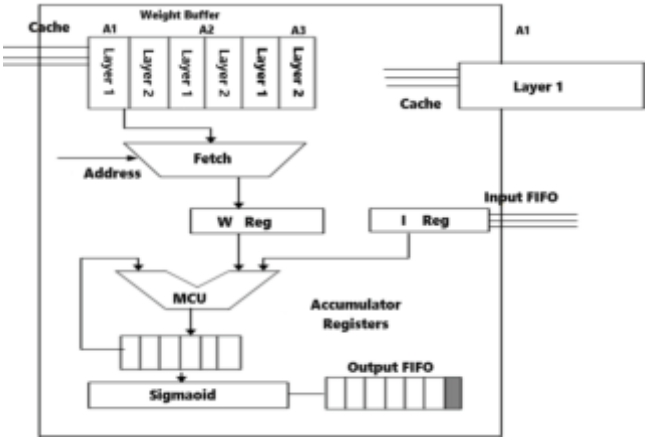

Fig. 3.2: Structure of PE used in the hardware architecture

controller is used to receive results from the classifier and give the required control signal to the approximator. As shown in Figure 3.1, in the initialization phase weights of classifiers are loaded. In the first stage, data comes from input FIFO to each PE. In stage 2, the PE computers the outcome of a neuron, and the result is sent to output FIFO. In the third stage, the result is sent to the controller from output FIFO. In stage 4 approximator is invoked by the controller only if the data is found to be safe to approximate, otherwise, the CPU is invoked for exact computations. In stage 5, input data is given to PEs present in the approximator for required computations. Then in stage 6, the results are sent to output FIFO. There is a need for a weight switch among approximators in the proposed design. Thus there are three scenarios supported. First, the weight buffer is capable of storing all weights associated with all approximators. In this case, the cache is not used for loading weights. Second, the weight buffer has less capacity and cannot accommodate the weights of all approximations.

3.4. Mathematical computations. in this section, brief notes on FPGA handling computations were explained. The error approximation, energy normalization, and power consumption are major elements of VLSI design. These parameters have been explained through the below Scalable computations. Approximation Error (AE):

$$AE = [ExactResult - ApproximateResult] \tag{3.1}$$

The above equation 3.1 clearly explains approximation error, if this error was less then say that the design provides fast scalable computations.

$$MAE = \sum\_i = 1^n \|ExactResult\_i - ApproximateResults\_i\| \tag{3.2}$$

Equation 3.2 clearly explains the Mean Absolute Error (MAE) parameter, indicating the error rate at high-speed operations.

$$NormalizedEnergyReduction(\%) = (Base - Power) - (educed - power)/(Base - Power) \tag{3.3}$$

In this case, a cache has been used to get Normalized power which is shown in eq 3.3. The weight buffer can store weights of only one approximation in the function. In this case, the cache is needed. Thus the proposed hardware architecture is capable of supporting all scenarios that may be experienced by an NPU (neural processing unit) design. It is achieved by adding a controller that switches approximators. Once data comes out of computations, its movement between steps remains the same.

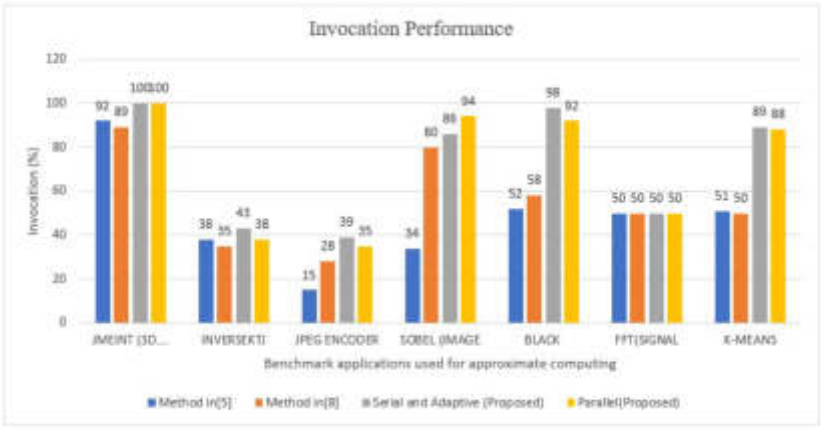

Fig. 4.1: Invocation performance across benchmarks

4. Results and Discussion. Experiments are made with 8 benchmark applications to which the proposed architectures are applied for approximate computing. The proposed methods are compared with two state-of-the-art architectures found in earlier studies. Multilayer perceptron (MLP) with backpropagation (BP) is used for all approximators and classifiers. Eight benchmark applications as mentioned in the Section 1 are used for empirical study. The models are evaluated using Root Mean Square Error (RMSE) and invocation of classifiers. The notion of error bound is used that is nothing but quality needs for the output. When the error bound is lower, higher in quality.

In this experiment, input vectors of 16, 32, and 64 bits were utilized. These input vectors were dynamically retrieved from a cloud server. The proposed design underwent verification using these test vectors, allowing for a comprehensive assessment of both its functionality and performance. The results showed that the proposed architecture showed better performance over the state of the art and error bound is well under threshold.

As presented in Figure 4.1, the benchmark applications used for approximate computing are provided in horizontal axis. The vertical axis shows the invocation percentage. More in invocation percentage indicates more performance a given architecture. The two proposed architectures are compared with the architectures in past models. With Jmeint (3D gaming) application, the two proposed methods achieved 100% invocation while methods of statistical guarantees and approximate computing showed 92% and 89% respectively. The proposed methods showed improvement in the case of all benchmarks except FFT (signal processing) application. Therefore, FFT is considered not suitable for approximate computing. Sobel (image processing), black-scholes (financial analysis) and K-Means (machine learning) applications exhibited improved invocation % for the proposed methods.

As presented in Figure 4.2, normalized approximation error about error bound is shown in the vertical axis while the horizontal axis shows all the benchmark applications used for approximate computing. The normalized error of the proposed methods is less when compared with the methods in [5] and [8] in the case of the Jmeint and JPEG encoder. In the case of the Inversektj application, the proposed methods outperform the method in [5]. The serial and adaptive methods showed better performance over all other methods in the case of the Sobel application. Concerning the FFT application, all four methods showed the same performance. Concerning K-Means the proposed parallel architecture showed better performance over all other methods which is shown in figure 4.1.

As shown in Figure 4.3, the error bound is shown in the horizontal axis and the vertical axis shows invocation (%). This experiment is made with the Black-Sholes benchmark application. As the error bound is low, the invocation percentage is less. As the error bound is increased from 0.025 to 0.1 gradually, the invocation percentage is increased steadily. In all error bounds, the proposed two methods outperformed the state of the art except in case of 0.1 error bound where the method in [8] showed better performance overall. But the

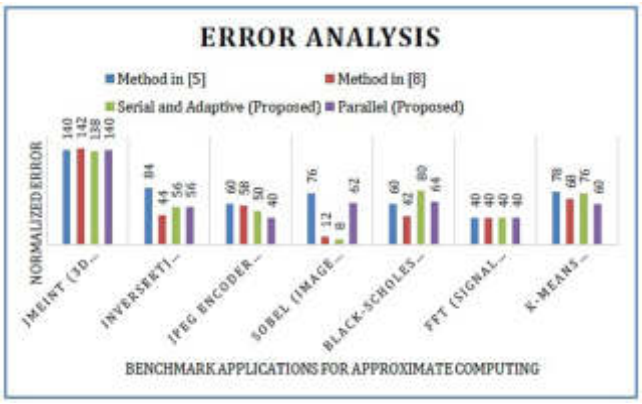

Fig. 4.2: Normalized error analysis for different benchmarks of approximate computing

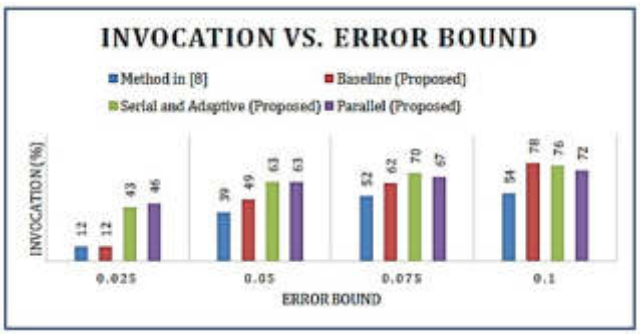

Fig. 4.3: Invocation percentage varying error bound (Black-Sholes benchmark)

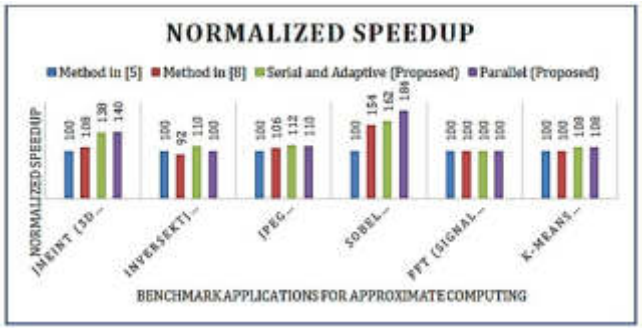

Fig. 4.4: Normalized speedup (with reference to Method in [5])

proposed methods showed better invocation performance over the method in [5]. From this experiment, it is understood that the proposed methods outperformed existing ones with higher invocation percentages that is much desired in approximate computing use cases.

As presented in Figure 4.4, the speedup normalized concerning method in [5] is proposed in the vertical axis while the horizontal axis shows the benchmark applications used in empirical study. The speedup of the proposed methods is increased in the case of all benchmarks except FFT. It is understandable as FFT is found not suitable for approximate computing earlier without improvement in invocation percentage. In the case of

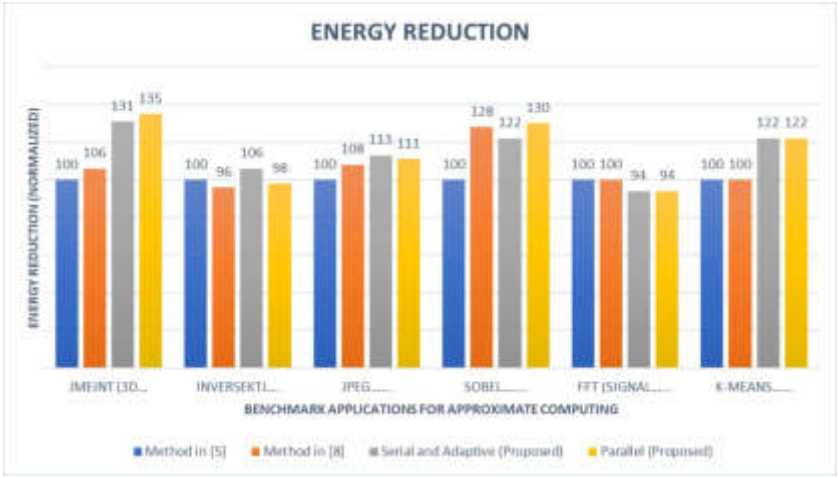

Fig. 4.5: Energy reduction performance comparison (normalized to Method in [5])

Sobel application, the proposed parallel method outperformed all other methods. Concerning Inversektj and JPEG encoder applications, the serial and adaptive methods showed higher speedup.

As presented in Figure 4.5, the normalized energy reduction for the method of statistical computing is shown in the vertical axis. The horizontal axis shows the benchmark applications. Energy efficiency achieved at the cost of loss of quality (acceptable) is the important proposition or hypothesis tested in this paper. Accordingly, energy reduction is achieved in the empirical study. More energy efficiency is achieved with higher invocation % of approximate computing. The proposed invocation-driven architectures led to higher energy savings. With the proposed methods, energy reduction is more when compared with methods like earlier computing techniques. Energy reduction is higher in all the benchmarks except in the case of the FFT application where the proposed methods could not achieve higher reduction in energy consumption. Higher energy reduction is achieved by the proposed parallel architecture in the case of the Jmeint application. From the results, it is understood that the proposed architectures showed better performance over the state of the art in [5] and [8] in case of invocation performance, speed up and energy saving. Thus, the hypothesis "performance improvement at the cost of an acceptable reduction in quality" has significance and relevance to present and also future hardware architectures.

5. Conclusion and Future Scope. In this research, two innovative architectural paradigms strategically designed to harness the potential of benchmark applications marked by both the cloud domain and FPGA VLSI platform towards heterogeneity. The objective is to organize the significant enhancements in terms of speedup and energy efficiency, thereby exploiting the potential of low-power FPGA designs in tandem with approximate computing. The study delves into the invocation performance of different approximate computing techniques, thoughtfully employed across a spectrum of mining (RMS) tasks. Through rigorous evaluation involving diverse benchmark applications, our proposed architectures stand out as powerful contenders. Empirical findings highlight their superiority over two existing methods. For instance, with the K-Means machine learning benchmark, the existing methods demonstrated 51% and 50% invocation performance, whereas our proposed serial and adaptive, as well as parallel methods showcased substantially elevated rates of 89% and 88%, respectively. Similarly, the proposed methods exhibited a striking 122% reduction in normalized energy consumption, overshadowing the 100% achieved by existing methods for the K-Means benchmark. This compelling evidence underscores the pronounced performance augmentation offered by our architectural innovations, as evidenced through noteworthy improvements in both speedup and energy reduction over existing state-of-the-art techniques.

Moreover this research trajectory aligns with an aspiration to further refine the architectural design by introducing dynamic search operations aimed at automatically identifying the most energy-efficient approximate

design while adhering to predefined quality constraints. This forward-looking pursuit holds the potential to revolutionize the landscape of approximate computing, ushering in enhanced energy efficiency without compromising on quality benchmarks. By relentlessly pushing the boundaries of innovation, we envision a future where the synergy between architectural ingenuity and intelligent optimization drives unprecedented advances in the domains of cloud-based RMS applications and low-power FPGA designs.

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ONWARD AND AUTONOMOUSLY: EXPANDING THE HORIZON OF IMAGE SEGMENTATION FOR SELF-DRIVING CARS THROUGH MACHINE LEARNING

TIRUMALAPUDI RAVITEJA*, NANDA KUMAR M† AND SIRISHA J‡

Abstract. Autonomous navigation is the leading technology in current era, in this intelligent traffic light, sign detection, ADAS and obstacle detections were playing major role. Image segmentation is the process of dividing an image into different regions, or semantic classes. This is a challenging problem in autonomous vehicle technology because it requires the vehicle to be able to understand its surroundings to safely navigate. The major challenges in this platform are the accuracy and efficiency of model performance. The proposed method in the abstract uses a convolutional neural network (CNN) to perform image segmentation. CNNs are a type of deep learning model that is well-suited for image processing tasks. The CNN in this paper was trained on a local city dataset, and it was able to achieve a mean intersection over union (IoU) of 73%. IoU is a measure of how well the segmentation results match the ground truth labels. A score of 100% indicates that the segmentation is perfect, while a score of 0% indicates that the segmentation is completely wrong. This means that the method can segment images at a very fast rate, which is important for autonomous vehicles that need to make real-time decisions. Overall, the proposed method is a promising approach for image segmentation in autonomous vehicles. It can achieve high accuracy and speed, and it is easy to implement using Python. The proposed method attains an accuracy of 98.34 %, a Sensitivity of 97.26 % and a sensitivity of 96.37 % had been attained. The method could be used to improve the safety and efficiency of autonomous vehicles by enabling them to better understand their surroundings.

Key words: Self-driving cars, CNNs (Convolutional Neural Networks), Image segmentation, Advanced driver assistance systems (ADAS), Semantic segmentation, Object detection, Deep learning (DL)

1. Introduction. The visual perception of autonomous vehicles (AVs) [1] is essential for their safe and efficient operation. This process involves the use of various sensors, such as Lidar, Radar, Camera, and IMU, to gather information about the surrounding environment. The gathered data is then processed to identify objects and their locations, as well as to track their movements. Image segmentation is a key technique in visual perception for AVs. It involves the partitioning of an image into different regions, or semantic classes, based on their visual properties. This allows AVs to identify and track objects in their surroundings with greater accuracy and precision. Traditionally, image segmentation has been a challenging task. However, the advent of DL has made it possible to achieve high-accuracy image segmentation with relatively little computational effort. DL models can be trained on large datasets of labelled images to learn the visual features that distinguish different object classes [2]. Once trained, these models can be used to segment new images with high accuracy [3].

In addition to its accuracy, image segmentation is also important for the real-time operation of AVs. AVs must be able to process visual information quickly to make safe and timely decisions. DL models can be implemented on high-performance GPUs to achieve real-time image segmentation. Overall, image segmentation is a critical technique for the visual perception of AVs. It allows AVs to identify and track objects in their surroundings with high accuracy and precision, and it can be implemented in real time using DL models [4]. Machine learning is a powerful tool that can be used to address many of the challenges encountered in the development of self-driving vehicles. By integrating data from various sensors, such as Lidar, radars, and cameras, machine learning can be used to improve the vehicle's understanding of its surroundings and make better decisions [5].

One of the most important tasks for self-driving vehicles is to accurately predict the weather conditions. This is because the weather can have a significant impact on the vehicle's ability to operate safely [6]. For

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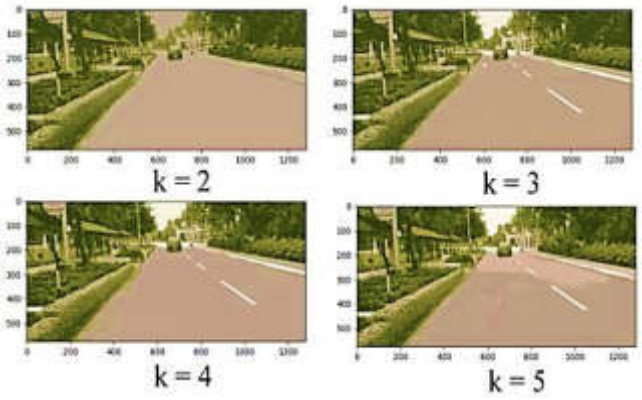

Fig. 1.1: Evaluating the Performance of K-means Clustering

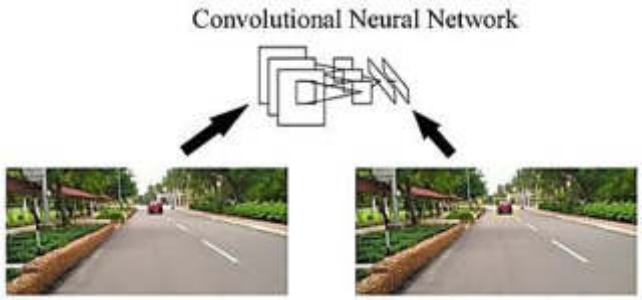

Fig. 1.2: Deep CNN for Image Feature Extraction and Object Detection

example, heavy rain or snow can reduce visibility, making it difficult for the vehicle to see other objects on the road. The K-means clustering algorithm is a popular machine learning algorithm that can be used to generate a comprehensive representation of the weather conditions. This representation can then be used to predict changes in the weather, which can help the vehicle to adjust its driving behavior accordingly.

In addition to predicting the weather, machine learning can also be used to perform other tasks that are essential for self-driving vehicles. These tasks include object detection, identification, classification, localization, and predicting the movement of agents by leveraging machine learning, self-driving vehicles can become safer and more efficient [7].

DL is a powerful technique that enables the possibility of self-. driving vehicles. Artificial neural networks (ANNs) are data processing frameworks inspired by the biological nervous systems, composed of simple processing units interconnected and operating in parallel and the sample figure is shown in figure 1.1. Sensor perception is a critical area of artificial intelligence (AI) where information must be extracted from images. With high demands and expectations in this field, it has surpassed previous beliefs, encompassing object detection, pattern recognition, activity recognition, and automated guidance, among others. Numerous papers have been published on this subject, particularly in DL and CNNs.

The CNN technique has found extensive applications in various domains, including image segmentation, AI, computer vision, and much more. In the realm of self-driving vehicle technology, the CNN technique is predominantly used for object detection and automation based on images, as shown in Figure 1.2. These CNN methods are primarily employed for object localization and recognition.

2. Literature Review. The self-driving car is a complex and sophisticated system that requires various sub-systems to enable effective perception and decision-making. These sub-systems are illustrated in Figure

Fig. 2.1: The Key Sub-systems for Perception and Decision-Making in Self-Driving Cars

2.1. The paper [8] propose a neural-based approach that uses the Overfeat CNN to recognize moving agents. This approach takes advantage of the unique visual patterns exhibited by moving agents, allowing for accurate identification. The authors of [9] focus on the crucial task of labelling moving agents and ego vehicles. This task is relevant to the closely related application known as "follow the ego vehicle," in which the self-driving car must track the movements of another vehicle.

The paper [10] explore the essential process of vehicle detection and recognition of traffic lights (red, green, and yellow). These capabilities are essential for self-driving cars to obey traffic laws and ensure safe navigation on roads.

The authors of [11] propose an ingenious Overfeat CNN model that predicts the distance from the current state of the vehicle to ego vehicles. This predictive model is instrumental in facilitating collision avoidance, a critical safety aspect in autonomous driving.

The paper [12] present a comprehensive survey that provides an in-depth overview of the diverse sub-systems involved in self-driving cars, as well as the challenges encountered in their development and deployment.

2.1. Advancements in CNN-Based Image Segmentation Techniques for Object Labelling and Semantic Segmentation in Autonomous Driving. The paper [13] proposed a real-time automated object labelling approach for CNN-based image segmentation. Their approach uses a combination of deep convolutional neural networks (DCNNs) and probabilistic graphical models to achieve high accuracy in object boundary localization. [14] addressed the challenge of image resolution in DCNNs by using convolution with unsampled filters and spatial pyramid pooling (SPP). This allowed them to divide objects at multiple scales, which improved the accuracy of their object detection and segmentation models. They achieved an IoU score of 79.7% on the KITTI dataset.focused on the challenges, datasets, and existing methods in deep multi-model object detection and semantic segmentation for autonomous driving. They identified several challenges, including occlusion, illumination changes, and the need for real-time performance. They also reviewed several existing methods and proposed several directions for future research and it is shown in below figure 2.2.

2.2. Advancements in DL-based Image Segmentation Techniques. We introduce the attention-guided lightweight network (AGLNet), a novel approach for real-time semantic segmentation. AGLNet uses an encoder-decoder architecture that enables efficient and accurate semantic segmentation, making it suitable for real-world applications such as autonomous vehicles and real-time image processing.contribute to the field of image segmentation with the lightweight feature pyramid encoding network (FPENet). FPENet is designed to achieve a balance between accuracy and speed, making it a promising solution for applications where real-time processing is critical.

We present a thorough investigation of picture segmentation techniques utilizing DL techniques in various domains. Their comprehensive review provides valuable insights into the current state-of-the-art and future directions for image segmentation research. Several well-known convolutional neural network (CNN) architectures, including AlexNet, DenseNet, MobileNet, and ResNet, have gained significant popularity in image segmentation. These widely recognized models have demonstrated their effectiveness in various image-related

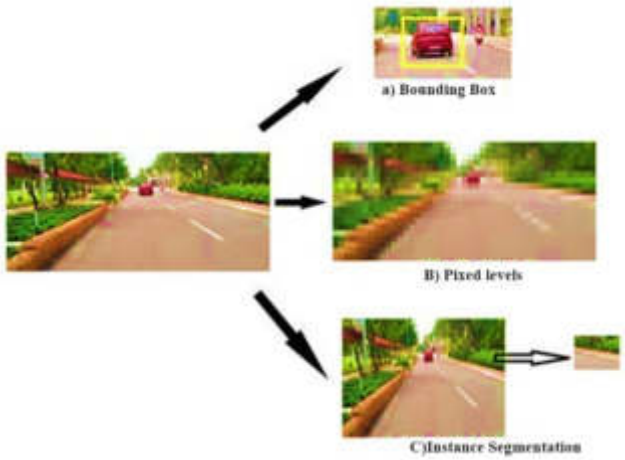

Fig. 2.2: Segmenting Images at Different Levels

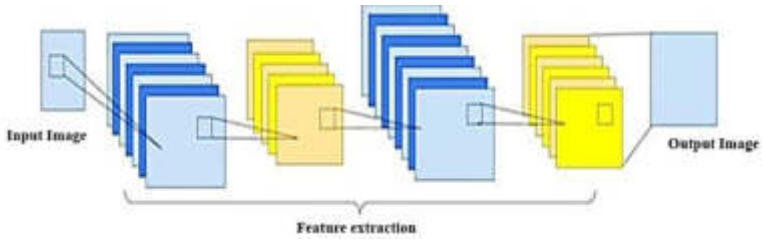

Fig. 2.3: The Building Blocks of CNN Architecture

tasks, including image segmentation.suggest a brand-new deep network architecture designed exclusively for picture segmentation. Their model incorporates processes that contribute to achieving high accuracy rates in the segmentation process. This advancement holds great potential for improving the performance of image segmentation systems across different applications and the sample figure is shown in figure 2.3.

