Design and Application of Intelligent Greenhouse Information Management System Based on Hybrid Architecture

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Abstract. In order for real-time greenhouse information management system to be applied in both local area network and wide area network, an intelligent greenhouse information management system based on C/S and B/S hybrid architecture, is designed. In the intelligent greenhouse information management system, factors like temperature, humidity, light intensity and CO2 concentration are considered, so that the greenhouse crops can grow in appropriate environment, to yield good economic benefits. Compared with the traditional greenhouse information management system, the system can monitor the main factors such as temperature, humidity, light intensity and CO2 concentration in the greenhouse. At the same time, customers can monitor the real-time conditions in the greenhouse and exercise real-time control, as long as the Internet is available.

1. Introduction
With the development of science and technology, great changes have taken place in agricultural production as well as the traditional farming mode. The modern scientific technologies, for example, the sensor, computer control, network communication and artificial intelligence, have all become essential in modern agriculture, which indicates the progress of modern agriculture. With the progress of modern society, traditional mode of agricultural production has been unable to meet the needs of modern civilization[1-3].

With the agriculture equipment getting more popular, it has been an ingredient part of our society. The so-called agricultural equipment, in fact, is mainly greenhouse facilities[4]. It is not constrained by time or space, anywhere in the plateau, mountains, desert and other special circumstances for agricultural production[5].

As is shown in Figure1, the greenhouse environmental monitoring system based on Internet of Things is an important part of intelligent greenhouse. The core of intelligent greenhouse environmental monitoring system is Greenhouse Information Management System[6-7].

![Modern Greenhouse](image)

Figure 1 Modern Greenhouse

At present, there are two main modes for the greenhouse information management system: the first is the stand-alone version of the management software, which relies on the server for data
collection, storage and management[8]. The Internet-based information network monitoring system, is composed of C/S architecture to achieve local area network. The scope as well as the efficiency of greenhouse information management, communication is real-time strong, but most do not allow remote multi-user access; the other is based on the B/S architecture, with only the browser, based on the standard HTTP and TCP/IP open protocol, the client can know the update information[9-10]. It is intended for wide area network, within the multi-user remote monitoring. This type of intelligent greenhouse system has good scalability and cross-platform, but the data throughput in LAN range is small, lacking real-time, and it is inconvenient to direct operation and management of the scene of the Internet-type greenhouse information monitoring system[11-12].

To overcome the shortcomings of the two referred models, and as good as possible to play the advantages of the two architectures, a hybrid architecture system appeared. The hybrid architecture model is not a simple addition of the C/S mode to the B/S mode, but a system architecture model that combines the two.

In order to balance the requirements of intelligent greenhouse information management in local area network and wide area network, a kind of intelligent greenhouse information management system based on C/S and B/S hybrid architecture is designed.

2. Design
It is well known that PLC control system are powerful, cost-effective, easy-programming and anti-interference. It is blessed with long life, easy system design, installation, commissioning, easy maintenance and many other features, which is in accord with the requirements of intelligent greenhouse control system. Therefore, the control system selected the use of PLC-based greenhouse control system, can be able to meet the needs of greenhouse control functions[13-14].

Based on C/S architecture, in the intelligent greenhouse control system, with the use of various sensors, like temperature, humidity, soil moisture, light intensity and CO₂ and other environmental factors, were collected and read through the special function module, and sent to the PLC for processing. The results are then sent to the greenhouse implementing agencies to ensure that the greenhouse environment meets the crop's growth environment.

Based on B/S architecture, the monitoring and control of the whole intelligent greenhouse can execute remote monitoring and control of the greenhouse, display real-time data, historical data, trend curve, report and alarm, and implement centralized management functions. The system also allows remote multi-users, as long as the client is configured with a browser, can log on the system, view, and execute related operations.

