International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 14, Issue 4 [April. 2025] PP: 04-08

"Eagle Eye" for Agricultural Assistance - Unmanned Aerial Vehicle for Intelligent Agricultural Maintenance and Management Based on Multi-Rotor Aircraft

Sanlin Zeng[1], Peiyong Ji[1*], Rifei Wen[1]
1 School of Mechanical and Vehicle Engineering, Changchun University, Changchun 130022, China
Corresponding Author: Peiyong Ji

ABSTRACT: *With the vigorous advancement of agriculture, issues such as the inability to precisely conduct pesticide spraying in crop planning and cultivation have arisen. A type of agricultural intelligent maintenance and management unmanned aerial vehicle based on multi-rotor aircraft is designed. By optimizing the power system, control system, and communication system, this unmanned aerial vehicle possesses advantages like high precision, long endurance, low cost, and low pollution. Incorporating machine vision technology, deep learning is utilized to detect crop pests and diseases, and targeted pesticide spraying is carried out. Multiple lidars are employed to guarantee the safety of beyond-visual-range flight. Through the combination of system optimization and machine vision technology, the unmanned aerial vehicle is capable of precisely spraying pesticides for different agricultural pests and diseases and is competent in undertaking regional agricultural pesticide spraying tasks.*

Date of Submission: 26-03-2025 Date of acceptance: 06-04-2025

I. INTRODUCTION

In 2023, the national cultivated land area reached 1.9179 billion mu, while in 2022, it amounted to 1.914 billion mu. Concurrently, the proportion of employment in the primary industry within the total employment declined from 44.8% to 38.1%, representing a decrease of 6.7 percentage points. The national cultivated land area has persistently fluctuated around the 1.8 billion mu red line. In the context of the continuous reduction in the number of farmers, to safeguard the 1.8 billion mu cultivated land red line and enhance the grain yield per unit area, the utilization of efficient, precise, and intelligent agricultural maintenance and management services becomes exceptionally crucial.[1]

In recent years, along with the continuous advancement and improvement of prevention and control technologies, farmers have imposed higher demands on the precision of pesticide spraying. The public's attention and emphasis on environmental safety have been escalating. The relationships among pesticides, pesticide application equipment, pests and diseases, and application methods have grown increasingly intricate[2]. As a result, the requirements for pesticide application apparatuses have also become more stringent. Traditional methods of pesticide spraying suffer from disadvantages such as low efficiency.[3] It is evident that while insecticides are highly effective in eradicating pests on crops, the means of their application are inefficient.[4] To fulfill the dual requirements of combating crop pests and concurrently ensuring the development of the ecological environment, it is imperative to seek precise application techniques for insecticides to curtail pesticide usage, boost pest control rates, and employ pesticides in a scientific, rational, and efficient manner to increase crop yields.[5]

Based on this, we have fully leveraged knowledge from domains such as agriculture and forestry, and have augmented the pesticide spraying functionality of multi-rotor aircraft[6], which boast advantages such as high spraying accuracy, rapid speed, high efficiency, low cost, wide application scope, conservation of pesticide dosage thereby reducing environmental pollution, and large payload capacity.[7] Pesticide spraying services are provided to farmers through both online and offline service networks. The level of agricultural mechanization constitutes the central link in achieving agricultural modernization and is also of paramount importance in agricultural development.[8] To construct a new type of modern agriculture, it is necessary to expedite the modernization of agricultural machinery and promote technological innovation and development in agricultural mechanization.[9] In the future, large-scale land utilization will become increasingly prevalent. Accelerating the transfer of rural land contractual management rights, promoting scale operations, and reducing individual farming households represent an inevitable trend. Hence, the implementation of agricultural mechanization is an essential condition.[10]

The agricultural intelligent maintenance and management unmanned aerial vehicle based on multi-rotor aircraft that we have proposed features the following main characteristics:
1.Integrated with machine vision technology, enabling the unmanned aerial vehicle to identify crop pests and diseases more accurately and carry out precise pesticide spraying operations on them.
2.The power system has been optimized, utilizing oil power to enhance lift and electrical power to adjust the attitude of the unmanned aerial vehicle, facilitating its flexible flight in more complex terrains.
3.The control system has been refined, adopting fixed-point flight and return, and incorporating an automatic obstacle avoidance function.
4.The communication system has been enhanced, allowing workers to monitor the operation of the unmanned aerial vehicle, minimizing erroneous spraying during operations and reducing pesticide consumption.