We provide the following summary of the work mentioned above and our Framework contribution:

- This model integrates the segmentation process with CNNs allowing for mor efficient and accurate results in visual perception tasks. By leveraging the power of CNNs, we can effectively analyse and understand complex visual data, which is crucial for applications such as self-driving cars, object recognition, and scene understanding.
- One key aspect of our framework is the incorporation of a K-means clustering layer. This layer plays a significant role in the optimization of our model, enhancing the accuracy and performance of the visual perception process. By effectively grouping pixels into clusters, we can achieve a more refined and precise segmentation of objects and regions in the image.
- To evaluate the effectiveness of our network model, we conducted rigorous experiments using various datasets. The results demonstrated that our approach outperforms existing methods in terms of mean Intersection over Union (IoU) scores and accuracy. We achieved impressive results with a mean IoU greater than our target value and ensured real-time processing, with a speed exceeding 100 frames per second (FPS).
- The combination of our novel model, K-means clustering layer, and optimization techniques contribute to the overall efficiency and accuracy of our framework. These results showcase the potential of our approach for practical applications in visual perception tasks, particularly in real-time scenarios where

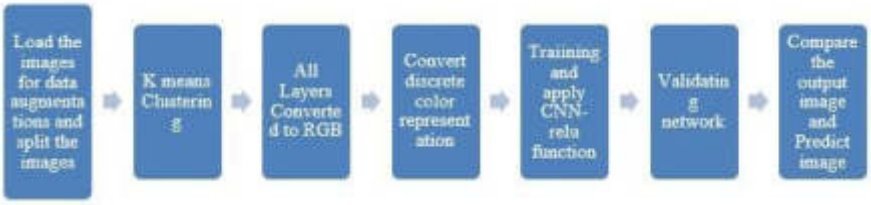

Fig. 3.1: Phases of Convolutional Neural Networks in Action and Enhancing Image Segmentation for Self-Driving Vehicles

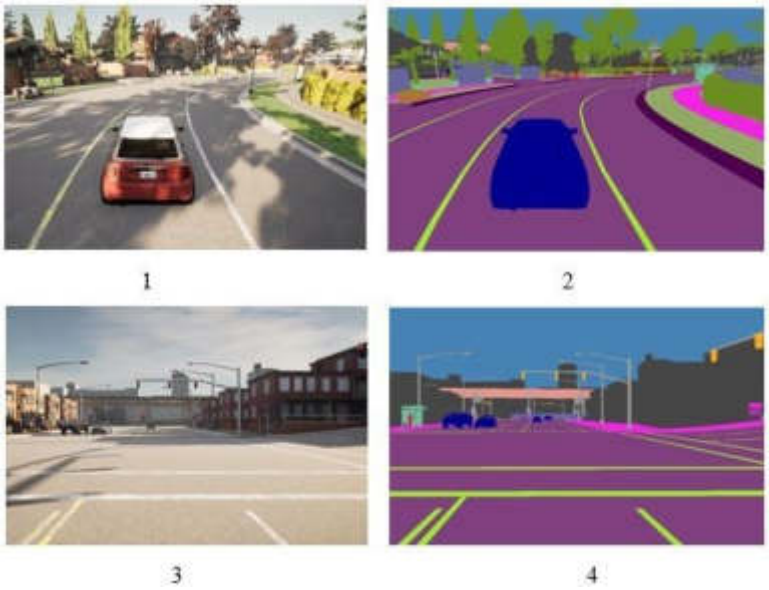

Fig. 3.2: Visualizing the Results of Image Segmentation

quick and precise decision-making is essential. With this research, we aim to advance the state-of-the-art in image segmentation and CNN-based visual perception for various domains, including autonomous vehicles, robotics, and computer vision.

3. Framework. The process of image segmentation starts with installing the required Python packages, such as NumPy, OS, cv2, kmeans, random, Conv2d, ReLU, Adam, and SGD. These packages are used for data loading, augmentation, clustering, classification, and training of the CNN model. After the packages are installed, the datasets are loaded and augmented using flipping and rotating. The augmented images are then split into training and testing sets and the sample figure for phases of CNN are shown in figure 3.1.

The next step is to cluster the images by colors using K-means clustering. K-means clustering is a popular algorithm for clustering data points into groups based on their similarity. In this case, the images are clustered into groups based on their color.

After the clustering process, the image layers are converted to RGB images. This means that each pixel in the image is represented by its red, green, and blue values are shown in figure 3.2. The RGB images are then classified into different classes.

This is done by using a CNN model. The CNN model is trained on the labelled images and then used to classify new images. The CNN model is trained for 1000 epochs. An epoch is a complete pass through the

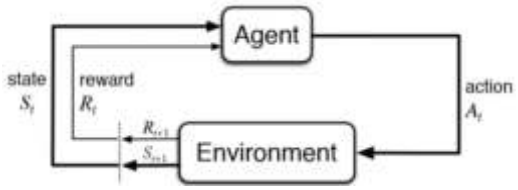

Fig. 3.3: Model Analysis

Table 4.1: Adjustable Size Table

	Class_ 001	**Class_ 002**	**Class_ 003**	**Class_ 004**	**Class_ 005**	**Class_ 006**	**Class_ 007**	**Class_ 008**	**Class_ 009**	**Class_ 010**
TP	3	4	4	4	3	4	4	3	3	4
FP	0	3	3	3	3	1	3	3	1	0
FN	1	0	1	0	0	3	0	0	3	3
IOU	0.7	0.7	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7

training dataset. After the model is trained, it is validated on the testing dataset. The validation results are used to evaluate the performance of the model and then the model analysis is shown in figure 3.3.

The final step is to visualize the results of the image segmentation. This is done by showing the color segmentation image and the true image classes [15]. The color segmentation image shows the different colors in the image, while the true image classes show the different objects in the image. The overall process of image segmentation is a complex one, but it can be broken down into a series of steps. By following these steps, it is possible to segment images accurately and efficiently. Keras is a popular framework for building and training CNNs. It is easy to use and has a wide range of features. TensorFlow is a powerful library for numerical computation. It is used by many researchers and developers for machine learning and artificial intelligence tasks. It has 4GB of GDDR5 memory and can process images at high speeds. The training data for our CNN consisted of a set of images that were labelled with the objects they contained. The results of the training will be discussed in the next session.

4. Experiment Results. According to Table 4.1, the Class IOU is determined by averaging the pixels that are True Positive (TP), False Positive (FP), and False Negative (FN).

$$Intersectionoverunion(IOU) = \frac{TurePositive}{TruePositive + FalsePositive + FalseNegitive} \tag{4.1}$$

F(x , θ) = [Class_01, Class_02, ——, Class_10]

The proposed network was compared with other state-of-the-art networks, including CGNet, ENet, ERFNet, FSCNet, FSCNN, and DABNet and the graph for performance measures are shown in figure 4.1. The results showed that the proposed network achieved better performance on all classes except class_04, as shown in Table 4.2 and then the graph for mean of the classes are shown in figure 4.2.

The proposed network also achieved better performance in terms of parameters, frames per second (FPS), and mean intersection over union (MIoU), as shown in Table 4.3 and then the comparision of models related graph are shown in figure 4.3.

Note: The parameter values represent the total number of trainable parameters in the respective CNN models. FPS indicates the frames processed per second during inference. MIou denotes the mean Intersection over Union score, which measures the accuracy of the segmentation predictions compared to ground truth masks.

Optimization of our CNN model, assume that the image classification to as X classes. The output probability sample is that,

$$P_n = [P_1, P_2, \cdots, P_x]^T \tag{4.2}$$

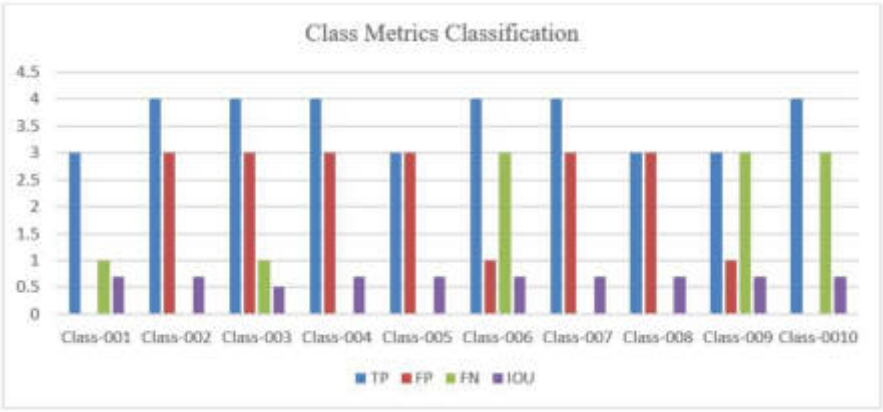

Fig. 4.1: Performance measures

Table 4.2: Results of Accuracy and Evaluation Against Other Networks for Individual Classes

Method	**Class_ 001**	**Class_ 002**	**Class_ 003**	**Class_ 004**	**Class_ 005**	**Class_ 006**	**Class_ 007**	**Class_ 008**	**Class_ 009**	**Class_ 010**
CGNet	89.8	80.8	29.1	96.3	83.15	71.62	32.09	81.32	52.91	53.9
EFNet	91.4	76.1	24.35	94.56	75.54	95.12	21.52	78.25	42.65	46.21
ERFNet	90.6	78.45	27.56	95.65	79.56	83.37	27.25	79.64	50.05	50.05
FSCNN	67.7	59.09	20.62	71.25	59.65	62.13	59.74	59.4	437.54	37.54
DABNet	68.4	73.61	25.52	89.65	74.62	78.06	26.54	4.64	44.77	46.92
Model	92.2	83.21	59.40	86.12	92.35	93.52	68.25	90.58	62.35	70.24

Table 4.3: Relation to other networks

Method	**Param**	**FPS**	**MIoU**
CGNet	0.56	96	67.5
ENet	0.31	93	56.4
ERFNet	3.01	143	70.1
FSCNN	1.08	248	56.4
DABNet	0.84	137	67.1
This Model	1.38	94.4	73.6

When the ground truth label index is gn, the output probability as px, where Pn is present state list.

$$P_n^* = [P_1^*, P_2^*, \cdots, P_x^*]^T \tag{4.3}$$

$$P_n^* = \{1 if x == g_n, 0 otherwise \tag{4.4}$$

5. Conclusion. In this work, effectively analyses and understands image features. Our proposed model has been extensively validated and demonstrates promising results. We provide comprehensive insights into the optimization details of our network architecture. The primary evaluation metric used to assess the performance of our model is the Mean Intersection over Union (Mean IoU), a widely accepted measure in image segmentation tasks. The Mean IoU quantifies the accuracy of our segmentation predictions by measuring the intersection of the ground truth masks and the anticipated segmentation masks. Our model achieves an impressive Mean IoU score of 72.4, indicating a high level of accuracy and precision in identifying and classifying different objects

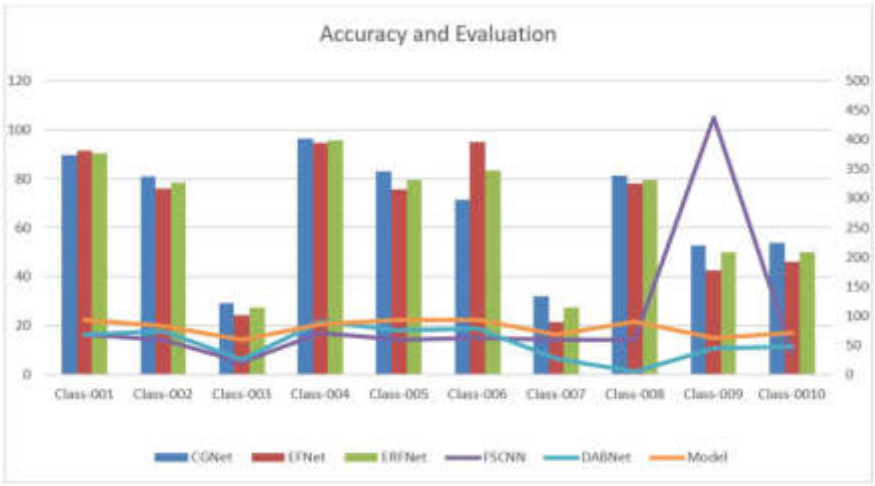

Fig. 4.2: Mean of classes

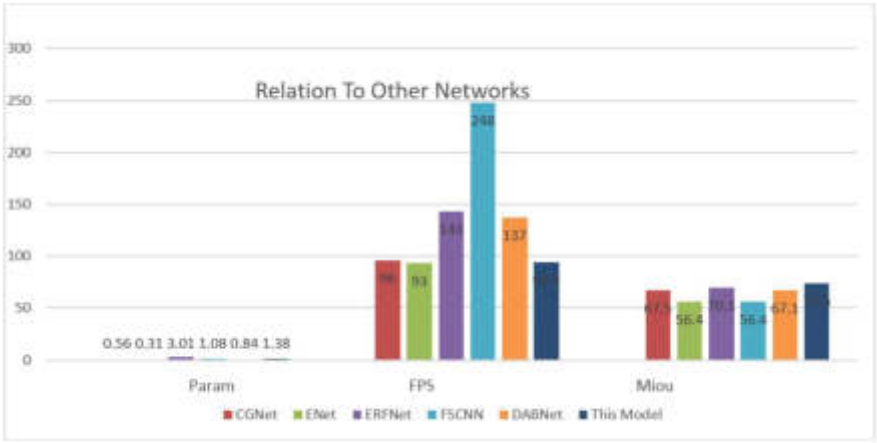

Fig. 4.3: comparision of models

and regions within an image. The inference speed of the proposed method was 90 frames per second (FPS) on an NVIDIA GeForce GTX 1050 GPU.

Additionally, a crucial aspect of any semantic segmentation model is its efficiency in processing images in real-time applications. Our network demonstrates exceptional performance in this regard, boasting a segmentation speed of over 100 frames per second (FPS). This level of efficiency is essential for real-time applications, such as self-driving vehicles, where rapid and accurate scene understanding is crucial for safe and reliable autonomous navigation. To ensure the reliability and robustness of our results, we conducted a comparative analysis with other existing network models commonly used for image segmentation tasks. The comparison revealed that our CNN model outperforms the other networks, showcasing a significant improvement in accuracy rates. This further validates the efficacy of our proposed approach in solving the image segmentation challenge. The combination of high accuracy, real-time processing capabilities, and superior performance compared to other models makes our CNN model well-suited for perception tasks in self-driving vehicles. By providing an accurate and real-time understanding of the surrounding environment, our model can significantly enhance the

safety and efficiency of autonomous driving systems. In conclusion, our research introduces a powerful global image semantic segmentation network with impressive Mean IoU results and real-time processing capabilities.

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CLASSIFICATION OF DIABETES USING ENSEMBLE MACHINE LEARNING TECHNIQUES

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Abstract. Diabetes is a widespread chronic condition that impacts people all over the globe and requires a clear and timely diagnosis. Untreated diabetes leads to retinopathy, nephropathy, and damage to the nervous system. In this context, Machine Learning (ML) might be used to detect health problems early, diagnose them, and track their progress. Ensemble techniques are a promising approach that combines many classifiers to improve forecast accuracy and resilience. This study investigates the categorization of diabetes using an ensemble machine learning technique known as a voting classifier. Using a variety of classifiers, including Light Gradient Boosting Machine (LightGBM), Gradient Boost classifier (GBC), and Random Forest (RF). The predictions are aggregated using voting methods to get a final classification result. The research is carried out using two benchmarking datasets: the Pima Indian Diabetes Dataset (PIDD) and the German Dataset. The Boruta technique is used to choose the best attributes from the datasets, while the Random Over Sampling approach balances the range of classes and eliminates abnormal data using the interquartile range approach. The findings showed that the combination of the Boruta feature selection algorithm and ensemble Voting Classifier performed better for both PIDD and German datasets with an accuracy of 93% and 90% respectively. These algorithms are evaluated and the maximum accuracy is produced using the combination of the Boruta feature selection algorithm and ensemble Voting Classifier. This research helps medical professionals in the early prediction of diabetes, reducing physician's time.

Key words: Machine Learning, Ensemble Voting Classifier, Random Over Sampling, Diabetes, Gradient Boost.

1. Introduction.

Diabetes is a metabolic disorder characterized by elevated blood glucose levels. Insulin carries glucose from blood arteries to tissues, where it is converted into energy. The body of a diabetic patient is unable to produce enough insulin. Pre-diabetes, gestational diabetes, Type 1 diabetes (T1D), and Type 2 diabetes (T2D) are the four forms of the disease. In type 1 diabetes (T1D), the immune system of the patient targets and kills the insulin-secreting beta cells in the pancreas [1].

To manage these diseases, additional investigation is necessary. This research work discusses diabetes, one of the long-term diseases. In T2D, the patient's insulin production minimizes, causing high blood glucose levels. Recent researches indicate that 80 percent of T2D can be prevented with early detection.

Pre-diabetes is a term used to describe a condition in which blood glucose levels are elevated but not adequate to be classified as Type 2 Diabetes. Women with elevated blood glucose levels during pregnancy are referred to as having gestational diabetes. According to the International Diabetes Federation (IDF), India has the second-highest number of diabetic patients worldwide, behind China. There are currently an estimated 77 million diabetic patients in India, and that figure is predicted to rise to 134 million by 2045. According to statistics, 17.5% of world diabetic patients were in the Indian population. Diabetes must be treated as soon as quickly as possible to avoid its negative effects. Diabetes is an unsafe medical condition, hence it is critical to diagnose it using an automated technique.

The use of machine learning techniques to improve illness categorization and diagnosis has gained popularity in the medical business [2]. Many machine learning (ML) algorithms have been developed in recent studies for categorizing diabetes data, including Support Vector Machine (SVM) [3], Decision Tree (DT) [4], XGBoost classifier (XGB) [5], etc. But DT achieves lower accuracy due to imbalances in data and the absence of choosing features method. The SVM algorithm is prone to data imbalance, which results in low data accuracy when one

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group has greater samples than another. If the data includes outliers and missing values, the SVM approach may produce incorrect classification. The poor quality of data obtained from various sources reduced the effectiveness of the XGBoost classifier, resulting in the low accuracy of the model.

The primary purpose of this research is to identify efficient prediction strategies among the many machine learning approaches that can benefit healthcare professionals and hospitals. This work could act as a foundation for researchers interested in learning more about diabetes research. Presenting the right approach for handling missing values, outliers, and unbalanced data sets is the main goal of the proposed approach. It also concentrated mainly on selecting the best feature extraction approach 3 for identifying the most essential features, as well as introducing the suitable ensemble method for diabetes prediction. Light Gradient Boosting Model, Gradient Boosting Classifier, Random Forest, and ensemble voting classifier are utilized in this study to examine PIDD and German datasets. The research also includes an effectively structured assessment of the models used.

The structure of the article is as follows. Section 4 presents the proposed method, which comprises Interquartile Range (IQR), random oversampling, and ensemble ML classifier techniques. Section 2 contains the relevant study based on ML methods in diabetes classification. Section 3 explains the benchmarking PIMA and German datasets. Section 5 shows the performance evaluation of selected attributes, with a comparison to past approaches, and Section 6 concludes the research.

2. Literature Review. Several studies applied the ML approach to classifying diabetes using the PIDD dataset [6]. Mushtaq et al introduced a novel method to classify DM using ML techniques. Initially, the dataset was balanced using the oversampling strategy SMOTE, and outliers were identified using the Interquartile Range (IQR) technique. The accuracy and other performance indicators were then tested using several classification algorithms, including NB (Naïve Bayes), KNN (K closest neighbour), RF (Random Forest), and GB (Gradient Boost). In this research, the maximum accuracy of 81.5% was achieved for the PIDD dataset [7]. Rajeswari et al proposed the Logistic Regression (LR) and SVM to classify diabetes. Data for this research was collected from NC University. SVM achieved 82% accuracy for the training dataset and for the testing dataset, and it was 75% accurate. [8].

A technique using SDKNN for diabetes categorization was proposed by Patra et al. In this investigation, the PIMA dataset was used and they split the dataset into 90% training and 10% testing. An accuracy of 83.2% was demonstrated by the suggested SDKNN method [9]. Kumari et al proposed a diabetes prediction paradigm based on Decision Trees (DT). The author used 200 patient data from a medical health center and compared the DT with SVM, NB, and KNN. The experiment's findings reveal that the results of the DT are better than the other methods [10]. An ensemble approach was proposed by Saloni [11] to predict diabetes. This work uses the PIMA diabetes dataset. The dataset's data were divided into 70% training and 30% testing categories. The execution was done in the Python platform. The work utilized Gradient Boost, XGBoost, CatBoost, AdaBoost, SVM, NB, LR, and Random Forest. The result of the work shows that LR outperforms the other techniques.

Joshi et al. predicted diabetes using DT and LR. The experiment made use of the PIMA diabetes dataset. In this research, the significant features were selected using a classification tree and obtained a 78.26% accuracy rate [12]. A novel approach to diabetes prediction based on XGBoost and RF ML algorithms was presented by Barik et al. The PIMA dataset was used in the course of the research. The execution of the research was done in the Python platform. XGBoost algorithm performs better than the RF algorithm and achieves 74% accuracy [13]. GA hybrid learning method was proposed by Tan et al., [14]. This research used the collected dataset for diabetes prediction. The important features of the study were extracted using the DT method.

Azad et al suggested a diabetes classification method based on the PMSGD algorithm. The PIMA dataset was used in this research. The suggested model achieved 80.70% accuracy [15]. Singh et al introduced an evolutionary NSGA-II model for the classification of T2D. The research made use of the PIMA dataset and its implementation made use of MATLAB. The suggested method achieves an accuracy of 83.8% [16]. Numerous machine learning approaches and ensemble methods have been employed to predict diabetes, as the publications on this subject show, but none of these systems have been able to attain an accuracy of greater than 85% [17,18].

ML has currently endured extensive research to properly detect the presence of diabetes in its early stages. Despite improved accuracy, they failed to tackle bias handling, database balancing, outlier removal, and choosing essential diabetes attributes. As a result, it was evident that the result had not been verified because the

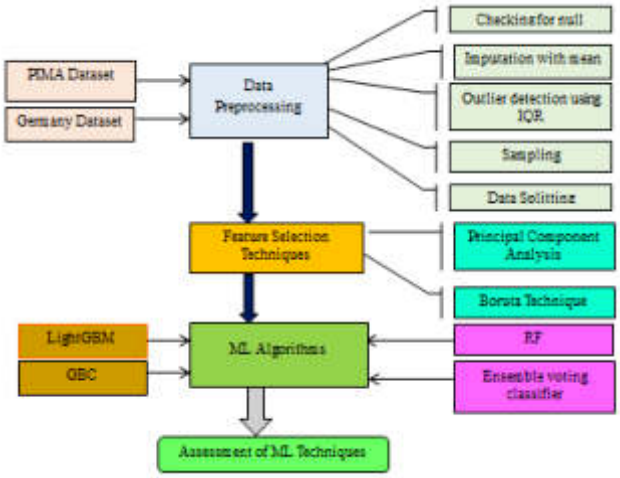

Fig. 4.1: Visibility approximation algorithm

presence of bias, an unbalanced dataset, and the lack of an attribute selection process would result in incorrect accuracy. Dealing values that are missing, concentrating on finding outliers, dataset balancing, and emphasizing selecting features approaches have been recognized as critical phases for diabetes classification investigation in the literature. ML models usually struggle to produce better results during the training phase when there are more missing values in the dataset. Detecting and working with missing data for every input attribute is an essential phase in the pre-processing step. Many survey studies on diabetes research reveal that ensemble models will produce better accuracy than common ML models.

