Design and Implementation of Crop Automatic Diagnosis and Treatment System Based on Internet of Things

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Abstract: This paper designs a smart agriculture Internet of Things system which combines crop disease detection with automatic diagnosis and treatment, and provides support for subsequent research on crop disease detection and control. The smart agricultural Internet of Things system uses TCS3200 colour sensor to identify leaf disease characteristics; colour sensor sends the data back; This system compares it with the recorded plant identification database, and carries out small-scale sprinkler irrigation diagnosis and treatment through valve irrigation system. The Internet of Things system consisting of STM32L431 single chip microcomputer, MG811 CO2 sensor, BH1750 illumination sensor and DHT11 temperature and humidity sensor monitors environmental data, which is uploaded to the cloud by BC35 module through NB-IoT protocol and can be viewed by users on the display screen. Users can adjust the exhaust system, lighting system and humidification system in the system through the cloud or mobile phone to improve the environment and alleviate crop diseases. The experimental results show that the intelligent agricultural Internet of Things system designed in this paper has achieved the initial goal, and can roughly judge the disease types of plants by leaf colour, which has great commercial application value.

1. Introduction
Prediction of plant diseases is an important basis for effective prevention and control of the occurrence and development of plant diseases, an important part of plant disease management, and plays an important role in agricultural and forestry production management and decision-making. Plant disease prediction is a subject with strong applicability. Traditional classification and identification of plant diseases are mainly obtained by experienced producers or plant protection experts based on certain standards and observed by naked eyes in the field. This method is time-consuming, labor-intensive, and the forecast is lagging behind. It is not suitable for large-scale development, and it can not be used for real-time and rapid disease identification.

In recent years, the application of intelligent information technology in the field of plant disease detection is increasing, and many experts and scholars have studied it. Wang Yong and others explored the application of machine learning in crop disease identification; Liu Yang et al. used lightweight CNN to study crop disease recognition; Gao Shi et al. studied ramie leaf pathology based on RGB eigenvalue. The results show that all kinds of intelligent information technologies are quite successful in crop disease detection. However, up to now, the diagnosis and treatment of crop diseases still stays at the level of manual diagnosis and treatment, and most of the non-manual diagnosis and treatment adopt large-area and extensive sprinkler irrigation, which is not suitable for land crops in all regions. Based on this, this paper designs a smart agriculture system for automatic diagnosis and treatment of crops combined with
the cloud of Internet of Things. In this system, the spectral features of leaf surface are obtained by color sensor, and compared with the pre-stored plant feature recognition library, and the diagnosis and treatment scheme that best meets the current plant disease characteristics is selected. Then, automatic diagnosis and treatment are carried out by the mechanical control device inside the system to ensure that the surrounding environment is always in a state suitable for plant growth. In addition, there is an Internet of Things sensor module in the planting area, which can detect the growth state of crops in real time and feed it back to the control system, and then the environment can be regulated by actual observation and computer analysis.

2. overall system design scheme

The intelligent agricultural system for automatic diagnosis and treatment of crops consists of an external support steel frame, a single crystal 12 V/100 W solar panel, a leaf surface detection and diagnosis and treatment control system, an Internet of Things cloud and an environmental control terminal. The leaf surface detection and diagnosis and treatment control system includes Arduino embedded development board, TCS3200 color sensor, multi-channel electromagnetic valve controlled irrigation device and multi-channel steering engine controlled mechanical arm device. Arduino receives the color data returned by TCS3200 through I2C communication, and then compares it with the plant recognition database in the system to determine the diagnosis and treatment plan. The plant identification database is obtained by analyzing the knowledge of plant pathology and many experiments.

After the diagnosis and treatment scheme is determined, Arduino embedded control system executes corresponding subroutines according to the scheme, and the subroutines control multi-way solenoid valves and steering gears through codes. In a diagnosis and treatment cycle, the solenoid valves and steering gears will work alternately to realize small-scale sprinkler irrigation or precise drip irrigation diagnosis and treatment scheme. The environmental parameters of the diagnosis and treatment process are monitored in real time through the NB-IoT Internet of Things system with multi-channel sensors, and the monitoring results are displayed in the cloud APP, with a refresh period of 1 s. According to the plant growth environment, the online codec plug-in has defined the threshold. Once the threshold is exceeded, the system will issue a warning, and the user can improve the device environment through the exhaust and lighting system in the mobile terminal or cloud control device.

