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DISTRIBUTED SYSTEMS FRAMEWORK FOR PACKAGING DESIGN INNOVATION USING VISUAL PERCEPTION AND ALGORITHM OPTIMIZATION

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Abstract. Food consumed by humans is becoming more and more customized to fit each person's unique demands, with a vast array of product labels readily available. As a result, many companies are beginning to concentrate on enhancing the practicality of contemporary packaging. Throughout the lifetime of a user-product engagement, sensory paradigms and emotional responses may shift. Traditional product packaging layout is largely based on the designer's emotional imagination and prior events; however, it is limited by uncontrollable content and a lack of expert advice; most earlier studies involving mental analysis of images focused on predicting the most prevalent viewers feelings. There are situations when an image's general impression is insufficient for practical purposes since the emotions it arouses are very subjective and differ from viewer to viewer. The proposed methodology uses Genetic Algorithm based Multi-Layer Ant Colony Optimization for analysing visual perception and emotion perception to identigy the senses of human being. A significant set of images called Image-Emotion-Social-Net is utilized to assess categorized and multivariate attitude representations. The collection, which comes from Flickr, has more than a million photos uploaded by more than 9,000 members.The results of this dataset's research indicate that the suggested approach performs better in personalized emotional identification than several contemporary methods. In comparison to other current methods, the experimental findings demonstrate that the suggested approach obtains a high packaging layout excellence rate of 95.1%, a performance success rate of 98.5%, and a mean square error rate of 1.5%.

Key words: Distributed Systems Framework, Packaging Design,Visual Perception, Algorithm Optimization

1. Introduction. In essence, packaging layout is the translation of symbols into images. It is a useful tool for promoting goods and enhancing the way they look due to its logic and useful characteristics. Pictures can express a wide range of feelings and intricate interpretations [24].Earlier research on emotional perception analysis have mostly focused on predicting the most prevalent feelings among viewers [4].This general emotion isn't always sufficient for practical purposes because the sentiments a picture inspires are very subjective and differ from viewer to viewer [9]. The main challenges facing picture emotion analysis are subjective assessment and emotional perception. Multimedia methods are becoming more and more common and showing varied growth [6]. The packaging of a good is one of the best ways to market it. Because of consumers' inescapable drive for material prosperity and their more accepting attitudes toward purchase, packaging layout has become an increasingly important tool in the marketing of goods [14]. Visual communications must therefore be incorporated into packaging designs. Communicating visually delivers visual information quickly and efficiently, forming buyers' first impression of the product.

The main objective of this research is to develop an advanced system applying distributed systems to optimize packing design which seeks to personalize and dynamically engage the user and product through our designed sensory paradigms and emotions. Genetic Algorithm-Multi-Layer Ant Colony Optimization (GA-MLACO) will be used to evaluate emotional and visual perception generating personalized insights on human sensory perception and emotional behaviours.

The primary objective of this method is to use visualization conversion to change the initial information into a format that models trained on deep learning can use.This technique increases the model's resilience and can withstand adversarial perturbations to some degree [11, 21]. The exterior appearance of brand packaging in today's market climate has a significant influence on consumer perceptions of items as well as their market performance. Any superficial flaw has the potential to harm a brand's reputation and decrease consumers' propensity to buy. As a result, it's critical to identify surface flaws in brand packaging promptly and precisely

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[18, 22]. A two-stage attention-based feature integration net was presented by author [17, 20] to identify surface flaws in trademark package. It first emphasizes how crucial it is to find surface flaws in product marketing.As customers' expectations for good quality and appearance grow, brand packaging's surface quality has a significant influence on what people decide to buy.

Food products need to be packaged in a way that wraps and protects them in order to protect them against ecological, microbiological, and transit dangers. An essential safety factor for packaging materials that come that come into contact with food is being as passive as possible with minimal food-material interactions. Additionally, shipping, logistics, advertising, and environmental advertising are all impacted by packaging [1, 12]. Adopting packaging that is environmentally friendly will need more work. First things first: when designing container for an atmosphere of comfort, remember the functions that it fulfills. The main goals of packaging are security, preservation, launching and transportation in addition to purchase, marketing, service, and guarantee.

