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ENVIRONMENTAL MONITORING AND CONTROL SYSTEM OF GREENHOUSE BASED ON INTERNET OF THINGS TECHNOLOGY

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Abstract: *Greenhouse is an important application scene of modern agriculture. In this paper, a set of greenhouse environmental monitoring, facility remote control and production management system is designed and implemented based on Internet of Things technology for the development needs of modern agriculture in greenhouse. The system selects STM32F407 control board as the main controller to realize real-time monitoring of greenhouse environmental parameters including temperature and humidity, soil nutrients, soil pH and other greenhouse environmental information, and can adjust greenhouse environmental parameters by controlling the irrigation system, roller shutters, fans, shading curtains and other facilities in the greenhouse. The main controller uploads the collected environmental data and the status data of the execution equipment to OneNet cloud platform in time. Users can obtain the environmental data and control the facilities in the greenhouse anytime and anywhere through the terminal monitoring software. he greenhouse environment monitoring and control system designed in this paper improves the safety and automation of greenhouse. The system is easy to operate, can help farmers remotely know the situation of greenhouse and carry out unified management of greenhouse which will greatly improve efficiency.*

Keywords: *Internet of Things, Modern Agriculture, Environmental Information Monitoring, Remote Control, Smart Greenhouse.*

Annotatsiya: *Issiqxona zamonaviy qishloq xo'jaligining muhim sohalaridan biri hisoblanadi. Mazkur ishda "Buyumlar interneti" texnologiyasi asosida issiqxonada zamonaviy qishloq xo'jaligini rivojlantirish ehtiyojlari uchun issiqxona muhiti monitoringi, obyektni masofadan boshqarish tizimlarining kompleksi ishlab chiqilgan va amalga oshirilgan. Tizimda harorat va namlik, tuproqnig ozuqa moddalari va pH darajasi hamda boshqa issiqxona muhiti to'g'risidagi ma'lumotlarini o'z ichiga olgan parametrlarning real vaqt rejimida monitoringni amalga oshirish uchun asosiy rostlash qurilmasi sifatida STM32F407 boshqaruv platasini tanlangan bo'lib issiqxona muhiti parametrlarini sug'orish tizimini, rolikli panjaralar, ventilyatorlar, soya beruvchi pardalar va boshqa issiqxonadagi mavjud qurilmalarni boshqarish orqali issiqxonadagi atrof-muxit parametrlarini nazorat qilishi mumkin. Asosiy kontroller to'plangan muhit va ijro uskunasining holati to'g'risidagi ma'lumotlarni o'z vaqtida OneNet bulut platformasiga yuklaydi. Foydalanuvchilar istalgan vaqtda va istalgan joyda terminal monitoringi dasturi orqali issiqxona muhitga oid ma'lumotlarni olishlari va issiqxonadagi qurilmalarnni nazorat qilishlari mumkin. Ushbu maqolada ishlab chiqilgan issiqxona muhitini monitoring qilish va nazorat qilish tizimida issiqxona xavfsizligini va uni avtomatlashtirish darajasini oshiradi. Tizim ishlatilishi oson, fermerlarga issiqxona holatini masofadan bilish va issiqxonani yagona boshqarish tizimi orqali nazorat qilish imkonini beradi, bu esa samaradorlikni sezilarli darajada oshiradi.*

Tayanch so'zlar: *Buyumlar interneti, zamonaviy qishloq xo'jaligi, muhit monitoringi, masofaviy boshqarish, aqlli issiqxona.*

