Greenhouse Design Using Visual Recognition and IoT Technology

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Abstract

This device is to solve the traditional pesticide spraying method on the human body has a greater impact and other issues, through the STM32-based visualisation of the intelligent greenhouse to achieve automatic spraying of pesticides and remote monitoring and other functions, the establishment of a visualisation of the intelligent greenhouse monitoring platform. This equipment through the MQTT protocol, not only through the Internet of Things platform real-time monitoring of crop growth status in the greenhouse, but also through the platform to determine whether to spray pesticides, data transmission, so as to use the cross slide to control the position of the nozzle, and then through the visual recognition algorithms to improve the accuracy of the visual recognition part of the accuracy of the spraying of plants affected by insect pests, the realization of the digital intelligent greenhouse.

Keywords: STM32, Monitoring Platform, MQTT, Visual Recognition

1. Introduction

This project is dedicated to solving problems such as the potential impact of traditional pesticide spraying methods on the human body. Through the STM32-based [1] visualised intelligent greenhouse, automatic pesticide spraying and remote monitoring functions are realised, and a complete visualised intelligent greenhouse monitoring platform is constructed. We adopted the MQTT [2] protocol, which not only monitors the growth status of crops in the greenhouse in real time, but also replenishes different colours of light in a targeted manner according to the light conditions inside the greenhouse to improve the efficiency of photosynthesis. This is not only more energy efficient than traditional white light supplementation, but also significantly increases crop yields and helps to make the system carbon neutral.

In addition, our system also features indoor temperature monitoring and control, which promotes the accumulation of organic matter in crops by adjusting the temperature difference between day and night. For a more precise response to pests, we utilise a cross slide to control the position of the nozzles and incorporate visual recognition algorithms to improve the accuracy of spraying on pest-affected plants [3]. For a sustainable energy supply, we added solar panels to the exterior of the greenhouse to provide a constant source of energy for the system, while improving long-term human health, reducing air pollution and greenhouse gas emissions, and positively impacting human health [4].

For the electrical control part of the project, we carried out systematic modelling and simulation through the Proteus simulation platform to determine the optimal operating conditions. Subsequently, we used Altium Designer to create the design, programming and debugging, and finally succeeded in building an efficient intelligent greenhouse monitoring platform [5].

The rest of this paper is organised as follows. The second part describes the hardware used and the theoretical calculations. The third part describes the method of controlling the nozzle and the visual recognition algorithm. Part IV describes how the smart shed works and shows some of the operational results. Part V summarises the main points of the paper.

2. Design of Hardware Structure

2.1. Selection of the main control board

This work needs to deal with a large amount of data, has a more complex circuit, and needs a lot of memory, so it needs a microcontroller that can deal with a lot of song peripheral devices at the same time, so the STM32F4 became the team's first choice. the physical diagram of the STM32F4 is shown in Fig. 1.

Fig. 1 STM32F4 Physical

2.2. Relay Modules

This work is controlled by mobile phone APP, through the Internet of Things platform, the corresponding signal will be sent to the STM32 core board, and it will control each module. In order to save power, they will use a relay to control the switch of some modules, so that some non-working modules are in the off state when they are not working, this work uses the JQC-3FF-S-Z relay, the physical picture is shown in Fig. 2.

Fig. 2 Relay Physical Diagram

2.3. Driver Modules

This work needs to be as precise as possible when it comes to pesticide spraying so that the pesticide can be sprayed where we need it, so we chose to use stepper motors and stepper motor drives. The physical drawing of the stepper motor and stepper motor drive is shown in Fig. 3.

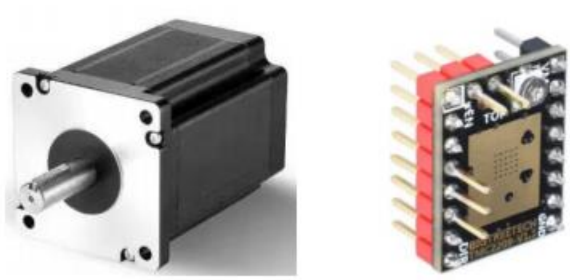

Fig. 3 Physical drawings of stepper motors and stepper motor drives

2.4. Mechanical components

The mechanical part is designed as shown in Fig. 7, its motion system consists of two axes, X-axis and Y-axis, to control the position of the nozzle and the pump.

The nozzle structure is to control different spraying methods and the pump structure is used to spray different concentrations of pesticides. The mechanical structure is modelled as shown in Fig. 4.

Fig. 4 Mechanical structure modelling drawings

The main issues considered in the design: Since the crops inside the greenhouse are scattered all over the place, a mechanical structure that can bring the nozzles and pumps to every part of the greenhouse is needed, they refer to the mechanical structure that controls the movement of the nozzles in the 3D printers, and they designed and chose the above solution.

