Design and development of locust monitoring system

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Abstract. Effective monitoring and early warning of locusts which are one of the main harmful insects in agriculture are the key to protecting farmland ecology. However, due to the large area of farmland, sparsely populated population, inconvenient transportation, network connectivity and other factors, coupled with the locust's own characteristics such as outbreak, migration, and occurrence uncertainty, the task of locust control is very difficult. Traditional survey techniques are far from being able to meet the requirements for real-time monitoring and precise forecasting of the occurrence of locusts. Therefore, this article provides a set of IoT solutions for locust situation monitoring in the context of the Internet of Everything.

1. INTRODUCTION

There are many types of locusts. According to current global statistics, there are as many as tens of thousands of species, and they are distributed throughout temperate and tropical regions. The locusts have extremely strong reproduction ability and fly long distances. Over 46.8 million hectares of land and 12.5% of the population in the world are threatened by locust disasters all year round. Most of the existing locust monitoring methods use satellite remote sensing and GIS to monitor the disaster after the locust plague occurs [1]. In the early stage of the locust plague, most of the monitoring methods are group prevention and group control, and relevant departments and ordinary people need to report the situation of locusts after they are found, which consumes manpower and material resources. Relevant studies have found that the growth of locusts is related to ecological environmental factors such as temperature, humidity, and light intensity [2]. At the same time, IoT communication technology and image recognition algorithms are gradually being widely used in the field of smart agriculture, which provides an IoT-based solution direction for the monitoring and early warning of locust situation.

2. OVERALL SYSTEM ARCHITECTURE

The overall architecture of the locust situation monitoring system is shown in Figure 1. The farmland environment monitoring module collects various data of relevant ecological environment factors through various sensors, communicates over a long distance through LoRa technology, and then uploads the data to the cloud server through the MQTT protocol. The locust density monitoring module obtains the environmental image through the camera and transmits it to the Raspberry Pi, and then uses the YOLOv3 algorithm to quickly identify and calculate the locust density, and then upload the data to the
cloud server through the MQTT protocol. The cloud server combines environmental data and locust density data to determine the occurrence and development of locusts and obtain the level of locust damage. Finally, the cloud server connects to the WeChat applet via WebSocket, and displays the monitoring results to the user.

3. FARMLAND ENVIRONMENT MONITORING MODULE

3.1. Hardware design
This module selects ATmega2560 as the microcontroller of the data monitoring point, and selects the small and exquisite Arduino Mega MCU as the processor. The Arduino Mega MCU has more pins and Flash memory than the Arduino UNO MCU, and compared to the STM32 MCU used in the LoRa market, it can better meet the needs of cost-sensitive users. The block diagram of the hardware design of the data monitoring point is shown in Figure 2.

3.2. Sensor selection
Changes in the number of locusts are related to environmental factors such as air temperature, soil humidity, light intensity, and rainfall [2]. According to this conclusion, the sensors connected to the Arduino Mega MCU should include temperature sensors, soil humidity sensors, light sensors and raindrops sensor. Starting from the comprehensive considerations of low cost, waterproof and sunscreen, strong durability, and good stability, the selection of each sensor is as follows: the temperature sensor is AM2305, the soil moisture sensor is FC-28, the light sensor is BH1750FVI, and the raindrop sensor is YL-83.

3.3. Power supply module selection
The monitoring point is in the farmland, so the number of users to replace the battery and manual charging should be minimized, and the power supply time should be increased. At the same time, in
order to power multiple sensors, the battery power supply should be sufficient. Therefore, the monitoring point adopts solar lithium battery alternate power supply modules [3]. When there is sunlight, the solar panel powers the Arduino Mega MCU and charges the lithium battery. At night and in rainy weather, the power saved by the lithium battery can supply power to the Arduino Mega MCU. To ensure the continuous use of the energy storage battery in rainy days, the power of the solar panel should be as large as possible. We choose 10W, 18V solar panels and 10AH3, 7V lithium batteries.

3.4. Communication technology selection
LoRa is a low-power ultra-long-distance wireless communication technology based on spread spectrum technology. It runs in a free frequency band around the world and can be independently networked. It is suitable for outdoor medium and long-distance coverage and is suitable for monitoring of farmland environments. Therefore, LoRa wireless technology is used to implement the data upload of Arduino Mega MCU. The LoRa module of each monitoring point and the LoRa gateway form a one-to-many star topology network. The monitoring point collects the collected data to the LoRa gateway through the LoRa module, and then the LoRa gateway uploads the data to the cloud server. The advantages of LoRa's star topology network are simple structure, small transmission delay and low power consumption. In addition, in order to further achieve low power consumption, the nodes in the LoRa network use air wake-up technology, that is, the receiver automatically wakes up periodically to check if there is a call signal in the air, if not, continue to sleep; if there is, it will be awakened and enter the reception status.