In anticipation of this trend toward acceptance, a brand-new area of computer vision known as computable image aesthetically has emerged.Relying on precise assessments and computations of picture aesthetics, human-computer communication success depends on users' visual interactions with image systems that communicate [27, 2]. As a result, designers are better able to assess and produce aesthetically pleasing statements that complement users' feelings. This study proposes LSTM and hypergraph machine learning techniques that, through combining audio, visual, written, and affective input for a more comprehensive view of emotional circumstances, may acquire the ability to predict multiple users' feelings at once. A hypergraph is a graph that has more vertices connected by hyperedges than a basic network. The main contribution of proposed method is given below:

1. The present research presents a novel approach to the analysis of visual and emotional sensations in personalized packaging design: Multi-layer ant colony optimization based on Genetic Algorithms.
2. Through the utilization of a substantial dataset, Image-Emotion-Social-Net, which is derived from more than a million photographs on Flickr, the suggested method seeks to improve the precision of emotional detection in user-product interaction.
3. In contrast to conventional packaging layout, that is constrained by the designers' subjective emotional creativity, the new approach offers a more tailored and data-driven way to record unique sensations.
4. The testing results, which show a package design perfection rate of 95.1%, an overall rate of achievement of 98.5%, and a mean square error rate of 1.5%, show that the suggested method works noticeably better than current methods.

The rest of our research article is written as follows: Section 2 discusses the related work on various Distributed Systems Framework, Packaging Design, Visual Perception, Algorithm Optimization. Section 3 shows the algorithm process and general working methodology of proposed work. Section 4 evaluates the implementation and results of the proposed method. Section 5 concludes the work and discusses the result evaluation.

2. Related Works. In order to compare the efficacy of Affectiva, Amazon Rekognition, Baidu Studies, Face++, and Microsoft Azure in identifying feelings the author conducted two experiments. First, how well the methods classified images from three different, highly uniform face emotion datasets. The results imply that investigators and programmers may use commercialized face expression detection systems. Using multimodal time-lapse infrared video sequencing, the author [8] presents a three-stage human-computer interaction (3s-HCI) method for identifying emotions and making entertainment recommendations.

Initially detect the palate, students, and nose using the Faster R–CNN structure. The facial ROIs in this thermal clip are monitored by the Multiple Instances Learning (MIL) technique. We discovered, through the use temperatures data and rival categorization systems, that our suggested methodology consistently yielded superior outcomes. One of the main limitations of the study is the limited sample size, which makes it difficult to draw generalizations about feelings among people. In order to identify EEG emotions, the author [26, 25, 16] suggested five classical machine learning (CML) and five ensemble machine learning (EML) methods. The free DREAMER collection contains nine sentiments that can be used for ML-based training of systems.

The food supply chain and the design of brand packaging are becoming more and more dependent on big data and computer-aided design (CAD) technologies. The effectiveness of the food supply chain and the

