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Intelligent Agricultural Greenhouse Monitoring System Based on Cloud Computing

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Keywords: Smart Agricultural Greenhouse, Cloud Computing, Intelligent Monitoring, Temperature Humidity Data, B/S Structure

Abstract: In view of the increasing material needs of the people and the lack of resources, agricultural greenhouses can efficiently provide a variety of crop products to meet the needs of contemporary society. This research mainly discusses the research of intelligent agricultural greenhouse monitoring system based on cloud computing. This system adopts the B/S structure, combined with the multi-core technology of modern browsers, the universal browser can realize the various needs of customers for the system, which greatly saves the cost of the project. DTH11 temperature and humidity sensor detects data from the temperature and humidity sensor drive module, collects temperature and humidity data for it through the bus, and outputs the collected temperature and humidity data in parallel. The cloud platform database uses the lower computer temperature and humidity sensor module to automatically monitor the temperature and humidity dynamic values of the agricultural greenhouse, and display it on the 12864 LCD panel in the greenhouse in real time; the data information displayed on the data screen in the greenhouse is transmitted to the LABVIEW host computer display interface ; For the air and soil temperature and humidity in the greenhouse, the cloud platform database management program can record correspondingly according to the day; the management program can query the ambient temperature and humidity information according to the day or month; the management program can set the warning temperature and prompt the greenhouse in time differences in the external environment; the management program can generate reports, output the reports in accordance with the relevant requirements of greenhouse management, and print the temperature record curve and data. The error is analyzed based on the test results of the upper computer interface of the PC cloud platform. The difference between the tested soil temperature and the actual temperature is about 1 degree, and the error of the light intensity value is about 3%. This research provides a reliable solution for the artificial cultivation of crops with large environmental gaps.

1. Introduction

In recent years, more and more high-tech technologies have been used in the agricultural field. At the same time, the research on the related technologies of agricultural automated production has also received extensive attention. In human life, food is the most important, so the development of a country, agriculture is its foundation. The small-scale peasant economic model of traditional agriculture has small production scale, relatively low technical level of agricultural production and management, low production efficiency and income, poor ability to withstand disasters, and product quality cannot be guaranteed.

The agricultural greenhouse environment is relatively small and closed, which is convenient for the arrangement and maintenance of related measuring equipment and network equipment. At the same time, the greenhouse provides a good working space for the equipment and has a protective effect. The development of smart greenhouses is an objective demand in the new stage of my country's rural agricultural financial development, and at the same time, it is a realistic choice to overcome resource and market constraints and respond to competition from various countries. The development of smart greenhouses can effectively improve labor productivity and resource utilization, and effectively solve the contradiction between population, resources and environment in our country.

Agricultural greenhouses are usually built around cities to provide residents with agricultural products or green plants. With the increasing demand for plant growth environment, the temperature and light in the greenhouse are counted especially in the cold winter. He Q proposed a new type of energy-saving agricultural greenhouse construction idea, which is to install solar collectors on agricultural greenhouses to improve energy efficiency. In addition, solar collectors do not occupy additional land resources and only affect the lighting in the greenhouse. According to the actual parameters of the agricultural greenhouse, the design and modeling of the solar energy system are introduced. Then the characteristics of energy harvesting and indoor lighting are explained through simulation. When the oblique incident angle of sunlight is in the range of -38 °-38 °, the receiving efficiency of rays in the receiver can reach more than 80%. Both the light environment and the thermal environment are important. When the scattered light and direct light are set to 40% and 60% of daylight respectively, the ground illumination can reach 8.38×105 Lux. The minimum illumination is not less than 4.22×105 Lux. Finally, he combined local weather data with simulated solar collection results to evaluate economics. Although the system he studied can provide heat in winter, it is not intelligently controlled [1]. He Y believes that investigating the regional relevance and influencing factors of agricultural greenhouse gas (GHG) emissions will help establish a regional coordinated emission reduction mechanism and achieve chain emission reductions. Different from the traditional geographic relationship analysis framework and linear analysis thinking, he uses social network analysis to identify the regional relevance of agricultural greenhouse gas emissions from the perspective of the relationship network, clarify the network function of each node, and return from the spatial and non-parametric economic and technical point of view. The emission network is stable, and there is a control relationship between regions. Although he has conducted research on agricultural greenhouse gases, he has not conducted in-depth discussions on the control of greenhouse gases [2]. On the basis of the IPCC method, Li N has improved the method after a large number of scholars' research. Then, based on the agricultural production data of China's inter-provincial regions from 1996 to 2014, we carefully estimated agricultural CO2, CH4, and N2O emissions. Then, based on the club convergence theory in the field of economics, the estimation results are normalized and further analyzed. His research only stays at agricultural greenhouse gas emissions and does not fundamentally contribute to smart agriculture [3]. Subhakala S focuses on the realization of smart villages through cloud computing and artificial intelligence (AI). Cloud computing is used to control the operation of great things with our free hands. It enables the path to connect everything anytime, anywhere, and everyone can use it. The meaning of "smart" represents useful information analyzed by sensors used in Internet technology. In order to improve agriculture and create world optimization in various fields, everything can be connected via the Internet. This in turn is connected to smart irrigation as smart agriculture and integrated into a smart village through cloud computing. Sensors related to soil moisture and temperature and humidity are used to record these values. The stored data can be retrieved using cloud technology. Although his research result is to connect the villages completely through the Internet, the research lacks innovation [4].

This system adopts the B/S structure, combined with the multi-core technology of modern browsers, the universal browser can realize the various needs of customers for the system, which greatly saves the cost of the project. DTH11 temperature and humidity sensor detects data from the temperature and humidity sensor drive module, collects temperature and humidity data for it through the bus, and outputs the collected temperature and humidity data in parallel. The cloud platform database uses the lower computer temperature and humidity sensor module to automatically monitor the temperature and humidity dynamic values of the agricultural greenhouse, and display it on the 12864 LCD panel in the greenhouse in real time; the data information displayed on the data screen in the greenhouse is transmitted to the LABVIEW host computer display interface. For the air and soil temperature and humidity in the greenhouse, the cloud platform database management program can record correspondingly according to the day.

2. Research Method

2.1. Agricultural Greenhouse

In natural growth, the requirements of the crop growth environment cannot be met, so some equipment and technology must be used to adjust the internal environment of the greenhouse, so that the greenhouse always maintains a top-level environment, consumes low energy and obtains high-quality and high-yield fruits. The temperature control greenhouse is a project that contains a variety of technologies. The indoor environment control process is a stage of complex coordination of multiple factors, which is more difficult than ordinary industrial control. To create an environment suitable for vegetation growth, we must first know the greenhouse control indicators (the environmental factors that regulate the growth and development of crops are closely related), and then make the overall design plan, control method and implementation method of the temperature control greenhouse. The smart agricultural greenhouse is shown in Figure 1.

