Research on the intelligent agricultural closed-loop system under the Internet of Things Architecture

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Abstract—In this paper, a remote closed-loop agricultural monitoring system based on the Internet of things and artificial intelligence decision-making was presented. It introduces two innovations: 1. through the ZigBee wireless sensor networking module, the collected field environment information data is sent to the ARM main controller. This sensor data will be converted into complied with TCP/IP protocol data types in the main controller and send to the cloud server for storage and processing furtherly, thus can conveniently access the server to manage and know the growth status of flowers through multiple types of the smart terminal. A mixed ad-hoc network data perception system not only reduces the reliance on the electric wire but also improves system reliability and usage range. 2. smart compensated light technology used in this system can accelerate plant growth by using photosynthesis to match different red-blue light ratios that can achieve maximum growth points. The system in this paper realizes the remote monitoring and control and multi-mode management of flower plants.

1. INTRODUCTION
As the CMOS process scale down, cloud computing, blockchain, Internet of Things(IoT), and artificial intelligence (AI) industries have developed rapidly. More and more sensor nodes are deployed in the smart home, urban, medical and other fields to collect information such as temperature, humidity, light intensity and human physiological signals in the environment to realize the perception of the surrounding environment and disease prevention [1]. According to forecasts, by 2020, the number of sensors will reach tens of billions of deployment in every corner of the world. Taking smart homes as
an example, wireless sensors can be used in a wide range to improve living comfort, such as remotely or autonomously operated temperature control, household appliances, security systems, etc., while also facilitating increased building energy efficiency [2]. Similarly, wireless sensors can also be used in the field of industrial buildings to achieve automatic control of working environment factors, such as temperature, carbon dioxide (CO2), and humidity, or to minimize the energy consumption of the factory and improve energy efficiency. However, the main problem with currently used wireless sensors is that each sensor requires a reliable energy source to make it work normally. For example, machine diagnostic may require up to 300 sensor nodes in industrial production and manufacturing space of 25 square meters [3]. According to the forecast of the number of wireless sensors, the number of wireless sensors will double from 2018 to 2023 when the Internet of Things technology develops. There will be more than 50 billion wireless sensors in our daily lives. This requires a huge of input energy to power these sensors [4]. To overcome the shortage of energy and broaden the life of sensors, more and more low power circuits design and energy harvesting technology has developed to reduce the node power and replace traditional battery power supply mode in recent years [5-10].

In recent years, modern emerging information technologies represented by Internet of Things have been extensively researched and developed in the field of agricultural modernization[11-15]. The agricultural practice in developed countries shows that the use of Internet of Things related technologies, combined with wireless communication equipment on the planting site, to achieve temperature and humidity monitoring and control, nutrient solution detection and supply, as well as hydrogen ion concentration, soluble salt content and other parameters detection and deployment, can make vegetable cultivation conditions reach the most appropriate level, and promote the maximum efficiency of agricultural production. In the past, some local crop intelligent management systems can make vegetable cultivation conditions have realized the informatization, scientific, and intellectualization of crop planting to a certain extent. The intelligent agricultural management system based on IoT is the general trend of future agricultural development. This article mainly introduces the technical achievements of closed-loop communication and smart compensated light in the flower planting system of the Internet of things.

This paper is organized as follows. After the system overview and design of Section II, Section III details the system hardware and software design of the monitoring and control smart terminal, smart compensated light technology, and web server and app design. Section IV summaries the measurement results of the system, and finally the conclusions are drawn in Section V.

