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RESEARCH AND DEVELOPMENT OF INTELLIGENT GREENHOUSE MONITORING AND CONTROL SYSTEM：A REVIEW

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Abstract: *Today, smart technologies are rapidly entering various areas of our lives. The role of intelligent technologies in the effective organization of control and management processes in the field of agriculture is incomparable. At the same time, intelligently controlled greenhouses are one of the main elements of agriculture. The article analyzes the importance of smart farming technologies associated with intelligent observing and control systems for greenhouses. These technologies include aspects such as the Internet of Things, artificial intelligence, and intelligent control. Based on the results of the analysis, prospects for the development of a monitoring and control system for a smart greenhouse are proposed to support future research.*
Key words: *smart greenhouse, internet of things, remote control, smart perception, smart control.*

Аннотация: *Бугунги кунда ақлли технологиялар ҳаётимизнинг турли жабҳаларига жадаллик билан кириб келмоқда. Қишлоқ хўжалиги соҳасида ҳам назорат ва бошқариш жараёнларини самарали ташкил этишда интеллектуал технологияларнинг ўрни беқиёсдир. Бунда интеллектуал бошқариладиган иссиқхоналар қишлоқ хўжалигининг асосий элементларидан бири ҳисобланади. Мақола иссиқхоналарни назорат қилиш ва бошқаришнинг интеллектуал тизими билан боғлиқ интеллектуал қишлоқ хўжалигининг муҳим технологиялари таҳлил қилинган. Бу технологиялар Internet of Things (IoT), сунъий интеллект, интеллектуал бошқариш каби соҳаларни ўз ичига олади. Таҳлил натижалари асосида келажакдаги тадқиқотларни қўллаб-қувватлайдиган интеллектуал иссиқхона мониторинги ва бошқариш тизимини ривожлантириш истиқболлари таклиф этилган.*
Таянч сўзлар: *ақлли иссиқхона, ашёлар интернети, масофадан бошқариш, ақлли идрок, ақлли бошқариш.*

Аннотация: *Сегодня умные технологии стремительно входят в различные сферы нашей жизни. Роль интеллектуальных технологий в эффективной организации процессов контроля и управления в сфере сельского хозяйства несравнима. При этом интеллектуально управляемые теплицы являются одним из основных элементов сельского хозяйства. В статье анализируются важные технологии интеллектуального земледелия, связанные с интеллектуальной системой контроля и управления теплицами. Эти технологии включают в себя такие области, как Интернет вещей, искусственный интеллект и интеллектуальное управление. По результатам анализа предлагаются перспективы разработки системы мониторинга и управления умной теплицей для поддержки будущих исследований.*
Ключевые слова: *умная теплица, интернет вещей, дистанционное управление, умное восприятие, умное управление.*

1. Introduction

Smart agriculture is the development direction of future agriculture and a high -level form of modern agriculture [1]. With the advancement and development of technology, biotechnology, information technology, computer technology and new energy technology have been widely infiltrated into the agricultural field. High -tech such as agricultural Internet of Things, agricultural big data and agricultural robots gradually applied to various fields of agricultural production [2]. Smart agriculture takes data, knowledge and intelligent equipment as its core element. By integrating modern science and technology with agriculture, smart agriculture realizes the digital perception, intelligent decision-making, precise operation and intelligent management of the entire process of agricultural production, showing a strong development momentum. Research and practice of various countries have shown that improving agricultural intelligence can greatly increase labor productivity, resource utilization and land production rates [3].

Greenhouse is an important application scenario of modern agriculture. With the improvement of people's life quality, the demand for fruits and vegetables has also increased, and the amount of greenhouses has developed rapidly. Greenhouse adopts artificial technical means to change natural light and temperature conditions, and to create environmental factors to optimize the growth of animals and plants, so that greenhouse crops can grow throughout the year and the weather. Compared with traditional planting methods, the greenhouse is more automated, intelligent, and mechanized. Promoting modern agricultural technology and equipment in greenhouses is an important manifestation of precision agriculture, information agriculture and intelligent agriculture [4]. Intelligent monitoring and control of greenhouse can effectively improve the production efficiency of greenhouses and reduce labor consumption which is a hot spot for research in recent years. The key technologies involved in intelligent agriculture mainly include Internet of Things technology , intelligent perception technology and smart management technology.