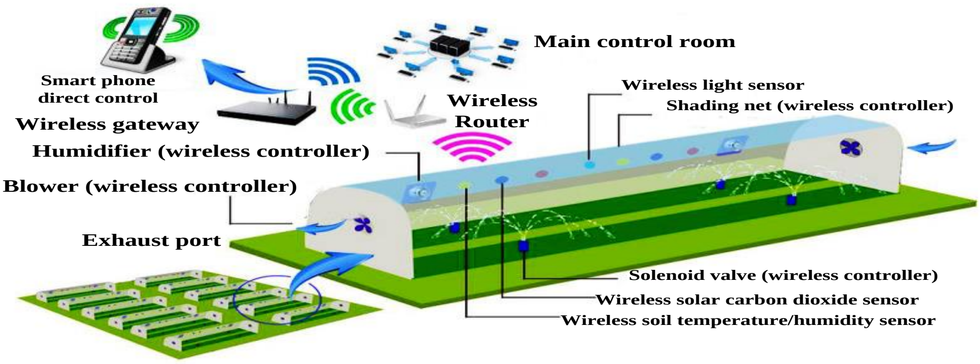

Figure 1. Smart agricultural greenhouse

Light is the source of life energy in the process of vegetation growth. The intensity and duration of light have a huge effect on the yield and quality of vegetation fruits. Light intensity refers to how much light passes through per unit area. Light has a direct impact on the progress of photosynthesis. In a certain interval, the intensity of light is directly proportional to the progress of photosynthesis. The demand of vegetation for light is mostly described by light compensation point and light saturation point. The amount of light required for plant growth is shown in Figure 2. The light compensation point refers to the light intensity when the photosynthetic rate is 0. When the light intensity is constant, the actual photosynthetic rate is the same as the respiration rate. Generally speaking, the light compensation point and light 101lx for shade-loving crops, the compensation point for sun plants is 500-1000lx; the light saturation point is that the photosynthetic rate is not affected by the light intensity, and tends to the maximum photosynthetic rate of the light intensity[5].

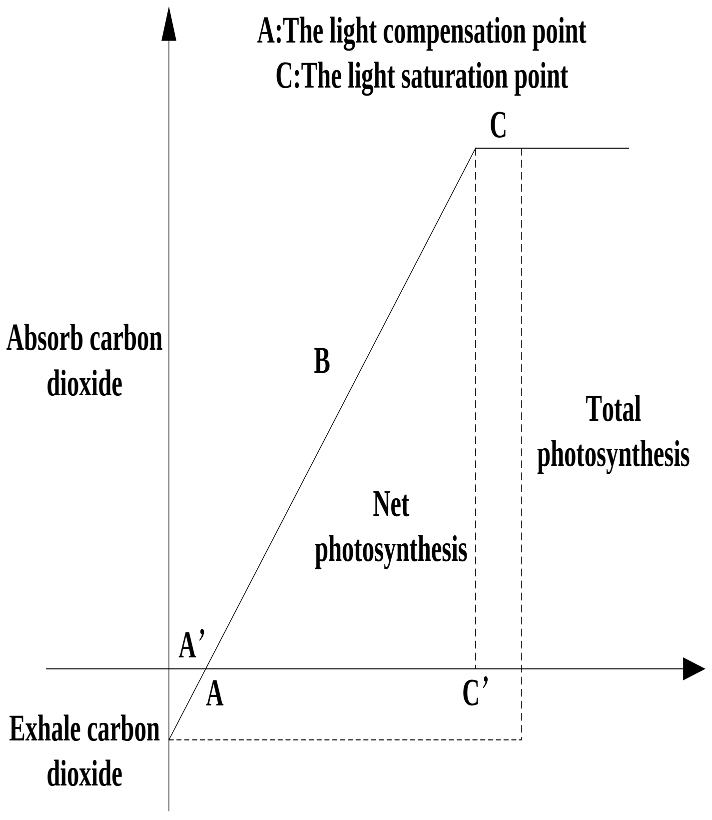

Figure 2. The amount of light needed for plant growth

2.2. Improved Adaptive Weighted Fusion Algorithm

In the experiment, the data of the single-type acquisition node was collected and preprocessed first, and the error of the large measurement distance was eliminated, and then the multi-sensor batch estimation method was used to extract the optimal estimated value and optimal variance at a certain moment. But the collection results under the forest area are produced by the data fusion of multiple sensors. The forest monitoring area is divided into pieces, the value of each area is estimated in batches, and the batched values are merged again to obtain the final fusion value.

Upload the batch value and the final fusion value to the host computer for display. In the collection process, through the principle of optimal weight distribution, adaptive weighted fusion is carried out in each group to minimize the collection error. Suppose the measurement data collected by a certain temperature sensor in a certain period of time is $x_1, x_2, ..., x_n$, and the distance between the i-th measurement data and the j-th measurement data is calculated based on the corrected distance [6]:

$$d_{[md]ij} = \sqrt{\frac{x_i^2 + x_j^2 + 2x_i^2 x_j^2}{x_i^2 + x_j^2}} \quad (1)$$

$$H(x_1, x_2 ... x_n) \geq 0 \quad (2)$$

In the formula, $d_{[md]ij}$ represents the distance between the node collection values x_i^2, x_j^2. Define the allowable function as [7]:

$$R(x_i, x_j) = \frac{2arc\cot d_{ij}}{\pi} \quad (3)$$

$$\sum_{j=1}^{n} x_j = 1 \quad (4)$$

Define the threshold function $A(x_i, x_j)$:

$$A(x_i, x_j) = \begin{cases} 1, R() \leq \overline{d_{[md]i}} \\ 0, R() \geq d_{[md]i} \end{cases} \quad (5)$$

$$A(y_j) = A(x_i) + A(y_j | x_i) \quad (6)$$

In this expression, ε is the maximum distance allowed by xi and xj, and the value of ε in the node can be obtained through multiple calibration experiments. When $A(x_i, x_j)$ is 1, it means that the values collected by the two nodes are within the allowable range. If it is 0, it means that there is no allowable meaning between the two collection points and needs to be eliminated [8].