2. SYSTEM OVERVIEW AND DESIGN

The presented flower planting system (Fig.1) is made of perceiving, transportation, service, and application layer. In

![Fig.1. System diagram of the presented flower planting](image)

the perceiving layer, the environment information and flower grow parameter that light, temperature, humidity, nutrient solution content, and so on can be acquired by sensors. These uplink data are sent by a wireless sensor network that was the automatic formation by the ZigBee node and coordinator. The ZigBee topology has stars, mesh, mesh-tree network structure, star topology called ad-hoc is usually was used in a wireless sensor network system. ZigBee protocol complies with the IEEE 802.15.4 standard that is facing the field of the low rate and ultra-low power personal local area and operated in ISM (Industrial Scientific Medical) frequency band. Thus, ZigBee and sensor nodes not only replace the traditional wire signal transport but also can broaden the range of sensor deployment. it can improve system reliability and enlarge the life of node battery. In the transportation layer, the main controller will receive the sensor data and red-blue light ratio information from the perceiving layer. This
information will be displayed in the TFT-LCD module and will be converted into complied with TCP/IP protocol data types, which is sent to a remote cloud server by using the Wi-Fi module for the next data process. In this layer except for data sending, we can adjust the threshold of environmental parameter and blue-green light ratio directly to provide a stable and fast-growing condition for flowers. In the service layer, the remote cloud server can analyze the data pack from the main controller. the data can be classified according to the sensor name and storage it in the MySQL database. After the data is stored and processed by the service layer, it can be used as a medium for multiple platforms to access field data of flower cultivation. Various platforms on the application layer can obtain sensor data and send control command information to the server to monitor and control the main controller. At the application layer, through the development of APP and webpage programs to access server data, the data is displayed according to curves, line graphs, etc., and we intuitively observe the environment and flower growth information parameters of the flower planting site through mobile phones, computers, and iPad platforms. In addition, through different maximum growth conditions of different flowers, the application layer can automatically generate corresponding environmental parameters and parameters such as flower photosynthesis blue-green light supplement light and pass them to the main controller through the cloud server head to reset the corresponding parameter thresholds and establish different flowers the best conditions for the maximum growth of the variety, and the application layer can also independently adjust the threshold of a single parameter and feed it back to the flower cultivation site to realize a closed-loop control system for multi-platform monitoring and control of a variety of flower cultivation. Through the simple introduction of the four layers in the system in Fig.1, we can have a basic understanding of the proposed flower planting Internet of Things system. Next, we will detail the system hardware and software design of the monitoring and control smart terminal, smart compensated light technology, and Web server and app software design.

3. System Hardware and Software Design

According to above the analysis of the system, we can have a basic concept for system implement. Next, we will focus on the key component of this system, which includes the smart terminal, smart compensated light, and Web server and app software design. In the smart terminal, we will simply introduce the main controller processor and ZigBee Chip. we will detail the analysis of the compensated light algorithm to achieve the maximum growth rate in the photosynthesis process of the flower grows. In the Web Server and app software design also will briefly analyze the design methods and techniques used.

3.1. Smart Terminal
The smart terminal hardware connection relation has been shown in Fig.2, we can clearly see the input and output signal of the main controller. The main controller in the system uses the STM32F103ZET6 of ST Corporation, which is based on the ARM Cortex-M3 kernel is the mainstream Micro-Control unit. This chip has a rich peripherals resources, fast process rate, and ultra-low power compared with other MCU. It can receive the sensor data and Beidou navigation satellite system signal from the ZigBee coordinator and BDS unit by the UART interface. The received information can be sent to a remote cloud server for further processing. However, if the collected data information exceeds the parameters set before, the microcontroller will trigger the corresponding condition compensation command to maintain the parameters within reasonable conditions to create the best growth conditions for flowers. The corresponding parameter compensation mainly includes temperature rising and cooling, humidification, dehumidification, and light compensation.
3.2. Smart Compensated Light

Plants such as flowers have different incompatible rates under different light conditions. Fig.3 shows the photosynthesis process of plants. Carbon dioxide, water, and corresponding enzymes produce sugar and oxygen during photosynthesis to promote the rapid growth of plants. Plants have special requirements for red-blue light in photosynthesis, but the color spectrum of red and blue light in different plant needs are different. In this system, a configurable red-blue light ratio compensated light system is proposed for different flowers to grow rapidly, shorten the time to market and reduce the time cost. Fig.4 is a schematic diagram of the $N \times N$ smart compensated light matrix proposed by the system. The ratio of Red-blue light can be adjusted freely according to different control signals. $R_{ix}$ is the red light control signals. According

$$R_{ix} = l(x = 1, 2, 3 \cdots n)$$  \hspace{1cm} (1)$$

to formula (1), if $R_{i1}=1$ is represented first row red light is open, $R_{in}=1$ has represented row n red light is open.