The primary focus of the proposed approach is to provide a suitable method for handling missing values, outliers, and unbalanced data sets. It also concentrated mainly on selecting the best feature extraction approach for identifying the most essential features, as well as introducing the suitable ensemble method for diabetes prediction. Light Gradient Boosting Model, Gradient Boosting Classifier, Random Forest, and ensemble voting classifier are utilized in this study to examine PIDD and German datasets. The research also includes an effectively structured assessment of the models used.

3. Datasets. There are two different datasets used in the proposed research. They are Germany Dataset [19] and PIDD (PIMA Indian Diabetes Dataset) [20]. The NIDDK Center generates this dataset. It includes medical markers for blood pressure, body mass index (BMI), pregnancy, skin thickness, parent's history of diabetes, insulin, age, glucose levels, and results. The dataset comprises 769 imbalanced data values. Diabetes data was obtained by the hospital in the German city of Frankfurt and acquired via Kaggle.

4. Methodology. As shown in Figure 4.1, the model stream is divided into six phases. The entire model is implemented in Google Colab with the programming language Python. The proposed work is an appropriate technique for dealing with values that are missing, outliers, and data sets that are imbalanced. Also, selecting the best feature extraction approach for identifying the most essential features, as well as introducing the suitable ensemble method for diabetes prediction.

4.1. Data Preprocessing. The procedure includes loading and organizing data to perform training, validating, and testing. After importing the dataset, the shape of the dataset was verified. Duplicate rows from the datasets were identified and dropped. Through a procedure known as "imputation with mean," all of the datasets' null data were replaced with the mean values of the respective characteristics. To find the outlier, Inter Quartile Range (IQR) algorithm was applied to the data. IQR is a statistically dispersed measure derived from the difference between Q3 and Q1 in a dataset. It is less susceptible to outliers because it shows the distribution of the middle 50% of the data. Outliers are detected in the IQR method by taking values greater than Q1-1.5IQR and Q3+1.5IQR. When there are disparities in the dataset between the classes, the model

may be biased during training and perform well for the majority class but badly for the minority class. For this study, the Random oversampling strategy is chosen to solve the problem of class imbalance. Since random oversampling involves reproducing samples from the minority group. The model obtains its knowledge directly from the data and it is suitable for a wide range of ML techniques. The dataset has two sets of data: training and testing. 20% of the datasets are chosen for testing and 80% for training using the train test split function.

4.2. Feature Selection Techniques. It entails selecting the most relevant attributes from the dataset that have a positive relationship with the prevalence of diabetes. In this system, two feature extraction strategies are proposed: Boruta Algorithm and PCA (Principal Component Analysis).

4.3. Boruta Algorithm. Boruta creates shadow features that are compared to the importance of the initial features in the dataset. Utilized as a comparative tool is the importance of the shadow features, which stand in for data noise. The steps below are the process of the Boruta method.

Step 1: Create a new feature matrix. Each matrix feature, B, is used to generate the shadow feature matrix B_D. Merge the shaded matrix B_D to the original matrix B, to construct the new matrix Bn. Equation (4.1) gives the expression for B_n.

$$B_n = [B, B_D] \tag{4.1}$$

Step 2: Train the model using the newly generated matrix, B_n.

Step 3: Determine the Z-score of the largest shadow feature, D_{max} for the matrix N and the attribute matrix, N_D.

Step 4: Check the state to determine the important and unimportant features. If D_{max} is greater than the Z-score, then it is considered an unimportant feature, and the features in which the Z score is greater than D_{max} is considered an important feature.

Step 5: Remove all shadow attributes.

Step 6: Carry out the above steps until all of the important features have been chosen.

4.4. Principal Component Analysis. The PCA approach is used for dimension reduction and to generate related features to describe the type of data. All these elements are linear mixtures of the primary attributes, ordered by their capacity to incorporate the greatest variance. To use PCA in a database, the data must first be standardized for all features to have an even scale.

Mean centered, M_{cen} is estimated as (4.2),

$$M_{cen} = M - mean(M) \tag{4.2}$$

where M represents the dataset matrix.

The normalized data's covariance matrix (4.3) is then determined, and it indicates how distinct attributes vary from the other.

$$CV = \frac{1}{(m-1)} M_{cen}^T M_{cen} \tag{4.3}$$

where CV indicates the covariance matrix, and m represents the data.

The dimension of the dataset is reduced from m to l by maintaining only the top l components, while l is frequently much less than m.

4.5. ML Techniques. After being processed with feature selection methods, the dataset is fed to ML models. The following classifiers are employed in the proposed work: LightGBM, GBC, RF, and ensemble voting classifier.

4.6. Light Gradient Boosting Machine. LightGBM algorithm determines a function that maps the input features to the target feature. Gradient-based One-Side Sampling is an advanced method that is used to reduce the amount of data of the gradient boosting method. The objective function of LightGBM is expressed in (4.4).

$$OJ(V) = \Sigma_{j=1}^{m} n(z_j, z_j^{1^{u-1}}) + \Sigma_{i=1}^{D} f_i(x_j; V_i) + \Sigma_{j=1}^{D} \Omega(f_i) \tag{4.4}$$

where V represents the set of parameters to be learned by the ML algorithm, D denotes the number of DT in total, x is the input attributes and z represents the target attribute, n is the loss function. This method builds an integrated DT to estimate f(x) using a gradient boosting technique. To carry out the classification, the combination of DT is trained with x. Estimation of DT P_D and estimated values of DT P_p is presented mathematically in equations (4.5)-(4.6).

$$P_D = \Sigma_{i=1}^{D} \Omega(f_i) \tag{4.5}$$

$$P_p = \Sigma_{j=1}^{m} n(z_j, z_j^{1^{u-1}}) + \Sigma_{i=1}^{D} f_i(x_j; V_i) \tag{4.6}$$

Equation (4.7) expresses the loss function of LightGBM.

$$f(n) = \Sigma_{j=1}^{m} n(z_j, z_j^{1^{u-1}}) + \Sigma_{i=1}^{D} f_i(x_j; V_i) - Z_j \tag{4.7}$$

The loss function of the LightGBM classifier allows the method to find the variation between the predicted values and target values during learning.

4.7. Gradient Boost Classifier. Gradient boosting classifier (GBC) operates by building a collection of DTs, with each DT attempting to correct the faults made by the previous DT in the sequence. This algorithm's result is a sum of all the DT's predictions. Data taken for training is given in equation (4.8).

$$T = \Sigma_{j=1}^{N} (x_j, z_j) \tag{4.8}$$

An approximation function of GBC is expressed in the below equation (4.9).

$$A_r(x) = A_{r-1} + R_r H_r(x) \tag{4.9}$$

where R_r represents the weight of the r^{th} approximation function, $H_r(x)$. Pseudo value (4.10)-(4.11) is used to train $H_r(x)$.

$$T = \Sigma_{j=1}^{N} (x_j, S_o) \tag{4.10}$$

$$S_o = \frac{\partial f(z_j, F(x))}{\partial F(x)} \tag{4.11}$$

GBC constructs a predictive model in the form of a sequence of weak DTs and then incorporates their predictions to produce a more powerful overall model.

4.8. Random Forest. A hybrid machine learning method called Random Forest (RF) combines many DTs to generate predictions. The number of random DTs (4.12)-(4.14) is represented as follows.

$$R_r(x, T_r) = EO'[R_r(x, O', T_r] \tag{4.12}$$

$$R_r(x, O') = \frac{\Sigma_{j=1}^{m} Z_j(x_j \epsilon B_m(x, O'))}{\Sigma_{j=1}^{m} (x_j \epsilon B_m(x, O'))} 1E_r(x, O') \tag{4.13}$$

Here, the randomizing element is represented by O' and $B_m(x, O')$ denotes the rectangular cell of $R_r(x, O')$.

$$EO'[R_r(x, O')] = EO' \frac{\Sigma_{j=1}^{m} Z_j(x_j \epsilon B_m(x, O'))}{\Sigma_{j=1}^{m} (x_j \epsilon B_m(x, O'))} 1E_r(x, O') \tag{4.14}$$

The approach begins by randomly selecting a set of features and sampling the data. This classifier's DT uses randomly picked features to train every single tree. The Random Forest method generates an estimated output by gathering votes from all the trees.

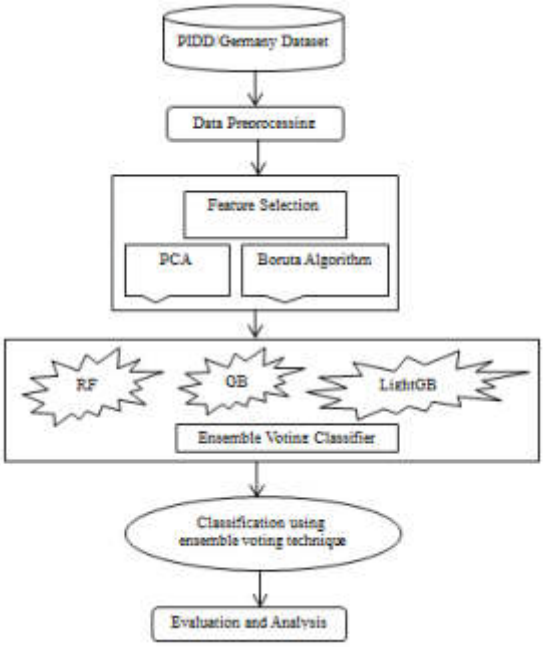

Fig. 4.2: Proposed ensemble voting method for diabetes prediction

Table 4.1: Parameters used for Experimental Analysis

Parameters	LGBM	GBC	RF
Step size	0.01, 0.05, 0.1, 0.2, 0.5	50, 100, 200	-
Maximum depth	3, 5, 7, 10	3, 5, 7	None, 10, 20
Number of estimators	50, 100, 200, 300, 500	50, 100, 200	50, 100, 200
Random state	-	-	42

4.9. Ensemble Voting Classifier. The voting technique employs a pair of voting methods: either soft or hard voting. In hard voting, the final prediction is determined by a majority vote in which the combiner selects the class estimate that appears most frequently from the models that comprise the foundation.

$$y = argmax_e(\Sigma_{j=1}^{M}||(I_j(Z) = e)) \tag{4.15}$$

where y is the voting algorithm's prediction, M indicates the total number of models, and e signifies the class label. $I_j(z)$ is the prediction of the j^{th} model for the input z.

Figure 4.2 shows the proposed model, which incorporates the Random Forest, GB, and LightGBM algorithms. A voting technique has been used to provide the probability of every targeted parameter. The initial training data and data points are then shuffled, and these data points are delivered to Random Forest, GB, and LightGBM techniques. The mathematical expressions of the performance measures are as follows. Table 4.1 shows the experimental parameters.

5. Result and Performance Evaluation. The proposed methodology combines three ML classifiers: RF, XGB, and LR with an ensemble voting technique. Experiments were conducted using the PIDD and Germany Diabetes datasets. To assess the ensemble voting technique's reliability and efficacy, accuracy, precision, and recall were assessed.

Table 5.1: Comparison of ML models for PIDD

Models	Algorithm	Accuracy	Precision	Recall
Light GBM	PCA	87	84	92
GBC	PCA	85	85	84
RF	PCA	87	85	89
Ensemble voting model	PCA	90	91	96
Light GBM	Boruta Algorithm	92	90	91
GBC	Boruta Algorithm	89	88	90
RF	Boruta Algorithm	90	91	92
Ensemble voting model	Boruta Algorithm	93	91	96

Table 5.2: ML model comparison for the Germany Diabetes Dataset

Models	Algorithm	Accuracy	Precision	Recall
Light GBM	PCA	87	80	93
GBC	PCA	84	82	88
RF	PCA	86	82	93
Ensemble voting model	PCA	88	83	95
Light GBM	Boruta Algorithm	89	85	95
GBC	Boruta Algorithm	88	88	95
RF	Boruta Algorithm	88	87	96
Ensemble voting model	Boruta Algorithm	90	85	97

$$Accuracy = \frac{TruePositives + TrueNegatives}{TruePositives + TrueNegatives + FalsePositivies + FalseNegatives} \tag{5.1}$$

$$Precision = \frac{TruePositives}{TruePositives + FalsePositivies} \tag{5.2}$$

$$Recall = \frac{TruePositives}{TruePositives + FalseNegatives} \tag{5.3}$$

Table 5.1 describes the comparison of ML algorithm results for the PIDD dataset. It shows that the Boruta algorithm and ensemble voting approach outperformed all other machine learning models with an accuracy of 93%. Figure 4.2 shows a comparison of ML algorithm outcomes for the German diabetes dataset.

Table 5.2 shows that the Boruta algorithm and an ensemble voting approach beat the German diabetes dataset. It achieved the highest accuracy of 90% when compared to other machine learning models.

In this study, diabetes was predicted by handling missing values and outliers, rebalancing the data that was out of balance, and selecting the best feature selection technique to extract the important characteristics (BMI, blood pressure, etc.) from the dataset. Next, by evaluating the performance of suitable ML techniques the reliability of models will be tested. The proposed model was compared with the existing research works. Table 5.3 presents the comparison, which shows that the proposed method outperformed prior diabetes prediction studies in terms of performance.

6. Conclusion. The proposed research determines the greatest accuracy and methodology for predicting patients with diabetes. The ensemble voting classifier technique is used in the proposed system. It is based on the combination of three ML models: Random Forest, XGB, and Logistic Regression. The PIDD was used for testing a proposed method and the developed model was also applied to the Germany diabetes dataset.

Table 5.3: Comparison of other diabetes prediction models

ML Classifier	Accuracy
SVM [8]	75%
KNN [9]	83.2%
DT [10]	73%
DT [12]	78.26%
XG Boost [13]	74%
DT [14]	85%
PMSGD [15]	80.70%
NSGA – II [16]	83.8%
Soft Classifier [11]	79.08%
Proposed model - PIDD	93%
Proposed model - German Dataset	90%

Comparing the Precision-recall curve with the ROC curve, the proposed method performs better. The ensemble voting Method has achieved 93% accuracy on the PIDD and 90% accuracy on the Germany Diabetes Dataset. The overall investigation of this research shows that the proposed ensemble voting classifier can be used for both PIMA and German Diabetes Datasets. This proposed system can be improved by introducing various deep-learning techniques.

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AN AI-BASED CLASSIFICATION AND RECOMMENDATION SYSTEM FOR DIGITAL LIBRARIES

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Abstract. The immense volume of online content linked to digital libraries has given emergence to the advancement of screening and recommendation systems. A recommendation system is vitally important in both academic institutions and e-libraries to assist professors, instructors, students, and researchers in finding appropriate sources of information. Distributed or collaborative screening is the most common method used in current recommendation systems. However, collaborative approaches cannot promote library repositories, including unrated or unpurchased electronic information. Thus, this paper deals with the automated classification and recommendation of a multiclass corpus found in virtual repositories (cloud databases). In various stages, Neuro-Fuzzy (NF) and Support Vector Machine (SVM) techniques are used as the base classifiers for the categorization of the essential subjects (contents). Later, a high-level ensemble learning strategy is utilized to recommend appropriate subjects from the available multiclass corpus. The methods use a CoC (Coherence of Content)-based inference mechanism to extract and filter the critical components before beginning the recommendation process. Experiments demonstrated that a recommended approach based on detailed conceptual descriptions instead of a handful of phrases/words might help academic and research communities to find relevant sources. Observing the results over a period of months shows that the suggested method increases user comfort, proving the system's acceptability to users in this way. In addition, compared to previous models, the accuracy in categorizing the requisite subjects is more than 97.16 per cent.

Key words: Digital Library, Accuracy, Cloud service, e-content, Webpage, Classification.

1. Introduction. Regular library services are migrating to the digital platform enabled with Internet service. All sorts of data are stored virtually in digital repositories that usually include user information such as profiles, reference histories, and document details, as well as users exploring and accessing log files and cataloguing information. The vast majority of the data is handled exclusively for user queries. Moreover, the usage of Web services to obtain information appears to be on the rapid rise. Consequently, digital libraries and Internet searches for library materials are becoming more popular.

Clearly, the Digital Library (DL) is a complicated domain in which a significant number of various disciplines, as well as specialties'', congregate with multiple attributes evident through its standard data structure. As a result of its interdisciplinary characteristics, the term "Digital Library" has evolved to symbolize diverse things to different people, each with its own unique viewpoint [1, 2]. The critical repercussion of this diversification is that, for the past decade, a significant number of DL systems were constructed in a sensible manner using specialized approaches that have been gained by integrating concepts drawn from many other sectors. It is remarkably complex to build DL systems that can be shared, reused, and developed collaboratively using a methodology that results in many disparate entities and unique processes for handling the required contents.

Most of the DL society has expressed the necessity to engage in DL system designs and create generalized DL management platforms with all the main elements that seem vital in enabling the complete scope of DL activity in many conceivable situations [3]. For this reason, DL management platforms should have features that address both general problems and the common elements used in several diverse issues. Aside from this consideration, its architectural design must be flexible enough to accommodate the specific needs of any given environment [4].

DL improves the capabilities of remote and virtual learning services [5]. The virtual learning approach illustrates that such infrastructure can be used to provide a diverse array of advancements to anyone's skill set.

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A wide range of virtual or e-learning materials from the DL system can be obtained, including e-documents via advanced web services, virtual communities, plus hypermedia. Most of the core components of DL are research/educational resources that can be shared across a variety of technological platforms. Formative assessment, corporations, federal agencies, entities, residences, and hubs of communal locations are all included in the domain of DL systems. DL could well be utilized to increase the efficacy of background and academic approaches to societal, technological, and research demands by instructors of host programmes [6].

Many researchers have identified the following advantages of DL based on the e-Learning paradigm [7]:
- In-depth training in innovative and collaborative learning with a continuous enhancement for participants.
- Enhanced capacity for information acquisition, expression, and comprehension.
- Learners' long-term drive to learn about complexity and collaboration, as well as their ability to examine critically and creatively.

On the other side, DL users can benefit from specific suggestions (recommendations) to retrieve required documents from a vast repository. In a conventional DL system, a user could search for a particular term and get outcomes based only on the terms entered. In this case, the user would have a hard time finding essential documents that weren't related to the search queries. The document recommendation service provides the user with a variety of possible contents of DL that are centred based on their own interests, lending records, or the identities of other users having similar interests. This enables users to find interesting documents they may not have previously fed as input terms. Since current DL users are likely to lend more significant numbers of documents, the new users will likely utilize the platform; the library administration can expect an increase in document checkouts. The amount of documents circulated in the larger society and the advancement of knowledge has made it more difficult for the DL to arrange and operationalize the soft contents. For this reason, it is vital to analyze the user's identities (profile) and associated metadata (queries applied, content demand, and so on) in order to predict their interests. Thus, such kinds of predictions and recommendations are possible using Smart Recommendation Systems (SRS).

1.1. Need of SRS for Digital Libraries. Smart Recommendation Systems (SRS) play a crucial role in various aspects of DL systems. They cater to the needs of both customers and businesses by providing personalized recommendations. These systems collaborate with diverse archives and repositories, offering users valuable suggestions based on their past preferences and sentiments. With the rapid growth of the internet and platforms like Twitter, Amazon, and Facebook, users now have a plethora of options to share their expertise, facts, and opinions. SRS helps manage data overload and facilitates multi-user relationship governance. It is widely beneficial in sectors such as e-library, e-regulators, e-business, and e-multimedia, aiding in cataloging management and knowledge representation techniques.

According to [8], an SRS may assist users in defining their interests, locating appropriate content, and aiding in interactive study activities. In current history, RS has established itself as a unique instrument that may be used to address the issue of data overload. When it comes to solving such problems, the role of recommendation systems is crucial [9]. RS may help users discover new, previously unknown content that is relevant to their present work. Users benefit from using RS because they assist them in locating required content that is not available elsewhere. Yet, many crawlers use RS to filter and locate non-conventional content. In 1990, JussiKarlgren, a professor at the University of Columbia, introduced a "Digital Bookshelf", in 1990 was the first reference to (RS) [10]. Subsequently, a number of notable specialists have added their insights. A significant amount of technical progress has been made during the RS conceptual transition. The recommendations that are made via DL systems must abide by the users' fundamental requirements [11].
- Users' prior knowledge.
- The system incorporates conceptual ideas.
- Information is needed to build a framework of conceptual understanding.

1.2. Categories of SRS. There exist a few significant categories of SRS; they are collaborative filtering, content-based filtering, and hybrid filtering. Therefore, gaining the base knowledge of all the filtering RS is essential. The classification of different filtering RS is depicted in Figure 1.1.

1.3. Content-Based Filtering RS. Contentcentric Recommendation Systems (RS) analyze the client's interests and offer tailored recommendations based on individual preferences. These RS store data from pre-

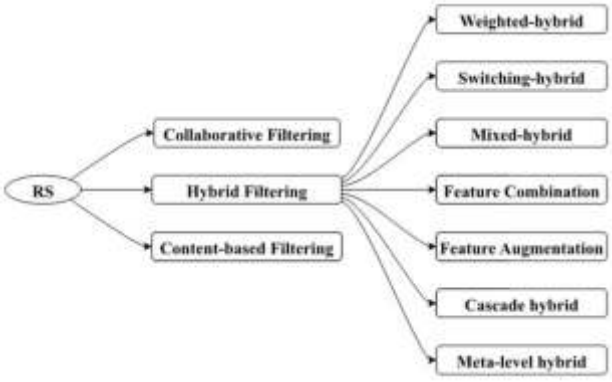

Fig. 1.1: Various RS Filtering Techniques

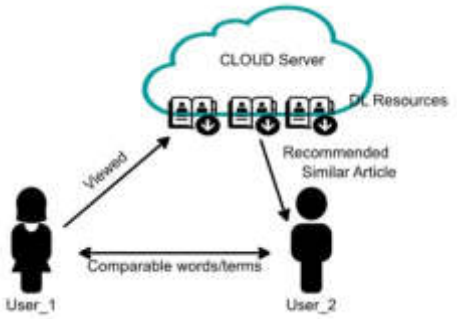

Fig. 1.2: Content-based Filtering RS

vious tasks in the user's record, providing a diverse range of entities and resources. Content-based filtering is extensively used to filter recommendations by focusing on the user's past records and the core content of documents shown in Figure 1.2. The dataset, consisting of phrases or words forming a narrative, is created by identifying comparable words/phrases and splitting the viewed content. The process of substance-based segregation involves identifying words, distinguishing them from referred items, and establishing a hierarchy of intellects to consider user logs and provide personalized recommendations. Content analyses are often used as the primary data source, and term breakdown from user reports is a common procedure. Phrases represent incident reports as feature variables in a multi-dimensional space using word vector representation and passive semantic sorting.

A user's logs or records can be incorporated via a range of techniques, including significance critique, inherited computations, neural networks, and probabilistic classifications. In addition, record-based communication methods can use word vector representation and passive semantic sorting.