2.3. Overall Design of the System

This system adopts the B/S structure. The B/S structure defines how the website is connected to the server. With the continuous improvement of Web browser technology, the Browser/Server structure has gradually become the mainstream of the architecture used in the development of software systems: combined with modern browsers. Kernel technology and general-purpose browser can realize the various needs of customers for the system, which greatly saves the project's expenses. No matter when and where to operate and debug the system, there is no need to install special software, which is the biggest advantage of the B/S architecture system. As long as there is a computer with Internet access to complete all operations, the expansion and maintenance of the system becomes extremely simple. The overall design scheme of the intelligent agricultural greenhouse remote monitoring system based on the cloud platform is shown in Figure 3.

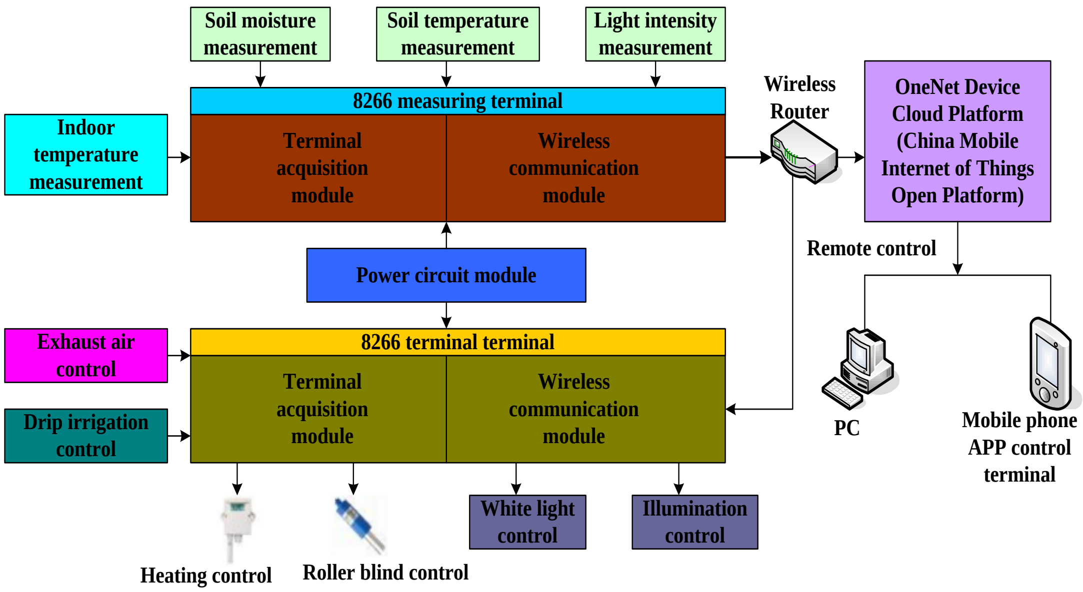

Figure 3. The overall design scheme of the remote monitoring system for the intelligent agricultural greenhouse based on the cloud platform

There are multiple sensors in the greenhouse environment, including temperature and humidity, light intensity, and CO2 concentration. Let's take the most typical temperature sensor as an example. At a certain time, n data collected are divided into 5 groups, and the data collected in the i-th group is $T_{i1},T_{i2}T_{i3},\ldots,T_{in/i}$. The corresponding variance is [9]:

$$\sigma=\frac{\sigma_{\overline{T1}}^{2}\sigma_{\overline{T2}}^{2}\sigma_{\overline{T3}}^{2}}{\sigma_{\overline{T1}}^{2}+\sigma_{\overline{T2}}^{2}+\sigma_{\overline{T3}}^{2}+\sigma_{\overline{T4}}^{2}},\quad i=1,2,3,4,5 \tag{7}$$

$$A(x_1x_{11},x_1x_{12},\ldots x_mx_{mn})=A(x1,x2,\ldots xn)+\sum_{j=1}^{m}x_jA(x_{j1},x_{j2},\ldots x_{jn}) \tag{8}$$

Using statistical batch estimation estimation theory, the optimal temperature estimation value T is extracted from the five single sensor groups, then the value of T is [10]:

$$T=\frac{\sigma_{T1}^{2}\overline{T_1}+\sigma_{T2}^{2}\overline{T_2}+\sigma_{T3}^{2}\overline{T_3}+\sigma_{T4}^{2}\overline{T_4}}{\sigma_{T1}^{2}+\sigma_{T2}^{2}+\sigma_{T3}^{2}+\sigma_{T4}^{2}} \tag{9}$$

$$A(y_1y_{11},y_1y_{12},\ldots y_my_{m1},y_my_{m2}\ldots y_my_{mn})\geq A(y_1,y_2,\ldots y_n) \tag{10}$$

After taking 5 sets of values for a single temperature sensor, the optimal variance of the data collected by the sensor is [11]:

$$X=\sum_{i=1}^{m}X_iW_i' \tag{11}$$

$$H(X_1X_2\ldots X_n)=H(X_1)+H(X_1|X_2)+\ldots+H(Xn|X_1X_2+\ldots.Xn-1) \tag{12}$$

2.4. Temperature and Humidity Sensor

The 12864 liquid crystal display of this system is connected in parallel with 8 bits. After the data processing module extracts the collected decimal temperature and humidity data bit by bit, the corresponding ASCII code is input into the 12864 display driver module, and the 12864 module controls the RS/RW/EN The signal updates the data of the 12864 LCD screen line by line to display the corresponding temperature and humidity values. When RS is low, the data on the data bus is a command, when it is high, the data on the data bus is the content that needs to be displayed. RW is the read and write control signal, and only the write function is used in this design. Therefore, it is always low. En is the strobe signal of 12864. When EN is low, the 12864 LCD module is selected to work. The 12864 drive circuit designed this time refreshes line by line by controlling the corresponding signals and data, and finally realizes the function of displaying temperature and humidity data in the shed [12].

(1) Hardware design of temperature and humidity acquisition and processing system

The top-level module inside FPGA (Field-Programmable Gate Array) is mainly composed of DTH11 temperature and humidity sensor drive module, data processing module, LCD12864 display drive module, PLL phase-locked loop frequency conversion module and serial communication module. DTH11 temperature and humidity sensor detects data from the temperature and humidity sensor drive module, collects temperature and humidity data for it through the bus, and outputs the collected temperature and humidity data in parallel. The data processing module converts the collected temperature and humidity information into 12864 recognizable BCD data and outputs it to the 12864 drive module. The 12864 drive module displays the processed temperature and humidity data line by line on the 12864 display screen, and constantly refreshes the displayed data.