$$C_{jx} = l(x = 1, 2, 3 \cdots n)$$  \hspace{1cm} (2)$$

In the same way, $C_{jx}$ is the column x blue light control signals

According to formula (2), if $C_{j1}=1$ is represented first blue row
light is open, $C_{jn}=1$ has represented column $n$ blue light is open. If the best ratio of red to blue light in the process of photosynthesis of certain plant is 3:2, we can set the ratio of the number of rows equal to 1 to the number of columns equal to 1 as 3:2, as shown in formula (3). In Fig. 4, all red and blue photodiode cathodes are connected to the ground. During the experiment, when multiple photodiodes are open at the same time, the current is low, making each diode unable to achieve the expected brightness. After many tests, the ULN2003 driver chip is selected to increase the pull-up current, which meets the design requirements of the system.

$$\sum_{j=1}^{n} R_{xi} = \frac{3}{2} \sum_{j=1}^{n} C_{jis}$$

(3)

3.3. Web Sever and App software Design

Through the establishment of a MySQL database on the webserver to store and process the sensing layer data. Web server is developed and designed with J2EE, ApacheTomcat, and MySQL. The program is written to obtain the sensor data submitted from MCU to the web server and store it into a database. The server receives the information flow of the smart terminal as shown in Fig.5. Through the application program on the webserver, the smart terminal can remote monitor the nodes of the flower planting system.

Application layer APP software adopts lightweight MUI framework and popular HTML5+ technology development, its development interface is friendly, all kinds of controls are complete, and it has become the first choice for app development. Fig.6 is a flow chart of the server responding to App requests. You can use mobile phones, iPad, and PCs to access the server to obtain real-time sensor monitoring data, send remote control commands, adjust and plant on-site related parameters, and implement closed-loop control systems purpose.
4. SYSTEM MEASUREMENT AND RESULTS

According to the above system design, build the "intelligent garden" flower monitoring platform, as shown in Fig.7. The location of each hardware module is placed according to the figure.

Fig.6. Server response to App request information Chart

The working diagram of the system is shown in the left figure of Fig.8. The TFT-LCD display interface (right figure of Fig.8) and smart light compensation working diagram can be clearly observed.

Fig.7. System physical diagram mode

Fig.8. System work diagram (left) TFT-LCD display (right)
Fig. 9. Design App in application layer

The APP interface developed in the application layer is shown in Fig. 9, which mainly includes real-time monitoring, parameter adjustment, mode choice, and other interfaces. Through the app, the sensor data collected by remote wireless sensor network nodes can be obtained in real-time and the control command can be sent to the intelligent terminal to adjust the parameter threshold and red-blue light compensation ratio to realize remote closed-loop detection and control. According to different plant growth environment parameters, the mode choice interface can select different plants independently, and automatically set the best conditions suitable for plant growth, which reduces the difficulty of plant planting and greatly promotes the progress and development of modern agriculture. (Note: Red font is the translation of Chinese characters in Fig. 8 and Fig. 9)

5. CONCLUSION
The research system described in this paper is a set of the emerging Internet of things, data analysis, and mobile Internet technology as a whole, relying on a variety of precision sensor nodes deployed in the "intelligent garden" flower monitoring platform for deep-seated processing and analysis. The presented system in this paper has many advantages in the field of modern agriculture, mainly in two aspects. On the one hand, smart compensated light technology used in this system can accelerate plant growth by using photosynthesis to match different red-blue light ratios that can achieve maximum growth points, which shorten time to market and reduce time cost. On the other hand, remote closed-loop communication technology can realize visual remote diagnosis, remote closed-loop control, and intelligent decision-making. The system scheme can effectively reduce the labor cost of the farm, and help the flower production to be industrialized and intelligent, making the traditional flower culture become a modern agriculture plant mode with high efficiency.

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