4. LOCUST DENSITY MONITORING MODULE

4.1. Hardware design
The hardware design of the locust density monitoring module is based on the Raspberry Pi 4B. It also includes a camera module for obtaining farmland pictures, and a LoRa module and a LoRa gateway for long-distance communication. The camera module is connected to the Raspberry Pi 4B through the USB interface. In order to ensure that each camera module can clearly capture the surrounding farmland environment, the camera needs to be installed at a certain distance from the ground surface and can rotate 360 degrees. Build a python and pytorch environment on the Raspberry Pi 4B, and transplant the trained YOLOv3-based locust recognition and counting algorithm to the Raspberry Pi to run. The Raspberry Pi calls the camera to collect pictures of farmland environment in real time. After processing and recognition by the algorithm, the density of locusts in the area captured by the camera is obtained. Then, like the farmland environment monitoring module, the monitored data is uploaded to the cloud server through the one-to-many star topology network formed by the LoRa module of each monitoring point and the LoRa gateway.

4.2. Algorithm design
In the image recognition algorithm, we choose the YOLOv3 algorithm. YOLOv3 has the characteristics of fast speed, low background false detection rate, and strong versatility. Compared with the previous generation, this algorithm has advantages in recognizing small objects while ensuring speed, and the detection rate of unnatural image objects by YOLOv3 is much higher than DPM and RCNN series of detection methods. In the practical application of this module, when the number of locusts is small, the locusts in the acquired pictures are not easy to overlap, and the locusts can be identified and counted more accurately. When the number of locusts is large, the density of locusts is too high, and the recognition accuracy will decrease, but the system can directly judge them as higher damage levels, thus covering up the defects of the algorithm. The recognition result of the YOLOv3-based locust recognition and counting algorithm is shown in Figure 3.
5. WECHAT APPLET MODULE

The main functions that the WeChat applet needs to realize are: real-time display of farmland ecological environment factors data for users to view, providing visual display of locust density and locust damage level data, pushing early warning messages, etc. The WebSocket protocol can realize server-based push and maintain long connections to meet the needs of real-time data acquisition. The WeChat applet establishes a WebSocket connection with the cloud server through the official API interface wx.connectSocket. After the connection is successful, it monitors the messages sent by the server to the applet through the wx.onSocketMessage method, and obtains and displays various data in real time. In addition, the WeChat applet uses the `<ec-canvas>` component provided by the third-party visualization tool ECharts to visualize the locust damage level and locust density data. The WeChat applet interface is shown in Figure 4.
6. CONCLUSION
The characteristics of locusts' own outbreak, migration, and occurrence uncertainty make the task of locust control very difficult. Effective monitoring and early warning of locusts is the key to protecting ecological development, controlling locusts, and preventing locusts. Therefore, this article proposes to establish a locust situation monitoring system to monitor farmland ecological environmental factors related to the occurrence and development of locusts, and combine the monitored locust density data to comprehensively judge the occurrence and development of locusts, and obtain the level of locust damage, and present relevant data to users through the WeChat applet. When the locust damage level is high, users can be promptly reminded to take precautions in advance to reduce losses. Through the data monitoring of relevant environmental factors and locust density, a real-time dynamic monitoring and early warning system is established to realize the automation, intelligence and efficiency of locust monitoring.

REFERENCES
[1] Zheng Yongjun, Wu Gang, Wang Yiming, Mao Wenhua. Image recognition method of locust based on fuzzy pattern[J]. Transactions of the Chinese Society of Agricultural Engineering, 2010, 26(S2): 21-25+430. (In Chinese)
[2] Kimberly Maute, Kristine French, Paul Story, C. Michael Bull, Grant C. Hose. Short and long-term impacts of ultra-low-volume pesticide and biopesticide applications for locust control on non-target arid zone arthropods[J]. Agriculture, Ecosystems and Environment, 2017, 240.
[3] Zhang Endi, Lei Sijun. Design of monitoring system for agricultural pest control based on GPRS[D]., 2015. (In Chinese)