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Design of an Intelligent Management System for Agricultural Greenhouses based on the Internet of Things

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***Abstract*—China is a large agricultural country with the largest population in the world. This creates a high demand for food, which is prompting the study of high quality and high-yielding crops. China's current agricultural production is sufficient to feed the nation; however, compared with developed countries agricultural farming is still lagging behind, mainly due to the fact that the system of growing agricultural crops is not based on maximizing output, the latter would include scientific sowing, irrigation and fertilization. In the past few years many seasonal fruits have been offered for sale in markets, but these crops are grown in traditional backward agricultural greenhouses and large scale changes are needed to modernize production. The reform of small-scale greenhouse agricultural production is relatively easy and could be implemented. The concept of the Agricultural Internet of Things utilizes networking technology in agricultural production, the hardware part of this agricultural IoT include temperature, humidity and light sensors and processors with a large data processing capability; these hardware devices are connected by short-distance wireless communication technology, such as Bluetooth, WIFI or Zigbee .In fact, Zigbee technology, because of its convenient networking and low power consumption, is widely used in the agricultural internet. The sensor network is combined with well-established web technology, in the form of a wireless sensor network ,to remotely control and monitor data from the sensors.**

In this paper a smart system of greenhouse management based on the Internet of Things is proposed using sensor networks and web-based technologies. The system consists of sensor networks and asoftware control system. The sensor network consists of the master control center and various sensors using Zigbee protocols. The hardware control center communicates with a middleware system via serial network interface converters. The middleware communicates with a hardware network using an underlying interface and it also communicates with a web system using an upper interface. The top web system provides users with an interface to view and manage the hardware facilities ; administrators can thus view the status of agricultural greenhouses and issue commands to the sensors through this system in order to remotely manage the temperature, humidity and irrigation in the greenhouses. The main topics covered in this paper are:

1. To research the current development of new technologies applicable to agriculture and summarizes the strong points concerning the application of the Agricultural Internet of Things both at home and abroad. Also proposed are some new methods of agricultural greenhouse management.

2. An analysis of system requirements, the users' expectations of the system and the response to needs analysis, and the overall design of the system to determine it's architecture.

3. Using software engineering to ensure that functional modules of the system, as far as possible, meet the requirements of high cohesion and low coupling between modules, also detailed design and implementation of each module is considered.

Keywords:Agricultural Internet of Things;agricultural greenhouse; style;sensor

I. INTRODUCTION

A. Subject research and development background

China is a large agricultural country containing 20% of the world's population. Consequently the yield and quality of crops is forcing agriculture, industry and the information industry to pursue common goals, which are to maximize agricultural output whilst maintaining quality. At present, domestic agricultural greenhouse management mainly uses a traditional mode of manual management ,this is based on experience to periodically and manually adjust the light, temperature, humidity as well as irrigation, fertilization and to use artificial cultivation. This method not only leads to higher management costs, but also brings a series of problems, such as low production efficiency, waste of resources and environmental pollution.

In view of the disadvantages of present agricultural greenhouse management, the use of information technology to make this management more efficient and intelligent is an important task in the information field. Networking technology is a new generation of information technology, it is the use of the internet or LAN technology to combine sensors, controllers and computers to connect people and 'things', thereby obtaining data, and enabling remote control and intelligent network management [1].

The development of software and hardware provides the technical requisites for intelligent agricultural greenhouses, which means it is possible to widely implement smart systems in greenhouses. Temperature sensors are well-developed, so though temperature sensing combined with communication technology one can communicate temperature information through a wireless network. At the same time, air humidity, soil moisture, light and other sensors are being further developed and these sensors and

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communication technology provide the necessary useful hardware for use in greenhouses [3][16].

In terms of software, the internet has penetrated into all aspects of life, a browser on the World Wide Web can be used to collect and send data, with no need to install software. The implementation technology of web servers is well-established, the front page can use the DIV+CSS technology, the business logic in the middle can use ASP.NET, J2EE, PHP and other types of technology, the background database is also very large, although a lot of talent is needed to master these techniques [7].