2. Research status of key technologies of intelligent greenhouse monitoring and control systems

2.1 Agricultural Internet of Things

Internet of Things technology is an important bridge to the development of smart agriculture [5]. In order to build an Internet of Things system, various information sensors, infrared sensors, radio frequency identification facilities and other equipment in greenhouses need to be installed. The Internet of Things system connects the agricultural environment with the network through a communication agreement, and then analyzes and sorts out different information collected by sensors, in the same time publishes the information gathered from the cloud server, and eventually displays it in the software terminal to achieve real-time monitoring of crop growth. Through the Internet of Things system, the extensive connection between things to things, things to people, and people to people is realized [6] [7]. Agricultural Internet of Things technology mainly involves wireless network transmission technology, multi -sensor network technology and RFID technology [8].

2.1.1 Wireless network transmission technology

The current mature wireless communication methods are mainly include LORA, ZigBee, WiFi, NB-IoT, Bluetooth, etc. [9]. Yao Maoxuan et al. [10] designed a detection system for the basic greenhouse ecological environment, and studied the wireless data transmission system based on LORA. TPYBOARDV102 is used as the core board to achieve automated detection and control of greenhouse. Wu Xiaofeng et al. [11] invented the smart greenhouse system based on LORA and the cloud platform Internet of Things technology, and the data between farmers can be shared. Luo Jialong et al. [12] designed an intelligent agricultural irrigation system based on ZigBee Internet of Things technology. It uses ARM processors to complete data processing and intelligent control, and achieved the function of ZigBee wireless data collection and intelligent irrigation. Liu Feifei et al. [13] designed a ZigBee -based environmental monitoring system. A distributed sensor network terminal through ZigBee technology is establish for data collection. The collected data is sent to the ONENet cloud platform through 4G modules for monitoring, and the real -time monitoring& display of environmental data and recording of historical data are successfully realized. Zhao Jindao et al. [14] designed WIFI -based farmland automatic irrigation systems. The LAN control adopted AP and STA mode. It controls relay status and information through serial ports to achieve the function of timing control and automatic collection information of the irrigation system. The control of the LAN adopts the AP and STA mode. The system controls the state of the relay and completes the information upload through the serial port. The function of timing control and automatic collection information of the irrigation system is implemented. Jiang Shixuan et al. [15]

designed a smart vertical agricultural system combining ZigBee and NB-IoT technology. The system uses STM32 as the core controller, and uses a coordinator to set up the network. In order to collect the environmental index in the greenhouse, terminal nodes are connected to the multi -way sensor. In order to achieve data communication between the bottom device and the cloud platform, NB-IoT technology is adopted. The system uploads the entire wireless sensing network data to the Internet of Things open platform through Internet of Things base stations and core networks, realizing real -time monitoring and remote regulation of environmental parameters.

2.1.2 Multi -sensor network technology

In the construction of smart agricultural greenhouses, the construction of the sensor network is essential. Multi -sensor data fusion technology integrates technologies such as signal processing, estimation theory, uncertain theory, optimization theory and pattern recognition. In the field of smart agriculture, the purpose of reducing data redundancy and improving transmission efficiency and accuracy can be achieved through data fusion processing [16]. Valente et al. [17] used specific data fusion algorithms to make multiple data fusion of upload data base on the ZigBee sensor network. Viani et al. [18] designed an embedded decision -making support system. Through artificial intelligence fusion of multiple sensors, the system can provide irrigation decisions based on weather conditions and actual water demand, and as a result, improve the output of crops. Liu Qian et al. [19] used data mining technology and fuzzy reasoning theory to conduct data fusion and analysis of data collected by environmental detection sensors, and formulated corresponding control strategies with an accuracy rate of more than 80 %.