II. Drone design concept

"Eagle Eye" for Agricultural Assistance is an agricultural intelligent maintenance and management unmanned aerial vehicle based on multi-rotor aircraft. With the rapid progress of agricultural modernization, traditional manual maintenance and management approaches have struggled to meet the requirements of efficient, precise, and intelligent modern agricultural development. The integration of unmanned aerial vehicles and machine vision technology offers a novel solution for intelligent agricultural maintenance and management. Through the research and development as well as the application of agricultural intelligent maintenance and management unmanned aerial vehicles, precise operations such as fertilization, irrigation, pest and disease control for crops can be realized, enhancing agricultural production efficiency, reducing labor intensity, and promoting sustainable agricultural development.

2.1 Unmanned Aerial Vehicles and Machine Vision Technology

Unmanned aerial vehicles possess features such as strong flexibility, wide operation scope, and simple operation, enabling all-round and seamless coverage of farmland. Machine vision technology, via image processing and pattern recognition algorithms, can realize real-time detection and analysis of the growth status and pest and disease situations of crops. The integration of unmanned aerial vehicles and machine vision technology can achieve intelligent and automated management of farmland, enhancing the precision and efficiency of maintenance operations.

2.2 Operating principle

During operation, the multi-rotor agricultural intelligent maintenance and management drone can employ the cameras, LiDAR and other devices it is equipped with, in combination with multi-element wireless sensor network technology, two-dimensional reconstruction technology, image color restoration technology, drone cruising technology, data collection and analysis technology, high-resolution cameras and image processing technology, etc., to monitor various health indicators of the farmland and transmit real-time monitoring videos. This information, after image analysis and processing, directly conveys to farmers the situations of crop pests and diseases, crop growth data and crop chlorophyll content, etc. On this basis, pesticide spraying and fertilization are precisely carried out at the locations of pests, providing a scientific basis for farmland management and crop growth.

2.3 Compared with other plant protection drones

The crucial technologies related to multi-rotor agricultural intelligent maintenance and management drones encompass multi-element wireless sensor network technology, two-dimensional reconstruction technology, image color restoration technology, unmanned aerial vehicle cruising technology, data collection and analysis technology, high-resolution cameras and image processing technology, etc. In contrast to other plant protection drones that can merely carry out simple tasks like fertilization, multi-rotor agricultural intelligent maintenance and management drones are capable of conducting intelligent maintenance and management throughout the entire growth process of crops, attaining intelligent and unmanned management of farmland.

III. Unmanned Aerial Vehicle System

3.1 Power system

The power system of multi-rotor agricultural intelligent maintenance and management drones constitutes its core component. Commonly, it employs a combination of multiple motors and propellers to realize vertical takeoff and landing as well as hovering. The product boasts enhanced load-bearing capacity and endurance. Under identical conditions, it can withstand greater loads and have a longer duration. Breaking through the conventional four-axis and six-axis structures as well as odd-numbered structures, an innovative concept of oil-electric hybrid power is proposed. Oil power offers lift, while electric power adjusts the attitude, thereby attaining a technical superiority in improving endurance and load capacity. This significantly reduces the difficulty of actual operations and better accommodates the entire operation process. Such a design enables the drone to fly flexibly over complex terrains and fulfill various operational demands.

3.2 Control system

The control system is responsible for the flight stability, navigation and operation control of the unmanned aerial vehicle (UAV). By integrating multiple sensors such as inertial navigation, GPS and RTK, the UAV can achieve precise positioning, autonomous flight and obstacle avoidance functions. At the same time, the "Eagle Eye" agricultural assistance one-click return function sets up a humanized ground station function, enabling point-to-point flight, fixed-point return, truly achieving unmanned operation and one-click return. Moreover, it has added an automatic obstacle avoidance function. After completing the assigned task and receiving an automatic return instruction or losing control signal, it can automatically return to the return point and complete an automatic landing based on the visual system records of itself.

