UAVs-Based Smart Agriculture IoT Systems: An Application-Oriented Design

Xiaoyu Li
Institute of Aeronautical Engineering
Jiangsu Aviation Technical College
Zhenjiang, China
1550573438@qq.com

Yongrong Sun
College of Automation Engineering
Nanjing University of Aeronautics and Astronautics
Nanjing, China
xznuaa@nuaa.edu.cn

Zhenshu Yang
Institute of Aeronautical Engineering
Jiangsu Aviation Technical College
Zhenjiang, China
1902176804@qq.com

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***Abstract*—Smart agriculture is the inevitable way for the development of modern agriculture. The current smart agricultural system has many problems such as multiple links, a huge amount of data information, low transmission efficiency, and poor system integrity. To solve the issues above, in this paper, we build a smart agriculture Internet of Things (IoT) System based on Unmanned Aerial Vehicles (UAVs), which attempts to complete the selection of agricultural plant protection UAVs and mapping UAVs. Meanwhile, the intelligent sensing layer, transmission layer, application layer and execution layer are designed to achieve the acquisition, processing, and analysis of soil moisture data, meteorological data, photosynthetically active radiation data, total solar radiation data, and insect data. The construction of the UAVs-based smart agricultural IoT system is thus completed. Finally, the experimental data results illustrate that the data accuracy error of this system is quite small and can fulfill the usage requirements.**

Keywords—unmanned aerial vehicles; smart agriculture; data; internet of things system; application-oriented.

I. INTRODUCTION

In recent years, governments have accelerated agricultural modernization, and traditional agriculture is being transformed and upgraded to smart agriculture. Smart agriculture refers to the use of remote sensing and telemetry, sensors, 5G modern communication technology and other technologies. Hence, smart agriculture can achieve precision planting, precision monitoring and automated management of agriculture. With the development of smart agricultural IoT, there are many links in the smart agricultural IoT system for the whole process of agricultural production. Links are highly correlated, and the amount of data information generated is relatively large, data coupling transmission efficiency is low. The system is encountering urgent requirements for more data collection, multi-dimensional data analysis, and more complex scene fusion applications. There is an imperative Demand to build an integrated smart agricultural system to improve production efficiency[1].

A lot of work has been done on the research and application of smart agricultural IoT technology at home and abroad. Most of the theoretical research lies in the study of IoT technology in achieving precise management of agricultural production. The research results confirm that the application of IoT technology has significantly improved the unit yield, photosynthetic efficiency and quality of crops[2]. In terms of applied research, it mainly focuses on the architecture design of the IoT, data monitoring design, decision theory and other fields. From the perspective of information collection and application research, the collected data is mainly used for display and relatively simple statistical analysis, and there are few studies on environmental data, image data and other multi-information fusion analysis and decision-making[4][5]. From the application research of UAVs in smart agricultural IoT systems. Most of them focus on the theoretical research of the system framework. There is also research on a certain module or function in the smart agricultural system, for example, the design of early warning and monitoring modules for plant diseases and insect pests, etc., there are few researches and practices based on the whole process of agricultural production[6][7].

The wide application of UAVs has promoted the development and innovation of modern agriculture. In this paper, UAVs with IoT technology are used in smart agriculture, to further improve the efficiency and quality of key links such as soil improvement, intelligent irrigation, intelligent sowing, and precise fertilization and drug delivery[8].

In this paper first, we first build a smart agricultural IoT system, which includes multiple subsystems ranging from soil moisture perception, meteorological data monitoring, photosynthetically active radiation perception, to total solar radiation perception and insect monitoring. Next, we complete the selection of agricultural plant protection drones and mapping drones, together with the integration design of drones and smart agriculture. After that, we design the intelligent sensing layer, transmission layer, application layer and execution layer, which thus construct a UAVs-based intelligent agricultural IoT system. Finally, for the designed system, the data accuracy test experiment and analysis are carried out. Pleasantly, the experimental results show that the data of all aspects of this system can be accurately sensed and interconnected to ensure real-time, accurate, and efficient data processing for smart agricultural production.