LCD display 12864:

1) Design idea: The production project needs the display function in the shed, so it is necessary to adopt the LCD screen to display the temperature and humidity in real time, so that the staff can check the temperature and humidity in the greenhouse directly on the device. The 12864 LCD screen can display four lines of Chinese characters with low power consumption. It is cost-effective and easy to operate, so the 12864 LCD is used as the local display. 12864 is divided into parallel and serial control modes. The parallel interface is a simple parallel bus mode, its control is simple, and it is easier to design a controller.

2) Design steps and principles: After the overall software planning in quartus, it was decided to design the 12864 display driver IP separately, which inputs temperature and humidity data, outputs the parallel bus drive signal of the 12864 LCD screen, and continuously performs the 12864 LCD screen Refresh the display to achieve the desired display effect. First, it is necessary to generate the 12864-driven clock. If the input clock is 50M in the FPGA, the frequency of the 12864 drive signal is generally below 1M, so the clock needs to be divided. This design uses a counter to divide the 50M clock. Get 1K module working clock. After debugging, the 12864 module works normally. After that, it is necessary to design the state machine inside the FPGA driver IP. Each character is used as a small state, so there are a total of 64 states for outputting characters (a Chinese character occupies two English characters), and the LCD screen is initialized and configured, as well as line feed, etc. Seven states. These states circulate each other, and constantly refresh the corresponding characters, and after debugging, the expected display effect is achieved. First enter the setting mode, setting state one: set the 12864 LCD screen to 8-bit format, set state two: then set it to the overall display mode, and turn off the cursor, the cursor does not flicker. State three: set the input mode, the increment does not shift, state four: clear the display. State 5: Set the cursor to the first line. Then

enter the data output state. After 16 states, the display data of the first row is successfully refreshed and enter the setting state. And switch to the second row in the setting state, and after 16 data output states, switch to the third row, and so on. After refreshing the display of the fourth line, the state machine jumps to the first line again. And refresh the first row according to the data input by the module. In this way, the input data is converted into 12864 LCD screen display effect. The UI software interface of the intelligent agricultural greenhouse remote monitoring system based on the cloud platform is basically established, as shown in Figure 4.

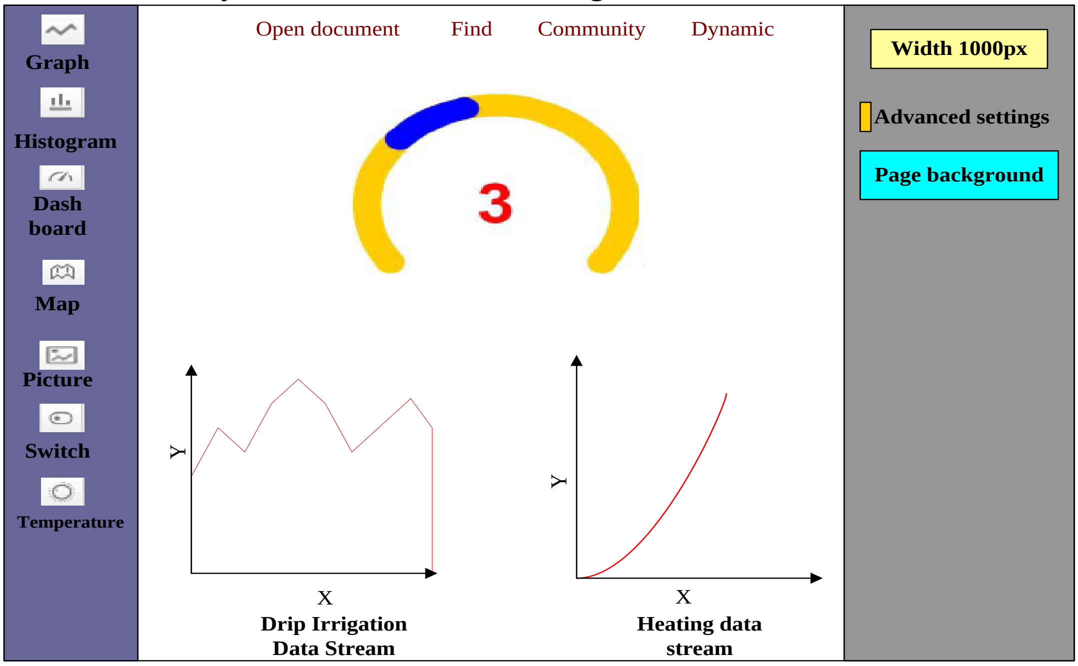

Figure 4. The UI software interface of the intelligent agricultural greenhouse remote monitoring system based on the cloud platform

(2) Design of temperature and humidity control program sub-module

According to the analysis of system requirements, the system is divided into five modules: login interface; VISA virtual resource configuration; temperature and humidity display; temperature and humidity difference alarm; temperature and humidity difference threshold adjustment.

1) Login sub-module of temperature and humidity monitoring system

The specific work flow of the block diagram corresponding to the front panel login interface is as follows: When the user name entered by the operator is the same as the set value, the program continues to execute downwards, enters the second while structure, and enters the password value again When it is the same as the setting value, click to confirm login, the login to the system is successful, otherwise, the system cannot log in. The tabs can make the login interface and the real-time display interface form a complete system in an orderly manner. In other words, if you do not execute the program of the login interface, you will not be able to execute the program of the real-time display, which greatly increases the safety and security of the system. Confidentiality and reliability.

2) Display module of temperature and humidity monitoring system

The temperature and humidity monitoring system interface mainly includes two-channel temperature and two-channel humidity curve display, two-channel temperature and humidity threshold alarm lights; two-channel temperature and humidity threshold adjustment knob; two analog thermometer displays. The specific block diagram of the temperature and humidity monitoring system of this program is shown in Figure 3.6.

3) Communication module of temperature and humidity monitoring system

The upper computer is passively received. When the upper computer does not know the beginning, the lower computer has already uploaded relevant data. There is a situation in which the upper computer starts to receive the data and the lower computer just sends it to the general situation. At this time, it can only continue to receive subsequent uploads. Therefore, the transmission method used in this type of communication is data frame. In this program, corresponding frame head, frame tail, and data are designed for the data frame communication mode. The frame header is to tell the host computer: the following data is the useful data that should be received. The frame header of this program uses two bytes. If only one byte is designed, in case this frame header happens to be the same as the data of the data frame, then it will make the program misjudge that the data is the frame header, and then make an error when analyzing the data. The same is true for the frame end. It allows the host computer to understand that the data before this data is valid. The function of the check byte is to check whether there is an error in the data during the transmission, and the check bit is also used when checking it. Its realization is the underlying hardware. The output of VISAREAD is a string. For this reason, in order to connect it together, the "connect string" function is usually used. After connecting it to the shift register in the loop structure, it is saved. If the shift register data in is full, or the amount of data has reached the processing requirements, then this loop will no longer continue to output the read data. The data forms received by LabVIEW are all character strings. For this reason, these character strings must be converted into ASCII codes, which can usually be achieved with the help of the "convert to U8 array" function. After using this function to convert the string, the result is in the form of an array, and the displayed data are hexadecimal and decimal respectively. To find the definition of the data frame format, first find the frame header F00F, and then find whether the frame end is EF. If the data is indexed, the required data is found.