2.1 System Block Diagram
As is shown in Figure 2, the whole system consists of 3 subsystems, which are the field management system, which is based on C/S architecture, the database system which is based on SQL, as well as the remote management system, which is based on B/S architecture.
Based on the C/S architecture, the field management subsystem can collect updated information, in which the application server is a stand-alone version of the management software, and based on the Internet of things, the greenhouse monitoring system is located in the same local area network, through the serial bus RS232 protocol and PLC-based programmable controller information Control system communication. The main functions of this part are: to continuously receive greenhouse information according to the growth habits of greenhouse crops, generate fuzzy control strategy.

The greenhouse system automatically controls the greenhouse environmental parameters, and can report to the managers with SMS and voice, and work with the remote management system. The task of real-time synchronization is the action mechanism of the greenhouse mechanism. Remote management subsystem is based on the B/S architecture, to achieve multi-user WAN wide access and management. The database subsystem is a communication bridge between the site management subsystem and the remote management subsystem. It supports Microsoft ADO.NET interface data access, which is responsible for real-time storage of greenhouse information, decision information and user management information.

2.2 Field Management System Based on C/s Architecture

As is shown in Figure 3, the greenhouse field management system can remotely monitor the greenhouse through the RS-232 communication. Based on the bus pre-state, including automatic/manual, start/stop of fan, opening/closing of sunshade, opening/closing of sunroof, start/stop of irrigation, start/stop of sprinkler, start stop of wet curtain pump, opening/closing state, but also through the greenhouse real-time parameter table, to observe the parameters of real-time data.

In addition, the most important thing is that the interface can control the window system, shade net system, wet curtain system, sprinkler humidification system, irrigation system and fill light.
Figure 3 Greenhouse Controlling System

The intelligent greenhouse control system mainly supports three kinds of controlling, which are the site manual control, remote manual control and automatic control. As is shown in Figure 4, which is the control system flow chart, PLC control system is in the initial stage, the first greenhouse parameter data initialization, the environmental factors on the upper and lower limits into the register, and at the same time to complete the greenhouse environment factor collection, Display and PLC automatic control program to improve the basis for the implementation.

When the greenhouse control system is in manual control, according to the needs, the scene can arbitrarily regulate the operation of the implementing agencies; and the system is in remote control, the control principle and on-site manual control caused.

To distinguish between the control end in the controlling room, when the system is in the PLC automatic control program execution, the system will be based on the pre-set environmental factor values and purpose. With value of the small breaks to compare, the results will be in accordance with the program’s control output actuator action, to achieve the role of regulating the greenhouse environment.
2.3 Database System
Whether in the B/S architecture or C/S architecture, whenever the client wants to submit the data operation request to the final implementation, it should rely on the database system. So the database system is designed, in order to directly manage the application system, and also allows the system to run efficiently and smoothly.

Relational database system in the data table is organized by the recordset, the record of each field are not sub-sub-basic data, and record records can not be repeated. In the design of data tables, in addition to the objective data stored in the data table, to design the relationship between the data table, the general key, external key definition to achieve, if the relationship between the data table and attributes, or attributes can subdivise, will have to form the data table to represent the relationship between the data table.

Database attributes designed to follow the integrity of the rules are mainly entity integrity, lead integrity, user-defined integrity and so on. Relationship standardization is an important aspect of database design, non-standard relationship design often lead to data redundancy, increase, update records produce different.

2.4 Remote Management Subsystem Based on B/s Architecture
**Figure 5** shows the general situation of the user interface, the user in any network where, can log on the system, real-time observation, read the report, view the relevant factors of the greenhouse dynamic curve, view the alarm system, and can be directly in the remote control.
Browser/Server structure is the use of a mature Web browser technology: a combination of the browser's multi-scripting language and ActiveX technology, with a common browser to achieve the original need for complex special software to achieve the powerful features, while saving development costs.

The biggest advantage of B/S is that you can operate anywhere, without having to install any special software, as long as there is a computer that can access the Internet. Zero installation, zero maintenance, and the system is very easy to expand.