3. system hardware design scheme

3.1. system control core module selection

Two independent embedded development boards are used as the control core of intelligent agriculture system for automatic diagnosis and treatment of crops. Among them, Arduino series development boards are used for leaf color detection and selection of plant diagnosis and treatment schemes; The STM32L431 series development board on the internet of things is connected with the cloud through BC35 NB-IoT module. On the Arduino development board, the on-board I/O port and multi-channel sensors can be used to directly collect various plant data and report them to Huawei cloud platform in real time via BC35 NB-IoT module.

3.2. environmental monitoring sensor module selection

Environmental monitoring sensor module includes temperature and humidity sensor, soil humidity sensor and CO2 sensor. TELESKY FC-28 is selected as the soil moisture sensor. The working voltage of the sensor is 3.3 ~ 5 V, which can transmit the soil environmental humidity in the form of analog data. After being converted by A/D module, the data is transmitted to single chip microcomputer, which makes the data more accurate.
DHT11 is selected as the temperature and humidity sensor. The sensor includes a capacitive humidity element and an NTC temperature measuring element, which can effectively measure temperature and humidity in fluid environment (such as air), and transmit the temperature and humidity to the MCU in a 4-bit effective way through ADC channel.

CO2 sensor is MG811. Compared with another commonly used CO2 sensor CCS811 HDC1080, MG811 sensor is equipped with thermocouple, which can measure the concentration of gas molecules more accurately. The MG811 CO2 sensor uses ADC to transmit data. The sensor directly collects the voltage changes and transmits the voltage values to the MCU through the onboard ADC channel. According to the data, there is an exponential relationship between the data collected by MG811 and the voltage value, so the actual concentration value can be obtained by calculating the average value of the collected data in the program and according to the above algorithm. The analog voltage output range of MG811 sensor is 0 ~ 2 V, so the voltage threshold can be determined. ADC sampling notes are listed in table 1.

| Name     | Signal type | Reserve note |
|----------|-------------|--------------|
| VREF+    | Positive reference input analog voltage | ADC high/positive reference voltage 18 V ≤ VREF+ ≤ VDD |
| VDDA     | Analog input power | The analog supply voltage is equal to VDD At full speed: 2.4 V ≤ VDDA ≤ VDD (3.6 V) at low speed: 1.8 V ≤ VDDA ≤ VDD (3.6 V) |
| VREF-    | Negative reference input analog voltage | ADC low/negative reference voltage, VREF=VSSA |
| VSSA     | Input for analog power supply | The voltage of analog power supply is equal to VSS |
| ADCx IN[15:0] | Analog signal input | 16 analog input channels |

3.3. Hardware design of crop diagnosis and treatment

TCS3200 color sensor is used in crop diagnosis and treatment hardware to collect spectrum. The color sensor can collect 255×255 spectral bit arrays, and can be sensitive to color changes.

The color of an object that people see every day is actually the reaction of colored light reflected from the surface of an object that irradiates this part into human eyes. White light is a mixture of visible light of various frequencies. According to the theory of three primary colors, various colors are mixed with three primary colors in different proportions, namely red, green and blue.

Based on the principle of three primary colors induction, if the three primary colors of the surface color of an object can be measured, the actual color of the object can be known. For TCS3200 color sensor, when a color filter is selected, it only allows the corresponding primary color to pass, and it will prevent other primary colors from passing. For example, when the red filter is selected, only red light can pass through the incident light, that is, the red light intensity is obtained; By the same token, the intensity of blue light and green light can be obtained by choosing other filters. The color of light projected on TCS3200 sensor can be analyzed by three primary colors. The flow chart of leaf surface spectrum detection is shown in Figure 1.
3.4. drip irrigation equipment construction

Multi-channel electromagnetic valves are used in the system to control drip irrigation equipment. Through the diagnosis and treatment scheme based on time sequence, the solenoid valve can be turned on or off according to the diagnosis and treatment process. Schematic diagram of solenoid valve controlling multi-channel medicament communication pipeline is shown in Figure 2.