At present, many companies already produce the hardware equipment needed by the Internet of Things, such as sensors with communication module and control equipment with the ability to self-network. Therefore, the main problem using the Internet of Things is the design and realization of the overall system. In fact, hardware vendors generally provide middleware technology of software and hardware interaction. (Middleware is a kind of software that needs to be installed on a specific computer [17] [18].)

This study combines hardware, middleware and web technologies to explore a new model of agricultural management automation, although this research is carried out in the small area of agricultural greenhouses, it could be applied more generally to achieve intelligent agricultural automation.

B. Project development meaning

China's agriculture is able to provide sufficient food for its 1.3 billion people, but in its degree of automation in the production of fruits and vegetables there is still a large gap between China and Europe or the United States. These fruits and vegetables generally require relatively constant humidity and temperature to achieve a high yield, but Chinese ordinary greenhouse technology does not guarantee such conditions, since this requires the use of information technology to quantify and implement precise control over temperature and other indicators[19]. Using the Internet of Things and agricultural management technologies, it is possible to design a new agricultural model. For example, a networking platform can be based on a smart greenhouse management system, the system using a variety of sensors and short distance wireless LAN technology to achieve all-weather monitoring of temperature and indoor environment parameters ;moreover the monitoring data can be transmitted to the monitoring center and site managers can achieve remote control of the parameters through the network or middleware system, thus obtaining both scientific and effective management of production. The proposed systemcan greatly reduce the labor cost of agricultural greenhouse management and effectively improve the efficiency of agricultural production in greenhouse cultivation. Agricultural automation and industrial production automation has the potential to meet the urgent need for precision agriculture in our country rather than the traditional methods used now. Therefore, research into, and the development of this system has both theoretical and practical significance.

C. Research trends at home and abroad

As early as the 1960s, foreign countries had begun research into and the application of agricultural intelligence and environmental information collection etc. to greenhouses. For example, France has used satellite technology to monitor weather conditions and hence predict greenhouse pests and diseasesin order to improve crop productivity[4]. Holland's greenhouse technology is leading the world ; in fact some of its famous Priva companies have developed facilities that have been sold overseas. The intelligent breeding management system VELOS has been widely applied in Europe and the United States, this implements automatic management of water feeding, data collection and alarm functions [5]. Finally, the remote bidirectional monitoring system developed by a Japanese electric power company can realize the comprehensive detection of indoor environmental indicators through a server, a decentralized controller and so on[19][20].

Compared with foreign countries, the research into smart greenhouses in China started late: the first intelligent greenhouse system was developed in 1997, but because of the lack of technology, it has not been used on a large scale. In the research into an intelligent greenhouse system, different scholars have put forward a variety of views. For example, systems could be based on GPRS (General Packet Radio Service), Bluetooth and other wireless communication technology, although these can be used to meet the basic requirements, this technology is expensive , has a complex internal protocol, high power consumption and other shortcomings. Compared with traditional wired monitoring technology, Zigbee wireless transmission avoids the complexity of wiring and it is widely used in the development of intelligent greenhouses, because of its flexibility and low power consumption[6].Based on the current development of a number of agricultural products for this technology, such as the famous Shandong Shouguang vegetable base in China, the development of the “greenhouse manager” is used to implement mobile phone monitoring and management of greenhouses. However, there are still some problems in the practical application of this system, such as the greenhouse manager cannot monitor environmental parameters. Fan Yunxiang, developed the intelligent water spray controller that can automatically adjust the amount of water spray according to environmental changes, but it works on the basis of a single environmental factor[21][22]. The greenhouse automatic monitoring system developed by Nankai University, can realize the monitoring of temperature and humidity, but this did not complete a scientific and technological industrialization of agriculture.