3. Key Technologies Referred

3.1 Greenhouse Multivariable Control System

Greenhouse environment system is a complex large system, the growth of various organisms in the greenhouse to consider the parameters is not to be very precise, as long as a certain reasonable range, the control system is controllable and feasible.

Intelligent control technology has been widely used in various fields, and greenhouse control is also an important branch of intelligent control applications. In the traditional control, most of the PID control is used, but the parameters of the greenhouse is difficult to set, and the parameters are in a relatively small range of effective. In recent years, some scholars put forward the fuzzy control theory, which can be a good way to overcome this problem. Therefore, users no longer have to accurately understand the situation of the object. And in the field of process control, it has been widely used.

Fuzzy control is very suitable for greenhouse control system. Fuzzy control is based on the development of nonlinear theory. It is based on fuzzy mathematics, fuzzy set theory, fuzzy language variables and fuzzy reasoning. This mode of control is ideal if the mathematical model is not available in a multi-parameter fusion system such as greenhouse control.

In the process of practical application, the design of the ventilation control system based on the fuzzy reasoning system (FIS) is adopted for the intelligent greenhouse control system. The heating and
ventilation model is adopted to realize the transformation between temperature and humidity to a certain extent. Mathematical model of control system, as is shown in the formula below.

\[
\frac{dT}{dt} = \frac{(q_i + q_h) - (T - T_{out}) - \rho V(T - T_{out})}{\rho C_p V}
\]

Where \( T_{out} \) is the outside air temperature of the greenhouse, \( T \) is the internal air temperature, \( \rho \) is the greenhouse air density, \( C_p \) is the heat transfer coefficient, \( q_i \) is the internal heat, \( q_h \) is the internal heater input heat, and \( V \) is the overall volume of the greenhouse.

The temperature is divided into five fuzzy levels, humidity and light are divided into three levels. In order to eliminate the temperature, humidity, strong covenant, the temperature and humidity are put together to consider. The temperature and humidity corresponds to the state of the implementation of a level. The fuzzy input is transformed into the fuzzy set by using the Gaussian membership function, and then the fuzzy output is obtained based on Mamdani reasoning. Then, the output value is obtained by using the gravity method to obtain the accurate output variable.

In order to improve the speed of operation, combined with Matlab fuzzy control toolbox and Simulink simulation tool, the fuzzy reasoning idea is transformed into fuzzy control table stored in the computer, then actual work through the offline lookup table for fuzzy decision.

When the greenhouse environment parameters exceed the set threshold, the field management system will automatically voice alarm, and send a prompt message to the designated user. Voice alarm system is based on Microsoft TTS voice recognition engine, and SMS prompts through the telecommunications capabilities interface to achieve. In order to prevent false positives and repeat the alarm, set the detection period \( T_1 \) and duration \( T_2 (T_1 > T_2) \) 2 parameters. Every cycle, with \( T_1 \) to detect whether the current value exceeds the set threshold, if exceeds, waiting for \( T_2 \) time after the re-detection. If still exceed the threshold, the alarm prompt, otherwise it is judged as normal and the system will not alarm.

3.2 Real-Time Synchronization of Greenhouse Mechanism Operation Status Based on Server Push Technology

The field management subsystem communicates directly with the PLC and can obtain the current working status (open or closed) of the greenhouse mechanism real-time conditions. The remote management subsystem needs to obtain the working status of the equipment through the on-site management subsystem. When the user controls the greenhouse mechanism through the on-site management subsystem or the remote management subsystem, it is necessary to know the working status (opening or closing) of the current greenhouse mechanism, so that the system can accurately determine whether the control operation is performed by the user. With the opening mechanism or the closing mechanism, the system control greenhouse institutions can notify each other to each other whether that is real-time synchronization of action status.