2.5. Sensor selection

In order to obtain more information about the greenhouse, this work chooses a variety of sensors. The temperature and humidity sensor can always sense the temperature and humidity inside the greenhouse, which is convenient for the adjustment of the internal temperature of the greenhouse [6]; the light intensity sensor monitors the change of the light intensity inside the greenhouse, so as to judge what colour and intensity of light needs to be reinforced; the visual sensor can intuitively observe the growth status of the plants inside the greenhouse and transmit the information to the user's mobile phone APP, so as to achieve real-time monitoring. The digital temperature and humidity sensor, light intensity sensor and OpenMV are shown in Fig. 5.

Fig. 5 The digital temperature and humidity sensor, light intensity sensor and OpenMV

2.6. Motion control of nozzles and pumps

Motion control of spray nozzles and pumps means that the mobile phone APP or various sensors send signals to the main board, so as to control the spray nozzles and pumps to move according to the predetermined paths and speeds in the two-dimensional space through the cross-axis structure. They use stepper motors to drive the nozzles and pumps along the X-axis and Y-axis, and the rotation angle and speed of the stepper motors are controlled by pulse signals sent from the main board, and the frequency and number of pulse signals are determined by the concentration of pesticides that need to be configured [7].

The principle of this mechanism is to control the movement of X-axis and Y-axis by two motors at the same time, when the left and right motors are in the same direction, they move towards X-axis, and when the two motors are in the opposite direction, they move towards Y-axis. The simultaneous action of the two motors provides a more stable force than a single motor controlling one axis, and reduces the weight of one motor on the XY platform. The formula is shown in Fig. 6.

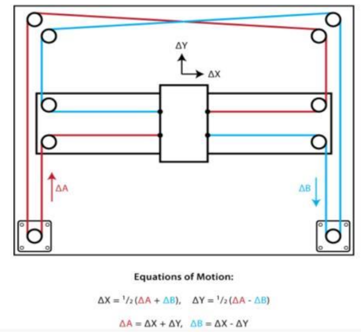

Fig. 6 Formula

2.7. Pesticide concentration configuration

They will configure pesticides in different concentrations according to the needs of different crops

There are several formulas for pesticide formulation:

Conversion between per cent concentration and parts per million concentration: parts per million (ppm) = 10,000 × per cent concentration

Conversion between the multiplier method and the percentage concentration: Percent concentration (%) = (original concentration/dilution times) × 100

Calculate the amount of diluent according to the active ingredient:

Dilution of 100 times or less: Diluent dosage = Weight of the original agent × (concentration of the original agent - concentration of the formulated agent) / Formulation Concentration of formulated agent

Dilution more than 100 times: Diluent dosage = weight of the original agent × concentration of the original agent / concentration of the formulated agent

Calculate the amount of diluent by the multiplier method:

Dilution less than 100 times: Diluent dosage = Original agent weight × Dilution times - Original agent weight

Dilution more than 100 times: Diluent dosage = original agent weight × dilution times

Mass percent concentration: Mass percent concentration (%) = solute mass/solution mass 100%

Molar concentration: molar concentration (mol) = solute moles / solution volume (litres) [8].

Equivalent concentration: Equivalent concentration = gram equivalent of solute / volume of solution (litres)

Mass-volume concentration: Mass - volume concentration = mass number of solute (grams or milligrams) / volume of solution (cubic metres or litres)

2.8. Solar panel steering design

A common method in solar panel steering design is to use a microcontroller and a photoresistor module to collect light intensity data in four directions, and then convert them into digital signals through ADC, and then drive the servo or stepper motor to adjust the angle of the solar panel through comparison and control algorithms.

The specific calculation process is as follows:

Collect light intensity data in four directions through ADC, respectively x0 , x1 , y0 , y1, and can take the average value several times to improve the accuracy. Calculate the difference between the two directions of light intensity, respectively, dx = x0 - x1 , dy = y0 - y1, these two values reflect the solar panel and the degree of deviation from the sun. Based on the positive, negative and magnitude of dx and dy, the direction and angle to be adjusted are determined. For example, if dx > 0 and dy > 0, the solar panel needs to be rotated to the upper left; if dx < 0 and dy < 0, the solar panel needs to be rotated to the lower right; and if dx = 0 and dy = 0, the solar panel has been aligned with the sunlight.

According to the direction and angle to be adjusted, calculate the corresponding PWM signals or pulse numbers, and then generate PWM signals or pulse signals to drive the servo or stepper motor to rotate the corresponding angle by timer interrupt or other means.