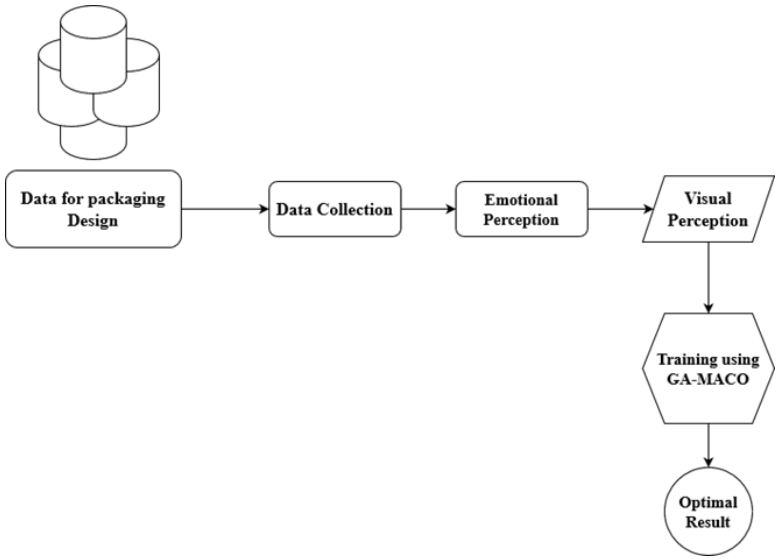

Fig. 3.1: Architecture of proposed method

creativity of brand packaging designers are further enhanced by the use of intelligent packaging technologies. The function of CAD-based and big data-driven autonomous packaging systems in the food supply chain and brand packaging design was investigated by author [10, 5]. The design of brand packaging has additional options thanks to the use of CAD software. CAD software allows architects to create precise models and simulate them, which speeds up the building and optimisation of complicated structures.As a result, packaging design becomes more sophisticated and unique while also increasing design effectiveness and satisfying the wide range of customer concerns about the look and usability of the product [23, 7, 3]. Simulated testing on packing effectiveness, including physical and barrier performance, can also be carried out with CAD technology to guarantee the dependability of packing in real-world applications.

A real-time system called the YOLO (You Only Look Once) method is used to determine broken or faulty goods by analyzing photographs of packing components for external flaws. The device evaluates packaged box quality instantaneously and can be applied in factories and manufacturing lines. The program consists of three basic steps: picture evaluation, item acknowledgment, and robot-assisted faulty item sorting [21,22]. A sorting robot system removes the damaged goods using a surface defect detection technology that combines machine vision with artificial intelligence [13]. The study [28] primarily focuses on how the use of blockchain technology handles the verification of coffee packages and promotes sustainable inclusion of the chain of supply for coffee.

The creation of this technology was sparked by the author's extensive empirical research on emotion recognition and prompt-based sentiment analysis (see [19]), which looks into the prejudices of large-scale pre-trained language model (PLM) technological advances towards emotional computing. The examination also piqued interest in prompt-based classification applications such as emotion recognition [19]. The connection among the layout of the packaging and the probability of consumers shopping online returning to Politeknik IT&B Medan is examined by the author [15]. The sample for this study is made up of 47 students from Politeknik IT&B Medan's Faculty of Business Administration, who were selected throughout both the second and forth quarters of the school year.

3. Proposed Methodology. The proposed methodology for Distributed Systems Framework for Packaging Design Innovation Using Visual and Emotion Perception and Genetic Algorithm based Multi-Layer Ant Colony Optimization. Initially, the packaging design dataset is collected and then the collected data is preprocessed. Next, the Emotion perception computing is evaluated and then the GA-MACO is used for training the dataset. Figure 3.1 shows the architecture of proposed method.

Customized food packaging design is one such trend that has caught the eye of many businesses. Companies are adopting this strategy due to strong effective performance. Instead of aiming for a mass-market approach, businesses can use customized food packaging that includes tailored design, logo or even messaging. The reason for this is that customers are now more concerned with originality, aesthetics, and emotions that the product can potentially spark. Packaging is not purely regarded as a wrapper, but it is an integral part of the product provides value during purchasing, and guarantees.

3.1. Dataset Collection. The suggested technique made use of the Flickr picture collection, whose Flickr30k dataset has become the industry standard for sentence-based image categorization. flickr-image-dataset at kaggle.com/datasets/hsankesara[24]. The present research presents Flickr30k Organizations, an addition to the 158k captions in Flickr30k that includes 276k manually annotated bounding boxes and 244k reference chains connecting image-wide citations of the same objects. They enable us to set a new benchmark for image entity-mention translation.With the integration of picture-text embeddings that frequent object sensors, a color classification algorithm, and a bias for larger objects in object selection, they offer a solid basis for this task. We show that, although our fundamental model is equally precise as more complex state-of-the-art designs, its advantages on image-sentence recall as well as additional problems do not translate to these new methods, emphasizing their limitations and the need for further research.