1.4. Collaborative Filtering RS. When a method falls under this category, it seeks to align a user's natural tendencies toward the interesting content with prior user actions. A vast proportion of user interactions, assessments, reviews as visitants and other forms of activity are analyzed before a consolidated server is delivered. At this step, it looks to see whether the user's perception is similar to that of another similar kind of user or neighbor. The basic premise of collaborative filtering is that a user could choose a privatized document's contents if another observer enjoys it just as much as they do. The recommender efficiency in a deriving technique may therefore be described as "people like you also viewed/referenced similar content" as a frame of comparison. Such systems are now widely utilized and have been shown to be quite effective for exploratory

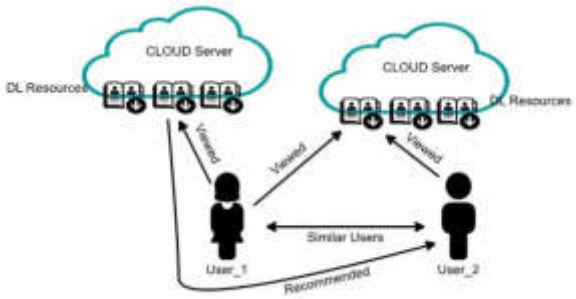

Fig. 1.3: Collaborative Filtering RS

searching and hence have risen in the marketing rating. To perform well, the platform needs an enormous amount of user-generated information-rich paradigms with the motivation of serving specific ideas. Because of the shrinking quantity of data, collaborative filtering is unable to discover the required content that nobody has looked at. In order to reduce the amount of frosty data points, various RS incorporate default procedures into the user experience, for example, by integrating them as the main page or adapting them into base content-building. While collaborative filtering can produce fresh, high-quality ideas, it needs some user information to recommend suitable content. It's much more challenging to use it on websites that don't need a user to log in. Figure 1.3 depicts the concept of the collaborative filtering technique.

1.5. Hybrid RS. Hybrid RS is a strategy that combines the best features of many different RS in order to meet the distinct requirements and concerns of a specific user. In particular, it provides numerical and statistical processes to demonstrate the optimal recommendations for user requirements. A mixed or hybridized RS tool that integrates a minimum of two recommendation methods is more likely to perform well than the other RS that relies on just one. Most of the time, neighborhood filtering data is acquired in conjunction with another technique in an effort to avoid the escalation of other problems.

Weighted-hybrid RS: Each model's outcomes are combined to provide a weighted RS that does not alter in weight between the training and testing sets. One benefit of using the weighted RS is that it lets users combine different approaches to help the available facts in a way that is additive (linear), especially during the recommendation phase.

Switching hybrid RS: Depending on the scenario, the switching hybridization uses a single RS. Users must configure the decision support eligibility requirements as per available patterns or other information to build the model for the component-level sensitive database. This strategy adds a new layer to the RS, which chooses the best model to use.

Mixed hybrid RS: A mixed-hybrid strategy begins by generating a range of potential datasets based on the user's portfolio and characteristics. Consequently, the recommendation engine receives various possible inputs, which are then used to integrate the predictions to arrive at a final suggestion. This RS model is capable of producing a high series of recommendations concurrently and sometimes adapts to the fragmentary information with a suitable model to improve its performance.

Feature Combination hybrid RS: In a feature combination hybrid, the user adds a virtualized contributory prediction algorithm to the recommendation framework to perform as a component synthesizer concerning the initial user record set. For instance, collaborative features can be added to a content-based approach. Furthermore, this model can take into account the information from the suggestive module, so it doesn't have to depend on just one model.

Feature Augmentation hybrid RS: A feature augmentation hybrid strategy is utilized to establish a ranking or categorization of the client portfolio that is subsequently incorporated into the primary RS to predict the overall result. No significant changes are made to the basic recommender systems when using a feature augmentation hybrid, yet it still enhances the system's predictive performance.

Cascade hybrid RS: In the case of cascade hybrid RS, the principal RS is responsible for delivering the primary

outcome. Later, the system is allowed to utilize the auxiliary model to address trivial concerns, like dissolving a deadlock in the score. Thus, the model exhibits a hierarchical-based operational mechanism. Also, when most datasets are small, the auxiliary model can help deal with problems like not enough data or scores that are almost the same.

Meta-Level hybrid RS: This type of hybrid RS bears some resemblance with the functional procedures of feature augmentation in the sense that the contributory engine supplies the primary recommender system with an enhanced dataset. But unlike feature augmentation, the input feed to the primary recommender model is replaced by an alternative model, which is seen as a learned contributor model.

However, any method can only provide recommendations for the viewer depending on the preferences that they already have. That is to say, the system is unable to go beyond the preferences already expressed by the users. As a logical consequence, the intention of this study was to examine the most emerging trends in machine learning (ML) due to their high suitability for the content recommendation processes in DL systems. The area of ML is most rapidly expanding in the computing industry. They are a component of artificial intelligence that was developed to offer systems some characteristics of human intellect. They build analytical models to make inferences and forecast results based on testing facts that they learned. Because of their precision and effectiveness, they have been used in a wide range of data processing and predictive activities. Such new technologies have enhanced recommenders' prediction and accuracy.

In this work, an ensemble learning (ESL) technique is used to identify suitable content areas from a multi-labelled archive, which is organized into two stages. The Support Vector Machine (SVM) and Neuro-Fuzzy (NF) approaches provide the basis for the initial stage (first-level) of ensembling. In contrast, the stacking ensembling approach is the central part of the second stage. Extracting and filtering all relevant data from a repository is a necessary step before the commencement of recommendation procedures. Thus, for that purpose, we utilized CoC, which performs conceptual filtering rather than focusing on individual keywords. It also works with the rationale and suitable categorization of queries/requests and relevant content (all associated digital content) to provide valuable and intelligible information.

1.6. Research Motivation and Contribution. In digital learning systems, learner preferences and habits are considered when delivering services. However, the focus on individual abilities is often overlooked in recommendation methodologies. Some learning techniques overload users with excessive linkage patterns, creating information burdens. The main research concern in online learning is the lack of a proper Recommendation System (RS). RS can provide recommendations based on user cooperation and offer some control over preferences, but there is also a need for regulation. This work proposes a smart recommendation system (SRS) that considers user abilities and preferences for online and offline complexities of digital learning content. It introduces an ESL technique to recommend suitable difficulty levels based on user traits from a large pool of data repositories. Observations suggest that this recommended RS has the potential to yield excellent results, facilitating efficient information retrieval for users and learners. The prominent objectives of the research work are,

- To increase the precision and dependability of content suggestions for readers and researchers using Ensemble Learning Strategies (ESL) to boost the performance of recommender systems (RS) in digital library settings.
- To enhance and verify the efficiency of the ESL-based digital library system, we will conduct thorough testing using a variety of datasets. Our goal is to minimize error rates, such as fallout, and achieve high accuracy. This will ultimately enhance user confidence and streamline accessing pertinent data from a wide range of digital content.

The entire article is organized in such a way as to make the reader understand the core concept of the work and to lead them to the future research process. Section 2 delineates the relevant work that has been carried out in recent times and identifies the research gap. Section 3 outlines the preliminary knowledge required to implement the proposed model. Section 4 elaborates on the core mechanism of the proposed methodology with sufficient information. Section 5 discussed the impact of model performance regardless of the objectives and explored the observation to the maximum degree. Section 6 summarizes the endnotes of the research work with possible future work.

2. Relevant Studies. As suggested [12] a paradigm for recommending individualized learning materials to students based on the specification and credibility of information. An investigation with the model indicated that obtaining resources that were appraised favorably increased the learner's contentment when esteem information was used. [13] also developed a collaborative filtering-based item RS. Search engines and content processing were reduced in complexity by using LDAP (Lightweight Directory Access Protocol) and JAXB (Java Architecture for XML Binding) approaches.

Using genetic computations [14] and a few additional suggested strategies, the preliminary model outperforms the previous techniques in obtaining data via Google Maps. Furthermore, with the use of bio-inspired grouping approaches, experts have been able to discover the best possible suggestions for a given grouping system. Different methods have been used in the past to solve the grouping problem, but now bio-inspired procedure requirements are being set up to make better recommendations.

To generate suggestions, investigators [15] used a technique focused on client grouping to examine "m" individuals as well as "n" objects. A K-means categorization strategy is also used to classify the visitors based on their preferences. Finally, it creates a suggestion using a brand-new technique called the voting process. A novel collaborative screening method is tested against a conventional approach. The findings have shown that the method is not only faster but also produces an outcome with higher precision than it was before. In this case, the phasing of the content is critical to creating more effective and tailored electronic learning systems. As compared to a traditional, unsorted series of learning resources, collaborative filtering that is more successful will provide recommendations for an instructional process that is referred to as the study route. This learning series needs to be in an appropriate sequence and include both a beginning spot and a concluding spot. Moreover, a proposed sequence must be tailored to the study interests of the participants, in particular, to boost their competence to gain knowledge. In addition, the duration of this sequencing is not cast in concrete for all participants since individuals vary in variables such as their degree of expertise, the preferred method of studying, and emotional state at any required time.

For e-learning via digital platforms, researchers [16] utilized a variety of strategies that have been examined to implement the recommendations that seem to be tag-based. Depending on vector (tensor) discretization and a refined method, a model ordering (ranking) was devised for generating efficient suggestions. To reduce the processing time as well as resource utilization while ensuring the integrity of the recommendations, this research work also advocated shrinking the tag range and using a grouping approach that relies on a preferred learning concept.

Introduced a novel [17] varying length optimization approach that has been employed to represent the Instructional Route RS that is utilized for digital learners. This representation considers the varying learning patterns as well as the different degrees of expertise. The research's outcomes confirmed the better efficacy of Instructional Route RS in a digital learning context. The RS is useful in improving user engagement. Only recently, the strategies adopted by [18] have suggested the Bat Computation methodology, which is intended to estimate the scores of the objects (or attributes) to determine a preferable neighborhood for proactive users. In conclusion, it was found that the intuitive techniques offered scores for numerous factors in order to produce tailored suggestions. By comparing the framework's functionality with the existing methods, it is proved that the BA scored 6.9 percent higher on mean absolute margin and an F1-measure. Furthermore, user interests in various contexts are taken into account by contextually sensitive RS. Whenever these methods were being designed, the absolute priority was to preserve the credibility of recommendation engines and drastically reduce the intrusions of prejudiced users that impacted the mechanism and its conclusion. Additionally, the core target was to reduce the number of skewed users. Besides this method, techniques exist for detecting malevolent users in various situations and contexts.

The research work of [19] exhibits the k-means grouping and bio-inspired strategies, which were used in a novel hybrid approach for a unique hybridized recommender method tested on the sample set of Movie lenses. This new deterministic approach obtained good results in the aspects of scalability and versatility. It made tailored film recommendations and made the cold-start problem easier to deal with.

An efficient method for selecting essential features has been devised by the authors of this research work [20]. This method is used in two different versions centred upon Artificial Bee Colony (ABC) employing Genetic Algorithm (GA) as well as (particle swarm optimization) PSO, respectively. These models are referred to as

the ABC-GA and ABC-PSO variants. Improvement procedures of the ABC approach have been included to achieve a perfect blend between extraction and investigation. Because of this, a subset of features was deemed to be effective in regard to precision throughout the experiment. Furthermore, web 2.0 content can now be accessed and organized using a new mechanism known as tag grouping. Therefore, this methodology could be used for efficient social labelling/tagging activities.

Implemented [21] an artificial intelligence-powered open-source conversational software platform named Rasa. The researcher advised its potential adoption by libraries as the author introduced the core of chatbot technology to apply to day-to-day / daily library applications. Further, the researcher concluded that AI-based conversational software have need of more profound investigation in order to perfectly study and emulate human conversations; it, however, has limitless controls to prompt action-packed services and to function in a way to satisfy the patrons of the library.

Introduced [22] a new working mechanism where a competency assessment was used to verify the students' behavior and academic abilities, and the assessment results were used to develop study materials. Tailored Ranking (page) and the Adaptive Knowledge Scheme, both of which use real-time personalization, provide the backbone of this approach. In the event, the Navy's Bayes predictor was used to categorize the students based on their performance on the competence exam. High-skilled users are given cutting-edge materials, whereas intermediate and novice users get less advanced materials. All of these factors are considered when evaluating how the students performed.

Collaborative Filtering and Content-Based Filtering, as well as Hybrid approaches in recommendations, are the commonest. The Content-Based technique relies on the user's plan as a guide. The previous operations, such as user rating, are practiced by Content-Based-based systems without the inclusion of user input. Hybrid approaches combine Collaborative and Content-Based Filtering procedures to achieve the best outcome [23].

In online learning [24], a Hybrid Action-Related K-Nearest Neighbor Similarity (HAR-KNN) recommender was suggested, which centralizes the efficiency of hybridization processing to enhance user activity lattice by generating the matrix of attributes. Race classifications will be used to sort the characteristics according to their quantity as well as performance. The suggested technique also overcomes the issues of the prior approaches in assessing user preference on items and balancing attribute evaluation effectively. When it comes to determining user usage statistics that correlate to certain user groups, the actual and digital content using the K-NN classifier has been shown to be an effective tool. Outliers and prediction metrics are used to assess the intended empirical outcome.

Successfully [25] extended the intellectual notion of RS to create a revolutionary SRS. Recommendation procedures are selected based on a hybrid strategy that incorporates and handles all critical data and individual recommendation requirements. Combining interactive filtering, information, and expert techniques is feasible with the hybrid version. Using four components, the data is filtered: the scenario, learners, curriculum, and digital materials; determining factors like socioeconomic factors; link traits; locale; and individualized learning preferences. Trials were performed to develop a curriculum to examine the architecture's intellectual ability and autonomy.

Have focused their [26] research on expertise learning trajectory recommendation strategies that do not produce multimodal instructional routes to meet various learning requirements in reality (in the real world). For this reason, a paradigm that recommends studying paths relying on multivariate domain knowledge is being developed. This approach maintains knowledge items independently and organizes them into several groups. The information graph then suggests six significant conceptual relationships among various learning items. Another method is to use multivariate knowledge base architecture to develop and offer tailored learning pathways depending on the e-target learner's training objective. This approach is referred to as the test pattern recommendation approach. The results of the research show that a system based on the data collected during the experiments can make and suggest good learning paths for online learners that are both competent and relevant.

As per the research work of [27], an iterative approach with content-based technique and vector decomposition features is used in a blended system to improve the resilience of cooperation filtering. Furthermore, the authors develop an incremental assessment technique for actual statistics while researching to test the outcomes. The report's hypothesis outcomes indicate that the highlighted blended system can be developed as a potential

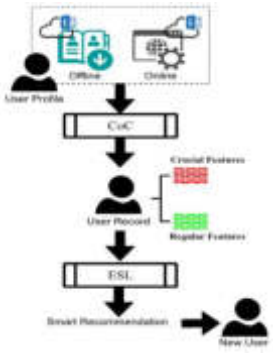

Fig. 3.1: RS Process Flow

research route. The presented method achieves superior outcomes in terms of both gaining knowledge rate and effectiveness.

Multi-label k-nearest neighbor (ML-KNN) and classifier chain k-nearest neighbor (CC-KNN), combined with latent Dirichlet allocation (LDA) implemented in order to avoid manual classification [28]. The researchers pointed out that manual classification is a time-consumption and expensive as the number of patent documents is increasing day by day. Further, researchers specified strongly that automated classification is indispensable to avoid such complicated assignments. According to the authors, the Automated classification harvests precise outcomes and based on it; they implemented quoted the above two algorithms.

Studies show that content phasing has a significant role in creating more effective and tailored RS. RS should propose a knowledge pattern through the preferred route, which must be in a reasonable order coupled with an appropriate beginning and finish point. The central objective of this research is to develop perfect RS for newcomers about how to use RS for reporting preferences in the existing DL models.

2.1. Summary of Research Review. Many RS do not allow for a tailored ecosystem to provide referrals to a population of learners focused on individual needs and their ability to encourage smart studying; this is a serious shortcoming. Giving learners/DL users relevant and reliable information is frequently a fundamental difficulty in DL systems. Huge data computation and code generation are required to handle complexity, training rate, and integration of enormous amounts of information with proper correlation to satisfying the demands. Any suggested system should proactively recommend substantial supplies to the user to increase the usability of DL. Personalization of RS via reactive training layout and tailored content are two of the most exciting aspects of any upcoming approach.

3. Methodology. The phrase ”Digital Library-DL” is commonly alluded to as ”e-library”, attributed to the reason that digital content distribution and its acquisition or digital repositories are sublines of the online platform of digitized objects. Such objects include text, static visuals (images) in various formats, multimedia content, and digital data accessible over the cloud services. The advancements in cloud computing have breathed fresh life into the process of creating digital libraries. Researchers have developed an RS for digital libraries that considers the unique needs of each user and actively sends the most relevant information based on their preferences. In order to achieve this, the library’s volumes, techniques, search documents, periodical documents, and other data repositories must be combined with the user’s patterns and preferences. In addition, users’ personal information and related procedures can be stored on the cloud infrastructure.

Usage records are employed to build user records that are maintained in either cloud-based virtual repositories or on-premises. Log files are used to store actual facts and essential data on visitants’ activities in DL, including both static data and dynamic web-oriented information. In addition, retrieving the necessary information takes time and constitutes a complicated procedure for DL users. As a practical issue, the recommendation engine forecasts the user’s interests and recommends the most relevant material as a result. In this regard, creating a user record, collecting data needed to develop a suitable RS, and retrieving and filtering

Table 3.1: Key Features of the Digital Library Datasets

	Features	Offline Log Files	Online Log Files
Regular Features	User Components (user ID, catalogue numbers)	$U = \{a_1, a_2, \cdots a_n\}$	
	Average page time	$\mu_{p_t}(f_p)$	$\mu_{p_t}(f_p)$
	Average Site time, $S = \{w_1, w_2, ., w_n\}$	-	$\mu_{s_t}(O_s)$
	Average visitant counts/Preference Count	$\mu_{V_t}(f_V)^{p_i}$	$\mu_{V_t}(o_V)^{p_i}$
	Exit Rate, E_r	-	$\sum_{U=1} l/\tau$
Crucial Features	Average page rank	-	$\mu_{R_t}(O_R)$
	Frequent content terms accessed at P_i	$\sum_{i=0}(F_t)^{f_p}$	$\sum_{i=0}(F_t)^{O_p}$
	Mean similarity among various content terms	$\mu_{\delta(c_1,c_2,\cdots,c_n)}[f_p]$	$\mu_{\delta(c_1,c_2,\cdots,c_n)}[O_p]$
	Mean of Frequent term utilized among various users	$\sum_{U=1}^{N}\mu\left(F_t^{f_p}\right)$	$\sum_{U=1}^{N}\mu\left(F_t^{O_p}\right)$
	Bounce Rate, B_r	-	$\sum_{U=1}\xi/\tau$
Total Instances		8134	1562
Total Instances per classes		10%	10%
*'a' denotes components, 'f' and 'O' denote offline and online log files			

pertinent data are always perceived as crucial. A CoC inference system is used to extract and select the required content in this model. The suggested RS process flow is shown in figure 3.1.

Three content-rich datasets are incorporated in this work to train the proposed RS model. The datasets are obtained from [29]; Cuneiform Digital Library Initiative, (n.d.) [30]; and Book Recommendation Dataset, (n.d.) [31]. All three datasets contain the required digital library component, comprising metadata, multidisciplinary literature under various catalogues, content ratings, user profiles, etc. As an initial process in the proposed RS, the appropriate information is extracted and filtered from the considered datasets using the CoC inference system. Then, CoC utilizes logs/records files from the datasets to filter the required content. Finally, the log/record files are created based on the access history, user's interests, and standard access phenomena in a unique database.

Digital library log/record files are stored and accessed via a cloud platform which is enabled with internet service. Thus, the files are viewed in two aspects: offline and online log/record files. The offline files are stored files, whereas online files are dynamic files accessed via the internet, and the associated log/record files are periodically updated. During the extraction process, a few prominent features of both offline and online log files are considered. Those notable features are represented as regular and crucial features. Table 3.1 illustrates the key features and their description, which all influence the training process of the RS model.

Bounce rate estimates the number of users departing a webpage (T) without accessing it in any manner (cumulative one-page visit, ξ). Exit rates measure the proportion of visitants (T) who departed the webpage after seeing a specific page (l), regardless of the number of webpages they had previously seen in the particular session.

In the process of creating a user portfolio, a strength component (ψ) is allocated to each class of features. Selective traits are given more strength by adding additional values. This tends to boost the precision of RS. The proposed system employs a ψ value that ranges from 0.0 to 0.1. The configuration of ψ in the described approach varies based on the available features, which are stated as follows:

- ψ is specified as 0.1 for the most crucial features (significant elements) of a user record in an attempt to boost its impact during the recommendation process.
- ψ is specified as 0.5 for the regular features of a user's record. The act of boosting with this strength nominally powers its impact during the recommendation process.

3.1. CoC Inference Process. CoC is the degree to which terms within a phrase or sentence are coupled to form connotations. In this way, it's connected to the formal principle of coherence. The cohesiveness ratio

is the totality of the relationships (similarities, δ) among all terms of content divided by the overall amount of possible terms of content. Considering a content that contains 'n' terms, the formal definition of the degree of correlation between two terms of that content, C_i and C_j, which refer to different sets of terms, T_i and T_j, respectively, is expressed as in equation (3.1),

$$\delta\left[\left(\mathbb{C}_i\right),\left(\mathbb{C}_j\right)\right]=\left\{\left|\left(T_i\right)\cup\left(T_j\right)\right|_{/\mathbf{n}}\right\}\cdot\left\{\left|\left(T_i\right)\cap\left(T_j\right)\right|/\min_{(}\left|T_i\right|,\left|T_j\right|\right)\right\} \tag{3.1}$$

The next level of the proposed procedure deals with the user's record that comprises preference factors and computations of CoC strength factors as input feed to the ESL model. As mentioned earlier in section 1, the proposed RS includes two ensemble processing stages, wherein the first stage employs the NF model and SVM techniques as the base classifier for recommending the preferred contents in the DL system. Later, utilizing the outcome of the first stage, the second stage, signifying ensemble technique, computes the available data and produces the optimal recommendation to the user, which is delineated elaborately in section 4.

In this section, a smart Recommendation System (RS) has been developed for digital libraries, considering user needs and preferences. User records, including personal information and browsing history, are stored either on-premises or in cloud-based repositories. The RS process involves creating user records, filtering data, and using a CoC inference system to extract content. Key features like page rank and frequent content terms are considered. The RS utilizes ensemble processing stages to recommend preferred content in the digital library system.

4. ESL Model. To improve the effectiveness of recommendation systems, techniques based on complementing the thematic information datasets are needed to be used. Thus, in this section, we elaborate on the core process of the ESL mechanism in recommending the appropriate content to the user in the DL platform. Out of two stages in ESL, the first stage comprises SVM and NF techniques for recommendations.

4.1. SVM in RS. Few studies have addressed the utilization of an optimized SVM concept for recommendation tasks. [32] presented the SVM, a revolutionary ML concept for learning digital content. In current history, the computing of SVM has evolved as one of the most powerful strategies for predicting and categorizing class labels. The SVM learns a splitting hyper-plane in order to optimize the error gaps and achieve high generalization. Many applications of the SVM have been practical recently, yielding impressive outcomes.

