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Design of Intelligent Greenhouse Monitoring System Based on Internet of Things

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Abstract: The development of modern agriculture in our country has increasingly relied on the application of intelligent equipment. In response to the problems of resource waste and non-quantitative in modern agriculture, there is an urgent need for the application of standardized and refined intelligent equipment. By combining IoT technology with wireless sensors, an intelligent greenhouse monitoring system based on the Ali Cloud IoT platform has been constructed. The system consists of two parts: environmental monitoring and action execution. The implementation of data collection, uploading, and remote control through 4G networks has solved the problems of low automation and weak real-time performance in modern agriculture, improved the economic benefits of agricultural greenhouses, and is of great significance for the construction of intelligent agriculture.

1. Introduction

The traditional agricultural production method heavily relies on the environmental parameters of greenhouses during implementation. Due to the uncertainty of factors such as temperature, humidity, and light, it cannot guarantee the yield and quality of crops, and requires a lot of manpower. With the development of Internet of Things technology, intelligent equipment has made a significant contribution in the agricultural field, which is conducive to wireless sensors and Internet technology to collect the environmental parameters of greenhouse and upload them to the cloud platform, and trigger the execution equipment according to the set threshold to ensure that crops always maintain a suitable growth environment, and achieve the purpose of remote monitoring crop growth.

2. System Introduction

2.1. System Architecture

The system applies technologies such as the Internet of Things, cloud platforms, wireless sensors, and intelligent control to greenhouses. Through advanced computer information technology and electronic devices such as sensors, it enables remote monitoring of crop growth through mobile phones or computers, improving the output value and efficiency of agricultural production. When using this system, environmental parameters are set in advance according to the needs of crop cultivation and growth stages. Various sensors installed on site monitor the greenhouse environment and soil conditions inside the greenhouse, mainly collecting environmental parameters such as air temperature and humidity, light intensity, soil temperature and humidity, soil pH value, carbon dioxide concentration, etc, and sending them to the cloud for statistical analysis and storage, controlling on-site execution equipment. The architecture of the Internet of Things greenhouse monitoring system is divided into three parts: physical perception layer, network transmission layer, and application layer. The system architecture is shown in Figure 1.

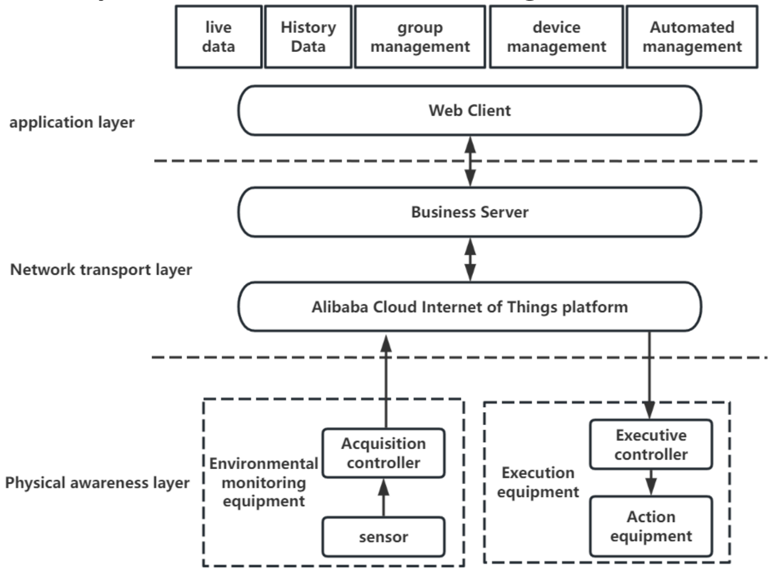

Figure 1: System architecture figure.

The physical perception layer includes collection and control nodes for data collection and control equipment, environmental sensors for data collection, greenhouse environmental control equipment, and facilitates and reliably transmits greenhouse environmental data to the network layer. Environmental monitoring equipment is responsible for collecting and uploading greenhouse temperature, humidity[1], lighting, carbon dioxide concentration and other environmental data. The executing device triggers an execution action based on the set threshold to regulate the greenhouse equipment.