Аннотация: *Теплица является важной сферой современного сельского хозяйства. В работе на основе технологии Интернета вещей разработан и реализован комплекс систем мониторинга окружающей среды в теплице, дистанционного управления объектом и системы управления производством для нужд развития современного сельского хозяйства в теплицах. Система включает в себя плату управления STM32F407 в качестве основного контроллера для осуществления в реальном времени мониторинга параметров окружающей среды в теплице, включая температуру и влажность, содержание питательных веществ в почве, pH почвы и другую информацию об окружающей среде в теплице, а также может регулировать параметры окружающей среды в теплице, управляя системой орошения, рольставнями, вентилярорими, затеняющими шторами и другими* *удобствами в теплице. Главный контроллер своевременно загружает собранные данные об окружающей среде и параметры состоянии исполнительного оборудования на облачную платформу OneNet. Пользователи могут получать данные об окружающей среде и контролировать работу оборудования в теплице в любое время и в любом месте с помощью программного обеспечения для мониторинга терминала. Система мониторинга и контроля окружающей среды в теплице, разработанная в этой работе, повышает безопасность и автоматизацию теплицы. Система проста в эксплуатации, может помочь фермерам удаленно узнать ситуацию в теплице и осуществлять единое управление теплицей, что значительно повышает эффективность и функционирования.*

Ключевые слова: *Интернет вещей, современное сельское хозяйство, мониторинг экологической информации, дистанционное управление, «умная теплица».*

1. Introduction

With the increasing scale of the agricultural industry and the implementation of centralized land farming, more and more agricultural products are cultivated in greenhouses. People have limited access to farmland information, mainly through manual measurement, which is a time-consuming and labor-intensive process and is not conducive to improving production efficiency and expanding production scale [1]. The Internet of things is the inheritance and development of the current technological achievements in communication and computer, which can realize the communication of things by using the means of Internet communication [2][3][4]. As the current key development of emerging industries in various countries, internet of things technology is also a strategic fulcrum for the future development of information industry and an important bridge to the development of smart agriculture [5][6], which can promote the transformation of traditional agriculture. Combining advanced Internet of things technology with big data and cloud computing can realize agricultural intelligence, reduce costs [7], and effectively improve the management efficiency of greenhouse. In this paper, we designed a greenhouse environment monitoring and control system based on Internet of things technology to monitor and adjust the environmental data in greenhouse in real time, and realize remote detection and control of greenhouse by users anytime and anywhere through OneNet cloud platform.

2. Overall System Design

The structural block diagram of this system is shown in Figure 1.

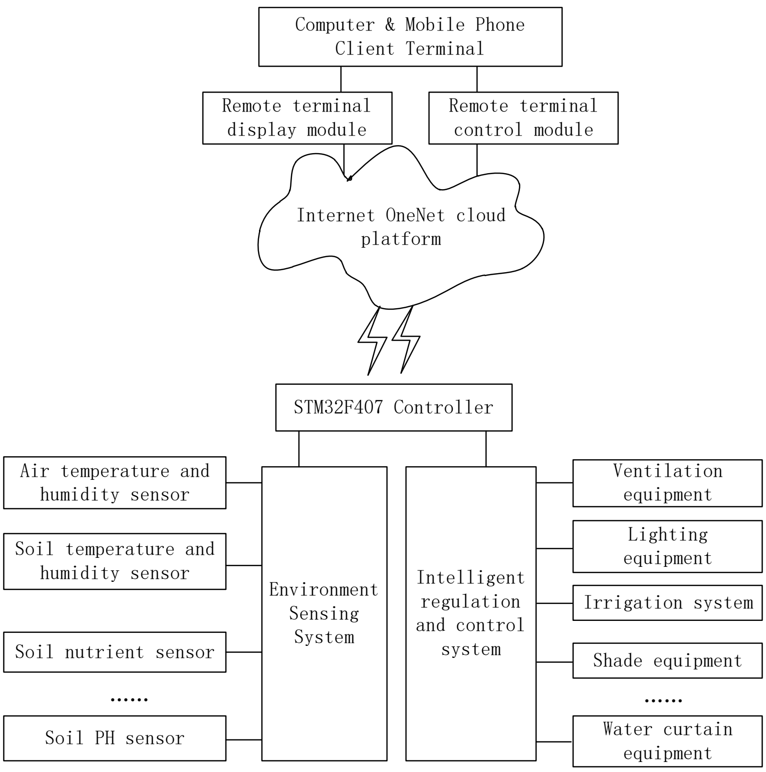

Fig. 1. ***System architecture block diagram.***

The main functional subsystems of the system include:

(1) Environment sensing subsystem. It mainly completes data collection of environmental information and real-time monitoring of the environment. This module contains a variety of sensors and wireless networks. The sensors include air temperature sensor, air humidity sensor, soil temperature sensor, soil humidity sensor, soil pH sensor and soil nutrient (mainly soil nitrogen, phosphorus and potassium content) sensor. The wireless data transmission module adopts LORA wireless module, which is responsible for two-way communication with the main controller, sending sensor data and receiving control signals from the main controller.