2.1.3 RFID technology

RFID (Radio Frequency Identification) is a technology that automatically obtains target -related information through radio frequency signals and space electromagnetic coupling to achieve non-contact automatic recognition of targets. This technology can be used in complex environments, which has attracted attention due to its huge application prospects. Huang Xiaoyan et al. [20] designed a new type of RFID sensor for soil moisture and salinity detection, simulated soil theory models with different humidity and salinity levels, and measured changes in water and salinity in sandy soil. Ma Shijun et al. [21] used RFID technology to establish an agricultural seed quality tracking system. According to the RFID tag, the seed quality tracking system can get an overall description. The system realizes the real-time monitoring of seeds detail information including breeding, transportation, sales, planting and other processes. Ning Wei et al. [22] invented a system that uses RFID labels to track greenhouse crops, which can locate the growth area of the crop and accurately obtain crop growth status.

2.2 Intelligent perception

Information such as crop growth environment, crop growth situation and crop disease and pests information of the smart greenhouse are the basis for intelligent monitoring and control system operations [23]. Many kinds of agricultural information can be obtained through satellite images, aircrafts or unmanned aerial vehicles and ground detection instruments.

2.2.1 Crop environment information monitoring

The rapid perception of crop growth environment information is the most basic and critical issue in the implementation of precision agriculture [24]. The growth environment of crops includes information such as soil temperature, soil humidity, and soil nutrients. Liu Fei et al. [25] used the IRI1011 infrared thermal image meter to measure the temperature of the soil, and predict the water content of the soil through soil temperature. The system realizes remote sensing monitoring of soil water within a small area. Xiao et al. [26] developed a wireless measurement system that can measure the depth of the water layer when there is water on the paddy field surface, and also the soil water content when the paddy field surface is waterless. The system can remotely control automatic irrigation and drainage according to the measurement results.

Effective nitrogen, phosphorus, and potassium in the soil are the most basic nutritional elements of crop growth. At present, the real-time online quick measurement of soil nitrogen, phosphorus, and potassium is still a world problem, and substantial progress has not been achieved. Sun Jianying et al.

[27] selected black land as the research object, and used spectral measurement technology to analyze the soil parameters and spectral characteristics of black soil and tide soil. And through laboratory analysis, the distributed diagram of P H and nitrogen, phosphorus, potassium and organic matter content can be given. Wang Zhenglang et al. [28] used GPRS wireless communication technology, sensor detection technology, and A/D conversion technologies to achieve remote detection of soil nitrogen, phosphorus, and potassium of farmland. DONG et al. [29] Try to use laser induction technology to determine nitrogen in the soil.

2.2.2 Crop growth information detection

The growth of crops mainly includes the growth status and yield of crops. The growth status includes information such as plant height, inverted area, biological content and other information. Pan Beito et al. [30] designed a visual-based wheat breeding growth information detection system. Based on CATIA software, wheat growth information collection robot and supporting handheld equipment are designed and developed. The counting of plants is achieved by the processing of wheat seedling images. Du Minghua et al. [31] discussed the use of near -infrared high spectral imaging technology to conduct non -destructive testing of tomato leaves chlorophyll content, and established a leaf chlorophyll prediction model, which provides a basis for tomato quality online testing. Tang Dong et al. [32] used image edge detection technology to design the crop inverted area evaluation system. Compared with the traditional inverted area evaluation method, the image detection rate is more than 78% and the overall area evaluation error rate can be controlled within 10 %. Jiang et al. [33-34] developed remote sensors. Compared with professional level high-spectrum instruments and multi-spectrum cameras, it has similar reflectivity and radiation illumination measurement accuracy. At the same time, the production rate of the growth topic picture and the decision-making efficiency of the variable fertilizer square diagram has been greatly improved.

2.2.3 Crop disease and pest information testing

Early information testing of crop diseases and pests can effectively reduce the possibility and severity of the occurrence of pests, eliminating and reducing losses caused by pests and is the basis for precision spraying and fertilization. At present, the commonly used disease and pest monitoring methods include spectral detection method, image recognition method and electronic nasal detection method.