3.2. Emotion Perception. In order to handle the expectations of consumers and the multifaceted nature of society, the article suggests that the design method of thought be highly regarded.It has been widely employed by corporations and charities to solve social and economic challenges. Over the past ten years, the idea of design thinking has been more and more well-liked among scholars as an approach that can provide novel solutions to issues in exceedingly complex environmental and social situations. Design thinking is well suited for training multidisciplinary teams. Design teams prioritize the relationships among subjects and end customers after doing a psychological assessment first. Recognizing the issue is the first step in the process, which then moves on to solving it, motivation, innovation, and operation, and finally, execution.For every experiment, there were five steps involved.Choosing the item at the store; Opening the package; Preparing and eating the meal; completing another buy.

3.3. Genetic Algorithm. A search heuristic based on Charles Darwin's theory of natural selection is called a genetic algorithm. The method emulates the process of natural selection, whereby the most suited people are selected for procreation in order to generate the offspring of the subsequent generation. The category of evolutionary optimization algorithms includes genetic algorithms (GA). There are three phases to it: reproduction, survival, and fitness.

The genetic algorithm's process is depicted in Figure 3.2. Individual populations are created initially. Fitness value is used to calculate each individual. After individual selection using genetic operators, the fitness calculations are performed on the newly selected individual.

3.3.1. Multi-Layer Ant Colony Optimization algorithm. Setting initial values for variables like α,β, p_g, p_1, q_0, and n ant in the first phase. To determine the initial pheromone, zero, a randomized solution is built. The fitness value is then used to evaluate the population's fitness, and non-dominated solutions or Pareto optimal groupings are discovered. Figure 3.3 displays the workflow chart created by MLACO.

3.3.2. Pareto Set. The MLACO approach preserves a Pareto set. For each solution, two goals (KKM and RC) were established once the strategy for retaining non-dominated responses was developed. The non-dominated systems are found using the goal variables. Every time a new installment yields a non-dominated result, we eliminate dominating alternatives from the group and update the Pareto optimal set. These Pareto groups produce a better response for the populations that will follow, which optimizes the exploring region.

Solutions within the Pareto set don't actually guarantee the maximum NMI or modularity. True net grouping is not the same as optimal modularity[4]. The Pareto set gives the outcome based on NMI and modularity principles, allowing for the maximum possible modularity and NMI numbers. The answer with the highest NMI/modularity values was selected as the global optimum inside the Pareto optimal group.

3.3.3. Initial Pheromone trail. The value τ_0, which has a very tiny number and is constant across all linkages in the graphs, defines the initial quantity of pheromones. The beginning pheromone quantity of τ_0

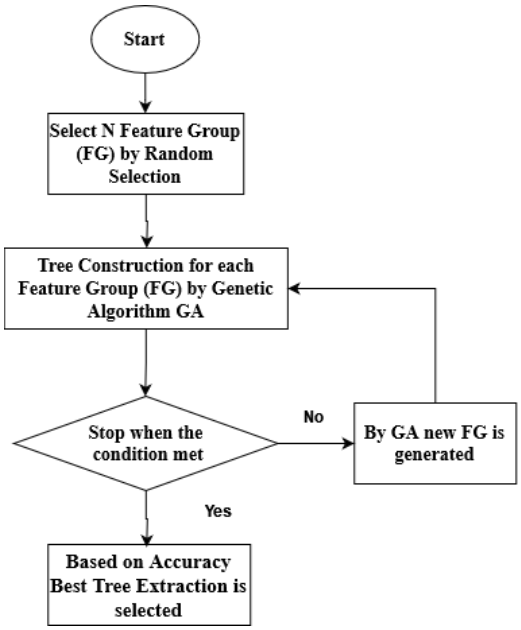

Fig. 3.2: Genetic Algorithm Process

is found using Eq.(3.1).

$$\tau_0 = \frac{1}{n \times [RC\,(S_0) + KKM(S_0)]} \tag{3.1}$$

The terms RC (S0) and KKM(S0) represent the response S0's RC amount and KKM values, respectively, whereas n represents the number of nodes in the network. S0, the initial response, is generated at random. KKM and RC, respectively, are the fitness functions that are determined.