II. THE CONSTRUCTION OF IOT SYSTEM FOR SMART AGRICULTURE

The IOT system for smart agricultural needs to obtain data information such as soil moisture, air temperature and humidity, light radiation energy, and insect pest for analysis and monitoring by the data management platform. Based on relevant sensors, this paper has built a soil moisture perception subsystem, meteorological data monitoring subsystem, photosynthetic active radiation sensing subsystem, total solar radiation sensing subsystem, and insect monitoring subsystem. Relevant data is collected through the gateway equipment and transmitted to the data management platform through the wireless network, The system block diagram is shown in Figure 1. Next, we will introduce the construction of each subsystem.

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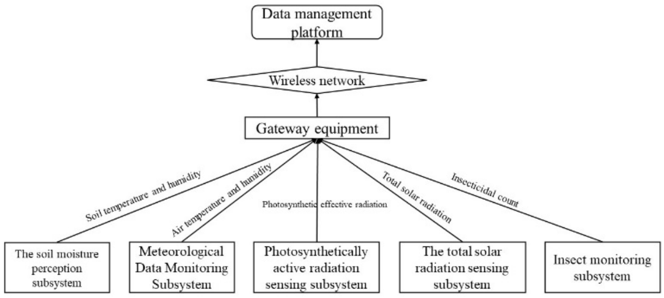

Fig.1. Block diagram of smart agricultural IoT system

A. *The soil moisture perception subsystem*

The function of soil sensors is to monitor soil temperature, humidity and conductivity data. The sensors are divided into monitoring terminals and control terminals. There are three probes on the monitoring part, which need to be buried about 15 cm below the soil for monitoring soil data; the control part includes switches for controlling sensors, gateway connections, etc.

B. *Meteorological Data Monitoring Subsystem*

Meteorological monitoring realizes data collection through the meteorological monitoring sensor, which monitors seven data parameters including air temperature, humidity, atmospheric pressure, wind speed, wind direction, rainfall, and light intensity. The meteorological sensor is connected to the data collector, and transmits the collected data to the data collector regularly, and the collection frequency can be adjusted remotely through the platform.

C. *Photosynthetically active radiation sensing subsystem*

Photosynthetically active radiation refers to the part of solar radiation with a wavelength range of 400~700nm that can perform photosynthesis for vegetation. The photosynthetically active radiation sensor adopts the principle of photoelectric induction, which can be used to measure the photosynthetically active radiation in the spectral range of 400~700nm. Photosynthetically active radiation is the basic energy for biomass formation, controls the speed of effective photosynthesis of terrestrial organisms, and directly affects the growth, development, yield and quality of plants. At the same time, photosynthetically active radiation is also an important climate resource, affecting the surface and atmosphere. Environmental substances, energy exchange, measurement and estimation of photosynthetically active radiation are of great significance in estimating the photosynthesis of plants, exploring the origin of green vegetation, and the mechanism of biological utilization of solar energy. They are also directly related to the formation of agricultural output and further improve agriculture.

D. *The total solar radiation sensing subsystem*

The total solar radiation sensing is to realize data collection through the total solar radiation sensor, and measure the first-level pyranometer that receives the irradiance on the earth plane. It is mainly used to measure the total solar radiation with a wavelength range of 0.3 to 3 microns. If it is placed horizontally downward, it can measure reflected radiation, and if it is added with a scattering shading ring, it can measure scattered radiation.

E. *Insect monitoring subsystem*

The module used for insect monitoring in the system studied in this paper integrates the functions of insect counting, pest area positioning, and auxiliary agricultural monitoring. It can be completed automatically without supervision. Insect trapping and insect killing operations not only solve the problem of frequent manual insect removal, but also provide a basis for the occurrence, development analysis and prediction of insect pests, provide modern plant protection services for agricultural production, and meet the needs of insect prevention and control in various planting scenarios.