Traditional Web-based servers only send data to the client when the Web client initiates a request, but the remote management subsystem of the greenhouse system does not know when the device status of the server (field management subsystem) changes, and it can not Send a request to the server to get the device status. The ideal solution is to allow the server to communicate with the Web client, taking the initiative to send information to the browser. The server push (C Server Push) technology is put forward based on this idea. Because the majority of browsers on the Internet are compelled to install Adobe Flash player. With the Flash-based XML socket interface, with the design of the server push, the framework has a very good compatibility. Information can be transferred using XML socket interface, thus the intelligent greenhouse information system 2 subsystems are in real-time synchronization state.

As is shown in Figure 7, when a user opens or closes (changes the state) through a dynamic Web page, ASP.NET sends instructions to JavaScript, JavaScript calls external flash. The addCallback method of the External Interface class is embedded in the page. Flash sends the command through the XML socket class. When the site management subsystem receives the data, it calls the reading method
of the Network Stream class to read the state change instructions sent by the remote management subsystem. This is a unicast real-time synchronization of a remote management subsystem to the site management subsystem, and in addition to the on-site management subsystem that has been connected to the greenhouse organization, there may be other users who are browsing the remote management subsystem. At the same time, online Web users who have real-time access to institutional status, can access the field management subsystem to a number of online remote management subsystem broadcast device status change instruction (call Network Stream class two ite method).

When flash receives data, it will automatically trigger DataEvent.DATA event, through external flash. Then the Interface class calls the JavaScript to control the Web page, to change the working state of the greenhouse. At this point, real-time synchronization of the working conditions of the greenhouse mechanisms between the two subsystems can be achieved.

![Figure 7 Server Push Technology for Real-Time Synchronization of Greenhouse System](image)

### 3.3 Asynchronous Web Data Interaction Based on Asynchronous Javascript and Xml (Ajax) Technology

Traditional web applications use a synchronous interaction process. Each time the browser executes one action, the user must wait for a long deal to continue the next action, because the client browser must reload the entire page. In our remote management subsystem, the web page and switch the greenhouse video or query historical data, if operated in the traditional interactive way, cannot display the video or historical data when the global refresh and cause the page and shake.

The system realizes the asynchronous interaction, based on AJAX technology, to construct the remote management subsystem, to provide clients with smooth data exchange experience. As is shown in **Figure 8**, AJAX engine between the client browser and Web server, through the client JavaScript call XMLHttpRequest object trigger AJAX engine to generate HTTP requests without waiting for the server response, the server returns XML format data, with the use of JavaScript operation DOM Implement dynamic local updates for Web pages. This approach minimizes the burden of redundant requests and responses on the server, thus improving the user experience. Also, since different browsers create XMLHttpRequest object methods differently, you need to use the Try-catch statement in turn, and try several different creation methods in order to make AJAX technology better for a web page, to support a variety of browser platforms.
4. Conclusion
This paper proposes an intelligent greenhouse information management system based on C/S and B/S hybrid architecture. In the intelligent greenhouse information management system, factors like temperature, humidity, light intensity and CO₂ concentration are considered, so that the greenhouse crops can grow in appropriate environment, to yield great economic benefits.

The method of access is described, and the system application of hybrid architecture is realized through database design and system engineering development, considering certain theoretical and practical significance, the rational choice of system architecture, reducing information system development cycle, improving the adaptability and life cycle of information system to different management requirements, and improving the flexibility and security of information system. And then with the use of the ASP scripting language, the database development technology of information system based on B/S architecture is realized. In this paper, we use Visual Basic 6.0 to develop the C/S model client application method.

The main skills used in the paper, are the greenhouse multivariable control system, the asynchronous web data interaction based on asynchronous Javascript and XML(AJAX) technology, as well as real-time synchronization of greenhouse mechanism operation status based on server push technology. With these skills, the whole system can execute real-time control, and enjoy smooth data exchange experience.

Compared with the traditional greenhouse information management system, the system can monitor the main factors such as temperature, humidity, light intensity and CO₂ concentration in the greenhouse. At the same time, customers can monitor the real-time conditions in the greenhouse and exercise real-time control, as long as the Internet is available.

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