The network transport layer is an intermediate link connecting the physical perception layer and the application layer, responsible for packaging and uploading the environmental parameters collected by the physical perception layer, and transmitting user instructions from the terminal application layer. The network transport layer is developed based on the Ali Cloud IoT platform and uses the MQTT/AMQP communication protocol to handle message publishing/subscription messages between the perception layer, cloud servers, and business servers. When transmitting data from the perception layer, each intelligent gateway is defined as the publisher of the message, environmental parameters are transmitted through the server, and response terminals are defined as subscribers to achieve remote monitoring of greenhouse environmental parameters. When controlling greenhouse equipment, the response terminal is defined as the publisher, and the proxy server sends the user's control instructions to the control equipment subscribed to the corresponding topic, achieving remote control of greenhouse equipment.

The application layer provides a human-computer interaction platform, which adopts the C/S architecture and is developed using the Vue framework as a web client. It has functions such as authentication, device management, data management, group management, and automation management[2]. The data management module uses Echart to achieve data visualization, which is used to monitor real-time environmental parameters, historical data, historical curves, etc. of the work.

2.2. Ali Cloud Internet of Things Platform

Ali Cloud Internet of Things platform is a comprehensive application platform integrating device management, data security communication, message subscription and other functions. It is an Internet based information carrier system. All ordinary physical objects that can be independently addressed can form an interconnected network. Its main function is to support a large number of downward connecting devices and upload the data collected by the device to the cloud; Provide cloud APIs to web servers, which can issue instructions to devices by calling cloud APIs. Low power sensors in IoT devices will regularly update real-time data from agricultural greenhouse environments, achieving remote monitoring functions.

2.3. MQTT Protocol

MQTT (Message Queuing Telemetry Transport) is an IoT application layer protocol developed by IBM. It is based on the TCP/IP protocol and runs at the TCP/IP application layer. It is an ISO standard message transmission protocol designed to connect different wireless sensors using unreliable networks. The MQTT protocol uses the C/S architecture, consisting of three identities: publisher, subscriber, and server. MQTT messages contain subscription topics and message subjects, and subscribers subscribe to publishers based on their unique tags. When the publisher publishes the same topic as the subscriber subscribes to, the message is sent out through the gateway and passes through the MQTT server intermediary station, ultimately forming a data transmission link. Based on the small bandwidth of MQTT messages, it reduces power consumption during device transmission in IoT systems and is very suitable for smart agriculture systems.

3. System Function Design

The IoT intelligent greenhouse system collects real-time information on crop growth environment, including temperature, humidity, light, carbon dioxide content, etc., remotely through various sensors. Implement automatic adjustment and irrigation according to the control strategy based on the on-site environment, ensuring that crops are always maintained in a suitable growth environment. By uploading data to the web management platform through the 4G module, users can monitor the crop growth environment in real time, saving manpower[3].

User Management Module: Provides the function of user registration and login. During registration, permissions are assigned based on the worker's identity type. Users who successfully register can enter the correct username and password to log in to the system. After successful login, identity is identified based on the username, and different levels of operation permissions are assigned. For example, ordinary workers can only view data, and managers can issue control commands to the executing device.

Device Management Module: This module displays all available devices on the system, such as exhaust fans, humidifiers, irrigation valves, etc. By editing, devices can be added, deleted, updated, and other operations. Simultaneously display the working status of the device, such as working, not working, faulty, etc.

Group management module: The module is set up as a group in greenhouse units, which makes it easy to manage, control, browse real-time data and history the equipment in each greenhouse;

Data Management Module: This module is used for real-time monitoring of greenhouse environmental data and drawing historical curves based on historical data. Users can analyze the optimal growth environment of crops based on recent trends. By comparing and analyzing real-time monitoring data with historical data, users can more effectively adjust the greenhouse environment to promote healthy crop growth.

Automation Management Module: This module is used to display all the automation lists of the system. The cloud server analyzes the data collected and uploaded by sensors, automatically sends control commands to trigger actuator actions, such as timing on/off humidifiers, turning on exhaust fans when the carbon dioxide concentration exceeds the threshold, and turning on lighting when the temperature is too low. Users can also add, modify, delete, start, disable, and trigger basic functions for automation projects.

3.1. Hardware System Design

The hardware system is divided into two parts: an environmental monitor and an action actuator, mainly responsible for collecting and uploading greenhouse environmental data, and issuing control commands according to the set control strategy. The 4G module communicates with the sensor using the IIC communication protocol[4]. The advantage of using this communication method is to ensure that the data collected by the sensor is accurate and will not be inaccurate due to line loss.

The environmental monitor consists of an Air724Ug module, temperature and humidity sensors, ambient light sensors, carbon dioxide sensors, etc. The Air724Ug module is an LTE Cat 1 wireless communication module designed based on the UIS8910DM4 platform. Supports 4G remote communication and Bluetooth wireless communication technology, supports WiFi scanning, WiFi positioning, supports audio, camera, display screen and other functions. In addition, the module also supports various universal interfaces, such as USB/UART/SPI/I2C/SDIO, to meet the different application requirements in the field of the Internet of Things, shown in Figures 2.