III. INTEGRATION DESIGN OF UAVS AND SMART AGRICULTURE

A. *Selection of agricultural plant protection UAVs*

In order to apply UAVs to smart agriculture, first of all, UAVs need to have an automatic flight control system. On the one hand, the UAV flight control system carries out data analysis and calculation based on the relevant data obtained by the sensing system, and generates control commands, thus changing the flight attitude of UAVs and realizing the operation tasks under different agricultural scenarios. On the other hand, with the help of the navigation system, the flight control system can enable the UAVs to complete the navigation and positioning, realize the route planning, complete the automatic driving of farmland operations, improve the intelligent level of agricultural plant protection, and improve the operation efficiency. Secondly, UAVs should have efficient data communication systems to realize real-time information exchange between UAVs and ground command systems. At the same time, agricultural plant protection also requires a high flexibility of equipment. Compared with UAVs with multi-rotor, fixed-wing, composite wing and other platforms, the advantages of multi-rotor flight platforms are simple operation, convenient takeoff and landing, and high operating efficiency. At the same time, due to its strong downwash air generated by the propeller during flight, it is conducive to the rapid and direct access of drugs to crops, and further improves drug penetration. In order to better meet the operation requirements under various agricultural plant protection scenarios, the task load system of agricultural plant protection UAVs needs to include pesticide spraying equipment, seed sowing equipment, etc. to improve the operation efficiency.

Based on the above analysis, the agricultural plant protection UAVs studied in this paper are mainly composed of a multi-rotor flight platform, navigation flight control system, power system, ground command system, sensing system, data communication system and mission load system.

B. *Selection of mapping UAVs*

Mapping UAVs applied in smart agriculture usually need to have the main functions of farmland mapping, disease and pest monitoring and early warning, which requires mapping UAVs to carry multi-spectral imagers to provide accurate multi-spectral data for agriculture. Based on the actual situation of the experimental base, the selected multispectral imager has five independent imagers, each equipped with a special filter, which can enable each imager to receive spectral information of the precise wavelength range. The number of bands of the target ground object obtained is between 3 and 12, and the spectral resolution is about 40 nm. It is mainly used for ground object classification and semi-quantitative remote sensing. The camera is performing the data acquisition task, The flight control system gives the trigger command, the five lenses of the multispectral camera are exposed at the same time, and the image data of five bands in the same field of view are recorded. The multi-spectral imager can monitor the growth situation of farmland, and generate RGB and Normalized Difference Vegetation Index (NDVI)real-time images, as shown in Figure 2. It can analyze and compare the relevant data, quickly grasp the health status of crops, monitor the growth situation, timely warn pests, and facilitate rapid decision-making.

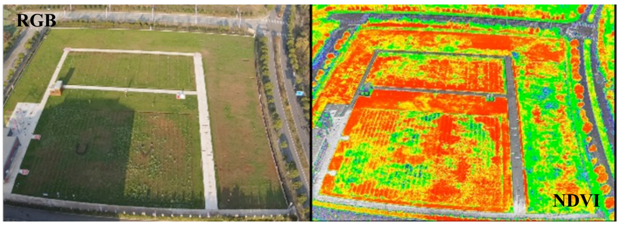

Fig.2. Real-time image comparative analysis between RGB and NDVI

IV. THE PLATFORM CONSTRUCTION OF UAVS-BASED IOT SYSTEMS

The UAVs-based smart agricultural IoT system studied in this paper is mainly composed of four layers, namely the smart perception layer, smart transmission layer, smart application layer and smart execution layer, as shown in Figure.3.

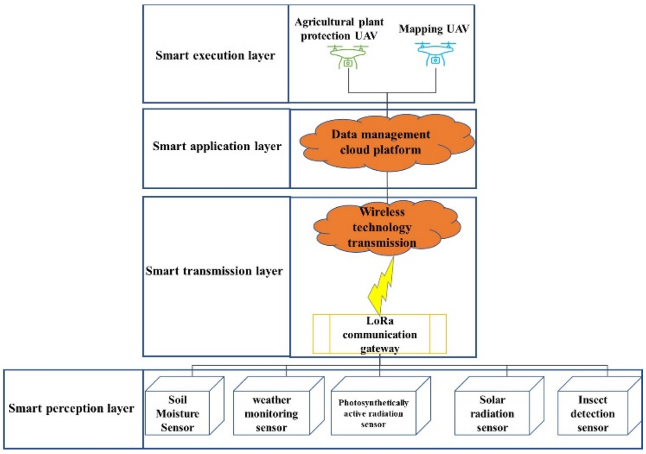

Fig.3. Smart agricultural IoT system based on UAVs

Step 1: The design of the smart perception layer. This layer is composed of various IoT device sensors. It is the basis of the Internet of Things system, and the monitoring is realized through various soil moisture sensors and weather monitoring sensor systems. The environmental information on crop growth can be obtained in real-time, including the temperature and humidity of the air, wind direction and speed, rainfall, light, etc., as well as the temperature and humidity of the soil, etc., and the growth status of crops can also be monitored in real-time.