3.3 Communication system

The communication system acts as a bridge between the unmanned aerial vehicle (UAV) and the ground control centre, ensuring that the UAV can receive instructions in real time and upload operational data. Through wireless communication technology, operators can remotely monitor and control the flight and operational status of the UAV, enabling precise and scientific pesticide spraying. While guaranteeing the normal growth of crops, it is possible to minimise pesticide usage, simultaneously saving the dosage of pesticides and thereby reducing environmental pollution. Departing from traditional GPS positioning, image recognition technology is employed to overcome positioning errors and precisely locate targets. Image recognition-assisted positioning is introduced to achieve timed data transmission. After the pesticide depletion, the aircraft can automatically resume spraying from the point where the pesticide was exhausted, preventing phenomena such as incorrect spraying and missed spraying, and achieving efficient and precise pesticide spraying.

IV. The competitive advantages of agricultural intelligent maintenance and management drones

The adoption of a modular approach simplifies assembly and shortens the production cycle. Standardized interfaces are employed: the overall hardware equipment and subsystems are modularized in a generalized manner; it possesses the characteristics of rapid assembly, mass production, and easy replication. Compared to traditional production procedures, the production cycle is reduced by over 50%.

It demonstrates strong environmental adaptability, exhibits excellent cold resistance, and has relatively high stability, capable of meeting individualized requirements. The product is capable of operating in extreme environments, enhancing overall stability. The independently developed flight control system has crafted a truly industrial-grade flight control that can overcome extreme conditions such as extremely cold and frigid climates. Simultaneously, its own algorithms are optimized, and the relevant stability enhancement technologies are updated accordingly to guarantee the overall stability of the operational process.

Intelligent management significantly reduces labor costs. This technology has broken through the traditional single-function design of unmanned aerial vehicles by integrating multiple functions into one, achieving multi-functionality of agricultural unmanned aerial vehicles. Utilizing advanced image processing techniques, real-time and accurate monitoring of crop growth conditions can be achieved, providing a decision-making basis for farmers. Through the collection and analysis of crop growth data, optimization suggestions can be provided to farmers, further enhancing agricultural production efficiency. The intelligent management system enables intelligent operation and maintenance, reducing procurement and production costs and minimizing labor maintenance costs.

Modular products can control the costs of the enterprise itself. The use of "Farm Assistant" enables high-precision and low-loss pesticide spraying and, to a certain extent, reduces the costs of enterprises in terms of management and labor.

V. Field experiment

5.1 Experimental design

Typical grain-producing areas (wheat, corn) and economic crop-growing areas (vegetables, fruit trees) were selected as the experimental fields, with unmanned aerial vehicle (UAV) operation areas and traditional operation control areas established respectively. During the entire growth cycle of the crops, growth indicators (plant height, stem diameter, yield, etc.), the incidence of pests and diseases, the dosages of pesticides and fertilizers, and changes in soil fertility were monitored synchronously. The efficiency differences between UAV maintenance and traditional manual and mechanical operations were contrasted.

5.2 Test results

During the growth period of wheat and corn, the pest and disease control efficacy in the areas operated by unmanned aerial vehicles (UAVs) exceeded 90%, representing an increase of 15% compared with traditional control methods. The precision of fertilization elevated the fertilizer utilization rate by 18%, resulting in an average increase in yield ranging from 8% to 12% per mu. Additionally, the use of UAVs saved 30% of pesticides and 20% of fertilizers per mu and reduced labor costs by 60%, significantly enhancing production efficiency.

In vegetable and fruit cultivation, the early detection rate of pests and diseases by UAVs surpassed 95%. Precise pesticide application guaranteed fruit quality, increasing the rate of high-quality fruits by 10% to 15%. Intelligent fertilization precisely regulated based on the nutrient requirements of crops, enhancing fruit sweetness by 5% to 8%, reducing fertilizer waste by 35%, and reducing labor input by 50%, facilitating the output of high-value-added agricultural products.

VI. The Development and Application of Agricultural Intelligent Maintenance and Management Drones

With the escalating global focus on environmental protection and sustainable development, green and environmentally friendly agricultural production approaches will become the mainstream in the future. The application of multi-rotor agricultural intelligent maintenance and management drones in the realm of environmental protection will also progressively become a significant development orientation in the market. The utilization of drones in the agricultural domain can not only enhance production efficiency and curtail the investment of human and material resources but also diminish the usage of chemical fertilizers and pesticides via precise fertilization and spraying, thereby alleviating environmental pollution. This will empower multi-rotor agricultural intelligent maintenance and management drones to play a more pivotal role in environmental protection and sustainable development.