3.3.4. Updating the Pheromone. The pheromone levels are updated with each cycle, therefore this data is utilized to explore a new search region. The usefulness of pheromones will also be diminished by the concept of pheromone evaporation. In MLACO, pheromones will be altered in two ways: locally and internationally. Eq. (3.2) represents the localized pheromone update approach.

$$\tau_{i,j}\,(T) = (1 - p_1)\,\tau_{i,j}\,(T - 1) + p_i\tau_0 \tag{3.2}$$

The localized pheromones evaporating variable, denoted as p1, has a range of 0 to 1. Use the local pheromone updates the rule to lower the number of pheromones if a link is formed between nodes i and j. The globally pheromone updated rules are used to upgrade the pheromone principles while the localized updated rules are utilized to adjust the pheromone levels. Non-Pareto global optimum or Pareto global optimum solutions were among the options for multi-objective function optimization. The global pheromone is altered using Equation (3.3).

$$\tau_{i,j}\,(T) = (1 - p_g)\,\tau_{i,j}\,(T - 1) + \frac{p_g}{RC\,(S) + KKM(s)} \tag{3.3}$$

Here p_g stands for globally pheromones evaporating variable, and its value ranges from 0 to 1.

3.3.5. Process of Multi-layer ACO. In a multi-layer ACO like this, eligible nodes are categorized at different layers. In networks, the number of components equals the size of the network. The total of the anticipated limits for each component equals the number of nodes. For a particular node, the permitted replies

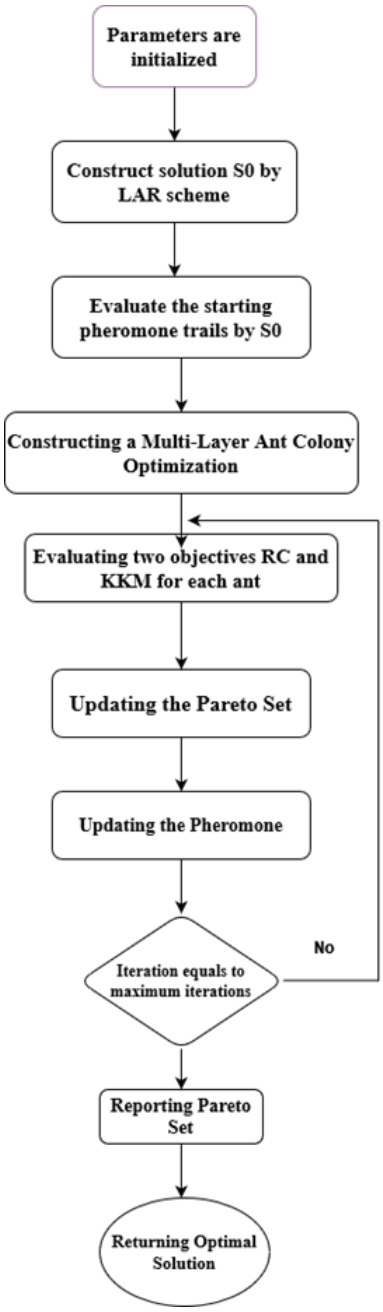

Fig. 3.3: Workflow of MLACO

are in fact the adjacent nodes. Ten levels are required, and each layer's options are determined by the values of its neighboring layers. The allowed nodes in layer 1 are 3 and 7, in layer 2 they were 4 and 5, and so on. I will select acceptable nearby nodes m for an ant k in level l nodes by using Equation (3.4)

$$m = \begin{cases} \arg\max\{[\tau(i,m)]^{\alpha}\left[\eta(i,m)\right]^{\beta}\} & if\ q < q_0 \\ M & otherwise \end{cases} \tag{3.4}$$

Table 4.1: Result of Emotion Rating

Time Step	Emotion Score	Anticipated Emotion
2.5	0.93	Happiness
5	0.52	Relaxation
7.5	0.61	Surprise
10	0.84	Joy
15	0.45	Sad
17.5	0.93	Happiness
20	0.32	Sad

$$P\left(i,m\right)=\frac{\left[\tau\left(i,m\right)\right]^{\alpha}\ \left[\eta(i,m)\right]^{\beta}}{\sum_{\omega\in I_i}\left[\tau\left(i,\omega\right)\right]^{\alpha}\ \left[\eta(i,\omega)\right]^{\beta}} \tag{3.5}$$

An assortment of non-dominated ants is selected to form a Pareto optimal set. A non-dominated mixture is transmitted when an answer is excluded from the Pareto set because it is dominating another response. For this reason, the Pareto set will change following each cycle.