Step 2: The design of the smart transmission layer. This layer is mainly responsible for the transmission of information. It is the communication center of the entire agricultural Internet of Things system. It transmits various information obtained by the intelligent perception layer through wireless technology transmission, and issues operation instructions to the intelligent application layer. The wireless transmission method used in this paper is mainly 5G communication technology.

Step 3: The design of the smart application layer. This layer includes functions such as data storage and analysis, data visualization display, and agricultural production task generation. It is mainly responsible for data analysis and application. It is the information terminal of the entire agricultural Internet of Things system. It can remotely understand, process and analyze the crop growth environment obtained by the intelligent perception layer. Guidance on precise irrigation, fertilization, etc. based on various information from various sources, based on data to establish functions such as auxiliary agricultural production management, crop tracking, remote monitoring of diseases and insect pests, and video monitoring of crop growth environment in farmland, as well as intelligent perception layer and intelligent transmission layer Jointly build a remote intelligent management and monitoring module for the entire growth environment of crops, and visualize them in the form of data, pictures, and videos through the data management cloud platform. As shown in Figure.4, the data obtained by the soil moisture sensor is displayed on the data cloud platform.

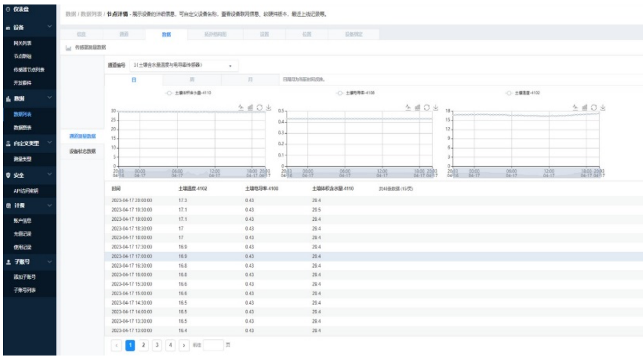

Fig.4. Soil moisture data monitoring map

Step 4: The design of the smart execution layer. It is mainly responsible for the execution of production tasks, which is one of the key links in the entire agricultural Internet of Things system. The intelligent execution layer researched and developed in this paper is mainly used for intelligent irrigation and precision irrigation. The surveying and mapping UAVs for situation monitoring will immediately execute the corresponding tasks after receiving the corresponding instructions from the intelligent application layer.

V. SYSTEM TEST EXPERIMENTS AND ANALYSIS

In the process of design and implementation of UAVs-based smart agricultural Internet of Things Systems, system testing is a key link in system implementation. The main purpose is to verify the accuracy and reliability of data collection and data transmission by the system, and to ensure that problems are discovered and adjusted in time before system promotion and demonstration. This article focuses on testing the accuracy of the soil moisture sensor data and demonstrating the use of the system.

In order to compare and analyze the accuracy and reliability of data acquisition and transmission in this system, the AM2320 temperature and humidity sensor is used to directly collect soil moisture data. This sensor is a temperature and humidity composite sensor with calibrated digital signal output and has a special digital module acquisition technology. And temperature and humidity sensor technology to ensure high reliability and good stability. The following two experiments were mainly carried out.

Experiment 1: Collect data for 8 different time periods on the same day. Soil temperature 1 and soil volume water

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content 1 are the soil temperature and humidity data obtained by this system, Soil temperature 2 and soil volumetric water content 2 are the soil temperature and humidity data obtained by the AM2320 temperature and humidity sensor, as shown in Figure.5 and Figure.6. After calculation and analysis, the relative error of soil temperature does not exceed 1.27%, the relative error of soil volume water content does not exceed 0.3%, and the data error is small.