Based on cost and material resources, the electromagnetic valve of this device adopts direct-acting electromagnetic valve. The principle is as follows: when energized, the electromagnetic coil generates electromagnetic force to lift the open part from the valve seat and open the valve; When the power is cut off, the electromagnetic force disappears, the spring presses the open part on the valve seat, and the valve closes. The structure principle of direct-acting solenoid valve is shown in Figure 3.

4. Internet of Things cloud platform construction plan

4.1. The application of NB-IoT protocol

The intelligent agricultural system for automatic diagnosis and treatment of crops is connected with the cloud of Internet of Things through NB-IoT protocol. NB-IoT is a new communication technology of Internet of Things, which has the characteristics of low power consumption, low cost, massive connection, deep coverage, etc. NB-IoT greatly enhances the communication capability of IoT. NB-IoT becomes the most competitive cellular Internet of Things technology in low-power WAN.
In the system MCU program, NB-IoT controls the communication with the base station through AT instruction of serial program, and mainly rewrites the connection domain name address and network port number.

4.2. Cloud Message Receiving and Processing and Command Reporting

Huawei Ocean Connect IoT cloud platform supports access modes such as NB-IoT, 2G/3G/ 4G /5G network and wired network. Different types of equipment access to the Internet of Things platform and build interconnection schemes need to go through the process of Profile definition, equipment development, plug-in development, testing and certification, etc. In view of this system, we have developed three sub-projects under the project "plant device": "CO2 data and response to wind regulation", "air temperature and humidity data and response to humidification" and "soil humidity data reminder".

In the aspect of equipment development and debugging, we adopt STM32L431 development board integrated with NB-IoT module. NB-IoT protocol supports massive connections and has the advantage of low cost. Its application scenario is consistent with this project, with smaller data packets and less change in equipment location. We decode the binary data transmitted from the device side to the cloud into JSON format by writing the codec plug-in online, and process the data through the IoT cloud platform.

Data processing results can be received and forwarded by the platform. After the development of Profile and codec plug-in is done online, the equipment side uses the equipment simulator to test the data receiving and sending. After the data is adjusted and measured by the adjustment and measurement department, the cloud application is developed on the Web APP side.

Huawei OceanConnect IoT Cloud provides an application development platform called IoT Booster, through which online application development can be carried out. The application side needs to use this platform for debugging, which is used for data monitoring, early warning and reporting. The northbound communication flow between the cloud and APP is shown in Figure 4.

5. system software design scheme

The automatic diagnosis and treatment part of the system is composed of Arduino embedded system and its related components. The north-south communication part of Internet of Things cloud consists of STM32L431 embedded system.

After the system is powered on, the two single-chip computers are initialized respectively. TCS3200 starts to work after Arduino embedded system is initialized. In the scanning period, if the spectrum does not meet the color threshold of general crops, wait circularly; When the crop color gamut is detected, Arduino embedded system will select the corresponding scheme to treat the plants.

After the STM32L431 embedded system is powered on, the BC35 module is initialized, and the key is sent to the cloud through the AT command to obtain the connection address and port number. Run the program in a loop until the connection is successful.

After the offline connection with the cloud is successful, the STM32L431 embedded system will read the sampled data of each sensor (such as MG811, DHT11, FC-28, etc.), and the data will be reported
according to the complete cycle of sending and receiving, and transcoded and displayed on the cloud platform. The workflow of Arduino embedded system software is shown in figure 5.

![Workflow Diagram](image)

Figure 5. The workflow of Arduino embedded system software.

6. test results
In the test, we selected a single orange oak leaf with insect pests as the experimental material, and found that the system can successfully formulate the pest treatment plan, and carry out drug sprinkler irrigation according to the set steps in one cycle, regularly report it to the cloud of Internet of Things, and display the environmental monitoring data. After 3 days' treatment, the spectral detection results of oak leaves showed that red decreased while green and blue increased among RGB colors.

The relative difference of RGB colors calculated by MATLAB under water shortage condition. Three days after treatment, the relative difference of RGB color calculated by MATLAB. It can be seen from that both the detection results and the treatment effect are effective.

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