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THE APPLICATION OF IOT TECHNOLOGY AND DEEP LEARNING IN AUTOMATED INTELLIGENT CONTROL SYSTEMS

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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 $\pm 0.5°C$ 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

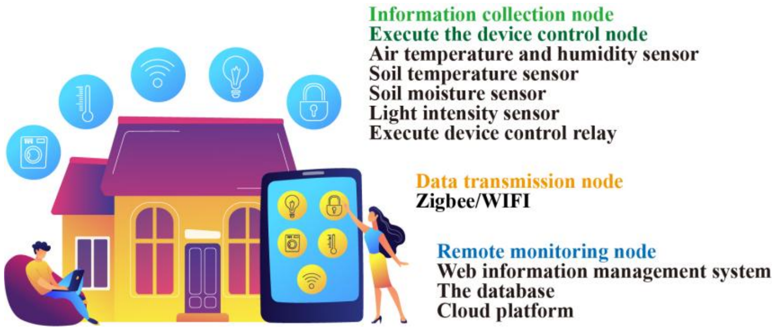

Fig. 3.1: Architecture diagram of smart agricultural greenhouse monitoring system based on Internet of Things technology

(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$5% RH; Temperature range 0 to 50$°C$, accuracy $\pm 2°C$. 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

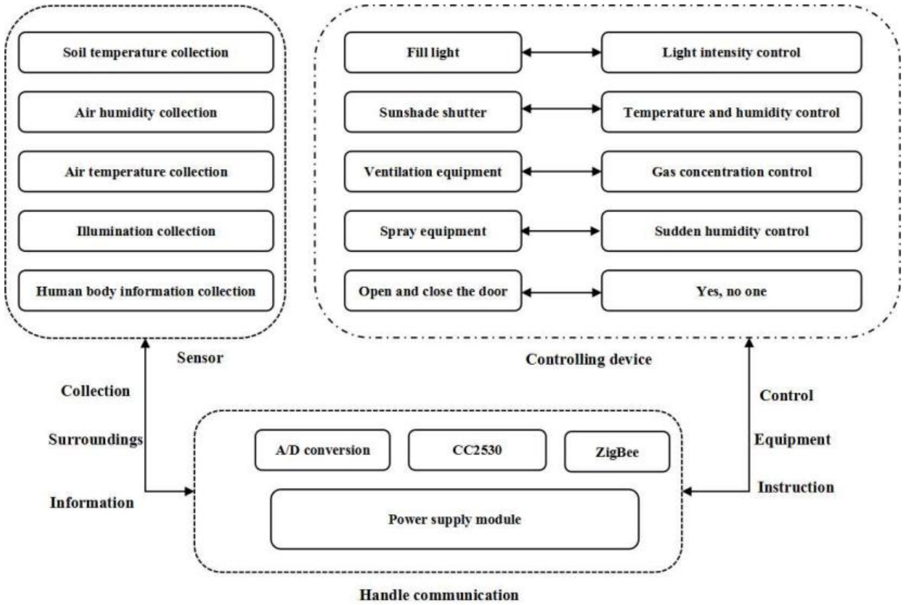

Fig. 3.2: Block diagram of the hardware structure of the sensing control node

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

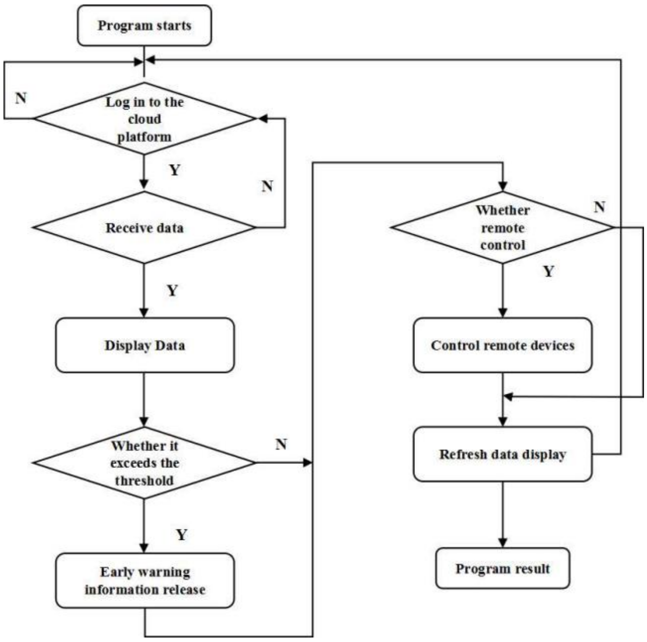

Fig. 3.3: Flow chart of smart agricultural greenhouse APP system

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 $\pm 0.5°C$ 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

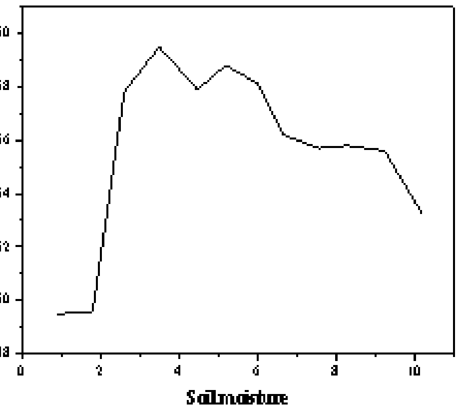

Fig. 4.1: Soil moisture value

Table 4.1: Comparison table of instrument monitoring and display data

Monitoring data/$°C$					
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.