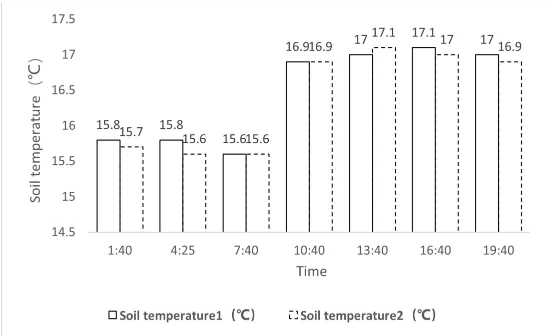

Fig.5. Comparison of soil temperature data in different time periods on the same day

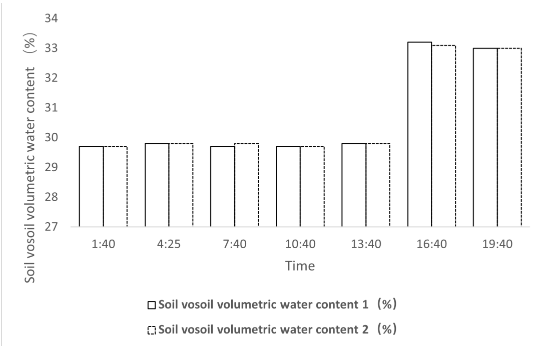

Fig.6. Comparison of soil volume water content data in different time periods on the same day

Experiment 2: Collect data for different days of the week and at the same time point. Soil temperature 3 and soil volumetric water content 3 are the soil temperature and humidity data obtained by this system, soil temperature 4 and soil volumetric water content 4 are the soil temperature and humidity data obtained by the AM2320 temperature and humidity sensor, as shown in Figure.7 and Figure.8. After calculation and analysis, the relative error of soil temperature does not exceed 1.12%, the relative error of soil volume water content does not exceed 0.34%, and the data error is small.

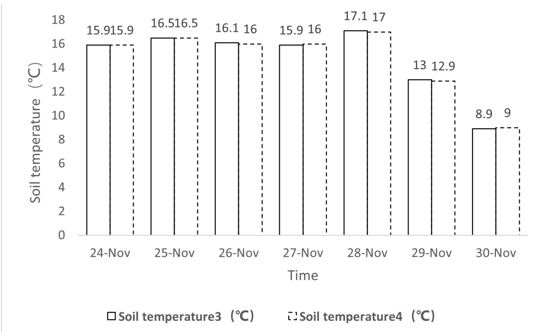

Fig.7. Comparison of soil temperature data at the same time point on different days in a week

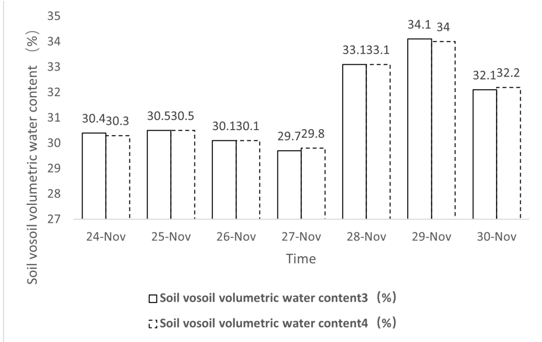

Fig.8. Comparison of soil volume water content data at the same time point on different days in a week

VI. CONCLUSIONS

Based on the necessity and urgency of UAVs for the development of smart agriculture, in this paper, we investigate the construction of UAVs-based intelligent agricultural Internet of Things system, which aims at improving the operational efficiency of modern agriculture. Through the organic integration of the intelligent perception layer, intelligent transmission layer, intelligent application layer and intelligent execution layer, the system gives full play to the important role of agricultural plant protection UAVs and mapping UAVs in the execution of agricultural tasks. The designed system realizes the whole process from data collection to data application to the efficient execution of tasks. Meanwhile, this system can provide powerful data and application guarantees for scientifically guiding agricultural production, and is of great significance to the development of the agricultural Internet of Things and the acceleration of agricultural modernization. Due to the system being in the design stage, some performance has been verified through experiments, proving that the accuracy of the system is suitable for industrial needs and its performance is stable. Based on this, a full system test will be conducted in the later stage to accumulate data and iteratively optimize.

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