Suppose the weight of each sensor in each group is [13]:

$$W_i = \left(\sigma_i^2 \sum_{i=1}^{m} \frac{1}{\sigma_i^2} \right)^{-1}, k = 1,2,3,4,\ldots,n/m \tag{13}$$

$$QN(x, y) = \sum_{n=0}^{N-1} Dn[C(\mathrm{x,y},\sigma\rho\ \partial^{n+1})\text{-}\mathrm{D}(\mathrm{x,y},\sigma\beta^{\mathrm{n}})] \tag{14}$$

The estimated value of the Kth sensor group after fusion is [14]:

$$X_k = \sum_{i=1}^{k} W_i T_i, k = 1,2,3,4,\ldots,n/m \tag{15}$$

$$Y_{\mathrm{k}} = \sum_{\mathrm{n}=0}^{N-1} (n+1) WT \tag{16}$$

The weighting factor of each group is [15]:

$$W_i^{'} = \left(\sigma_i^2 \sum_{i=1}^{m} \frac{1}{\sigma_i^2} \right)^{-1} \tag{17}$$

$$R(x,y)=\eta\sum_{n=0}^{N-1}\| K\varepsilon - K_{\omega \mathrm{hc}}^{\mathrm{n}}(x,y)\| \tag{18}$$

Therefore, in the case that all sets of weights are obtained, the final result of n collection nodes can be known from the adaptive weighted fusion [16]:

$$X=\sum_{i=1}^{m} X_i W_i^{'} + m, i=1,2,...,m \tag{19}$$

$$Y(K_k)=\sum_{\forall I_i \in I}\| K_k - K_i \| \tag{20}$$

2.5. Cloud Platform Database

The development of database application system is based on software engineering. Compared with other software systems, its structure, composition, and use are the same. Therefore, when developing database application systems, you must relevant methods and rules of the database must be strictly observed, so as to ensure the quality of the database. As an Oracle database system management tool, Navicat for Oracle has very powerful functions. It can also run smoothly in versions of Oracle Database 8i and above, and it supports the latest Oracle functions, including types, synonyms, triggers, directories, Data table space, etc. The user interface (GUI) provided by Navicat is a cleverly conceived graphic. With the assistance of Navicat for Oracle, it is relatively simple to use, but a very safe method to easily create, access, share and organize information. It can make the corresponding managers step into the next level. Navicat Oracle's platforms are mainly Linux, Mac OSX, and Microsoft Windows. Users can connect to local/remote Oracle Server, and provide import/export, data/structure synchronization and many other tools to manage data more conveniently[17].

The overall design of the oracle database: The database design of this project refers to the design and optimization of the physical structure and logical mode of the database under the cloud platform environment, and the establishment of corresponding application systems and databases on this basis, so that it can be used for data Effective storage and management can meet the needs of users in data operation and information management. Information management requirements: store and manage data objects in the database. Data operation requirements: query, add, modify, delete and many other operations for data [18].

After the demand analysis of this project, the expected functions of the system are as follows: use the lower computer temperature and humidity sensor module to automatically monitor the temperature and humidity dynamic values of the agricultural greenhouse, and display it on the 12864 LCD panel in the greenhouse in real time; the data information displayed on the data screen in the greenhouse transmitted to the display interface of the LABVIEW host computer; for the air and soil temperature and humidity in the greenhouse, the cloud platform database management program can record correspondingly according to the day; the management program can query the ambient temperature and humidity information according to the day or month; the management program you can set the early warning temperature to prompt the difference in the external environment of the greenhouse in time; the management program can generate reports, output the reports according to the relevant requirements of the greenhouse management, and print the temperature record curve and data [19].

3. Results

Different servers have different delay times. The Oracle Database device cloud platform data delay time used in this system is 1-3 seconds. The time delay error is shown in Table 1.

Table 1. Time delay error

Control function name	Switch delay time (seconds)
Exhaust	1
Dropper	2
heating	1
Roller blind	3

Use a 12V power supply to power the white lamp lighting control system. At a frequency of 1Khz, the greater the duty cycle, the greater the current output by the light drive controller, which makes the combined lamp brighter. The relationship between the different duty ratios of the waveform generator output and the output current of the light controller is shown in Table 2.

Table 2. The relationship between the different duty cycles of the waveform generator output and the output current of the light controller

Gear	Rectangular duty cycle (%)	Output current (mA)
Turn off	0	0
Open	25	223
Files	50	461
Second gear	75	689
Third gear	100	923

Read data from the cloud platform, and parse the string sent by the cloud platform, extract useful data, and simulate the generation of PWM waveforms based on the data sent by the cloud platform, as shown in Table 3.

Table 3. Simulation to generate PWM waveform

Cloud platform sends data	8266 receive data	Theoretical duty cycle (%)	Actual duty cycle (%)
0	0	0	0
1	1	25	24
2	2	50	52
3	3	75	76
4	4	100	98

In addition, the error is analyzed based on the test results of the upper computer interface of the PC cloud platform. The difference between the tested soil temperature and the actual temperature is about 1 degree, and the error of the light intensity value is about 3%. The error values of various parameters are shown in Table 4.

Table 4. Error values of various parameters

Index parameter	Test paper (Celsius/%/Lux)	Standard value (Celsius/%/ Lux)	Error (Celsius/%/Lux)
Air temperature	30	29	1
Air humidity	20	22	2
Soil temperature	27	28	1
Soil moisture	72	70	2
Light intensity	72	70	2

Constantly changing the distance between the convergence and sensor nodes, deploy sensor nodes and convergence nodes, detect LOI link quality indicators in two outdoor situations with and without obstructions, and use the communication distance in the data processing module to realise. In the case of outdoor unobstructed, the communication distance of the data processing module can reach up to 0.8 kilometers. As the communication distance continues to increase, its signal gradually weakens; however, when the communication distance is 0.2 kilometers and there are obstructions, The data processing module has been unable to communicate. After increasing the distance, the signal weakening phenomenon is very serious. The test result of data processing communication performance is shown in Table 5.