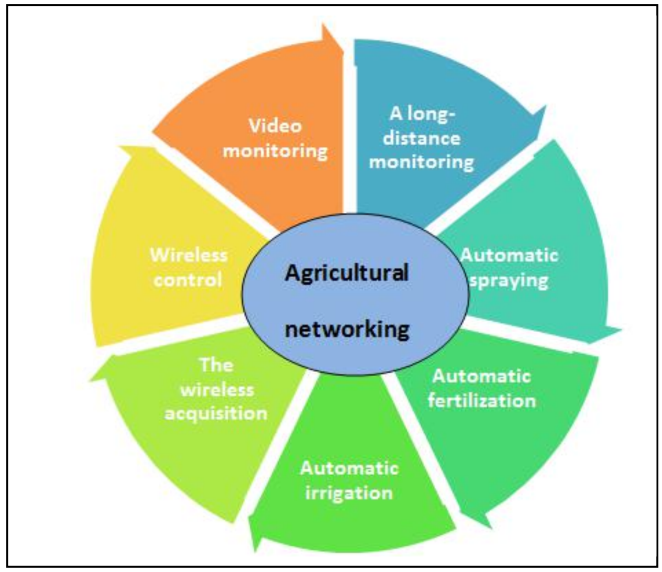
In our country, there is no clear standard for greenhouses to meet, indeed because of the geographical spread it is very difficult to establish a uniform standard for the large span of longitude and latitude and the variety of climates encountered. Greenhouse control systems are expensive, which is not conducive to the full realization of smart greenhouses, so that simple greenhouses are commonly being built.

D. *Introduction to Internet technology*

The source of the internet can be traced back to 1999 and the Massachusetts Institute of Technology's automatic identification center[2].However, the definition of the Internet of Things varies from scholar to scholar, but in general it is a concept based on combining information technology, sensor technology, wireless communication technology and internet technology. Networking is an important part of a sensor network, to achieve its ideal state an object, for example crop, can be monitored and signal its current state in the real world via a network connection, this is mainly achieved through sensors with communication functions. The sensor network has obvious basic characteristics, namely network data exchange, a convenient network, the ability to make dynamic changes and transfer data. In particular, in wireless sensor networks sensor nodes with low capacity, low power consumption and small size can complete the operations of data acquisition and transmission; through the sensor nodes and the main equipment it is possible to connect the internet and communication network, this combination of a small sensor network and the internet should have many applications in general.

The broad sense of the Internet of Things is ubiquitous, but it is difficult to achieve this broad definition and now most research is limited to a certain area of 'things'. The Agricultural Internet of Things is considered as the third information revolution following the computer, internet and mobile communication. In traditional agriculture, pesticide, fertilization and irrigation mainly depends on the experience of farmers; although this experience is of great value in greenhouse production it does not guarantee the accuracy, especially temperature, humidity, lighting and other indicators, which are difficult to determine and adjust just from experience. In a smart greenhouse a large number of sensors are laid out, the collected data is communicated using communication technology to the internet and hence an administrator. The administrator can in turn use an internet interface to control fertilization, irrigation, heating, lighting and other parameters. The schematic diagram of the Agricultural Internet of Things is shown in Figure 1 [17].

The agricultural greenhouse intelligent control system proposed in this paper is based on the concept of combining networking, systems, software, hardware and middleware. Being able to have access to an internet system means it is possible to view the status of sensors in controlled greenhouses, thus enabling the system's automatic thermostat, auto-fill light, automatic irrigation, and other parameters, to be set.



1 Agricultural network diagram

II. OVERALL DESIGN OF THE SYSTEM

The system does not take into account how the system design and implementation of the system to achieve the use of what technology, the overall design is at a relatively high level of the overall layout of the system design. The overall design of the system is analyzed from the aspects of system structure, network topology and so on. The overall agricultural greenhouse system networking needs to achieve networking and system control two functions, networking the wireless LAN, cable network and Internet together, the network structure is a system; system control by hardware and software to complete the overall structure of hardware needs to be able to do the actual operation, the software system provides control interface for orders [27].

A. *System structure design*

The structure of the system is analyzed from the network, including the Zigbee wireless communication network, the serial port converter, the server and the internet. Description of each part is as follows:

1) *Zigbee Wireless communication network:*

The hardware is the system commands the final executive but also need communication between hardware devices, the communication to complete if use the traditional wired network is not conducive to hardware deployment, but also will lead to the greenhouse line complex, is not conducive to management; if there is a kind of short distance wireless communication technology to various hardware node connection together you can form a small network, is very conducive to the deployment and replacement of [24]. Short distance communication technology, including Bluetooth, WIFI, etc., the system uses a more flexible and low-power Zigbee communication technology. In this system, it is necessary to have a main device to complete the Zigbee communication with other sensors.