Kernel operations and computational processing are two critical components of SVM's deployment in RS. A non-linear separation plane in the high-dimensional feature space is created by employing kernel operations. Suppose the cost of computing the kernel functionality is comparable to that of computing the input space. In that case, a non-linear intervention of this kind does not result in an improvement, especially in the computation complexity. SVM makes use of a polynomial equation to deal with the input feed of digital content that can be expressed as in equation (4.1),

$$\rho\left[\left(\mathbf{a}\mathbb{C}_i\right),\left(b\mathbb{C}_j\right)\right]=\left[\left(\mathbf{a}\mathbf{C}_i^T,\mathbf{b}\mathbb{C}_j\right)+\boldsymbol{\beta}\right] \tag{4.1}$$

where kernel ρ denotes the inner component of feature vectors in the training datasets, aC_i and bC_j represent the input attributes of the concerned contents C_i and C_j, respectively. signifies the degree of polykernel. In the SVM training, both crucial and regular attributes are utilized to recommend the required content. The SVM uses a hyperplane that separates with a given range to the learning sets nearest data point to provide recommendations for various types of content demand. Such data points are referred to as a "support vector". Using optimal margin, the hyperplane divides a collection of highly desired content from a collection of disregarded stuff. Suppose if there are k number of content demands from different users, which can be paired as $(a_1,b_1),(a_2,b_2),,(a_n,b_n)$, and a corresponding vector is depicted as $a_i\in C_i, b_i\in -1,1$.

SVM is tasked with learning the mapping of pairs $(a_i->b_i)$. In the finished result, all of the suggested hyperplane-boundary vectors are included. It is characterized as the spacing between the higher dimensional space and the closest data point, especially in the linear condition. Figure 4.1 demonstrates the sample graphical representation of the SVM process in recommending the content to the user.

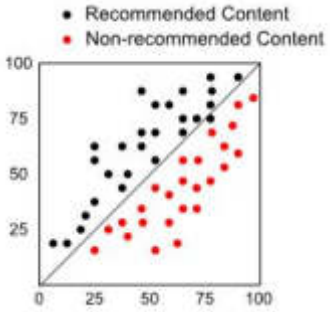

Fig. 4.1: Sample illustration of SVM in Content Recommendation for i^th User

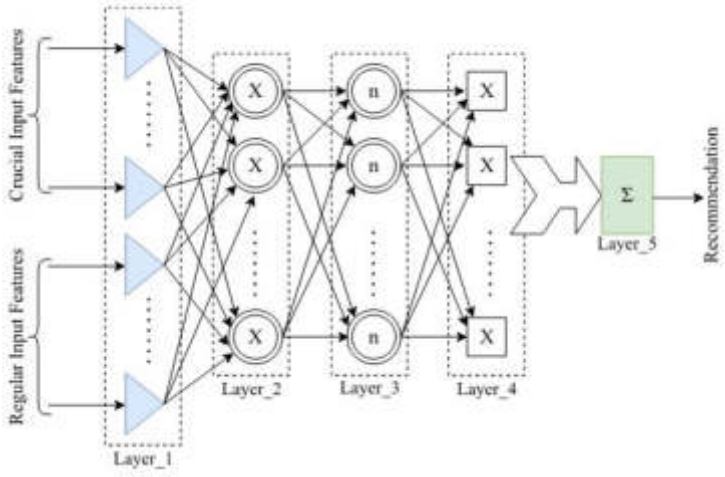

Fig. 4.2: ANFIS Architecture

4.2. NF. Adaptive Neuro-Fuzzy Inference System (ANFIS) was utilized as the second base classifier. All the computation processes of ANFIS were derived from the work of [33]. The membership function (mf), fuzzy inference repository, and rationale process form a significant part of ANFIS. In addition, ANFIS employs gradient descending to tune the vital parameters. To formalize the application of ML methods, the ANFIS design can be considered a multi-layered connectionist framework, as represented in figure 4.2. The model's knowledge base uses Takagi and Sugeno's [34] fuzziness models. Fuzzy sets correspond to both crucial and regular input feature variables, and fuzzy rules are made by linearly combining a constant and a data object. ANFIS follows a multi-layered (six layers) architecture mechanism that combines the basic computation of both fuzzy logic and neural networks.

Layer_0: A collection of input data that is fed to the ANFIS system is represented through this layer. Typically, this tier is not explicitly exposed in the primary ANFIS architecture.

Layer_1: Each incoming vector is measured as a fuzzy set, and furthermore, this defined mf is used to build this fuzzification layer. The mf accepts the input parameter and returns the input's degree of membership as an outcome ranging from 0 to 1. This result was obtained by fuzzifying the crisp data. Adaptive mf is applied to each unit at this stage and is expressed as in equation (4.2),

$$\mathrm{e}_{\mathrm{i}}^{\boldsymbol{l1}} = U_{[\boldsymbol{p}_j]}(\boldsymbol{x}) \tag{4.2}$$

where, $\mathrm{e}_{\mathrm{i}}^{\boldsymbol{l1}}$ indicate the node i's outcome, and $U_{[\boldsymbol{p}_j]}(\boldsymbol{x})$ denotes the mf's outcome of content preference

set, P_j (fuzzy set) of users. This means that the component variables can be revised using gradients descendance instructional strategies for each mf which is continuous and piecewise distinct in characteristics. In ANFIS, several kinds of mf's are employed; however, simplified bell functions and Gaussian-based computation processes are frequently employed.

Layer_2: In the second layer, fuzzy rules are computed using the product of their respective outcomes from the preceding layer. The layer's i^th unit's outcome is shown in equation (4.3),

$$\mathrm{e}_i^{lz} = \left[\boldsymbol{U}_{[\boldsymbol{p}_i]}(\boldsymbol{x}) \cdot \boldsymbol{U}_{[Q_i]}(\boldsymbol{y})\right] \tag{4.3}$$

In equation (4.3), e_i^{lz} is the multiplicative result of the mf,$\boldsymbol{U}_{[\boldsymbol{p}_i]}(\boldsymbol{x})$ and $\boldsymbol{U}_{[Q_i]}(\boldsymbol{y})]$, which determines the intensity of each rule's output generation.Thus, for example, the output generation intensity of the seventh rule can be calculated as, $\left[\boldsymbol{U}_{[\boldsymbol{p}_i]}(\boldsymbol{x}) \cdot \boldsymbol{U}_{[Q_i]}(\boldsymbol{y})\right]$. There are several other fuzzy operators (e.g., min) available to attain this result.

Layer_3: Each fuzzy rule's normalized activation intensity is represented by every i^th node of this layer. Normalized activation intensity is computed by the jth rule's activation intensity divided by summing the output intensity for all formulated regulations (j^th rules). In this layer, in general, the j^th unit generates the following outputs,

$$\mathrm{e}_j^{l3} = \left[\phi_j / \Sigma_{i=1}^{r} \left(\phi_i\right)\right] \tag{4.4}$$

In equation (4.4), ϕ_i denotes the output triggering intensity of any i^th rule, r.

Layer_4: There are units/modes with updatable attributes related to this stack, making it adaptable like layer 2. Each node's result is a sequential transformation via linear function and is defined as follows,

$$\mathrm{e}_i^{l4} = \left[(\alpha_i x + b_i x + R_i) \times \bar{\phi}_i\right], \text{ where } \eta = (a_i x + b_i x + R_i) \tag{4.5}$$

In equation (4.5), represents the result of the i^th unit of this layer, whereas a_i, b_i, and R_i denotes the coefficients of fuzzy operation functions, which are fine-tuned at the attribute optimization processes.

Layer_5: As the total of all incoming signals, this layer contains one node that quantifies the aggregate outcome of this tier using the summation of all the signals generated in the previous layer, which can be expressed as ϕ,

$$\mathrm{e}_i^{i5} = \left[\sum_i \left[\boldsymbol{\eta} \times \phi_i\right] / \Sigma_i(\phi)\right] \tag{4.6}$$

In equation (4.6), the attainment of the final recommended outcome is denoted as e_i^{i5}.

4.3. ESL. ESL is a sophisticated ML approach that uses a unique blend of more than one base classifier to address a specific issue in computational learning. In ESL, there are indeed a variety of strategies to combine models, including boosting, stacking, and bagging. Stacking is a prominent and widespread ESL strategy [35] which effectively predicts the most complex outcome from heterogeneous data features. The final prediction is made via constructing a new model (meta-classifier) and enhancing the system's effectiveness. To boost performance, we can aggregate the results of ANFIS and SVM models that have been trained to address comparable problems. This technique is known as "stacking." The proposed stacking-based ensembling technique is illustrated in Figure 4.3.

For a better perspective, the fundamental steps of the generic stacking technique are shown via pseudocode in Table 4.1 In the initial phase of this process, the first stage base recommenders are modelled by utilizing the actual dataset. Then, SVM and ANFIS, the primary recommenders, undergo a training process for optimal recommendations. Finally, the weighting pattern of the input dataset is dynamically adjusted to match the primary predictors. Because of this, the algorithm's parameters are tuned in order to get more accurate results.

Compiling the outputs of base recommenders generates new datasets. Primitive categories from prior learners are used to build the subsequent level of recommenders. In contrast, estimates of the first stage recommenders are used as a newer feed to the second stage model. It is preferable to utilize recommenders'

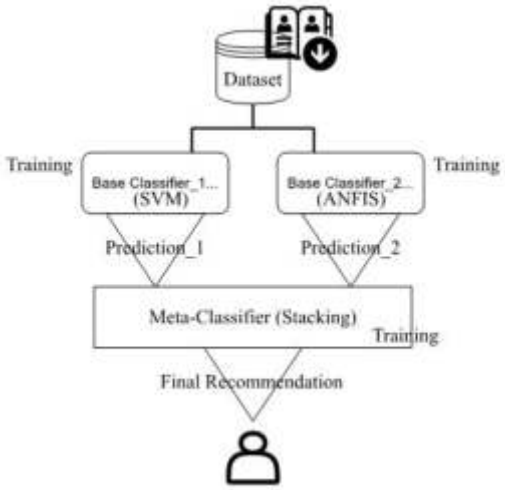

Fig. 4.3: Generalized Stacking Ensemble Technique

Table 4.1: Ensemble Learning

Input: $I_d = \sum_{k,l=1}^{m} (\delta_i) \in \gamma_i (\mathbb{C}_i, \mathbb{C}_i) \gamma_1 \leftarrow SVM; \gamma_2 \leftarrow$ ANFIS; Output: $\mathcal{G}_c$ //ensemble recommender
Step 1: $\forall : I_d - >$ (1 to n)do Step 2: $\zeta \rightarrow [\gamma_i \mid d]$; / learning phase Step 3:$\forall n \rightarrow (1$ to $N)$ do Step 4: $\mathrm{Z}_d \leftarrow \left[\left(N_n^2, \varepsilon_l\right) \mid d\right]$ // new dataset Step 5: $\boldsymbol{G_c} \leftarrow \left[\left(d_j^{\text{new}}\right) \mid \left\{N_n^2, \varepsilon_l\right\}\right]$ // Meta-classifier Step 6: Return G_c; / Final Recommendation

likelihood estimates rather than projected labels. The non-linear activating factor of softmax was used to create additional attributes. Next, a more effective targeted class is forecasted using a newly obtained data set.

In summary, The ESL mechanism combines Support Vector Machines (SVM) and Adaptive Neuro-Fuzzy Inference System (ANFIS) to enhance recommendation systems in digital libraries. SVM uses a splitting hyperplane to optimize error gaps and recommend preferred content based on user demands. ANFIS employs fuzzy logic and neural networks to make recommendations using fuzzy sets and rules. Through stacking, the outputs of SVM and ANFIS are combined to create a meta-classifier for more accurate predictions. This approach improves recommendation effectiveness in digital libraries shown in Figure 4.2.

5. Performance Measures and Analysis. The proposed model was created for SRS using ML to enhance the content recommendations in DL. This section's analytical review serves to demonstrate the validity of the work. Using distinct data sets, the findings of the study are obtained. To illustrate the efficiency of the suggested model, the parameters of the datasets were categorized based on two attributable factors: crucial and regular attributes in each trial. In evaluating the proposed approach for diverse performance metrics, training, as well as test sets from datasets, is combined in various ways with distinct combinations. However, in each research phase, the weights attributed to user records and content parameters are maintained constant since preferable weight configurations have previously been tested by determining the semantic similarity among individuals and various content. Assessments of attained precision and errors [36] are used to verify the actual facts of these investigations. The suggested model's outcomes are ultimately compared to recently reported, state-of-the-art approaches. The models compared to the proposed ESL model are the standalone performances of SVM, ANFIS, HAR-KNN, and K-means. Metrics like accuracy, Mean Absolute Error (MAE), and Root

Table 4.2: Specific Requirement of the Study

Aspect	Recommendation
Tool	TensorFlow or PuTorch
Libraries/Packages	scikit-learn, NumPy, pandas, matplotlib, fuzzywuzzy
Programming Language	Python
Implementation	Develop a custom implementation using the chosen framework and libraries/packages
Parameterization	Experiment with different hyperparameters for SVMand ANFIS models (e.g., kernel type, regularization parameter, degree of polvkernel, number of layers and nodes in ANFIS)
Evaluation	Use appropriate evaluation metrics such as accuracy, Mean Absolute Error (MAE), and Root Mean Square Error (RMSE), rate of fallout
Replicability/Reproducibility	Provide detailed documentation, code comments, and instructions to ensure replicability and reproducibility of the study

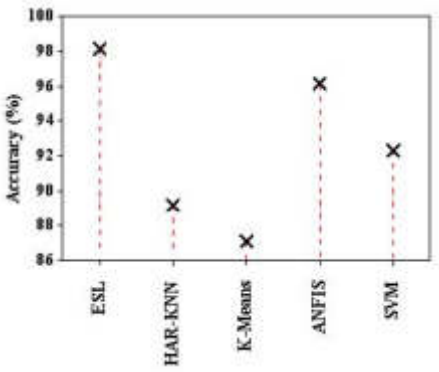

Fig. 5.1: Accuracy Analysis

Mean Square Error (RMSE) [37] measurements are used to assess the effectiveness of the proposed RS in the DL context. In addition, the fallout rate is included for analysis purposes. These metrics are referred to as efficiency checkers, and a lower error margin indicates that the approach is performing better overall. The in-depth analysis of this measure's outcomes is outlined in subsequent sections.

After several training and testing trials at each stage of the ESL models, comparable accuracy-based outcomes are obtained and shown in Figure 5.1. According to the result, ESL-based RS in the DL context obtained an optimal accuracy of 98.15%, which is 7 per cent greater than the prevailing RS. Also, as seen by the vertical drop line, alternative approaches have an average accuracy rate of 91.19%. Conventional techniques could not provide a precise recommendation, negatively impacting the platform's stability and efficacy in real-world scenarios. In ESL, users' records can be sorted by term similarity to determine which terms they commonly seek that are connected to one another. While searching for terms with numerous meanings in the lexicon dictionary, this function helps to prevent term-level uncertainty. Moreover, selecting appropriate features with fixed weightage aided the models in re-tuning the feature parameters to attain the optimal outcome (recommendation).

Figure 5.2 depicts the confusion matrix of RS, where it is observed that the results of ESL signify maximum coverage of topics in various fields and attained an average accuracy of more than 98%. Only the sociology and literature sector reports around 97% accuracy level which is due to the strong dependence of sociology on literature as a critical source of information.Initially, to investigate the model's potentiality in recommending the user's required library content, we opt to set four different training and testing proportions, (80:20), (70:30), (60:40), and (50:50), respectively. From Figure 5.3, when we analyze the performance of the ESL model using

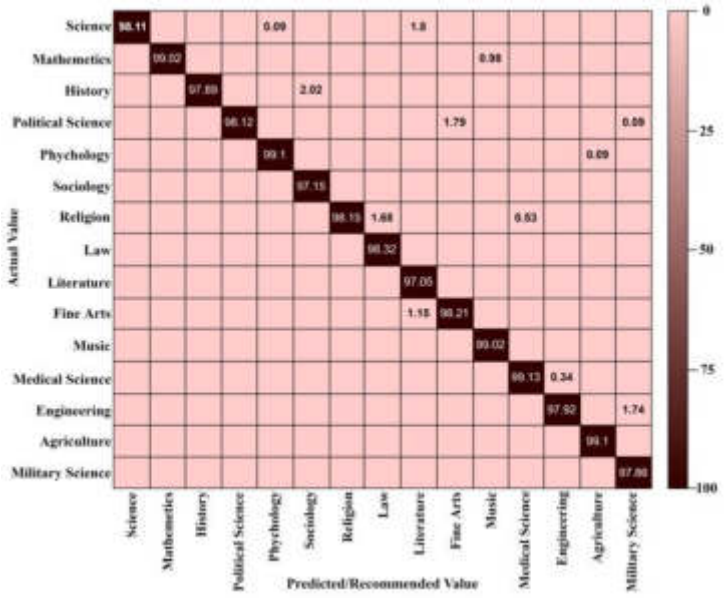

Fig. 5.2: Confusion Matrix

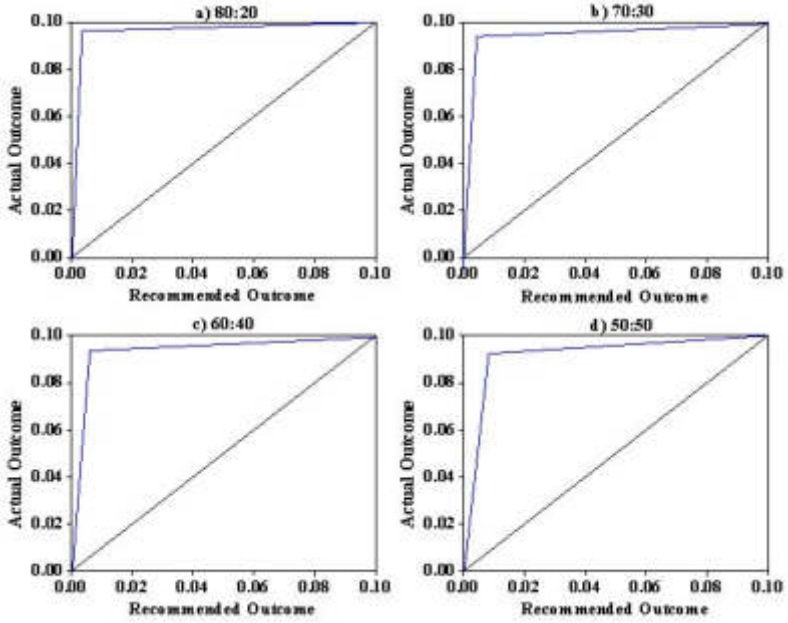

Fig. 5.3: Analysis of MAE at varying Training: Testing sample ratio

MAE, it's been noted that the model's performance is batterer at proportion (80:20). The model's efficiency degrades gradually as the ratio of the training dataset gradually decreases, which are evident from the outcome (Figure 5.3 a, 5.3 b, 5.3 c, 5.3 d). Despite the performance degradations, the model sustains to get least error margin (below 0.1).

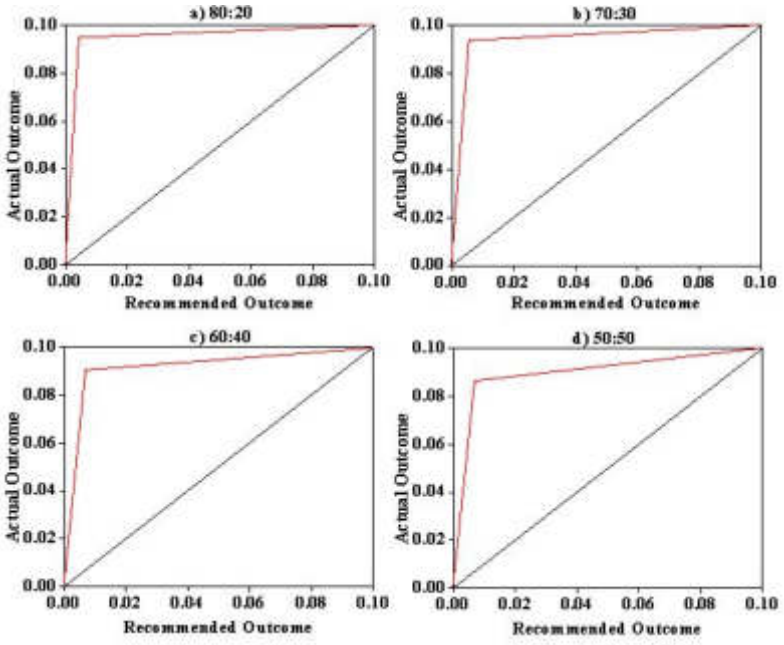

Fig. 5.4: Analysis of RMSE at varying Training: Testing sample ratio

The RMSE calculates the discrepancy between the actual results and those estimated. The variance of the estimation error or latent variables is computed using the RMSE formula. Researchers look at the accumulated depreciation to determine how far the trend lines deviate from the standardized residuals. Figure 5.4 shows that the RMSE improves with fewer latent irrelevant vectors (Root Mean Squared Error). However, it was also discovered that the RMSE error varies depending on the training-to-testing ratio, contrary to what would be expected. Though the minuscule error margins are maintained for all four proportions, it is necessary to note that the proposed model performs effectively when the ratio of the dataset is 80:20, which signifies that the model with a specific dataset proportion for training and testing has a mild impact on the intended outcome. But at the same time, if the sampling and learning rates are tuned as per the volume of available datasets, this kind of proportion's influence may deeply impact the desired outcome. From the resultants exhibited, it is noted that the error value associated with this metric has the most negligible significance to the RS since the reported value is below 0.09 for all the proportions; this indirectly signifies the precision level of the proposed model. The RMSE variance for a two-feature vector (crucial and regular) is lower, as seen from the Figure 5.4, (5.4a, 5.4b, 5.4c, 5.4d). For this reason, we decided to limit the range of subliminal variables to two; this is indeed a decent strategy because the range of implicit vectors selected must always need to be minimal.

Rate of Fallout (RF): It is defined as the recommended percentage of webpage's/e-content that was not pertinent to the overall count of the content/pages that were suggested. equation (5.1) is used to compute RF.

$$RF = \text{ falsePositive } /([\text{ truePositive }] + [\text{ falsePositive }]) \tag{5.1}$$

Figure 5.5 represents the outcome of RF, which insists that the proposed ESL maintains the minimized fallout (2.16), which shows more than 90% improvement compared to the other four models. All the other existing models exhibit average fallout of 6.43, which may considerably deviate from the outcome of the recommendation process. As a consequence, RF increases for any user requirements.

6. Conclusion and Future Work. It is becoming more important for researchers to employ recommender systems to expedite quality research and boost user confidence in finding the right information. Ensemble learning methods were employed in this work to boost RS's effectiveness. For digital library infrastructure,

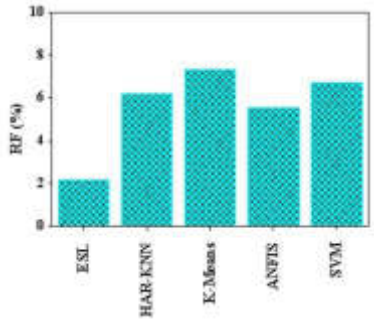

Fig. 5.5: RF Analysis

ESL-based RS was suggested in this research. The key strategies for optimizing the efficiency of an ESL-based DL system were also discussed in this paper. First, essential components are extracted and then filtered using a CoC (Coherence of Content) inference methodology. Next, we tested the conceptual model using three different datasets [29, 30, 31]. They were then compared to the standard method. The outcome of the random forest (RF) model, indicating that the proposed ESL achieves a significantly minimized fallout (2.16) compared to other models with an average fallout of 6.43. This highlights the effectiveness of ESL in providing accurate recommendations. It was noted that the ESL model performs best at the 80:20 proportion and gradually degrades as the ratio decreases and registers an average accuracy of over 98%. As shown by these findings, a proposed methodology may be used to provide suggestions for billions of pieces of content available across billions of documents.

Limitation: Although the study compares the proposed system with a standard method and utilizes multiple datasets, there is no mention of external validation against independent datasets or real-world scenarios. External validation is crucial to assess the system's performance in diverse environments and ensure its effectiveness beyond the specific datasets used in the study.

Future work: Re-tuning hyperparameters (such as learning rate) on our suggested model will be investigated in a future study. We would also like to use this idea to make document categorization frameworks available as a cloud service.