(2) Intelligent control subsystem. This subsystem includes controlled facilities in the greenhouse, including water curtains, fans, irrigation systems, shading curtains and lighting equipment. The system is able to adjust the working status of the controlled units through both automatic and manual modes.

(3) Control and data transmission subsystem. This module selects STM32F407 as the controller to receive and process sensor data. And then, the controller cooperates with the ESP8266 wireless network module to upload the environmental data to the server of OneNet cloud platform and is also responsible for completing the control of controlled facilities in the shed.

(4) Remote terminal subsystem. By connecting to the OneNet cloud platform server, the remote terminal subsystem can realize remote sharing and display of greenhouse environmental monitoring data in both the computer client and cell phone client. Users can also check the history records of monitoring data and the operation status of the facilities in the greenhouse, and adjust the facilities through manual control mode.

3. System hardware design scheme

3.1 Controller Module

The STM32F407 series chip is based on a high-performance ARM Cortex-M4 32-bit RISC core and can run a speed up to 168 MHz. The chip integrates high-speed embedded memory, provides three 12-bit ADCs, two DACs, a low-power RTC, twelve general-purpose 16-bit timers including two PWM timers for motor control and two general-purpose 32-bit timers. And it also has up to three I2C, three SPI, and two I2S full duplex, as well as Ethernet and camera interfaces. The system selects STM32F407ZGT6 as the main control chip and node control chip.

3.2 Data Transmission Module

The transmission modes of the system data transmission module include RS485 wired data transmission, LORA wireless data transmission and WIFI wireless network transmission. The relationship between each transmission mode is shown in Figure 2.

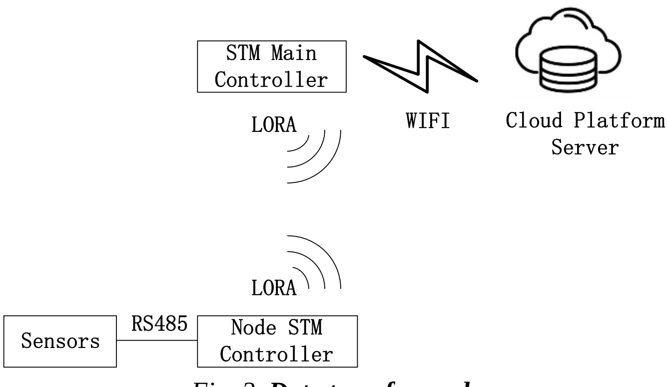

Fig. 2. ***Data transfer mode.***

RS485 wired data transmission using SP3485 chip. The chip supports RS-485/RS-422/MIL-STD 1553B and other communication protocols, integrated overvoltage and low voltage protection, support bus rate up to 30Mbps and built-in overcurrent and short circuit protection, with low power consumption, good anti-interference and high-speed transmission capabilities, etc. Wireless transmission module use the ATK-LORA-01 module. The ATK-LORA-01 is designed with a high efficiency ISM band RF

SX1278 spread spectrum chip, the module operates at 410Mhz~441Mhz, with 1Mhz frequency as a step channel, 32 channels in total. It has advantages of small size, high sensitivity, low power consumption and power saving. The WIFI wireless network transmission adopts the ESP8266-based ATK-ESP-01 module, which has a built-in 10bit high-precision ADC, serial port rate up to 4Mbps, and supports UART/GPIO/ADC/PWM/IIC interface, and its schematic diagram is shown in Figure 4.