2) Series of network interface conversion settings:

The low level hardware device mainly uses the Zigbee protocol to communicate, the data is very limited, and most of them are simple numbers. The main equipment is also very simple, complex communication management, internal integration network interface module, so the data mainly in the serial output, while the upper control system is constructed based on the Web mode, the serial data must be converted to network data to interact and servers.

3) Server:

Because the control interface of the system is given in the form of Web, the upper PC can be used as a Web server, providing Web services to the outside world. The Web program is responsible for hardware node status of collection and display, and through the Internet to transmit data to the remote client, Web program is responsible for hardware and data records, the records stored in the database for later analysis of the data. Figure 2 is the network structure of the agricultural greenhouse management system.

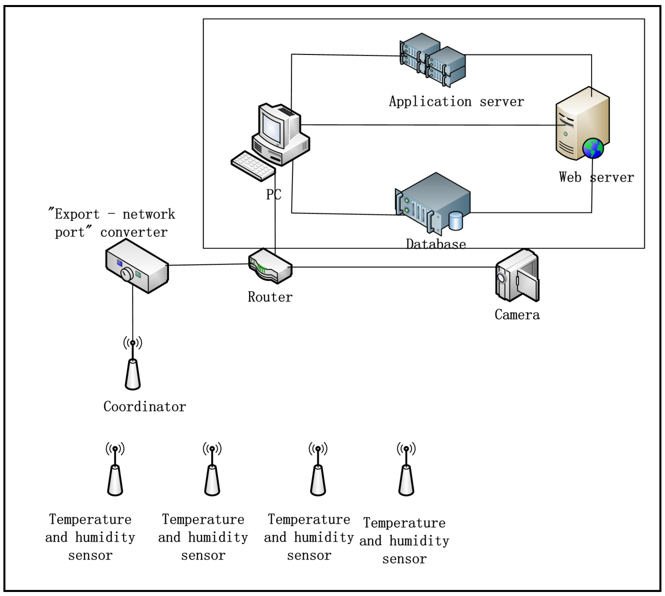


Figure 2 network structure diagram

General database server, Web server, middleware on a computer, the computer through the network cable is connected with a router, and on network port converter are connected by cable to the router, the router interface can directly connect multiple network camera. One end of the converter is connected with the main device, namely, the serial port, and the other end of the Zigbee network.

Before the overall deployment of the system, the first to test the string to network converter, if the test is carried out on the network hardware devices. After the completion of networking in the host computer is installed and set up the middleware program, and then deploy the Web server through the Web server settings, network server and Web middleware and IP transceiver port settings, if you set the success and success is the hardware network through the Web server to view hardware and issued relevant command [27]. Thus we can get the overall structure of the system as shown in figure 3.

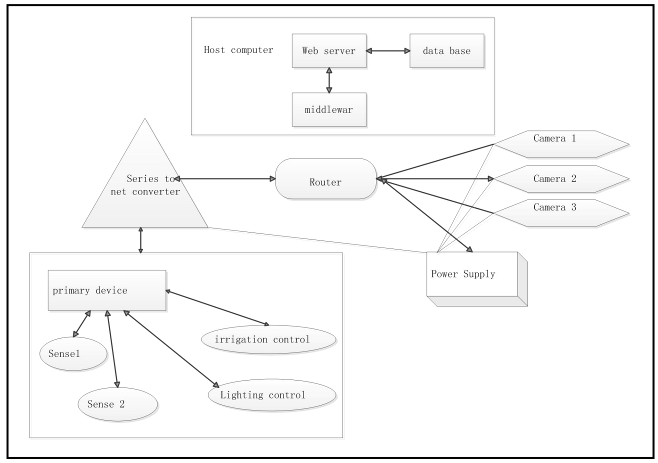


Figure 3 System architecture diagram

B. *Functional module Design*

According to the overall structure and user analysis system is the result of the system can be divided into several modules according to the software engineering ideas to try to ensure a high cohesion and loose coupling between modules, the implementation of the division one by one module in the system in the process of realizing the function module of the system is divided as follows:

1) User management module:

The user management module is independent of the whole system, the system must ensure a successful connection Web database program in the implementation process, user login can query the database to determine whether to log on to the system, and user privileges to modify and add users are also adding to the system database to check operation. However, there are many different ways to write the database operation code of user management.