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PREDICTION OF DIABETES MELLITUS USING ARTIFICIAL INTELLIGENCE TECHNIQUES

G L SUMALATA*, JOSHITHA C† AND KOLLATI MEENAKSH‡

Abstract. Diabetes Mellitus (DM) is a global health challenge, demanding proficient predictive models for early identification and intervention. This study adopts a comprehensive strategy for diabetes prediction with Machine learning algorithms, utilizing PIMA Indian diabetes dataset which encompasses clinical, demographic and lifestyle data. Employing techniques like Recursive Feature Elimination (RFE) and correlation analysis, the feature selection process identifies influential predictors, including glucose levels, Body Mass Index (BMI), Blood Pressure and diabetic history of family. A distinctive facet of this study involves integrating IBM Auto AI, automating the machine learning pipeline for tasks like feature engineering, hyperparameter tuning and model selection. Through comparative analysis, the research evaluates the efficiency and performance enhancements achieved through automation in contrast to manually-tailored models. Evaluation metrics encompass accuracy, precision, recall, and F1 score. Cross-validation, particularly k-fold cross-validation, ensures model generalization to diverse subsets of the dataset. The research outcomes offer valuable insights into the optimal amalgamation of AI techniques for diabetes prediction, underscoring the significance of interpretability, performance, and automation in healthcare analytics. The proposed Methodology is evaluated with different classifiers with Auto AI and without Auto AI techniques. Using IBM Auto AI,Gradient boosting algorithm performed well with 84. 4 % accuracy and Logistic Regression showed good accuracy of 84. 4% among conventional machine learning techniques without Auto AI using Pima Indian Diabetes Dataset.

Key words: Diabetes Mellitus, IBM, Auto Artificial Intelligence, Extreme Gradient Boosting, Gradient Boosting Classifier

1. Introduction.

Diabetes Mellitus is a pervasive metabolic disorder which serves as a harbinger for intricate complications that causes multiple physiological changes in human body. The uncontrolled glycemic imbalances due to Diabetes Mellitus result vast changes in cerebrovascular system. The other effects of the Diabetes mellitus are ocular afflictions leading to visual impairment and also causes nephropathies which affect the renal function [20]. This disease is receiving global attention due to its long term health complications which affects the subjects suffering with the disease. According to World Health Organization (WHO) and International Diabetes Federation(IDF) estimates 387 million people are suffering from the disease. It is forecasted that by the year 2034 the growth will be escalated up to 592 million patients [10]. There are two types of diabetes- type 1 and type 2 [2]. Type-1 Diabetes is caused if pancreatic cells that produce insulin is attacked by the immune system because of which secretion of insulin will be less. This type of diabetes mostly seen in children. WHO stated that number of children having Type-1 diabetes is very high . In patients having Type-1 diabetes, the risk of cardiovascular diseases is more . Not only heart strokes but also various organs like eyes, kidneys etc. get affected [12]. Further, the disease shows gradual deterioration of the circulatory system damaging the retina which may cause diabetic retinopathy causing visual impairement [19]. Type 2 diabetes is caused by overweight or obesity which is due to lack of physical activity and causes resistance to insulin. This further causes one of the dangerous risk factors for cardiovascular diseases. Type 2 diabetes is due to lifestyle, physical activity, diet and also hereditary. Most of the diabetic people i. e 90 % are of Type-2 . The underlying cause of type 1 or type 2 diabetes is irregular blood glucose levels leading to pancreatic dysfunction which finally causes deficiency in insulin production in type 1 and apart from this cellular resistance to insulin in type 2 . The third type of diabetes is gestational diabetes mellitus which occurs due to glucose tolerance during pregnancy[5] . While the exact cause remains elusive, the genetic factors and lifestyle are believed to significantly contribute to diabetes. Although incurable, the condition can be effectively managed through treatment and medication.

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Early detection and treatment play a vital role in preventing complications and reducing the risk of severe health issues. As technology is improving in almost all fields [8, 9, 11] , Even in the health care AI many improvements and researches are done. The realm of bioinformatics, numerous researchers have endeavored to address diabetes, creating systems and tools for prediction. Predictive Analysis is a methodology which integrates diverse machine learning algorithms, data mining techniques, and statistical methods and shows great potential in the context of Diabetes Mellitus. By analysing both current and historical data, this approach aims to extract valuable insights and forecast future events related to diabetes. When applied to healthcare data specific to diabetes, predictive analysis becomes a powerful tool for making informed decisions and generating predictions regarding the disease. Employing machine learning techniques for predictive analytics in diabetes care is directed towards achieving precise disease diagnosis, enhancing patient care strategies, optimizing resource allocation, and ultimately improving clinical outcomes in the management of Diabetes Mellitus. Various machine learning algorithms such as Decision Trees, Support Vector Machine (SVM), and Linear Regression, have been commonly employed . Additionally, the use of Artificial Neural Network (ANN) is explored for the same and, more recently, Deep Learning (DL) as an enhancement to ANN, also has shown promising results. The variation in accuracy rates obtained from these methods made the researchers to explore more and more novel classifiers or combinations of existing classifiers to improve accuracy. Many studies in diabetes prediction have utilized the publicly available Pima Indian Dataset from the UCI repository. Some surveys in the field have focused on specific machine learning and deep learning techniques for predicting diabetes [3].

This research paper distinguishes itself by discussing both conventional Machine Learning techniques and implementation using IBM Auto AI models for diabetes prediction, comparison between both the methods. The paper systematically discusses the step by step process of implementation of Auto AI model. The results obtained are subjected to comparative analysis with other research studies employing the same dataset. The paper is organized into subsequent sections. In Section II titled Related works, literature review and a taxonomy of machine learning algorithms related to diabetes prediction are presented. Section III outlines IBM Auto AI services. Section IV delves into the methodology of proposed model for diabetes prediction. Section V discusses the summary of Progress map. The Simulation results and discussions are detailed in Section VI. The Conclusion and Future scope are outlined in Section VII followed by References.

2. Related works. Health care AI intruding in the medical field to reduce the burden of physicians in the decision making. Early detection and diagnosis of Diabetes Mellitus are crucial for timely intervention, improved treatment outcomes, and preventing complications. AI techniques helped the physicians to predict the life challenging diseases such as cancers, tumors using the machine learning techniques[7, 6] . The examination of existing research reveals that predictions are done for diabetes detection through a range of techniques and methods. Some of them are data mining techniques, machine learning algorithms, or combinations of them. As the complexity is increasing many researchers are exploring deep learning algorithms. Different research works using Pima Indian Diabetes dataset have been reviewed thoroughly. First the Research began with introduction of neural networks leading to build adaptive models for diabetes prediction. ADAP [15], a neural network is used for the prediction of Pima Indian population dataset and obtained specificity and sensitivity as 0. 76. Next approaches are done using traditional statistical methods and clinical risk factors. Early models often used simpler algorithms, such as logistic regression. Some of the literatures concluded that the direct and distribution free feature of neural networks is used for prediction but observed that reliability is not upto the mark. Some researchers stated that general regression neural networks (GRNN) are showing good performace in comparison with multilayer perceptron (MLP) and radial basis function (RBF). Next phase of the research is exploring feature selection methods. Broader adoption of machine learning techniques gained importance in this area.

Kemal Palat et al. [13] employed a two stage Generalized Discriminant Analysis and least square support vector machine for the Diabetes Mellitus detection and obtained an accuracy of 82. 05%. Support Vector Machine cannot give probability of chances of accuracy. The use of Automated Machine Learning tools has streamlined the machine learning pipeline and these tools automate the process of feature engineering, hyperparameter tuning, and model selection, reducing the need for extensive manual intervention. Yashi et al. [16] stated advantages of Auto AI Classification is done using Microsoft Azure, which makes the classification easy by reducing the time. The references [4, 14, 18, 1] implemented using the same dataset and obtained

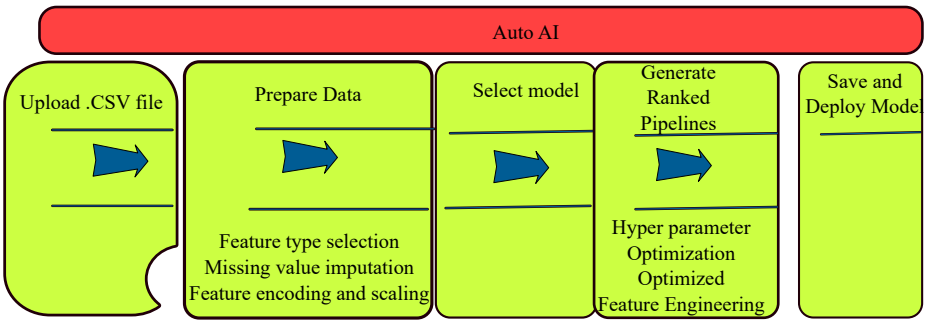

Fig. 3.1: IBM Auto AI procedure in general

results using different classification algorithms. With the surge in computational power, Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks were applied for their ability to capture intricate patterns in data. Ensemble techniques and hybrid models considering the combinations of multiple algorithms are becoming popular. These models often integrated the strengths of different approaches, improving prediction accuracy. Many researchers worked on techniques like bagging, boosting, and stacking for prediction of diabetes. Interpretability and explainablity is the ongoing trend in Explainable AI models especially in healthcare. Tasin et al. [17] Proposed semi supervised model with extreme gradient boosting algorithm with Domain adaptation and by using frameworks like LIME and SHAP ,an explainable AI approach was used for model predictions.

Recent advancements focus the importance of robust validation methods like k-fold cross-validation and model performance can be assessed by considering various Evaluation metrics such as accuracy,precision etc. The main objectives the proposed work is:

- The proposed model employs IBM Auto AI services for the intelligent automation of the entire AI lifecycle for developing a predictive model for the diabetic Mellitus detection.
- Unlike conventional machine learning algorithms, the IBM Auto AI steps of using data sets for training, finding the optimized model for the given data, feature selection, hyperparameter optimization and ranking the pipelines based on evaluation metrics accuracy and precision. The best performing pipelines are brought to train the new data and prediction outcomes are considered based on the model training. This relieves the doctors from the rote of manual processing.
- A comparative study is made with the conventional machine learning algorithms to prove that the auto AI based methods have shown superior performance compared to the conventional machine learning algorithms.

3. IBM Auto AI Services. Proposed work uses IBM Auto AI services. Auto AI reduces experimentation time. So many researches are going on with Auto AI dealing the problems like classification and other applications in almost every field. Auto AI does automation of complete life cycle of AI i. e from data preparation to hyper parameter optimization. It includes development of model, feature engineering etc. with one click deployment. The general architecture of IBM Auto AI Services and its application to the disease Diabetes Mellitus is depicted in Fig. 3.1 and Fig. 3.2. The following services are used in IBM Auto AI:

1. IBM Watson Studio
2. IBM Watson Machine Learning
3. Node-RED

3.1. IBM Watson Studio. IBM Watson Studio is a vital tool to work with Artificial Intelligence and take decisions in optimized manner on IBM Cloud Pak. It integrates many open source frameworks, tools, high level languages like python to program, analyse the outputs, compare various algorithms with different parameters and for identification of best one among them.

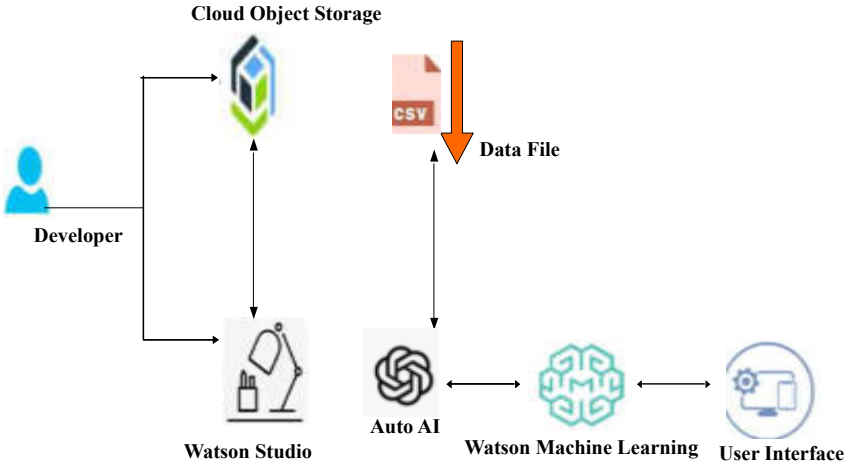

Fig. 3.2: IBM Auto AI for Diabetes Prediction

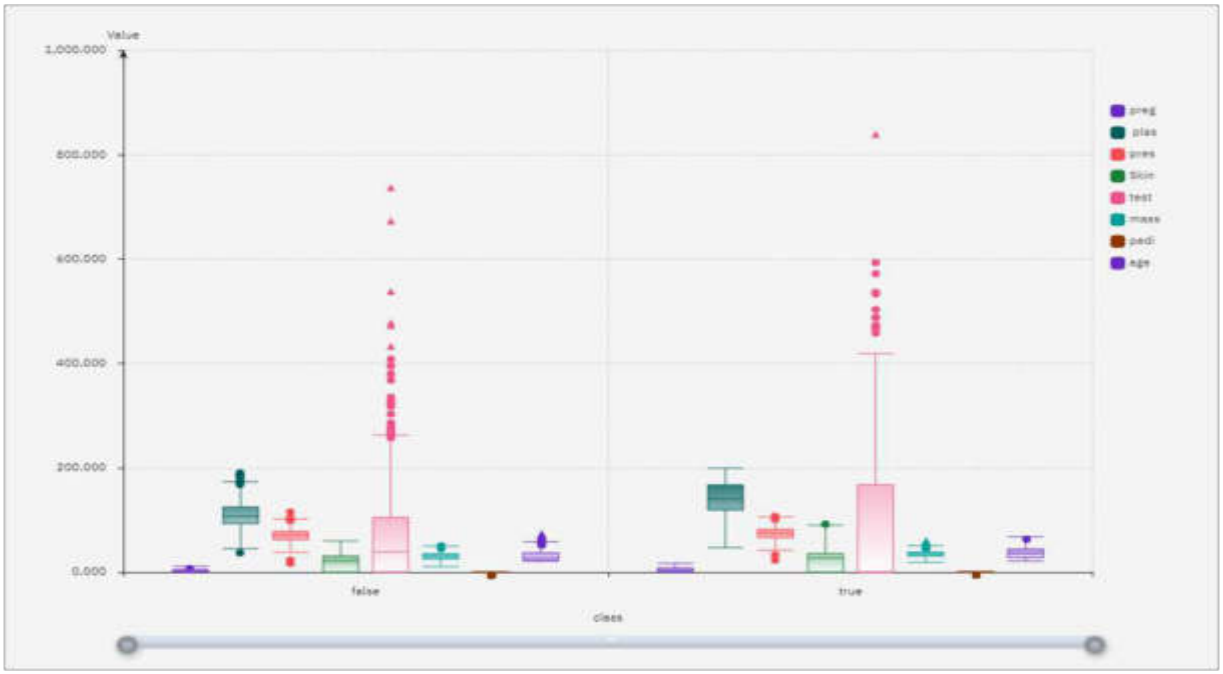

Fig. 3.3: Box Plot Representation of data

3.2. IBM Watson Machine Learning . IBM Watson Machine Learning provides provision for building models, neural networks and analyzing them is possible. It is possible to load the data set and training with our own data to build an application. It is used to test the model and successfully deploy it. All these tasks are possible by tools and wide range of services provided by IBM Watson studio to make the process fully automated which saves the precious time of the user so that prototyping can be done at a faster rate.

3.3. Node-RED. Node-RED is an environment to represent the messages in visual form through a programming technique of following the flow. It is a "Flow based Programming" tool. The program is broken into data and processes. Processes are one which operate on data and these processes are connected together by

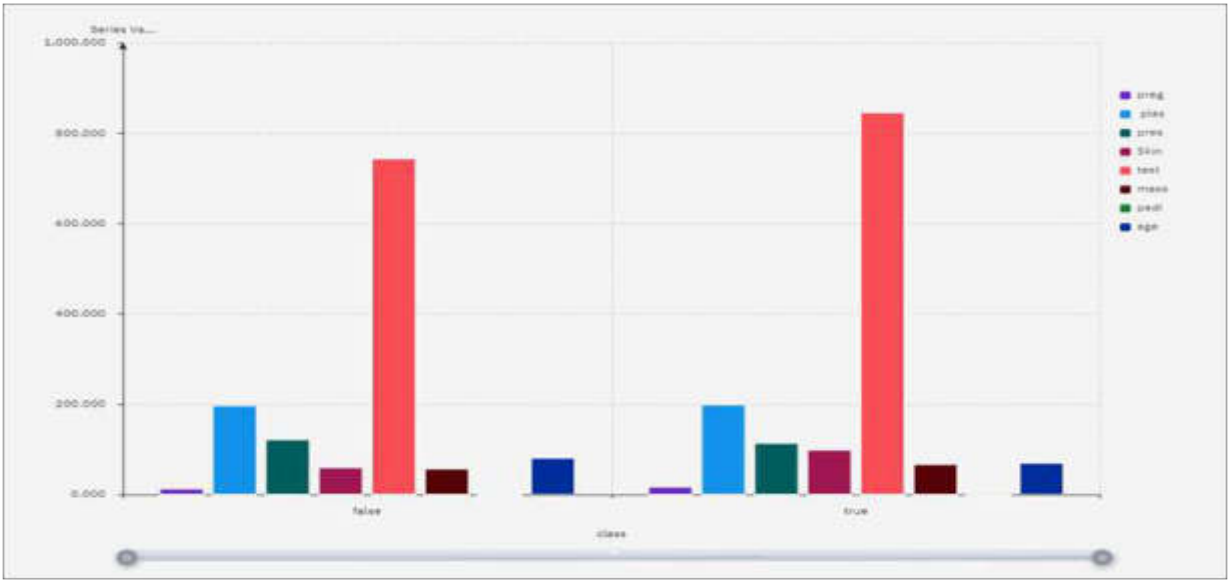

Fig. 3.4: Scatter Matrix Representation of data

network. All this is done to achieve an objective finally. This tool is used to connect together various hardware, APIs etc. Many online services too can be wired up using this tool. It provides editing via browser and with one click deployment can be done. Creation of functions of java script can be done within editor. Reuse of some useful templates also is possible using some functions which are built in. To do the description of metadata Node-RED uses "JavaScript Object Notation i. e JSON". These flows which are created with JSON can be easily shared with others. It can be run anywhere from local computer to cloud. It can run even in hardware devices for building IOT applications like Raspberry Pi too. Due to all these vital features Node-RED is become popular.

3.4. IBM Cloud Object Storage. IBM Cloud Object Storage facilitates low cost solution for storage of data on edge. Performance of it can be increased by increasing the capacity of storage with many more interesting features. It can be used for storage of AI, image repositories etc in an effective manner. Video or analytics of many customers can be stored on cloud. The very important feature is the protection of data with built in authentication tools in it. From any location the stored data can be easily accessed, which is a very important feature i. e simplicity. Time can be saved for searching the data as meta data is created. So easily the stored data can be searched

4. Methodology. The proposed model uses Auto AI Architecture. The General approach of Auto AI using step by step procedure can be depicted in Fig. 4.1. The foremost step starts with loading the data set in . csv file format and then reading the data file, analyzing it by plotting various types of appropriate plots and running the Auto AI experiment by data preparation which undergoes 3 main steps called Feature type selection, Missing value imputation, feature encoding and scaling. Next step is the model selection which can be done by selection of best estimator for the data. After that Generation of Rank model pipelines after hyper parameter Optimization (HPO) and Optimizing Feature Engineering. Finally the best model is saved and deployed. In this proposed work for diabetes Mellitus Prediction, . csv file of Pima Indian dataset is loaded and all the steps in block diagram shown in Fig. 4. 2 specific to Diabetes Mellitus Prediction are executed for the optimized model building.

4.1. DataSet details and Step by Step Approach of Implementation . The proposed system uses 8 vital parameters that can predict the chances of acquiring the diabetes which uses machine learning techniques to learn from hundreds of patient data, fit the best performing model consistent with the training examples

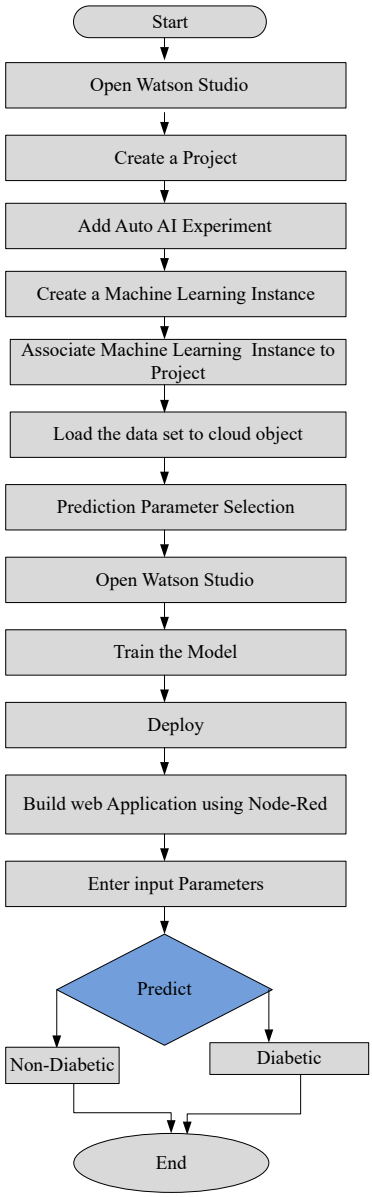

Fig. 4.1: Flowchart for Diabetes Prediction

given and it is tested or validated with unseen data also. It is found to perform with about good accuracy in its predictions. So, an application built on this will be highly reliable with good prediction accuracy. The dataset contains 8 input parameters which are of different data types. Diabetic Pedigree Function and BMI are double and the remaining parameters are in integer format.

4.2. Dataset description is given below:. The data is taken from Kaggle . The link to the dataset is $https : //www.kaggle.com/datasets/uciml/pima - indians - diabetes - database/data$. The ratio used for experiment is 80:20. Majority of the data which is 80% is used for training and 20% for testing.

1. No. of Pregnancies - Number of times pregnant
2. Random Glucose - Plasma glucose concentration a 2 hours in an oral glucose tolerance test

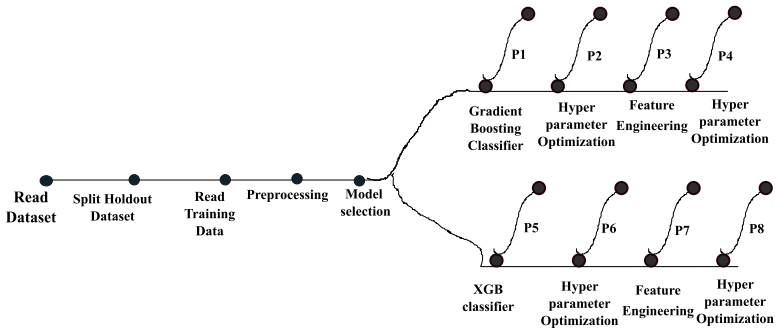

Fig. 5.1: Progress Map

3. Blood Pressure - Diastolic blood pressure (mm Hg)
4. Skin Thickness - Triceps skin fold thickness (mm)
5. Insulin - 2-Hour serum insulin (mu U/ml)
6. Body Mass Index - weight (kg) / [height (m)]2
7. Diabetes Pedigree Function - A function which scores the likelihood of diabetes based on family history. It provided some data on diabetes mellitus history in relatives and the genetic relationship of those relatives to the patient
8. Age - Age (in years)
9. Outcome - The outcome label 1 for Yes (for chances of acquiring diabetes and 0 for No (for no chances of acquiring diabetes)

4.3. Data Visualization. The data can be visualized and analyzed in a better way by checking the distribution between the parameters, finding the correlation between them by using different plots. Fig. 3.3 and Fig. 3.4 shows Box Plot Representation and Scatter Matrix Representation of data respectively.