Table 5. Test results of data processing communication performance

Communication distance (m)	Outdoor unobstructed LQI	Outdoor shaded LQI
5	0X135	0X89
10	0X121	0X78
20	0X99	0X61
50	0X86	0X40
100	0X80	Can't communicate
150	0X76	-
200	0X71	-

Through the experimental data, it can be seen that as the number of workers in the work process increases, the processing capacity of the cluster will also increase. Since the workers determine the work process of the nodes, in the facility agriculture IoT cloud platform, as the number of later bases increases Increase, for the upgrade of the cloud platform, without modifying the middleware, the upgrade of the cloud platform can be achieved by increasing the number of nodes. Compared with the stand-alone version of the program, the cloud platform based on distributed computing has stronger processing capabilities and better scalability. The expansion performance of the platform cluster is shown in Figure 5.

Figure 5. Platform cluster expansion performance

The performance of the improved adaptive weighted fusion algorithm is evaluated through actual numerical simulation. The simulation environment setting parameters are shown in Table 6.

Table 6. Simulation environment setting parameters

Parameter settings	Unit
Number of nodes	100
Send data size	4000bit
Initial energy of sensor node	0.25J
Energy consumption on the circuit	50nJ/bit
Channel parameters in the free space model	10pJ/bit/m2
Channel parameters in the multipath model	0.0013pJ/bit/m4
Energy consumption of data aggregation	5pJ/bit/signal

Figure 6 shows the energy consumption of the cluster head node by comparing the improved adaptive weighted fusion algorithm and the routing algorithm. In 100 rounds, it is better than the improved adaptive weighted fusion algorithm. The routing algorithm has better performance and lower energy consumption than the improved adaptive weighted fusion algorithm.

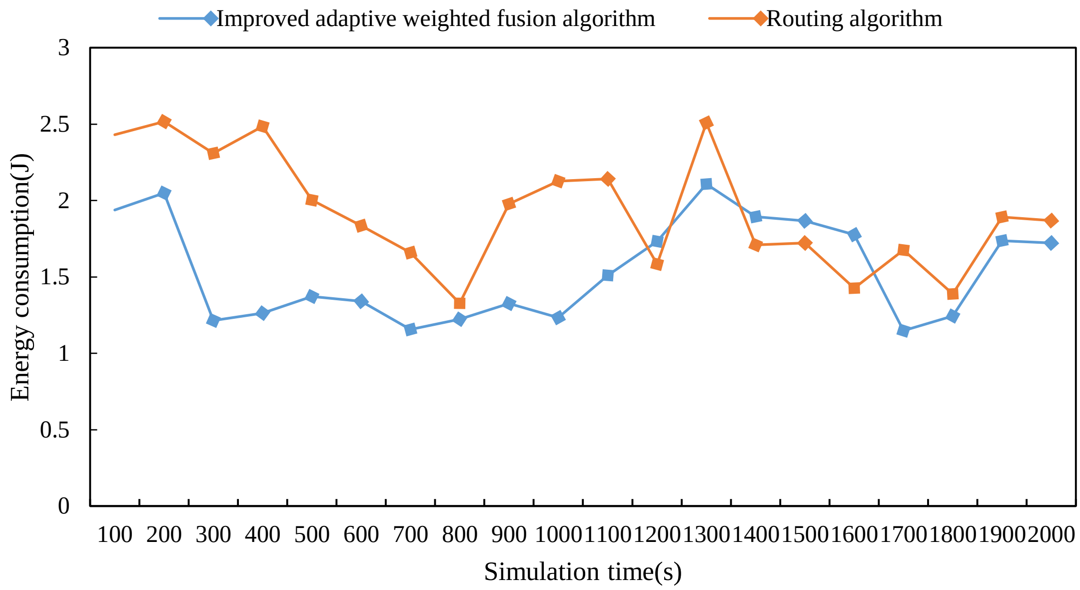

Figure 6. Energy consumption of cluster head nodes by comparing improved adaptive weighted fusion algorithm and routing algorithm

In addition, the packet loss rate of the improved adaptive weighted fusion algorithm and the routing algorithm is compared as shown in Figure 7. When it runs to the 500th round, a big change begins. The packet loss rate of the routing algorithm is 13%, which is better than the improved adaptive weighted fusion algorithm protocol by 8%. Finally, when the simulation cycle reaches 1000 rounds, the routing algorithm is far superior to the improved adaptive weighted fusion algorithm in terms of packet loss rate.

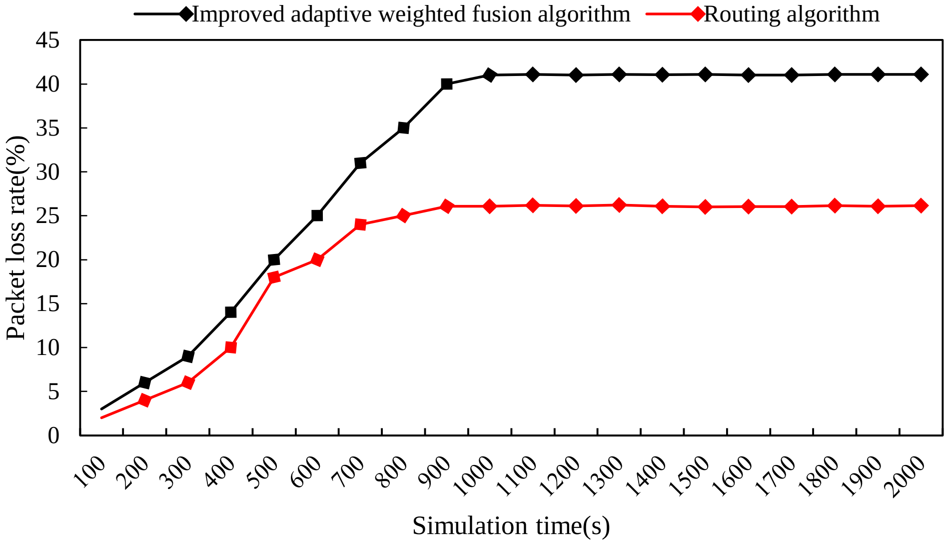

Figure 7. The packet loss rate of the improved adaptive weighted fusion algorithm and routing algorithm

In the experiment of testing the communication distance of the wireless sensor network, the communication frequency band is at 433MHz, the modulation method is GFSK, the transmission power is set to 10dBm, and the data transmission rate is set to 38.4kBaud.In the experiment, the gateway and the notebook are connected through the serial port, and the collection node is connected to the The gateway is at the same height, and each test site is tested 50 times, and the data printed on the serial debugging assistant on the PC side is recorded. The test result is shown in Figure 8.