Zhou Xiaoli et al. [35] designed automatic detection methods of forest diseases and pests based on spectral images, set up deep learning networks and completed the monitoring of the forest -staining area through unmanned aerial vehicle experiments. Zhou Zhankun et al. [36] used the greenhouse tomato as the research object, and used THZ-NIR high-spectrum fusion technology to study the rapid monitoring methods and recognition methods of tomato leaf mold and tomato leaf miner. The improved Bayesian network's recognition rate of tomato moldy samples was 97.12%, and the recognition rate of tomato leaf miner was 93.35%. Prasath B. et al. [37] designed a new pest detection and classification model based on optimized YOLOV3 models and deep learning algorithms. The accuracy and F1 scores of this method reached 96 % and 84 %, respectively. Zeba Anwar et al. [38] effectively completed the classification of pests based on the CNN deep learning model, with the model accuracy of 82.5 %. Wu Zhilu et al. [39] invented a method of detection of crop disease and pests. This method completes the training of visible optical pest image samples through convolutional neural networks, and then completes feature extraction and classification. Sun Yubing et al. [40] used electronic nasal technology to analyze the tea trees harmed by different types of pests. The damage time and quality loss of tea trees can be obtained, and the best time point for using electronic nose detection has also been discussed. Rakesh Kumar Raigar et al. [41] used hybrid electronic nose and fuzzy logic methods to evaluate and predict the storage time and rotten of peanuts, and achieved non -destructive detection of peanut quality.

2.3 Smart Management

The management of smart greenhouses integrates cloud platform technology, big data technology, mobile internet technology, and Internet of Things technology. It is a cross -regional operation control system that integrates smart agricultural equipment, cloud wisdom, and service platforms [42]. The functions that the intelligent management system needs to complete mainly includes remote monitoring and controlling of both various environmental parameters and working status of work facilities in the greenhouse, and conducting fault warning and remote scheduling [43]. The greenhouse equipment mainly includes fans, water curtains, irrigation systems, and shading curtains [44]. Smart management system connects the cloud platform through network, and uploads the data from main control point to the cloud. Users can complete the remote control of greenhouse equipment and remote monitoring of the crop environment through the PC or mobile phone side. Li Guoxin et al. [45] designed a multi-node distributed smart agricultural greenhouse monitoring system, setting a private cloud platform through EMQTT and Node-Red, and can realize the automatic monitoring, intelligent control and scientific management of agricultural greenhouse environment information. Lee [46] invented a precision control system for smart greenhouses and can obtain environmental parameters of multiple greenhouses. The greenhouse control server completes remote regulation of multiple greenhouse environments. Wu Yan et al. [47] built a smart management platform for small three-dimensional GIS reservoirs for agricultural irrigation, organically coupling the needs of agricultural irrigation, water conservancy scheduling and disaster prevention, solved the problem of three -dimensional simulation and visual management of irrigation districts. Francisco G. Montoya et al. [48] set up the cloud platform database, designed Android applications based on Linux and Python and achieved the acquisition and precise monitoring of agricultural environmental parameters. Liu Jixi et al. [49] built a cloud -based service model based on the cloud service model, and introduced information push services. The push service terminal based on the XMPP protocol can automatically and intelligently recommend decision - making information for users. Han Ruifeng [50] invented an agricultural greenhouse environment control system based on big data technology, increased the enters the greenhouse appointment module, timely adjust the air oxygen content in the greenhouse, and ensure the safety of staff. The system has increased the reservation module for entering greenhouses, and can timely adjust the air oxygen content to ensure the safety of staff.

3 Conclusion and prospect

At present, the new generation of information technology represented by the Internet, big data and artificial intelligence is booming, which has a profound impact on economic development, social progress, and people's lives and is promoting the rapid development of smart agriculture. This article introduces the important position and research progress of key technologies such as Internet of Things technology, intelligent perception technology and smart management technology. At present, the construction of smart greenhouses has just begun, and the problems that need to be solved for large - scale promotion and application include:

1) Study low -cost and efficient smart greenhouse monitoring and control systems, and achieve rapid construction in application scenarios, thereby improving the efficiency of the construction of smart greenhouses and reducing construction costs.

2) Study the new principles and algorithms of high -precision, fast real -time sensors such as chlorophyll and nitrogen sensors, and soil nutrients sensors to improve the accuracy and reliability of monitoring.

3) Optimize the identification technology and algorithm of diseases and pests, improve the recognition efficiency, and reduce the negative effects caused by the changing external environmental factors.

4) Build a large cloud database, develop decision-making system supported by artificial intelligence algorithms, realize the more efficient and stable of remote monitoring and mobile terminal control of smart greenhouses.

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