Repeat the above steps until dx and dy are close to zero, i.e. the solar panel is perpendicular to the sunlight.

3. *Software design*

3.1. Pesticide spraying design

When the vision system detects that a plant is infested, it automatically feeds back a signal to the stepper motor system. The stepper motor system responds quickly and accurately drives the pesticide nozzle to position itself near the infected plant. The stepper motors then co-ordinate the spraying of the pesticide to ensure efficient and precise spraying of the pesticide in the affected area. This intelligent system not only responds to pest problems in a timely manner, but also provides a reliable solution for plant healthcare by maximising spraying efficiency through the collaborative operation of the vision system and stepper motors [3], [7]. The stepper motor working process is shown in Fig. 7.

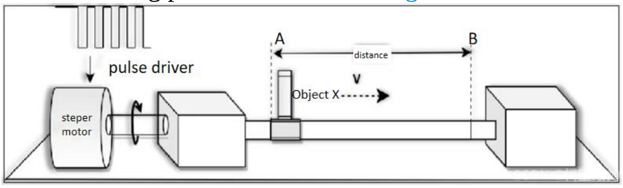

Fig. 7 The stepper motor working process

3.2. Visual Inspection

(1) Acquisition of plant leaf datasets

They acquired a detailed and rich batch of plant leaf datasets and leaf disease datasets, a valuable resource that will fully support in-depth research. The data covers multiple dimensions, including plant growth, dynamics of physiological parameters, and the potential impact of environmental factors on tobacco quality. By carefully analysing this dataset, they will be able to gain insight into all aspects of plant growth. The plant leaf dataset is shown in Fig. 8, and the diseased plant dataset is shown in Fig. 9.

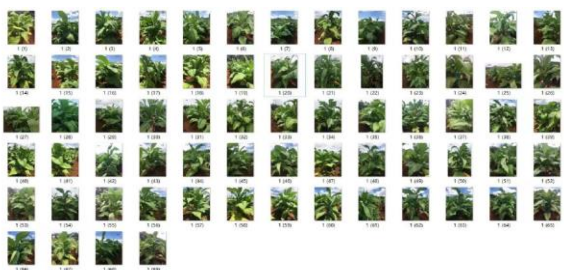

Fig. 8 The plant leaf dataset

Fig. 9 The diseased plant dataset

(2) Annotate

He carefully and systematically annotated the leaf dataset and leaf disease dataset of this batch of plants. Through the annotation scheme designed by him, he captured and recorded the characteristics of the plants at different growth stages, from roots to leaves, from physiological parameters to environmental adaptations. And he captured the characteristics of plants suffering from pests, diseases and so on. This kind of annotation not only enriches the connotation of plant data, but also lays a solid foundation for subsequent data analysis and model construction. The process diagram of leaf annotation is shown in Fig. 10, and the process diagram of disease point annotation is shown Fig. 11.

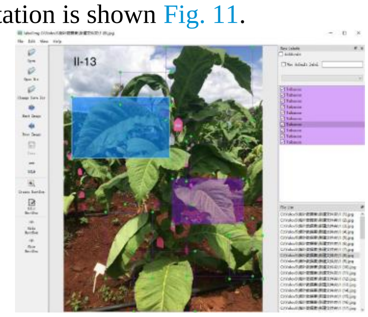

Fig. 10 The process diagram of leaf annotation

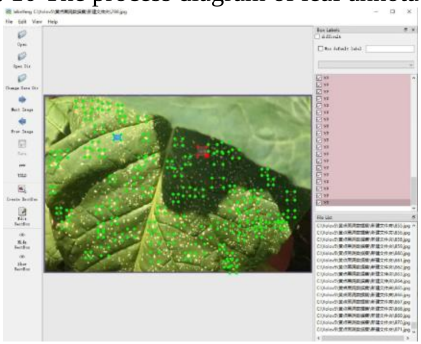

Fig. 11 The process diagram of disease point annotation

(2) Identification

Through CNN neural networks, he successfully implemented the functions of leaf recognition and pest identification [9], and cleverly combined them to form an efficient and comprehensive system. Through deep learning and computer vision techniques, he accurately recognised different types of tobacco leaves in the leaf images, and based on this, the system was able to keenly detect possible insect pests through careful algorithm design. The leaf recognition and pest recognition diagram is shown in Fig. 12. The final recognition result is shown in Fig. 13.