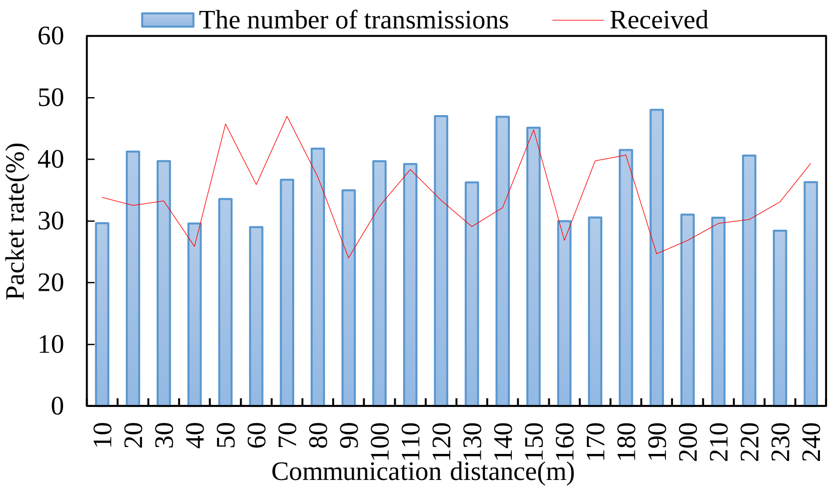

Figure 8. Testing the communication distance of the wireless sensor network

Intelligent temperature control greenhouses should consider the data of environmental factors needed for vegetation growth, which can make crops grow best. Because there are more vegetables and cucumbers grown in greenhouses in the north, the growth parameters of these two crops have been sorted out for users to set independently. The air temperature and humidity parameters of cucumber are shown in Table 7.

Table 7. Air temperature and humidity parameters of cucumber

Growth stage	Illumination	CO2	Temperature	Humidity
Seedling stage	105Lx	500PM	10℃-30℃, the most suitable 25℃	45%-65%
Flowering period	400Lx	800PM	15℃-30℃, the most suitable 25℃	45%-65%
Fruit period	350Lx	600PM	15℃-35℃, most suitable for 25℃	45%-65%
Harvest period	105Lx	300PM	15℃-35℃, most suitable for 25℃	45%-65%

The air temperature and humidity parameters of green vegetables are shown in Table 8.

Table 8. Air temperature and humidity parameters of green vegetables

Growth stage	Illumination	CO2	Temperature	Humidity
Germination period	80Lx	200PM	The most suitable 20℃-25℃	45%-65%
Seedling stage	150Lx	500PM	The most suitable 15℃-20℃	45%-65%
Rosette stage	105Lx	300PM	The most suitable 15℃-20℃	45%-65%

When the signal-to-noise ratio is 0.1, the greenhouse environment is collected when the real environment is 25℃. Three algorithms are used for data fusion for each collection node, and the final result is shown in Figure 9. Compared with algorithm one and algorithm two, the overall variance and limit deviation of the algorithm in this paper are the smallest, so the fusion effect of this algorithm is the best.

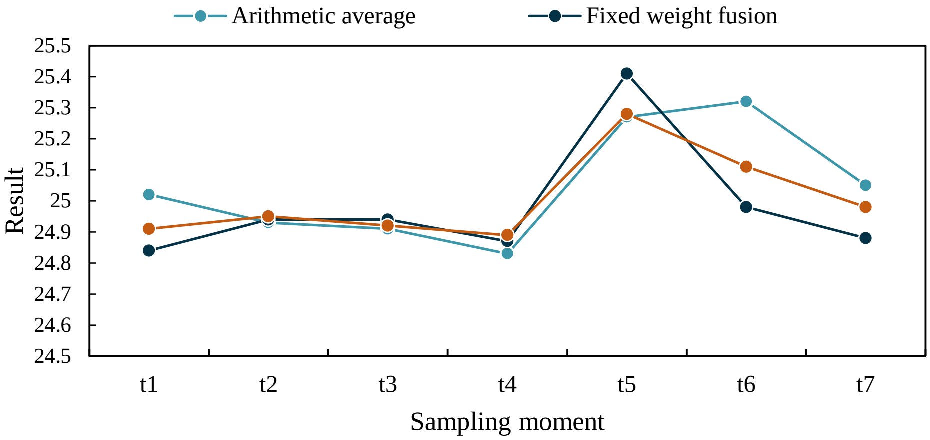

Figure 9. The results of the fusion of various algorithms

In addition to the stability of the hardware structure of a system, the software system module is also an important testing step for the product. Therefore, before the popularization of smart greenhouses, the stability test of the system must be carried out. Through system simulation, we mainly tested the improved adaptive fusion algorithm, and the result is shown in Figure 10. It can be seen from the figure that under the improved weighted fusion algorithm, the fluctuation range of the measured value is the smallest, the variance is the smallest, and the relative error of the fusion value is the smallest, which can meet the requirements of precision agriculture.

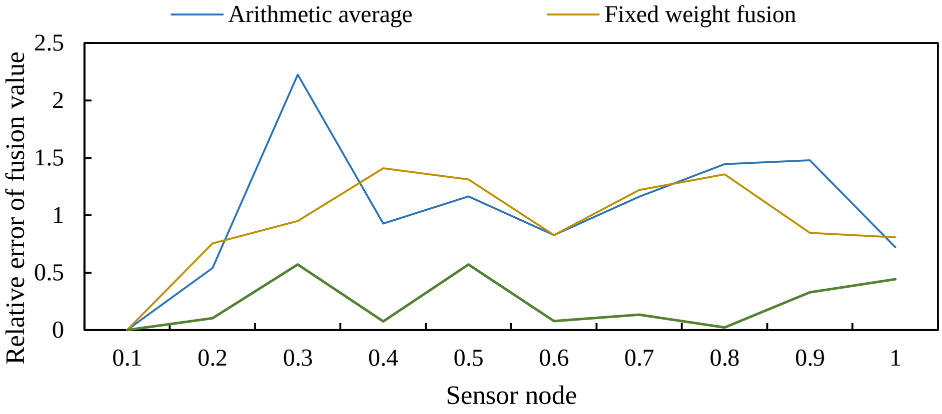

Figure 10. The improved adaptive fusion algorithm was tested

This system combines the remote transmission mode of the intelligent cloud platform, and we can make a corresponding comparison between the collected data and the current real-time situation through the mobile APP terminal. Through comparison, it is found that our collection of information has a certain delay. The error comparison between the remote control terminal and the real-time semaphore test is shown in Table 9.