A key feature of this process is the use of a Pareto optimal set to guide the optimization. Non-dominated ants, whose solutions are not outperformed by others in terms of multiple criteria, are selected to form this set. A non-dominated mixture is generated when a solution is excluded from the Pareto set because it dominates another response. As the process progresses, the Pareto set dynamically evolves, ensuring that only the most optimal solutions are retained. This continuous refinement of the Pareto set across iterations allows the multi-layer ACO to effectively converge toward high-quality solutions while maintaining diversity in the search space.

4. Result Analysis. The suggested technique made use of the Flickr picture collection, whose Flickr30k dataset has become the industry standard for sentence-based image categorization. hsankesara/flickr-image-dataset.kaggle.com. The present research presents Flickr30k Entities, an addition to the 158k captions in Flickr30k that includes 276k manually annotated bounding boxes and 244k reference chains connecting image-wide citations of identical objects.

By utilizing the possibility of concurrent multimodal input, GA-MACOcan transform understanding, production, and data interaction. It is more advanced than traditional machine learning. This first section presents an overview of GA-MACOeffective abilities and lays the groundwork for investigating its possible uses and implications. The model's evaluation of the intensity of feelings over a certain time period is shown by the Emotion Rating in Table 4.1, ranging from 0.30 to 1. The categorization that the framework assigns to identify the state of mind of the data that is offered at every stage is known as the Expected Mood. Figure 4.1 shows the result of emotion analysis based on time steps.

It is very important to use Image Emotional Perception technology in packaging design. We've already talked about the importance of hues and designs in package design as well as the best way to put these elements into practice. To improve the efficiency of information flow, a designer has to incorporate cultural implications into the packaging layout for the product via aesthetic visual symbols or language. Unlike traditional visual symbols, people usually use two-dimensional design images or symbols as graphic symbols. No matter what color scheme or visual design is used, designers have to make sure that the general public can grasp it.The 3s-HCI, AFED-CR, and PLM modeling are used to compare the suggested method's efficacy in raising the caliber of packaging layout. GA-MACO systems are able to recognize and classify the emotions expressed by product designs through the use of photo analytics.GA-MACO can identify a variety of emotions through visual cues like color schemes, gestures, and facial expressions, include happy, passion, confidence, unexpectedly and discontent. GA-MACO enables the quantitative analysis of packaging design perceptions based on feelings. The overall quality of design evaluation is displayed in Fig. 4.2.

Analyzing the expected emotion labels revealed that inaccurate categorization commonly occurred within similar emotional perception. The mean squared error can be computed as the disparity between the anticipated and actual values of the hypergraph. Reducing errors in prediction through improved modeling accuracy,