Steps followed to build the model The step by step procedure is shown in Fig. 4.1 as a flowchart for diabetes prediction using IBM Auto AI.

The main steps involved are:

1. Creation of a project in Watson Studio
2. Diabetes Prediction
3. Adding Auto AI experiment
4. Creation of a Machine Learning instance
5. Association of ML instance to the project
6. Loading the dataset i. e PIMA Indian data set to cloud object storage
7. Selection of the target variable (prediction parameter) in the dataset
8. Training the model
9. Deployment of the model
10. Building web application using Node-Red

5. Summary of Progress Map. Progress map helps to see the steps for creating the pipelines of the model. Each step of the progress map are shown in Fig. 5.1

The process begins with reading the data set, next splitting holdout data. After reading training data , preprocessing in which the features are to be detected and categorization takes place. Then Model Selection takes place. Here different algorithms are applied and which ever matches well for this particular data set will be selected. Here PIMA Indian dataset is applied out of different algorithms, two best algorithms are matched for this data and selected . Comparison of pipelines can be done. The chart in Fig. 5.2 shows 8 pipelines P1,P2,.... P8 with respect to cross validation and holdout scores.

Ranking is given to pipelines based on performance metrics. Comparison between two best classifiers i. e Gradient Boosting Classifier and XGB classifier chosen from data set is done. Different types of analysis can

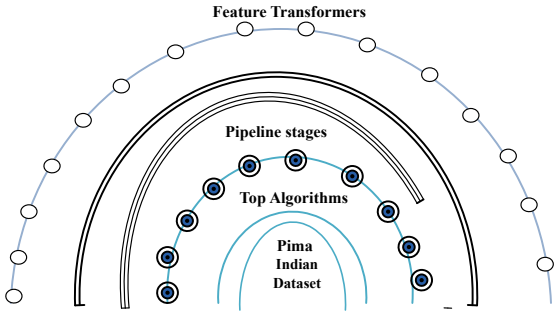

Fig. 5.2: Pipeline Comparision

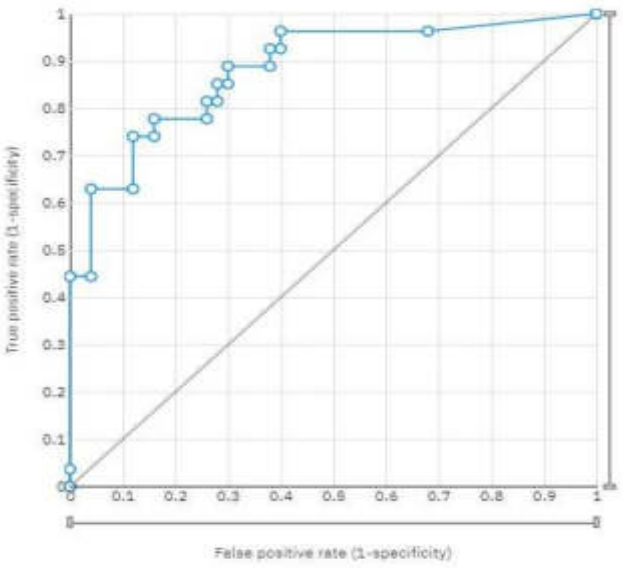

Fig. 5.3: ROC of Gradient Boosting Classifier

be done using relationship maps, Metric charts etc. Relationship map helps to know about the pipelines and the sharing between them, the unique properties of them. Pipelines which are associated to a particular node in the leader board and analysis between the relationship can be known. While creating the relationship map the number of pipelines are decided by algorithms selected. Once the experiment is run then Auto AI generates pipelines using different estimators or enhancements like hyper parameter optimization i. e HPO (used for building number of models and to do comparison between them by automatically exploring parameters) and feature engineering i. e FE (depending on problem which parameters are to be included for accurate prediction by considering raw data). Once the run has completed relationship map can be viewed. The pipeline which has highest ranking is best classifier i. e Gradient Boosting Classifier in this diabetes mellitus prediction model. So it can be saved. Next step is Promotion to deployment space and it can be done using API reference. Next Testing the prediction model can be done after giving input parameters and depending on the parameters output will be shown as 1 or 0 as output diabetic patient or not respectively. Finally user Interface can be built with cloud foundry applications. Using Node-Red building nodes and deployment can be done. It also connects APIs and online services. It is used for building user interface for users to enter data so that the status of diabetic can be predicted.

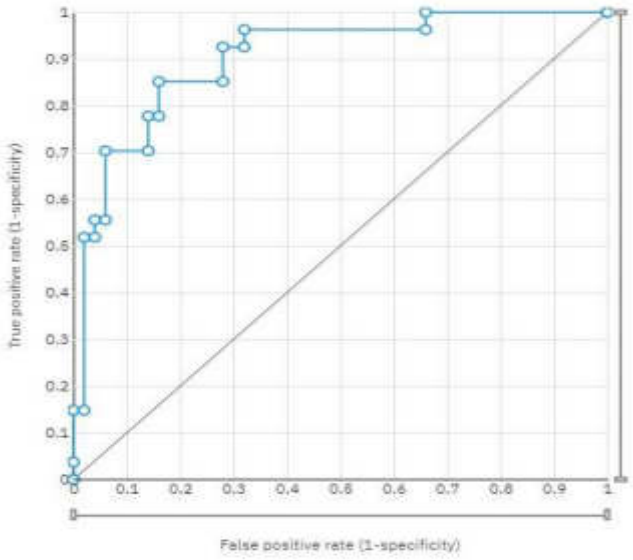

Fig. 5.4: ROC of of XGB Classifier

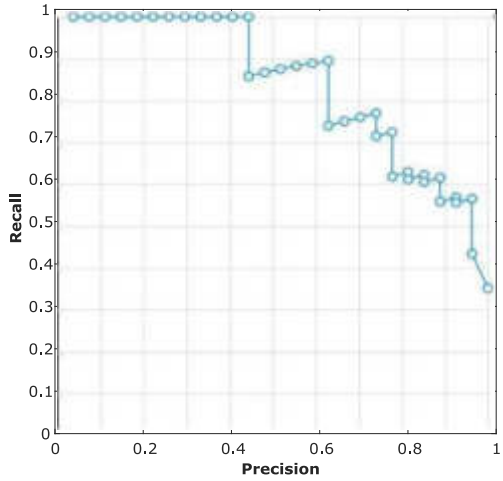

Fig. 5.5: Precision Recall curve of Gradient Boosting Classifier

6. Simulation Results and Discussions.

6.1. Test beds used in the work. The Pima Indian Diabetes dataset itself serves as a foundational test bed. This dataset includes various health-related features, making it suitable for both conventional machine learning and IBM AutoAI approaches. The experiment is performed using Auto AI or without using Auto AI, the performance can be evaluated using few performance metrics like Accuracy, ROCAUC, Precision, Recall and F1 measure. They are shown in Equ. 6. 1,6. 2,6. 3,6. 4,6. 5 and 6. 6.

Accuracy:

$$Accuracy = (TP + TN)/(TP + FP + TN + FN) * 100 \tag{6.1}$$

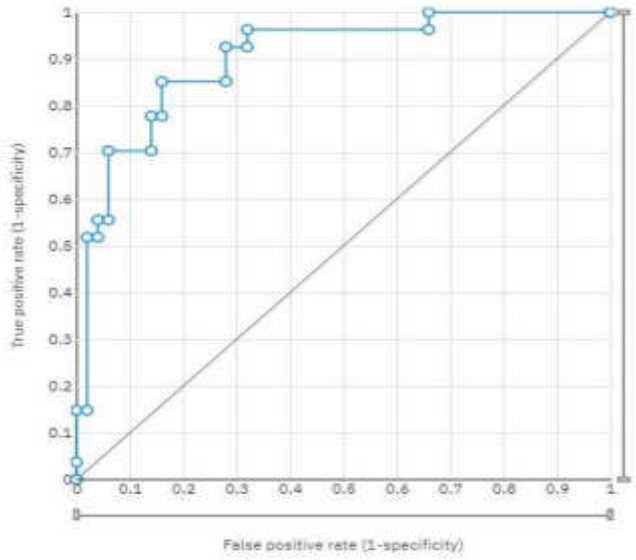

Fig. 5.6: Precision Recall curve of XGB Classifier

Precision:

$$Precision = TP/(TP + FP) * 100 \tag{6.2}$$

Recall or Sensitivity:

$$RecallorSensitivity = TP/(TP + FN) * 100 \tag{6.3}$$

F1 Score:

$$F1 = 2 * (precision * recall)/(precision + recall) * 100 \tag{6.4}$$

Specificity:

$$Specificity = TN/(TN + FP) * 100 \tag{6.5}$$

AUC:

$$AUC = \int_0^1 TruePositiveRate(FPR)d(FalsePositiveRate) \tag{6.6}$$

where TP,TN,FP,FN in Equ. 6. 1,6. 2,6. 3,6. 4,6. 5 and 6. 6 are True positive, True Negative, False Positive and False Negative respectively. In this equation, the True Positive Rate (TPR) is also known as Sensitivity or Recall, and the False Positive Rate (FPR) is the complement of Specificity.

This experiment for prediction of diabetes Mellitus is performed using 2 methods. First method is experimenting by utilizing IBM Auto AI tools and resources for diabetes prediction and same experiment is repeated without Auto AI using conventional Machine Learning Process . Model building using different machine learning algorithms is done manually . Here 12 such algorithms are used for evaluating the model using same PIMA Indian dataset and different performance metrics are obtained such as Accuracy,Precision,Recall,F1 score, ROC etc. and results are compared with IBM Auto AI results. Comparison of AI with Auto AI is done in this work. The advantage of using Auto AI is faster execution and good performance. Table. 6.1 depicts results obtained by Auto AI process. In Table 1 GB referes to Gradient Boosting Classifier and XGB refers to XG Boost Classifier. Comparision of performance metrics without Auto AI are tabulated in Table. 6.2 . Similarly for Table. 6.2 the abbreviations are listed in detail.

Table 6.1: Comparision of performance Metrics using IBM Auto AI best models

Model	GB (Auto AI)	XGB (Auto AI)
Accuracy	84.4	80.5
ROC AUC	90.3	82.1
Precision	85.7	75
Recall	66.7	66.7
F1	75	70.6

Table 6.2: Comparison of performance Metrics without Auto AI

Model	L R	R F	SVM	KNN	GB	GNB	XGBt	XT	LGB	AB	BNB	DT
Accuracy	84.415	80.51	80.51	79.22	77.92	77.92	77.92	75.32	74.02	74.02	72.72	66.23
ROC AUC	80.69	78.69	77.752	77.71	74.84	75.79	75.79	71.94	72.85	70.96	69.04	64.14
Precision	81.81	70.37	72	67.85	68	66.66	66.66	64	60	61.53	60	50
Recall	69.23	73.07	69.23	73.07	65.38	69.23	69.23	61.53	69.23	61.53	57.69	57.69
F1	75	71.69	70.58	70.37	66.66	67.92	67.92	62.74	64.28	61.53	58.82	53.57

1. LR: Logistic Regression
2. RF: Random Forest
3. SVM: Support Vector Machine
4. KNN: k-Nearest Neighbors
5. GB: Gradient Boosting
6. GNB: Gaussian Naive Bayes
7. XGB: XGBoost
8. XT: Extra Trees
9. LGB: LightGBM
10. AB: AdaBoost
11. BNB: Bernoulli Naive Bayes
12. DT: Decision Tree

Using Method 1, Gradient Boosting Classifier is selected by the Auto AI experiment as the best performing model after fine tuning all the hyper-parameters. Fig. 5.3 and Fig. 5.4 depicts ROC curve of Gradient Boosting and XGB classifiers respectively. Fig. 5.5and Fig. 5.6 depicts Precision Recall Curve of Gradient Boosting and XGB classifiers respectively.

The Area Under the Curve (AUC) is also satisfactory which depicts the TPR (sensitivity) and FPR (specificity). The models having higher AUC are said to perform better.

In method2 ,the experiment is repeated without Auto AI i. e conventional machine learning algorithms are optimized using a new approach called as grid search and consolidated Accuracy and ROC AUC results are tabulated in Table. 6.3

Optimized Logistic Regression is good at Accuracy i. e 84. 4 percentage and ROCAUC is 88. 98%. When the Experiment is performed with IBM Auto AI, Gradient Booster Classifier is best among others which achieved hold out accuracy of 84. 41%. The cross validation score of 77. 1%. The Area under ROC,Precision,Recall,F1 score, Average Precision and log loss of Gradient Boosting Classifier which is top Performing Classifiers using IBM Auto AI are 90. 3%, 85. 7%, 66. 7%, 75%, 83. 6%, 38. 8% respectively. The next best classifier is XGB classifier having holdout accuracy as 80. 5% and cross validation score of 76. 1%. The Area under ROC, Precision, Recall, F1 score, Average Precision and log loss of XGB classifier are 88. 6, 75, 66. 7, 70. 6, 83. 3 and 39. 0 respectively. If we compare Gradient Boosting Classifier in AI and Auto AI technique 6. 42% increase can be observed in accuracy in Auto AI technique. Similarly in XG Boost classifier 2. % increase can be observed in Accuracy. However using AI techniques Logistic Regression (LR) model is performing well in accuracy i. e 84. 4%. A Comparison with Existing Works The Comparison is done with existing works both

Table 6.3: Optimized results after using grid Search

CLASSIFIER	ACCURACY	ROC – AUC
LR	84.4	88.98
KNN	75.32	82.35
SVC	84.4	89.14
GAUSSIAN NB	78	87.48
BERNOULI NB	73	79.41
DECISION TREE	66	64.14
RANDOM FOREST	80.51	85.89
EXTRA TREES	75.32	82.5
ADABOOST	79.22	87.4
GRADIENT BOOST	77	81.82
LIGHT GBM	74	83
XG BOOST	77.92	84.31
GRADIENT BOOSTING (AUTO AI)	84.4	90.3
XGB CLASSIFIER (AUTO AI)	80.5	76.1

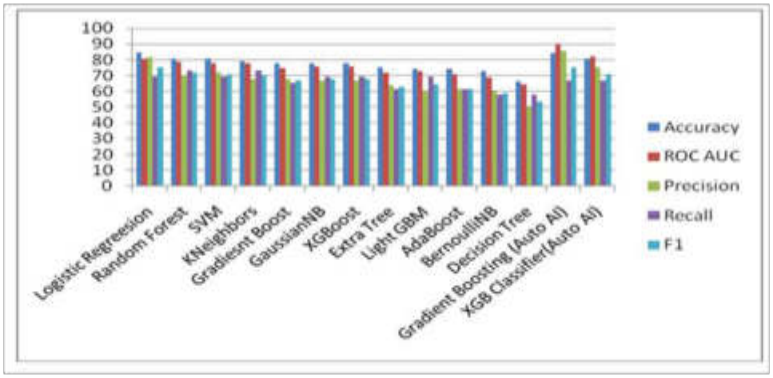

Fig. 6.1: Graphical Representation of AI and Auto AI Algorithms

AI and Auto AI in literature and results are consolidated in Table6.4 . The graphical representation of AI and auto AI algorithms are shown in Fig. 6.1.

7. Conclusions and Future Scope. The paper presents diabetes mellitus prediction using different approaches of Artificial Intelligence. The endeavor to do this prediction employing both conventional methods and cutting-edge technologies like IBM AutoAI, holds significant promise for giving early alerts and lifestyle changes for a better and healthy life. The deployment of advanced algorithms of Auto AI will enhance accuracy in predicting diabetes. The comparative analysis between Auto AI and conventional methods provides us with valuable inputs on the strengths and limitations of each approach but also explores the potential of automation in streamlining the predictive modeling process. Using Auto AI technique for Pima Indian diabetes data set,Gradient boosting classifier showed better performance with 84. 4% accuracy and conventional Machine learning techniques gave Logistic Regression,the better performance with 84. 4% accuracy. The findings of this research will contribute to the growing body of knowledge in healthcare analytics and machine learning applications. The insights gained are crucial for healthcare professionals and doctors in adopting proactive strategies for diabetes management. The emphasis on interpretability, validation across diverse datasets, and usability in realworld healthcare settings underscores the practicality and applicability of the developed models. The future scope of this research extends towards continual refinement and adaptation of predictive models. Further investigations could explore the integration of additional clinical parameters, genetic data, and lifestyle factors to enhance the predictive power of the models. Exploring the potential of explainable AI (XAI) techniques

Table 6.4: Comparison of proposed work with Existing works

Authors /papers	Algorithm	Accuracy	Precision	Recall	F1score	ROC-AUC
Victor chang et al.[4]	J48 decision tree	75.65	70.86	60.36	79.26	80.84
	NB	77.83	81.25	86.09	83.6	84.1
	RF	73.91	80.79	79.74	80.26	81.77
shafi salliah et al. [14]	NB	74.28	75.7	76.1	75.8	81.7
	SVM	63.1	42.2	64.9	51.1	54.4
	DT	71.81	73.3	73.6	73.4	74.9
Ahmed Nazin et al.[1]	NB	78.95	72	68	70	87.98
	DT	76.32	68	68	68	74.15
	RF	80.25	79	62	64	86.96
	SVM	80.26	83	58	70	87.76
	LR	77.63	79	58	68	85.49
	GB	78.95	72	70	70	83.83
	KNN	75	70	60	63	78.65
Neha Prernax et al.[18]	LR	74.4	85.6	77.5	81.3	76.5
	KNN	70.8	83.2	74.8	78.7	81.5
	SVM	74.4	85.6	77.5	81.3	77.1
	NB	68.9	84	82	83	76
	DT	69.7	74.4	78.1	76.2	84.2
	RF	75	84	78.9	81.3	1
Yashi srivastava et al.[16]	LR Auto AI	77.8	75.6	45.9	57.1	77.8
Proposed Model without Auto AI	LR	84.4	81.8	69.2	75	80.6
	RF	80.5	70.3	73	71.6	78.6
	SVM	80.5	72	69.2	70.5	77.7
	K Neighbors	79.2	67.8	73	70.3	77.7
	Gradient Boost	77.9	68	65.3	66.6	74.8
	Gaussian NB	77.9	66.6	69.2	67.9	75.7
	XG Boost	77.9	66.6	69.2	67.9	75.7
	Extra Tree	75.3	64	61.5	62.7	71.9
	Light GBM	74	60	69.2	64.2	72.8
	Ada Boost	74	61.53	61.5	61.5	70.9
	BernoulliNB	72.7	60	57.6	58.8	69
	Decision Tree	66.2	50	57.6	53.5	64.1
Proposed Model using IBM Auto AI	Gradient Boosting (Auto AI)	84.4	85.7	66.7	75	90.3
	XGB Classifier (Auto AI)	80.5	88.6	66.7	70.6	88.6

could contribute to improve the interpretability of machine learning predictions, fostering better collaboration between algorithms and healthcare professionals. Additionally, the generalization and scalability of the models across diverse populations are also to be focussed. The customization of models should be done by focussing on specific demographic groups, considering variations in healthcare practices, genetic predispositions, and also environmental factors. The collaboration between data scientists, healthcare experts, and technology developers will play a key role in ensuring that predictive models not only meet rigorous standards but also align with the dynamic landscape of healthcare advancements. As Health care analytics is the ever evolving field , the integration of machine learning for diabetes prediction is very important. The continuous developments in innovation and practical implementation will pave the way for diabetes management and prevention in future.

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A FRAMEWORK OF DIGITAL TWINS FOR IMPROVING RESPIRATORY HEALTH AND HEALTHCARE MEASURES

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Abstract. The investigation describes an inventive use of digital twin technology and LSTM-based machine learning models for real-time patient lung disease monitoring and nutrition planning. The suggested application uses various patient healthcare data, treatment processes, dietary habits, and real-time sensor information to construct digital twins, which are virtual reproductions of specific patients. The LSTM model is trained on this large dataset to predict patient health improvements and dietary needs. For each patient's digital twin, the program provides personalized treatment plans and nutritional advice, enabling proactive interventions and optimizing patient care. Using performance measures, the trained LSTM model achieves high scores for accuracy (92%), precision (89%), recall (93%), and F1 score (91%), proving its usefulness in generating credible health predictions. Patient feedback on the program shows that patients (98.8%) agree on the accuracy and importance of health feedback, as well as the convenience of access to health information (95.4%). The application's response rate study reveals an average response rate of 85.87%, assuring prompt feedback. To secure patient information, the study emphasizes data privacy and security, adopting multi-layered authentication and data encryption. The outcomes of this study demonstrate the application's potential to revolutionize patient-centered healthcare by providing data-driven, personalized solutions to patients and healthcare professionals.

Key words: Digital Twin, health care, IoT, machine learning, database, health model.

1. Introduction. Digital twin technology is a cutting-edge idea that entails creating virtual clones of tangible assets or entities, and its use in healthcare offers great potential [1]. Digital twins contain a wide variety of patient data in the context of patient health monitoring, including treatment processes, dietary habits, and real-time sensor data from wearable devices and Internet of Things (IoT) sensors. These virtual representations are dynamic and constantly updated with fresh data, representing specific patients' real-time health conditions [2]. Digital twins give healthcare practitioners with a complete and granular perspective of their patient's health, allowing them to monitor not just individual data points, but also the intricate relationships and dependencies between various health indices [3]. Digital twins give a complete view of a patient's health by combining data from different sources, giving crucial insights into illness development, treatment success, and potential health hazards [4].

In several fields, research on the application of digital twins in healthcare has shown promising findings. Digital twins have been utilized for individualized treatment planning, enabling doctors to model and optimize treatment plans for specific patients based on their distinct health profiles. Healthcare professionals may forecast treatment responses and customize treatments to maximize efficacy while minimizing unwanted effects by incorporating patient-specific data into the digital twin model. Digital twins have also shown promise in the prediction and prevention of illness [5]. The digital twin can detect early warning signals of illness development and inform healthcare practitioners by continually monitoring a patient's health data, enabling for prompt intervention and proactive treatment of chronic disorders [6].

Furthermore, one of the most common applications of digital twins in healthcare is real-time patient monitoring [7]. Digital twins offer continuous monitoring of patient health by gathering real-time data from IoT sensors and wearables, delivering immediate feedback to healthcare practitioners, and empowering patients to actively engage in their treatment [8]. Long Short-Term Memory (LSTM) is a type of recurrent neural network (RNN) that is used to analyze time-series and sequential data [9]. LSTMs, unlike standard RNNs,

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have memory cells and numerous gates, such as input, output, and forget gates, which allow them to learn and store knowledge over extended data sequences [10]. The capacity of LSTMs to grasp long-term relationships and temporal patterns in sequential data is its primary benefit. As a result, they are well-suited to analyzing complicated healthcare data, where patient health information frequently demonstrates temporal linkages and dependencies [11].

2. Literature Review. To solve complicated issues, traditional methodologies in a variety of disciplines frequently depended on substantial feature engineering and personal interaction [3]. This was especially the case before the broad use of more sophisticated machine learning techniques, such as deep learning and digital twin technologies. Using traditional methods, models had to be manually designed and developed by domain specialists to fit particular situations. This frequently required a thorough comprehension of the underlying systems and processes. The management of intricate and non-linear interactions within data was limited by manual intervention [4]. The dependence on manual methods created a bottleneck as systems got increasingly complex.

Through remote monitoring, digital twins improve patient outcomes by enabling preventative treatments and offering real-time, tailored information about a patient's health state. Digital twins gather and evaluate data from a variety of sources, including wearables, sensors, electronic health records, and medical equipment, by building a virtual image of the patient [5]. Without the patient having to be present in person at a medical institution, healthcare personnel may remotely monitor vital signs, medication adherence, activity levels, and other pertinent metrics thanks to this thorough monitoring. Digital twins can identify minute changes in health markers and foresee possible health problems before they worsen, allowing for prompt treatments and preventative actions through predictive analytics and machine learning algorithms [6].