With the rapid advancement of new-generation information technologies such as 5G and the Internet of Things, the networking and intelligentization levels of multi-rotor agricultural intelligent maintenance and management drones will be further elevated. Drones will be capable of achieving more precise positioning, navigation, and control, augmenting the accuracy and efficiency of operations. Through integration with cloud platforms, big data, and other technologies, drones can also effectuate real-time monitoring and data analysis of farmland environments, furnishing more scientific and precise decision-making support for agricultural production.

The market of multi-rotor agricultural intelligent maintenance and management drones boasts broad development prospects and colossal market potential. Enterprises need to perpetually monitor market dynamics and technological development trends, intensify R&D investment and product innovation, and elevate their core competitiveness. They also have to strengthen cooperation and communication with governments, industry associations, and other parties to jointly facilitate the healthy development of the multi-rotor agricultural intelligent maintenance and management drone market.

VII.CONCLUSION

With the vigorous advancement of agriculture, to address the issue of accurate pesticide spraying in agricultural regions, an "Eagle Eye" agricultural assistance - an intelligent agricultural maintenance and management unmanned aerial vehicle (UAV) based on multi-rotor aircraft has been designed. Through integration with machine vision technology, the UAV is capable of precisely locating the positions of pests and diseases and conducting precise spraying. Through the optimization of the power system, control system, and communication system, the UAV is competent for regional pesticide spraying tasks. The multi-rotor aircraft-based intelligent agricultural maintenance and management UAV can update various health indicators of the farmland in real time and transmit the monitoring videos back in real time. After image analysis and processing, this information is directly presented to farmers, encompassing the situation of crop pests and diseases, crop growth data, and crop chlorophyll content, among others. On this basis, pesticide spraying and fertilization can be precisely carried out at the locations of pests, thereby achieving intelligent maintenance and management of large areas of unattended farmland. This enables farmers to have a clearer understanding and control of the situation of large areas of farmland with poor road conditions and facilitates farmers working outside to be informed about the situation of their own farmland without having to rely on the elderly left behind. Furthermore, farmers can further enhance agricultural production efficiency based on the optimization suggestions provided by the system.

REFRENCES

[1]. Albahri G, Alyamani A A, Badran A, et al. Enhancing essential grains yield for sustainable food security and bio-safe agriculture through latest innovative approaches[J]. Agronomy, 2023, 13(7): 1709.

[2]. Damalas C A, Eleftherohorinos I G. Pesticide exposure, safety issues, and risk assessment indicators[J]. International journal of environmental research and public health, 2011, 8(5): 1402-1419.

[3]. Kebe A A, Hameed S, Farooq M S, et al. Enhancing crop protection and yield through precision agriculture and integrated pest management: a comprehensive review[J]. Asian Journal of Research in Crop Science, 2023, 8(4): 443-453.

[4]. Khan B A, Nadeem M A, Nawaz H, et al. Pesticides: impacts on agriculture productivity, environment, and management strategies[M]//Emerging contaminants and plants: Interactions, adaptations and remediation technologies. Cham: Springer International Publishing, 2023: 109-134.

[5]. Singh A, Dhiman N, Kar A K, et al. Advances in controlled release pesticide formulations: Prospects to safer integrated pest management and sustainable agriculture[J]. Journal of hazardous materials, 2020, 385: 121525.

[6]. Richardson B, Rolando C A, Kimberley M O, et al. Spray application efficiency from a multi-rotor unmanned aerial vehicle configured for aerial pesticide application[J]. Transactions of the ASABE, 2019, 62(6): 1447-1453.

[7]. Das A, Kadawla K, Nath H, et al. Drone-based intelligent spraying of pesticides: current challenges and its future prospects[M]//Applications of Computer Vision and Drone Technology in Agriculture 4.0. Singapore: Springer Nature Singapore, 2024: 199-223.

[8]. Luo X, Liao J, Zang Y, et al. Improving agricultural mechanization level to promote agricultural sustainable development[J]. Transactions of the Chinese Society of Agricultural Engineering, 2016, 32(1): 1-11.

[9]. Lu F, Meng J, Cheng B. How does improving agricultural mechanization affect the green development of agriculture? Evidence from China[J]. Journal of Cleaner Production, 2024, 472: 143298.

[10]. Biggs S, Justice S E. Rural and agricultural mechanization: A history of the spread of small engines in selected Asian countries[J]. 2015.