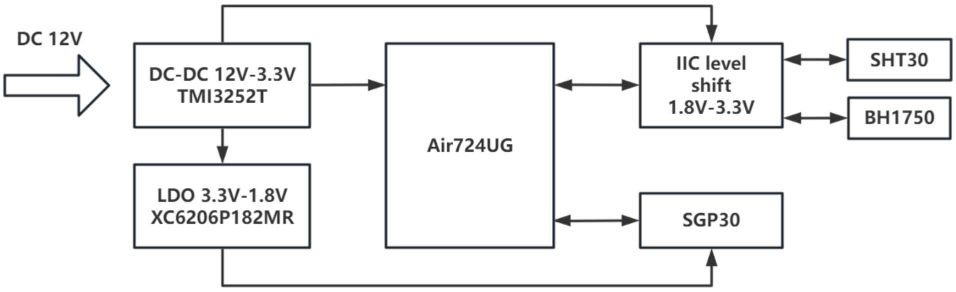

Figure 2: Monitoring equipment schematic figure.

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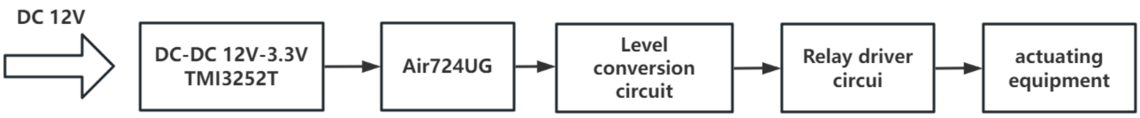

Figure 3: Execute equipment schematic figure.

3.2. Software System Design

This system is divided into a web client and a server side, developed based on Vue3 and Echart. The main purpose of the client is to enable management personnel to monitor the greenhouse in real-time, ensuring that crops can be planted and cultivated in a scientific environment. The web server is developed based on the Gin framework and is mainly used to process client requests and return data. In the interconnection part with the Ali Cloud IoT platform, AMQP is used to subscribe to the Ali Cloud IoT platform. It can monitor the model data reported by devices in real time and store this data in Redis for the client to obtain device information.

The program of the environmental monitor is divided into four modules, namely cloud networking, sensor sampling, rule filtering, and data reporting. After device initialization, the module first starts the connection to the 4G network. If the connection is successful, the current status of the module and sensor sampling data will be reported to the cloud; Sensors use the IIC protocol for communication[5], and we only need to know the IIC address of the sensor and the instructions for reading data to read the data from the sensor. In this system, sensor acquisition involves setting up a task for timed collection, and storing the collected data locally; The main function of rule filtering is to reduce the frequency of data reporting. The main principle is to determine whether there is a significant difference between the sensor data reported to the cloud last time and the data collected by the current sensor. If the difference is too large, rule filtering will actively report the current sensor data.

The program of the action executor is mainly used to receive commands from the cloud and parse them to control the opening and closing actions of the relay. After device initialization, the module first starts the connection to the 4G network. If the connection is successful, it reports the current status of the module to the cloud and subscribes to the specified Topic address. The command issued by the cloud will be issued through this Topic, and the device can receive the content of the command issued by the cloud. Based on the command, it controls the opening and closing of the relay, thereby controlling the switch of external devices.

4. Conclusions

The intelligent agricultural greenhouse monitoring system based on the Internet of Things designed in this article aims to improve the yield and quality of greenhouse crops. Through the greenhouse automation system, corresponding strategies can be formulated according to different environments. In addition, the monitoring system is capable of real-time monitoring of temperature, light, humidity, carbon dioxide content, etc., ensuring that crops are in the optimal growth environment. This monitoring system has laid the foundation for scientific planting in greenhouses and is conducive to the development of the greenhouse planting industry. Smart agriculture promotes the transformation and upgrading of the agricultural industry chain through the intelligence of the production field, achieving agricultural refinement, efficiency, and greening, ensuring the safety of agricultural products, enhancing agricultural competitiveness, and promoting sustainable agricultural development. Smart agriculture is an inevitable trend in the modernization of agriculture in China. The accuracy of data and the efficiency of MQTT protocol transmission in intelligent greenhouse systems based on the Internet of Things will undoubtedly promote the development of smart agriculture in the future.

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