2) Hardware node management module:

This module is mainly determined by the host computer issued a query command, the main equipment for the sensor and control device's current status is collected and transmitted to the host machine, and the Web Program to display to the user. System equipment in the form of a list of all columns in the table, if a user wanted to know details of a device parameters and working status, you can click on the appropriate link to view specific information, this module allows the user to close down some nodes [26]. Hardware vendors also offer a stand-alone version of the hardware node to view software, this software lets you view and control the nodes, but the software can only be run on a single computer cannot be called a system. By analyzing the hardware node management features.

3) System control module:

The main control module of the system is the control center of the whole system. This module is mainly responsible for displaying the current state of the system, including the indoor temperature, humidity, light, etc.. Users can also automatically adjust the scope of the system through the temperature below or above a certain value automatically adjust the temperature and humidity, while the user can be achieved by the corresponding button irrigation, lighting and other operations. This module is the most common user module, the user through this module to complete the system control.

4) Network settings module:

This module is relatively simple, the Web server display the relevant page, then input by the user Web server and middleware IP and port, although this module in the implementation is relatively simple but can set up the correct IP address so that the normal work of the whole system, so this module should be humanized design as much as possible, to prompt the user whether to set the the network correctly[7] 。

The system includes three parts: Web server, middleware and hardware, and the correct communication between Web server and middleware is the guarantee of the normal operation of the system [8]. Because the structures of the system may be in different LAN which has different IP address allocation in different ways, even if the PC machine, network camera, network port on converter connected to a router, the router also has a different IP address different initialization methods, so the system needs to provide a set of IP middleware. The way, in the Web system built up in the PC machine after that can set the middleware IP address, namely PC's IP address.

5) Monitor module:

Management is in the greenhouse to monitor the regional layout of the camera in the greenhouse, generally in every rectangular greenhouse can arrange a webcam, and in the greenhouse and the greenhouse at the entrance to layout a small camera. You can use the camera with Web function, so in the system only need to set the appropriate IP can be displayed on the web page. Through the image of the user does not need to be able to observe the situation in the field of greenhouse internal situation, when a person controls a lot of greenhouse monitoring and management becomes very important [29]. Generally, the monitor and control network is connected directly with the system's main route, which can be independent of the hardware system.

6) Weather module:

In agricultural systems, weather the very large, although now we can through the Internet, television, check the weather, but the weather forecast function is integrated into the system can facilitate the administrator to check the weather conditions, the system can also be based on the years of data make some suggestive explanation to the administrator.

The weather forecast is very important for the agricultural system, and now there are many ways to understand the weather changes, you can watch the weather through television, China Meteorological Station, etc.. For agricultural greenhouse intelligent management system for the weather forecast is integrated into the system very convenient for the administrator to check the weather, but also can do some suggestive operation, prompting administrators in different weather conditions have different set of system. Weather forecast by the server directly through the background of the China Meteorological Observatory to obtain access to JSON data, the server needs to analyze the JSON data, and then the corresponding weather displayed in the front page [30] 。

According to the instructions of the software engineering, each module should be independent of each other, the function of each module to achieve a single, can not make the module large and full. Of course, completely independent of the module is not present in the various modules still need to communication, then you can take the design of the external interface module is more compact, the change of this module will not affect other modules connected. The system module diagram shown in figure 4.