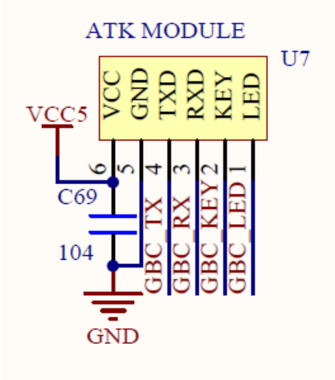

Fig. 3. ***ATK-LORA-01 module connection diagram.***

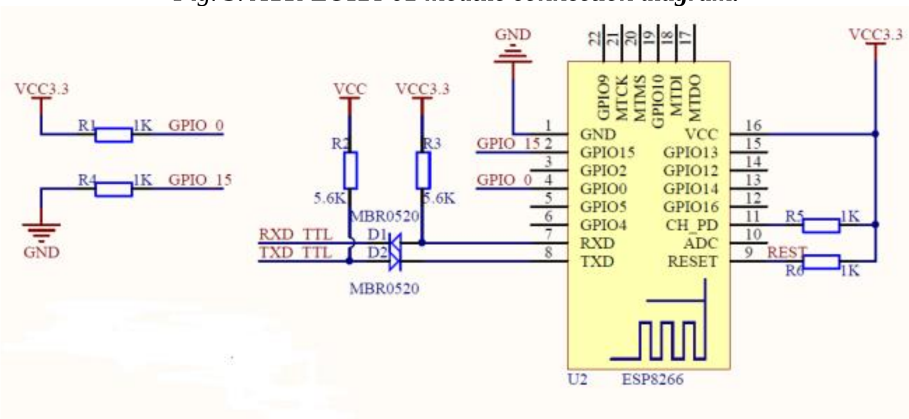

Fig. 4. ***ATK-ESP-01 module schematic diagram.***

3.3 Sensors and facilities

A variety of sensors are used in the system environment sensing module. Each sensor communicates with the node controller through RS485 data transmission. In order to cope with the unbalanced detection parameters in each area of the greenhouse, the various sensors are divided into different groups and placed in different areas of the greenhouse. The system collects the measured values of multiple sensors in different areas and takes the average value to improve the measurement accuracy. The system controls the working status of the greenhouse facilities through solenoid valves. When the acquired environmental parameters exceed the set threshold value, the controller will activate the relay to control the solenoid valve for water supply, fan cooling and other operations.

4. System software design scheme

4.1 Realization of greenhouse facilities control

The relationship between each control device and environmental factors in the greenhouse is not a simple one-to-one correspondence, and the control of any one of them will have certain effects on different environmental factors. The relationship between each control equipment and environmental factors is shown in Figure 5.

The system uses a combination of threshold method and fuzzy control algorithm to complete the control of the greenhouse facilities. The threshold method is used for automatic control of greenhouse equipment that only affects a single environmental factor, such as lights. Users can set the upper and lower thresholds of the corresponding environmental factors on the user service platform. The fuzzy control method is used for automatic control of facilities such as fans and water curtains that have different degrees of influence on various environmental factors. Users can also modify the upper and lower thresholds of the corresponding environmental factors through the user service platform.

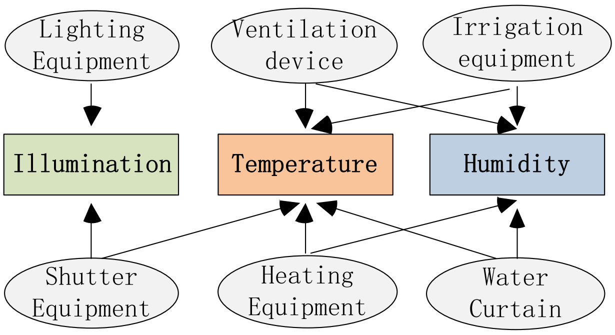

Fig. 5. ***Diagram of the relationship between equipment and environmental factors.***

4.2 Realization of software and hardware information interaction

In order to realize the remote information interaction between the system software and hardware, this paper completes the construction of the OneNet private cloud platform and writes the service program with MQTT as the communication protocol. OneNet cloud platform is a PaaS Internet of Things open platform developed by China Mobile [6]. It can realize device access and provide comprehensive Internet of Things solutions, support fast access and big data services for all kinds of sensors and smart hardware, provide rich API interfaces, and can effectively reduce Internet of Things application development and deployment costs [7]. The system builds OneNet cloud platform product based on MQTT protocol and successfully tested the connection status of the cloud platform using the network debugging assistant.