Predictive analytics and decision support are two areas where digital twins and the Internet of Things (IoT) has significant benefits. IoT devices constantly gather information from several sensors and sources, delivering a steady flow of up-to-date data [7]. More accurate predictive analytics and decision-making are made possible by the accurate representations of physical assets or systems that may be produced by feeding this data into digital twin models. Digital twins are tools that can identify probable problems or malfunctions before they happen by evaluating data from IoT sensors are implanted in machinery or equipment [8]. This predictive maintenance strategy improves asset performance, lowers maintenance costs, and minimizes downtime. Organizations may uncover inefficiencies, bottlenecks, and opportunities for improvement and optimize their operations by combining digital twins with IoT data analytics [9].

Relying on predetermined rules that were manually encoded by specialists, many old systems were rule-based. These solutions worked effectively for clearly defined issues, but they were not flexible enough to handle uncertain or dynamic situations. Robust feature design was a major component of traditional machine learning models. Choosing, modifying, and combining input variables were all part of the feature engineering, which improved model performance[10]. To increase the accuracy of the model, engineers had to invest a lot of effort in the fine-tuning of characteristics. Iterative changes depending on the model's performance were necessary during this process, which was frequently trial-and-error. The complexity and amount of datasets increased, making feature engineering more difficult. For many interrelated component systems, it was very labor-intensive. Digital twins reduce the need for considerable manual intervention by utilizing simulations and real-time data. With no specified feature, machine learning algorithms, such as deep learning, may automatically extract pertinent patterns from data [11].

It may be difficult to identify and forecast uncommon or underrepresented medical diseases due to datasets that are skewed toward more common disorders. Assumptions on the underlying physiological processes are frequently made by models employed in digital twin research. These presumptions could reduce the intricacy of real-world settings, which might restrict the accuracy of the model in some circumstances. Certain models presume linear correlations among variables, which could not apply to every medical condition or patient response. Variations in health conditions across various ethnic or socioeconomic groups may not have been properly taken into consideration in this study. The findings' ability to be applied to larger groups may be hampered by this lack of variety.

LSTM-based machine learning models have been successfully used in a variety of healthcare applications [12]. Researchers have used LSTMs to diagnose diseases, monitor patients' health, predict drug adherence

and predict patient outcomes. LSTMs have proven outstanding accuracy in illness diagnosis by analyzing patient data such as medical imaging scans and physiological signals to detect and categorize disorders [13]. These models can detect minute patterns and characteristics of certain illnesses, assisting physicians in making accurate and timely diagnoses. Another area where LSTM models have thrived in patient health monitoring. LSTMs can anticipate patient health trends, detect abnormalities, and deliver timely alerts for potential health problems by analyzing time-series data from wearable devices and medical sensors [14]. Because of this real-time monitoring, proactive intervention, and personalised healthcare management is possible. In addition, LSTMs have been used to predict patient outcomes such as hospital readmission rates and illness progression. Concerns about data privacy extend to data sharing and data aggregation, since digital twins may combine patient data from several sources to increase prediction accuracy. Obtaining patient permission and anonymizing data are critical factors in maintaining patient privacy and adhering to data protection standards.

While there are significant challenges, there are also positive opportunities for progress in the application of digital twins in the healthcare sector. Since digital twins include building virtual portraits of specific patients, one difficulty is guaranteeing the confidentiality and privacy of critical medical data. It's critical to strike a balance between protecting patient anonymity and making data accessible to healthcare providers. Technical challenges may arise when combining many complicated healthcare data sources into a coherent digital twin model. Positively, there is great promise for customized medicine, therapy optimization, and predictive analytics using digital twins.

Healthcare professionals may forecast the evolution of diseases, customize therapies, and optimize treatment strategies by modeling the unique traits and reactions of each patient. To completely achieve the transformative potential of digital twins, the healthcare sector has to resolve these issues with robust data governance, privacy regulations, and technological advancements [15]. It may be difficult to identify and forecast uncommon or underrepresented medical diseases due to datasets that are skewed toward more common disorders. Assumptions on the underlying physiological processes are frequently made by models employed in digital twin research. These presumptions could reduce the intricacy of real-world settings, which might restrict the accuracy of the model in some circumstances. Certain models presume linear correlations among variables, which could not apply to every medical condition or patient response. Variations in health conditions across various ethnic or socioeconomic groups may not have been properly taken into consideration in this study. The findings' ability to be applied to larger groups may be hampered by this lack of variety.

To continually monitor patient health data from multiple sources, including IoT sensors, digital twins, or virtual replicas of patients, are generated and combined with LSTM models. The LSTM model forecasts patient health improvements and nutritional needs, resulting in proactive interventions and optimized treatment regimens. The results show great accuracy and favorable patient feedback, demonstrating the application's potential to revolutionize patient-cantered healthcare and enhance overall health outcomes.

3. Methodology.

3.1. Architecture of digital twin. Digital twin technology is used in this innovative investigation to enhance patient health monitoring. An LSTM machine learning model is trained using a range of healthcare data, such as patient treatment processes, dose levels, and health gains or declines. The machine learning system also considers the patient's eating habits and how they impact health.

Figure 3.1 depicts the architecture of the proposed approach, which integrates digital twin technologies, LSTM machine learning, and IoT sensors. Healthcare practitioners may monitor and manage patients in a data-driven way with the aid of this complete system. The study's findings have the potential to change the healthcare business by improving patient outcomes and increasing overall healthcare efficiency by providing personalized and optimum treatment. Because of its promise as a powerful tool for real-time health monitoring, digital twin technology will lead to future medical breakthroughs.

Digital twins are more adaptive when LSTM models are included because they can learn from and adjust to shifting patterns in time-series data. For Digital Twins to effectively reflect and forecast the behavior of dynamic systems under changing conditions, this flexibility is essential.

A huge IoT sensor network captures real-time data on patients by tracking crucial health parameters and physical activities. Following the loading of this sensor data into the LSTM model, each patient may get personalized treatment programs and nutritional advice. The technology maintains an up-to-date virtual

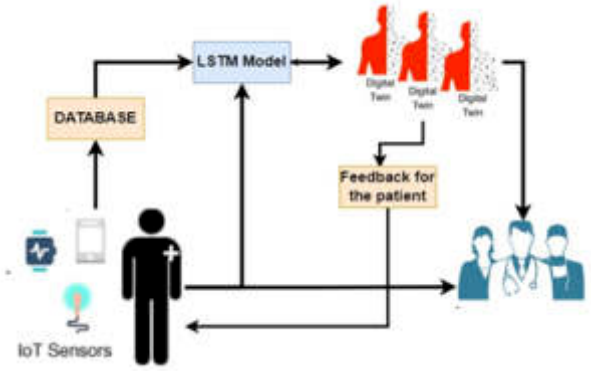

Fig. 3.1: Architecture of the proposed system

image of each patient, known as their "digital twin," by routinely monitoring and updating each patient's health condition through prescribed prescriptions and diets. This digital twin uses machine learning as a dynamic feedback system to continually enhance patient care. IoT sensors give continuous real-time data, and the LSTM model modifies its predictions based on these variations to deliver accurate and timely evaluations of health status. This proactive strategy helps medical personnel to detect possible health risks early and respond quickly.

3.2. Digital twin. The architecture for using digital twin technology in the proposed study offers a complete approach to real-time patient health monitoring. The digital twin framework is intended to bring together patient healthcare data, treatment processes, nutritional information, and IoT sensor data to create a unified and dynamic virtual depiction of each patient's health condition. This system uses the capabilities of LSTM (Long Short-Term Memory) to analyze and learn from previous patient data, allowing for precise predictions of patient reactions to different therapies and diets. The framework's initial stage is collecting and preparing various healthcare datasets, including patient information, treatment methods, doses, and health outcomes. The collection also includes information regarding patients' food habits and their influence on health improvement. The disease mainly used to monitor in this research is lung diseases like pulmonary disease, asthma, lung cancer, and respiratory infections. These diseases databases are taken as input to the model. The dataset in the Kaggle is taken for analysis. It has a data set of various lung disease histories described above and medical conditions for the disease. Also, the diet for the disease is trained using medical professionals. The LSTM machine learning model learns the intricate temporal patterns and correlations between treatments, diets, and health states using this extensive data as training input.

The first step of the framework's development is gathering and organizing diverse healthcare datasets, such as those about patients, treatments, dosages, and health results. Additionally, data about patients' eating habits and how they affect the improvement of their health is gathered. Lung illnesses, such as lung cancer, asthma, pulmonary disease, and respiratory infections, are the primary diseases monitored in this study. The model uses this database of illnesses as input. The Kaggle dataset is used for analysis. It contains a data set of different lung disease histories, as well as the corresponding medical problems. Medical professionals are also used in the training of the disease-specific diet. Using this comprehensive data, the LSTM machine learning model learns the complex temporal patterns and relationships between therapies, diets, and health states.

The system then progresses to real time data gathering using IoT sensors, which continuously collect vital health metrics, physical activities, and other relevant patient data and shown in Figure 3.2.

The real-time sensor data is sent into the pre-trained LSTM model, which creates individualized treatment plans and dietary suggestions based on each patient's current health status. Healthcare personnel may make data-driven choices in real-time due to the digital twin's dynamic nature, which facilitates early diagnosis of possible health concerns and prompt treatment.

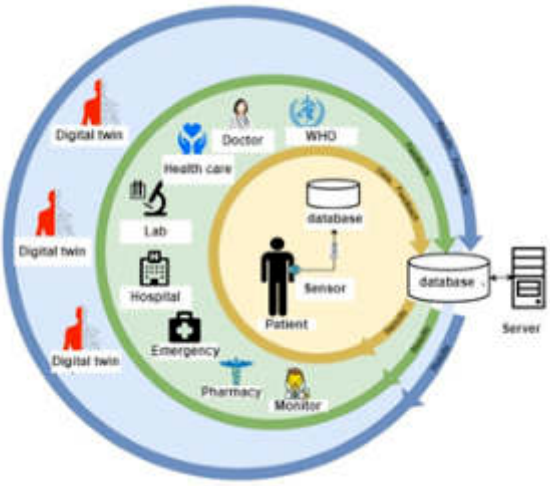

Fig. 3.2: Methodology of the proposed research

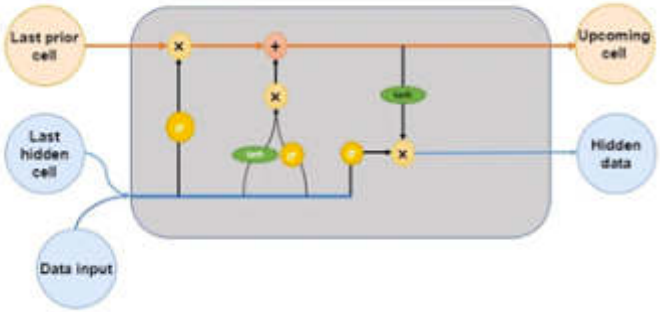

Fig. 3.3: LSTM architecture with various cells

3.3. LSTM model. The LSTM (Long Short-Term Memory) model is significantly employed in the proposed study for real-time patient health monitoring. The popularity of LSTM originates from its capacity to handle sequential and time-series data, making it ideal for the investigation of complex and dynamic healthcare data in this study. The LSTM design, which is made up of a huge number of memory cells, each with its own set of gates that regulate information flow, enables the model to record and maintain long-term interactions. An input gate, a forget gate, and an output gate are the three primary parts of an LSTM cell. To handle sequential data, these gates function well together. The input gate chooses which input data components will be stored in the memory cell first. By taking input from both the current input and the preceding output, the model assists in determining the significance of new information in the present context. To prevent the memory cell from getting overloaded with unneeded data, the forget gate chooses if data from the memory cell should be removed at the same time. To selectively forget or retain information, the forget gate evaluates both the current input and the preceding output. Figure 3.3 depicts the architecture of the LSTM model, highlighting how many LSTM cells are linked. The hidden state and cell state are moved to the following time step as each cell in turn examines the incoming input. Because of its recurrent nature, which allows it to successfully capture temporal patterns and correlations.

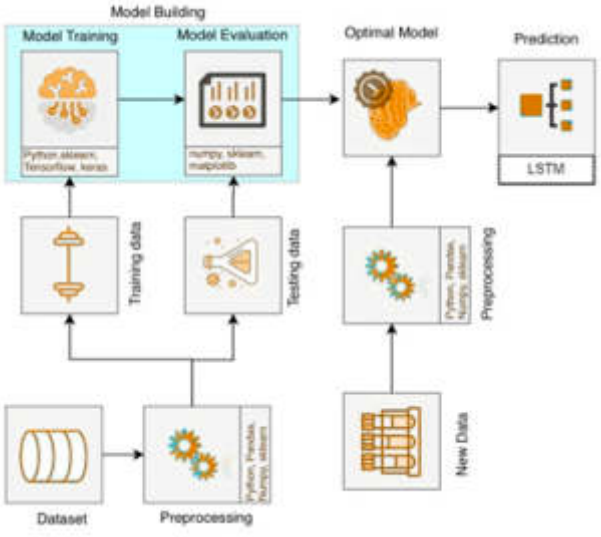

Fig. 4.1: Workflow of the proposed system

4. Implementation of the Proposed System. The process of implementing real-time patient lung health monitoring utiliZing the LSTM model and a variety of sensors is multi-layered and thorough to provide personalized and data-driven healthcare solutions.

This research seeks to revolutionize patient care by continually monitoring patient health using different sensors such as temperature, pressure, glucose, and pulse oximeter sensors, in conjunction with medical reports such as X-rays, and CT scans and shown in Figure 4.1. The core of this program is the LSTM model, which predicts patient health improvements and quantifies the percentage of improvement over previous occurrences. To attain the best performance in predicting patient health reactions, the training technique includes fine-tuning the LSTM model's parameters and improving its architecture.

Simultaneously, the system incorporates medical information, including lung CT scans and X-rays. These reports provide detailed information on the internal health status of the patient, which enables the LSTM model to include more context and enhance prediction accuracy. After the IoT sensors are placed and the LSTM model has been trained, the next step is to continually monitor the health of the patients. Patients provide real-time data from sensors, which is analyzed by the LSTM model to predict improvements in their health based on individualized treatment regimens and dietary guidelines. Additionally, the application calculates the patients' progress percentage above their pre-programmed health condition.

4.1. Feedback to the patient and doctor from the model. A unique application has been created to give both patients and healthcare practitioners personalized feedback on patient health and dietary suggestions according to the LSTM model. Figure 5 demonstrates how it utilizes patient data and the capabilities of the LSTM model to address various healthcare concerns.

Patient's vital signs, symptoms, and other crucial health data are collected using an easy-to-use interface. This information, together with the patient's medical history, dietary preferences, and real-time health indicators from IoT devices, are used by the LSTM model to give tailored solutions for each patient's unique health requirements. The user-friendly interfaces assist both patients and healthcare practitioners. Patients may obtain personalized health feedback, treatment plans, and dietary advice through a dedicated site, while healthcare practitioners can monitor patient data, track health progress, and access LSTM model suggestions as shown in Figure 4.2.

4.2. Authentication access. The authentication system serves as the first line of defense, making sure that only authorized users have access to private health information and dietary plans. Before accessing their

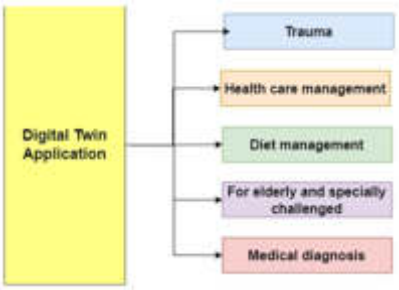

Fig. 4.2: Application output from digital twin

Table 5.1: Performance score of the model

Metric	Score
Accuracy	0.92
Precision	0.89
Recall	0.93
F1 Score	0.91

information, the patient must provide their login credentials, preventing unauthorized parties from seeing critical information. A biometric fingerprint access method is offered by the software as an extra degree of authentication. When the patient enters their login credentials, their fingerprint is scanned to verify their identity. Limiting access to private medical information by unauthorized parties, this strategy protects patient privacy.

5. Result and Discussion. Various performance criteria were used to test the trained LSTM model's usefulness in giving accurate and trustworthy predictions for patient lung health monitoring and food recommendations. Among the evaluation criteria used are F1 score, recall, accuracy, and precision.

The performance metrics of the trained LSTM model are compiled in Table 5.1. The accuracy score, which represents the percentage of true predictions generated by the model, was determined to be 92%. The precision score was judged to be 89%, which assesses the ratio of real positive predictions to all positive predictions. The recall score was determined to be 93%, signifying the ratio of accurate positive predictions to all real positive events. Lastly, the accuracy and recall harmonic mean, or F1 score, came out to be 91%. These performance measures show that the LSTM model is very accurate and capable of making trustworthy predictions about patient health problems and dietary recommendations. The precision score shows that the model has a low false positive rate, which means that it predicts positive situations incorrectly less often.

Figure 5.1 depicts the statistical analysis of the patient input on the usability and functioning of the program.According to the findings, 98.8% of patients highly believe that the program gives accurate and meaningful health feedback. Furthermore, 95.4% of patients feel that the program provides quick and easy access to their health information and dietary plans.

Table 5.2 includes columns for patient demographics (Patient ID, Age, Gender, Health Condition), nutritional goals, and specific nutritional information (Daily Caloric Intake, Protein, Carbohydrate, and Fat Intake). This table facilitates a comprehensive approach to health tracking, allowing healthcare professionals to monitor and analyze various aspects of a patient's well-being. By regularly updating this table, healthcare providers can gain insights into a patient's adherence to nutritional goals, effectiveness of medications, and overall satisfaction with the tracking system. Additionally, including physical activity levels contributes to a more thorough understanding of the patient's lifestyle, enabling tailored recommendations for improved health outcomes.

As shown in Table 5.3, the Timestamp denotes the date and time when the feedback was delivered. Feedback type indicates the type of feedback provided by the LSTM model (e.g., Nutritional Advice, Exercise Guidance,

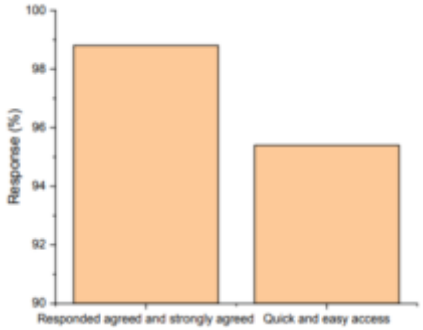

Fig. 5.1: Statistical analysis of patient

Table 5.2: Patient characteristics, dietary objectives, and dietary data

Patient ID	1	2	3	4	5
Age	35	28	45	50	40
Gender	Female	Male	Female	Male	Female
Health Condition	Hypertension	Diabetes	None	Heart Disease	Obesity
Usage Frequency (per week)	5	3	7	4	6
Usability Score (1-10)	8	7	9	6	8
Satisfaction Score (1-10)	9	8	10	7	9
Nutritional Goals	Weight loss	Blood sugar control	General well-being	Heart health	Weight management
Protein Intake (grams/day)	1800	2000	2200	1800	2500
Carbohydrate Intake (grams/day)	70	80	90	70	100
Fat Intake (grams/day)	150	180	200	150	250
Physical Activity Level	Moderate	Sedentary	Active	Light Exercise	Moderate
Medications	None	Insulin	None	Aspirin	None

Progress Update, Meal Plan Review). LSTM Reaction Rate (1-10) is the numerical score representing the reaction rate of the patient to the feedback, on a scale from 1 to 10. Table 3 serves as a vital tool for healthcare providers and administrators to systematically collect, analyze, and respond to patient feedback. The inclusion of a timestamp enables the tracking of feedback trends over time, allowing healthcare organizations to identify patterns and make timely adjustments to services or systems. The Patient ID column facilitates personalized follow-ups and interventions, ensuring that specific concerns raised by individual patients are addressed promptly.

The Feedback Type categorization allows for a nuanced understanding of the nature of patient feedback, aiding in prioritizing areas for improvement. The LSTM Reaction Rate is a key metric that reflects the efficiency of automated systems in processing and responding to patient feedback. Monitoring this rate provides insights into the responsiveness and adaptability of the automated system, allowing for continuous optimization. Overall, this table supports a proactive and data-driven approach to enhancing patient satisfaction and the quality of healthcare services by providing a comprehensive view of patient feedback and the automated system's responsiveness. Regular analysis of this data can inform strategic decisions to improve patient experience and healthcare outcomes.

Figure 5.2 depicts the LSTM model's reaction rate while delivering feedback to patients. The reaction rate was calculated by measuring how long it took the model to provide health feedback after receiving input from patients. The performance measures show that the LSTM model is very accurate and capable of making trustworthy predictions about patient health problems and dietary recommendations.

According to the results, the average reaction rate for fast feedback was 85.87%, demonstrating that the

Table 5.3: Tracking the feedback of patients at different timestamps

Timestamp	Patient ID	Feedback Type	LSTM Reaction Rate (1-10)
LSTM Reaction Rate (1-10)	1	Nutritional Advice	8
LSTM Reaction Rate (1-10)	2	Exercise Guidance	7
LSTM Reaction Rate (1-10)	3	Progress Update	9
LSTM Reaction Rate (1-10)	4	Meal Plan Review	6
LSTM Reaction Rate (1-10)	5	Motivational Quote	8

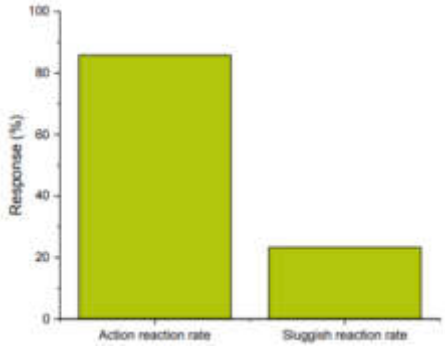

Fig. 5.2: Model response rate

model typically responds quickly to patient inputs. The sluggish reaction rate, on the other hand, was observed at 23.3%, indicating that the model's response is occasionally delayed. The model's effectiveness in giving timely health forecasts and dietary suggestions is confirmed by the high average response rate for immediate feedback. However, the presence of a sluggish reaction rate suggests that the model may take longer to produce feedback in some cases.

It is critical to emphasize the significance of further research for validation and possible expansions when concluding a study on digital twins with LSTM models in medical imaging. While the current study's results may show that digital twins and LSTM models have promising uses in medical imaging, more validation is necessary to guarantee that the conclusions can be applied to a variety of patient demographics and medical problems. The accuracy and feasibility of the proposed method may also be improved by investigating possible expansions, such as adding new data sources or improving model topologies. To advance the area of digital twins in healthcare and realize their full potential in improving patient outcomes, diverse teams of researchers, doctors, and industry partners must collaborate.

6. Conclusion. Finally, the proposed research has shown the ability of digital twin technology and LSTM-based machine learning models to change patient health monitoring and dietary planning. The production of virtual patient replicas that represent the complexity of individual health conditions and treatment responses has been made possible through the use of digital twin technology. By combining various patient data such as healthcare records, treatment procedures, food habits, and real-time sensor information, the LSTM model rapidly learns and predicts patient health improvements and dietary needs. The trained LSTM model was assessed using performance metrics, with good results. Recall was 93%, accuracy was 92%, precision was 89%, and the F1 score was 91%. the model has proved its ability to generate accurate and consistent health predictions. Patients had overwhelmingly positive responses to the application, with strong agreement (98.8%) on the accuracy and usefulness of the health feedback provided. Furthermore, 95.4% of patients said the app gives them fast and simple access to their medical information and dietary suggestions. These results highlight the app's usability and the app's potential to engage consumers in their healthcare journey. Future research might concentrate on improving the model's response rate and developing additional features to suit to certain

patient demographics and health circumstances.

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