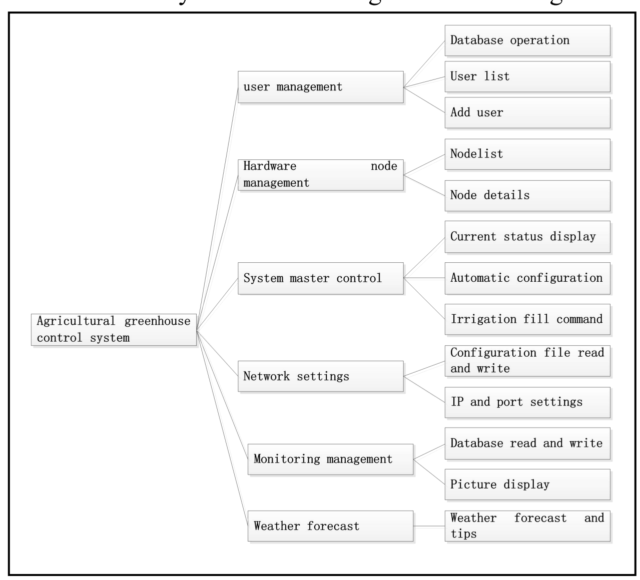


Figure 4 System block diagram

C. Summary in this chapter

Complete the overall design of intelligent management system of agricultural greenhouse in this chapter, the overall design of the main design and analysis of network structure, the overall structure of the system from a macro perspective, the network topology and the overall structure diagram are given.

III. Summary and Outlook

A. Summary in this paper

In the information age, the development of agriculture is developing towards the direction of information and automation. This paper studies the intelligent management of agricultural greenhouse based on the Internet of things.

Greenhouse is commonly used for planting precious fruits, vegetables and other crops, can ensure that crops in a constant temperature, humidity and other conditions, the environment is particularly important for demanding crops. In this paper, through a certain hardware and sensor technology combined with software technology, making the control of greenhouse environment can be achieved through the form of Web site, to facilitate the administrator of the remote operation. In this paper, the main use of hardware assembly and writing, Java platform, HTML+CSS and other technologies, the article from the needs analysis, the overall design, detailed design and implementation, system testing and other aspects of the elaboration. Mainly include the following functions:

1) User management module:

The user management function is a system must have the module, the system user management including user login, user permissions settings, user delete and add. The system does not support the registration of individual users, the system administrator can add a number of ordinary users, ordinary users do not add user permissions, system related security issues ordinary users can not view.

2) The hardware node management features:

The hardware node includes temperature and humidity sensors, lighting equipment, irrigation equipment, etc., these devices can be managed through the hardware node view and maintenance, you can close some nodes. Through the node management function can list all the nodes, the user can view the details of each node. Users can also use this function to detect a simple system, if you can't see some nodes that the node may be damaged or system communication failure[31].

3) The General control functions of the system:

The total control function of the system is the most direct control interface of the greenhouse which is provided by the system, and the general control interface can display the current state of the system, including indoor temperature, humidity, light, etc.. Users can also automatically adjust the scope of the system through the temperature below or above a certain value automatically adjust the temperature and humidity, while the user can be achieved by the corresponding button irrigation, lighting and other operations. This function is the most commonly used functions, the user through this function to complete the system control.

4) Network settings:

This system includes two parts of hardware and software, and the communication between hardware and software through the middleware, the middleware is a software installed on the server, the Web server must communicate to set appropriate address to IP and middleware, in addition to the IP set also includes sending and receiving port settings.

5) Monitoring and management features:

Intelligent automation of agricultural greenhouse management is inseparable from the camera, through the images the user doesn't take field trips to observe inside the greenhouse, when one control many greenhouse monitoring and management becomes very important. Monitoring and management using a webcam directly connected with the system routing , functionally independent of the hardware system, not because of a hardware failure or middleware monitoring function.

6) The weather forecast function:

The weather has a great influence on the agricultural system, although now we can through the Internet, television, check the weather, but the weather forecast function is integrated into the system can facilitate the administrator to check the weather conditions, the system can also be based on the years of data make some suggestive explanation to the administrator.

B. Prospects for future work

Although management has some exploration of intelligent greenhouse, there are still many problems to be solved , The resolution of these issues is conducive to comprehensive promotion system:

(1) The greenhouse for experimental system of smaller, limited number of sensors, Zigbee networks simpler, which must be improved in the area of large greenhouse, which will increase the complexity of the system, which is the follow-up to resolve problems [26].

(2) Intelligent greenhouse management systems can now do temperature and humidity automatic control, but still require human intervention such as fertilizing, weeding, automation still needs to be improved [28].

(3) Systematic security mechanisms need to be further strengthened, in a small area when using the system security issues may not be prominent, if the system is being widely promoted, you must research to strengthen security mechanisms.

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