5. System function testing

5.1 User server platform function test

After testing, the system host controller is able to successfully establish a connection with the OneNet cloud platform through the MQTT protocol and upload environmental data and device status data. The successful connection of the main controller to the OneNet cloud platform is shown in Figure 6.

Fig. 6. ***OneNet cloud platform server connection status.***

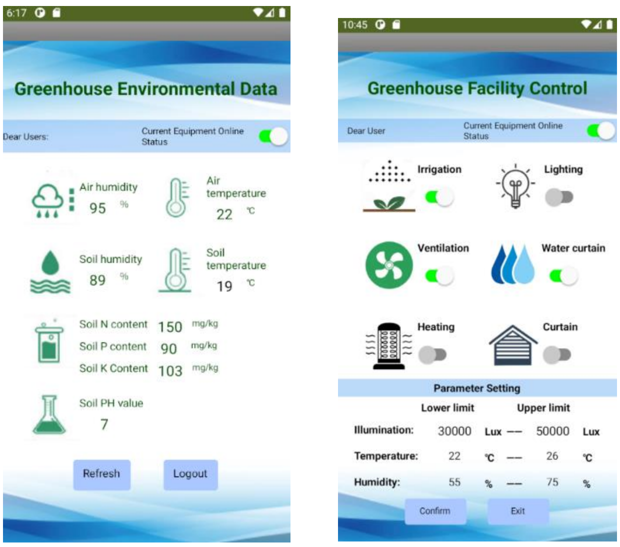

Fig. 7. ***Client terminal service platform.***

In order to realize the information interaction of software and hardware, the system has designed client programs both under Windows-based operating environment and Android-based system. The administrator can log in to the system by entering the correct account and password. Through the test, users can get the environmental data in real time through the user server, and can realize the command to control the status of the facilities inside the shed remotely. The test of the client terminal service platform is shown in Figure 7.

5.2 Automatic control function test

In this paper, according to the specific conditions of the greenhouse facilities, the automatic control function of the system is tested in the laboratory environment. Among them, the light equipment and the rolling shutter equipment mainly have a large impact on the light intensity, which is set to be manually controlled by the user. The working status of the remaining controlled devices under different temperature and humidity is shown in Table 1. The results are as expected.

Table 1

Automatic control function test

Input		**Output**			
Temperature/℃	Humidity/%	Ventilation	Irrigation	Heating	Water Curtain
15	30	Off	On	High	On
15	60	Off	Off	High	On
15	90	Off	Off	High	Off
20	30	Off	On	Low	On
20	60	Off	Off	Low	On
20	90	Low	Off	Low	Off
25	30	Off	On	Off	On
25	60	Low	Off	Off	On
25	90	High	Off	Off	Off
30	30	Low	On	Off	On
30	60	High	Off	Off	On
30	90	High	Off	Off	Off
35	30	High	On	Off	On
35	60	High	Off	Off	On
35	90	High	Off	Off	Off

6. Conclusion

This paper designed a greenhouse environment monitoring and control system based on Internet of Things technology. The system uses STM32F407 control board as the main controller. The collection of environmental data in the greenhouse and the automatic control of various greenhouse facilities are realized. The system built the OneNet cloud platform server to realize the data storage and sharing. The user terminal application is designed to realize remote and real-time intelligent monitoring and control of agricultural greenhouse. After the system is put into use, it can effectively improve the degree of agricultural informatization, realize the rational use of agricultural resources, and improve agricultural production efficiency and management level.

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