Fig. 12 The leaf recognition and pest recognition diagram

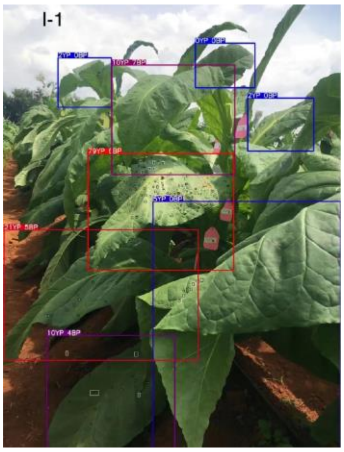

Fig. 13 The final recognition result

3.3. Optimisation

Since the disease target is very small, the sensory field of the original smallest detection head is still larger than the size of the target, so it is necessary to improve the original network, starting from the optimisation algorithm, firstly, the activation function is improved, they use leaky relu activation function in the middle layer, and the S-type activation function is selected for the last detection layer, and at the same time, the mish activation function is used; and the loss function is improved , using the CIOU loss as the loss of the bounding box, which can bring faster convergence speed at the same time, have better performance [10]. The activation function is shown in Fig. 14.

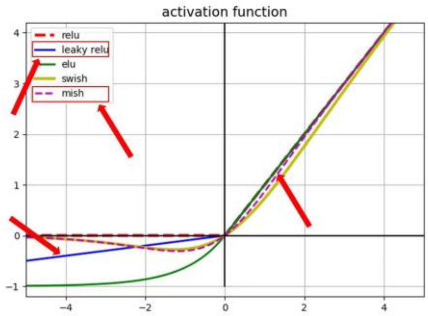

Fig. 14 activation function

4. Experiment

4.1. Pesticide spraying programmes

In the smart greenhouse system, they have introduced an advanced disease monitoring and prevention mechanism. Once the system recognises the presence of a plant disease, the automated control system is instantly activated, transferring the information to the stepper motor system. The stepper motors precisely manoeuvre the pesticide nozzles to move to the exact location of the infected plant. The intelligent system then implements precise and efficient spraying according to a pre-set pesticide spraying programme to maximise the suppression of the spread of the disease.

Future research directions include further optimising disease detection algorithms, improving the system's ability to accurately identify different disease types, and incorporating advanced pesticide selection and use techniques to achieve more precise and sustainable disease prevention and control strategies. Such innovations will lead to more sustainable and efficient plant health management solutions in the field of smart agriculture.

4.2. Mobile Application Programming

By running a well-designed mobile application, he successfully implemented a real-time greenhouse monitoring system on his mobile phone. The application provides an intuitive and detailed user interface that enables users to easily monitor the status of the greenhouse remotely and access key environmental indicators in real time. Users can easily access data such as temperature, humidity, light and soil moisture, as well as plant growth conditions in each area of the greenhouse, anytime, anywhere, using their smartphones [11].

Through the mobile app, users can set customised alarm thresholds, and the system will immediately send notifications to alert users of any abnormal changes in environmental conditions. This real-time monitoring and response mechanism provides users with timely decision support, enabling them to quickly take the necessary measures to safeguard plant health and growth.

In addition, the mobile app supports remote control of the greenhouse system. Users can adjust parameters such as temperature control, humidity regulation, light management, and irrigation system through the mobile phone to achieve intelligent remote control of the greenhouse environment. Such flexibility enables users to make adjustments according to real-time changing needs, improving the adaptability and operability of the greenhouse system. The running diagram of the programme is shown in Fig.15.

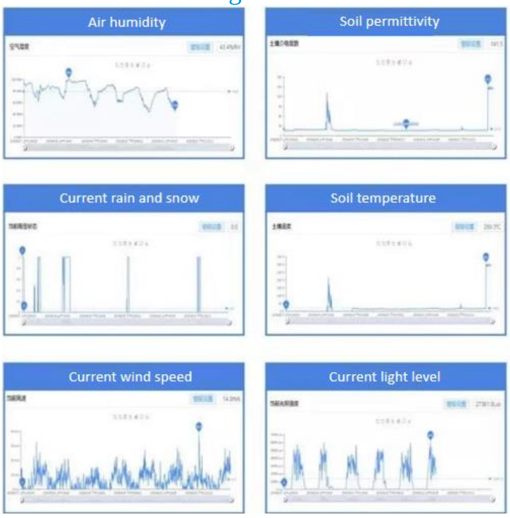

Fig. 15 The running diagram of the programme

5. Conclusion

Nowadays, with the rapid development of artificial intelligence and Internet of Things technology, the visualised smart greenhouse designed in this paper is precisely in line with the trend of technological development, combining the knowledge of microcontroller, machine vision, artificial intelligence, and many other things with each other to form a complete system, and it is believed that in the future, this design will be more widely used in the agricultural market. This design combines the knowledge of multiple disciplines, improves the human-computer interaction experience, and improves efficiency while protecting people's safety, and I believe that the demand for this type of product in the agricultural market will grow.

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Authors Introduction

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