Table 9. Error comparison between remote control terminal and real-time semaphore test

Actuator function	Switch delay time (s)
Shade net	2
Sprinkler	1
Blower	2
Heater	1

By adjusting the PWM wave, the voltage change in the optical driver is finally controlled. At the same time, it can be combined with the HTTP GET method on the PTZ to download the string, and finally extract the keyword. The data sent under the cloud platform is given to EP8266 and STM32, and finally generated PWM waveform, its receiving state is shown in Table 10. It can be seen from the table that the error between the duty cycle and the actual duty cycle is relatively small, can be controlled within an ideal range, and can be used in production practice.

Table 10. PWM waveform receiving status

Sending data in the cloud	WiFi reception	Theoretical duty cycle	Actual duty cycle
0	0	0	0
1	1	25	22
2	2	50	55
3	3	75	96

4. Discussion

The construction of agricultural greenhouses mainly includes the construction of agricultural greenhouses and the construction of monitoring systems. The agricultural greenhouse monitoring system is divided into a greenhouse environmental data real-time collection system and a greenhouse environmental data monitoring system. The real-time data collection system will monitor various environmental factors according to the relevant sensors arranged in the greenhouse, and then gather the sensor data through a wireless sensor network communication system, which not only replaces the traditional manual reading of crop environmental parameters and wired wiring. It also adapts to the characteristics of multi-point monitoring required by the agricultural environment. However, the communication between nodes has limitations in long-distance transmission, and agricultural greenhouses are generally located in relatively remote locations. To obtain remote monitoring data, the environmental factor data information gathered by the sensor wireless network can be used, which is highly reliable and has The cost-effective GSM short message is used as a carrier for long-distance transmission [20-21].

The agricultural remote monitoring system enables users to log in to the system through mobile phones or computers to monitor agricultural field data and equipment operation information in real time, and even issue control commands, which brings great benefits to managers. For example, farmers do not need to stay in the greenhouse every day. They only need to look at the computer at home to know the growth status of their crops in the greenhouse. Therefore, the remote monitoring system has always been valued and favored by the public, but its stability and reliability cannot be guaranteed. With the continuous update and progress of computer Internet technology, the cost of network construction and maintenance has been continuously reduced. Network interconnection technology has penetrated into all walks of life, but the technology used in the agricultural field is not particularly extensive [22].

The remote intelligent agricultural greenhouse monitoring system designed in this paper adopts cloud computing framework development technology, which can give real-time growth environment status information of crops, and can automatically give corresponding control decisions based on the growth stage of crops in combination with expert data sheets. When the equipment fails alarms will also be issued to farmers from time to time to deal with abnormalities in time. The system allows managers to obtain abnormal information about the growth environment of crops in the fastest time, assists farmers in locating and handling problems, and realizes intelligent monitoring. The popularization of this system can help farmers reduce agricultural cost input, improve crop production efficiency and product quality, and accelerate the pace of agricultural production informatization [23-24].

Agricultural greenhouses are popularized nationwide at a faster speed. At the same time, more and more science and technology will be applied to the production and management of agricultural greenhouses. The intelligent agricultural greenhouse monitoring system can conduct scientific and automated management of the production of agricultural greenhouses, solve human and financial resources, and increase the output ratio. Therefore, the monitoring system will also develop in the direction of low cost, easy management, reliability and stability. Promote the innovation of agricultural greenhouse planting technology and accelerate the pace of informatization of agricultural greenhouses [25].

The intelligent agricultural monitoring system is mainly divided into data collection, data field transmission, data remote transmission, server data processing and analysis, decision-making plan formulation, and network publishing. For the data acquisition module, it mainly requires the accuracy and reliability of the sensor. With the advancement of computer hardware and measuring instrument technology, the performance of the sensor is gradually improved. Excellent sensors can measure accurate environmental parameter information for the acquisition system. The field transmission of data has gradually changed from the traditional physical wiring method to wireless network transmission, and the application of wireless sensor network is paid more and more attention, which will be a development direction. The long-distance data transmission is mainly realized through GPRS and GSM technology. For monitoring server software modules, the traditional design is mainly realized by pure JSP code. The coupling of each code module of such a system is very high, the scalability is very poor, and it is very difficult to maintain. In recent years, the development framework technology J2EE, which has gradually developed and matured day by day, represents a development direction of Web development. For the designation of the decision-making plan, a mature expert data sheet is required, and agricultural scientific researchers are required to find the best environmental factor parameter range for a certain type of crop according to the characteristics of its different growth stages, so that the system designer can work out standardized, complete and reliable expert data sheets, these empirical data are the basis for judgment before intelligent software decision-making. Therefore, continuous improvement and standardization of the expert data sheet is the top priority of the agricultural greenhouse monitoring system design [26].

In a suitable temperature range, photosynthetic respiration will become active due to the rise in temperature. Since photosynthesis and respiration occur together when there is sunlight, it is better to have a higher daytime temperature in a certain range [27]. In addition, vegetation only breathes at night, and the respiration becomes active as the temperature rises, and more and more organic matter is consumed. Therefore, the lower the temperature at night in a certain range, the better. Therefore, grasping the characteristics of the temperature difference between day and night can also improve the yield and quality of vegetation. To sum up, it is very important to control the air temperature in the greenhouse. The temperature control generally adopts equipment such as heating and heating, fans, and opening windows for ventilation.

Soil temperature and humidity are important factors affecting the growth of crops. If the water supply in the greenhouse is too much, it will cause the roots of the crops to rot due to waterlogging, and the plants will grow poorly or die; insufficient water supply will cause the crops to fail to grow normally. Maintaining life within a certain range can lead to death in serious cases. Therefore, insufficient water supply will also cause the quality and yield of plants to decline. At the same time, different plants have different requirements for water [28]. Controlling the temperature and humidity of the soil has a great relationship with the yield and quality of crops.

5. Conclusion

In response to the needs of control, this paper designs and develops a smart greenhouse monitoring system based on B/S technology. This system can analyze the information collected by the sensors, and then perform automatic or manual control, which can get rid of the influence of the natural environment and achieve planting off-season crops greatly improves the quality and efficiency of crop production, and has broad application prospects. From a technical perspective, this project conforms to the development of the times, combines cloud computing and the IoT, comprehensively uses detection technology, IoT real-time communication technology, and embedded technology to achieve centralized and remote control and management of the greenhouse; The various modules of the system are clearly divided, the interface is unified, and each module is independently designed, which saves development costs and cycles, and pave the way for future expansion and market promotion. In the later stage of research and development, after actual engineering construction, implementing agencies such as cooling fans, insulation walls, and roller shutters can be configured.

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