REFERENCES

[1] Xl, A., Yu, L. B., Xf, B., & Yq, B. (2021). Building the internet of things platform for smart maternal healthcare services with wearable devices and cloud computing. Future Generation Computer Systems, 118, 282-296.

[2] Marcu, I., Suciu, G., Blceanu, C., Vulpe, A., & Drgulinescu, A. M. (2020). Arrowhead technology for digitalization and automation solution: smart cities and smart agriculture. Sensors, 20(5), 1464-.

[3] Hui, T., Donyai, P., Mccrindle, R., & Sherratt, R. S. (2020). Enabling medicine reuse using a digital time temperature humidity sensor in an internet of pharmaceutical things concept. Sensors, 20(11), 3080.

[4] Mohammadian, A., Dahooie, J. H., & Qorbani, A. R. (2020). Identifying and categorizing data analytics applications of internet of things (iot) technology in the field of smart agriculture by using meta synthesis method (in persian). SRELS Journal of Information Management, 6(1), 1-23.

[5] Chuang, J. H., Wang, J. H., & Liang, C. (2020). Implementation of smart agriculture depends on intention: young farmers' willingness to accept the internet of things. International Food and Agribusiness Management Association, 23(2), 253-266.

[6] Ramasubramanian, M., Babu, T. R., Krishna, V. A., & Syed, K. (2021). Design of intelligent control and monitoring system for agriculture based on renewable energy and iot. Journal of Physics Conference Series, 1964(4), 042031.

[7] Shafique, K., Khawaja, B. A., Sabir, F., Qazi, S., & Mustaqim, M. (2020). Internet of things (iot) for next-generation smart systems: a review of current challenges, future trends and prospects for emerging 5g-iot scenarios. IEEE Access, PP(99), 1-1.

[8] Umashankar, M. L. (2021). An efficient hybrid model for cluster head selection to optimize wireless sensor network using simulated annealing algorithm. Indian Journal of Science and Technology, 14(3), 270-288.

[9] Yu, M., & Jiang, H. (2020). Application of computer internet of things technology in building intelligent system. Journal of Physics: Conference Series, 1648(2), 022184 (5pp).

[10] Friha, O., Ferrag, M. A., Shu, L., Maglaras, L., & Wang, X. (2022). Iot for the future of smart agriculture: a comprehensive survey of emerging technologies. IEEE/CAA Journal of, Automatica Sinica, 8(4), 718-752.

[11] Wang, Z., Yu, H., Cao, C., & Zhang, T. (2020). Application of internet of things technology in intelligent orchard. Journal of Physics: Conference Series, 1533(4), 042055 (5pp).

[12] Kour, V. P., & Arora, S. (2020). Recent developments of the internet of things in agriculture: a survey. IEEE Access, 8(99), 129924-129957.

[13] Kumar, H. (2021). Involvement of cloud computing and iot in the field of health care. Journal of Trends in Computer Science and Smart Technology, 3(1), 220-226.

[14] Lin, L. (2020). Low power consumption and reliability of wireless communication network in intelligent parking system. Journal of Ambient Intelligence and Humanized Computing(5), 1-9.

[15] Lv, X., & Li, M. (2021). Application and research of the intelligent management system based on internet of things technology in the era of big data. Mobile Information Systems, 2021(16), 1-6.

[16] Pei, P., & Petrenko, Y. N. (2020). Mobile robot automatic navigation control algorithm based on fuzzy neural network in industrial internet of things environment. Informatics and Education, 1(1), 59-67.

[17] Wu, Y. (2021). Intelligent agricultural automatic control system based on internet of things. Journal of Physics: Conference Series, 2143(1), 012009-.

[18] Yue, S., Du, Y., & Zhang, X. (2021). Research and application of agricultural internet of things technology in intelligent agriculture. Journal of Physics Conference Series, 1769(1), 012020.

[19] Gavrilovi, N., & Mishra, A. (2020). Software architecture of the internet of things (iot) for smart city, healthcare and agriculture: analysis and improvement directions. Journal of Ambient Intelligence and Humanized Computing, 12(1), 1315-1336.

[20] Awan, K. A., Din, I. U., Almogren, A., & Almajed, H. (2020). Agritrust-a trust management approach for smart agriculture in cloud-based internet of agriculture things. Sensors, 2020(1), 1-21.

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