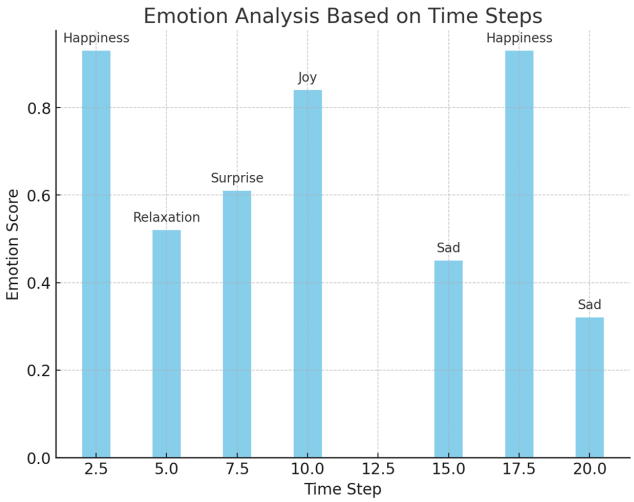

Fig. 4.1: Emotion Analysis using Time Steps

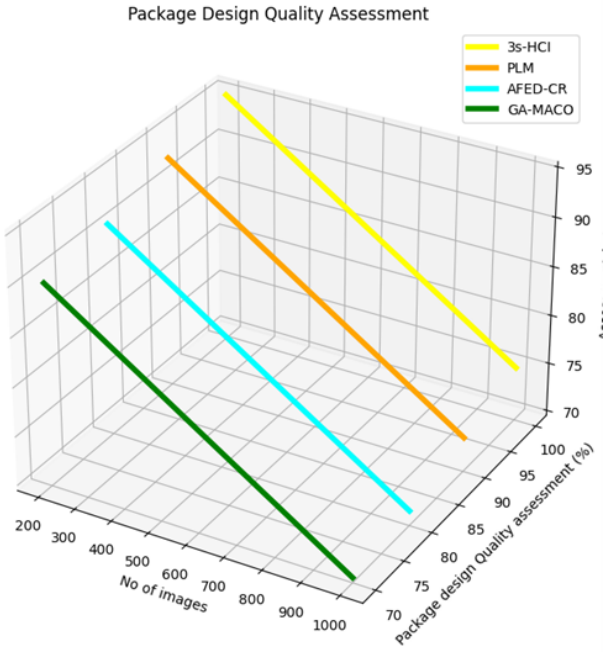

Fig. 4.2: Package Quality Design Assessment

feature evaluation, accuracy of data, and ensembles strategies is the main objective of GA-MACO models during package design. By employing these tactics, GA-MACO could substantially improve the evaluation of packaging design and optimize emotional effect. The mean square error rate can be seen in Fig. 4.3.

5. Conclusion. Human food consumption is becoming increasingly personalized to meet the specific needs of each individual, with a wide variety of product labels easily accessible. Because of this, a lot of businesses are starting to focus on making modern packaging more useful. Over the course of a user-product interaction, emotional reactions and sensory paradigms may change. Conventional packaging layout relies heavily on the

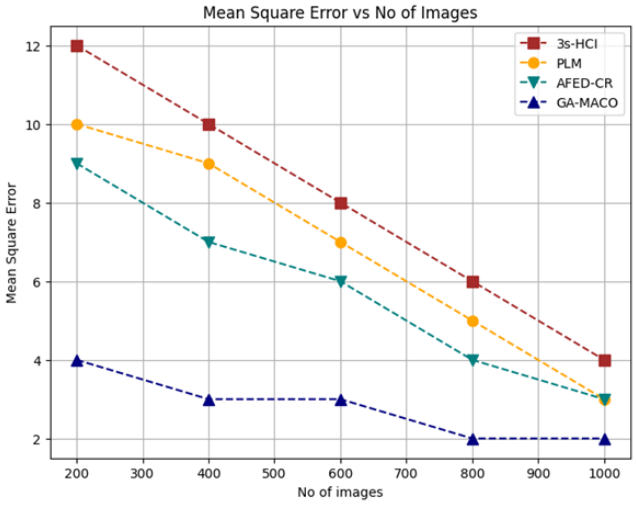

Fig. 4.3: Result of MSE vs number of images

designer's sentimental creativity and past experiences, but it is constrained by unpredictable content and a dearth of professional guidance; previous research on mental image analysis mostly predicted the most common emotions of viewers. Because the feelings evoked by a picture are very personal and vary from viewer to viewer, there are occasions in which the general impression of the image is inadequate for use in reality. The suggested methodology analyzes sight and feelings in order to identify human senses using Multi-Layer Ant Colony Optimization based on Genetic Algorithms. To evaluate classified and multimodal attitude depictions, a large image set known as Image-Emotion-Social-Net is used. More than 9,000 people have contributed more than a million photographs to the Flickr library.The research conducted on this dataset shows that the proposed strategy outperforms various modern approaches in tailored emotional recognition. The research conducted on this dataset shows that the proposed strategy outperforms various modern approaches in tailored emotional recognition. In the case of future studies, they could assess the possible long term effects that such optimization of the packaging design may have on consumers, retentions levels, and sales return.

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