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Technological Advancements in Agricultural Spraying Drones: A Review of Efficiency and Environmental Impact

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Abstract

Developing an unmanned aircraft system with cutting-edge sensors for accurate pesticide and fertilizer delivery, crop monitoring, and resource optimization in agriculture is the main goal of the agricultural spraying drone project. The initiative intends to minimize chemical usage and lessen environmental effects while providing a sustainable and environmentally friendly alternative. Real-time monitoring, obstacle avoidance, GPS-based navigation, and data analytics are some of the key features. Airframe design, propulsion, cargo delivery, and software components for mission planning and data analysis are all included in the extensive project scope. The result is an affordable, incredibly effective, and adaptable drone that gives farmers more control over their crops and boosts productivity. Precision farming has been transformed by agricultural spraying drones, which apply pesticides, fertilizers, and other agricultural inputs precisely and efficiently. This assessment focuses on how drones have advanced technologically, how well they preserve crops, and how they affect the environment. The paper examines developments in sensors, software, and drone hardware that have increased environmental footprint reduction, decreased waste, and increased precision. The advantages, difficulties, and potential applications of drone technology in sustainable agriculture are also covered.

Keywords: Drone, agriculture, sensors, pump, spray, payload

INTRODUCTION

Within the framework of agriculture in the twenty-first century, the agricultural spraying drone presents itself as a novel approach to current crop management problems. Unlike traditional methods that depend on large machinery and human labor, this self-governing drone incorporates cutting-edge technology, including unmanned aerial vehicles (UAVs), precise sensors, and complex algorithms. Its main goal is to make accurate and sustainable crop management easier, with an emphasis on increasing productivity, cutting back on fertilizer and pesticide use, and lessening the impact on the environment. By combining data analytics, obstacle avoidance, and real-time monitoring, the project aims to transform agricultural practices and ensure that they can adapt to a wide range of crop varieties and field circumstances. The main objective is to create an autonomous drone that can monitor crop health, optimize resource use, and advance the general objective of improving agricultural sustainability.

Growing demands for increased crop yields, better resource efficiency, and environmentally benign methods are placed in the agricultural sector

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globally. Conventional techniques for applying fertilizers and pesticides can be inaccurate and inefficient because they frequently require manual labor or large-scale ground-based machinery. This can result in overuse of chemicals, uneven application, and significant environmental harm. In recent years, drones used for agricultural spraying have become a creative response to these problems.

With their sophisticated sensors, navigation systems, and spraying mechanisms, these drones provide farmers with a more accurate and effective approach to monitoring crop health. They can fly over fields fully or partially autonomously and administer chemicals precisely, even in hard-to-reach locations. This study examines developments in agricultural drone technology and evaluates how they affect environmental and operational efficiency.

Within the framework of agriculture in the twenty-first century, the agricultural spraying drone presents itself as a novel approach to address current crop management issues. Unlike traditional methods, which depend on large amounts of machinery and human work, this self-governing drone incorporates cutting-edge technology, including UAVs, precise sensors, and sophisticated software. Its main goal is to make accurate and sustainable crop management easier, with an emphasis on increasing productivity, cutting back on fertilizer and pesticide use, and lessening the impact on the environment. By combining data analytics, obstacle avoidance, and real-time monitoring, the project aims to transform agricultural practices and ensure that they can adapt to a wide range of crop varieties and field circumstances. The main goal is to create an autonomous drone that can optimize resource utilization principles, drone components, different types of spraying systems, components required for drones, and various types of spraying systems.

DESIGN AND WORKING OF DRONE

The design process for a quadcopter involves estimating the payload, selecting components based on weight considerations, choosing an appropriate battery, calculating thrust requirements, and designing the frame with the necessary number and length of arms to accommodate payload applications.

The quadcopter configuration, distinguished by its four arms, utilizes an EMAX motor, F450 frame, and 9-inch propellers. The main frame, composed of a carbon fiber composite material, was designed with each arm measuring 450 mm in length. At the end of each arm, an EMAX motor was affixed and mechanically coupled to a 9-inch propeller. The electronic speed controller (ESC) connects the output side to each EMAX motor, whereas the ESC input interfaces with the flight controller. The power distribution board, which draws power from the Li-Po battery, is linked to the other inputs of the ESC. All four EMAX motors, ESCs, and 9-inch propellers were interconnected.

A receiver was linked to the flight controller for signal reception from the transmitter. The quadcopter features a storage tank that is coupled mechanically to the frame. The tank was designed to have a sloped bottom for efficient drainage. A plastic tube, spanning 1.3 meters in length and equipped with four nozzles spaced 45 cm apart, was attached to the tank. A pump powered by the power distribution board is drawn from the storage tank and feeds into the plastic tube with nozzles.

To ensure a safe landing, a landing frame with a height of 300 mm was connected to the main frame, preventing direct contact between the storage tank and the ground. This configuration highlights the essential components and their interconnections in the design of a quadcopter agricultural.

Drones are one of the developing technologies used in agriculture today; however, too many other technologies are engaged for this purpose. People handling pesticide application procedures suffer numerous detrimental side effects when pesticides are manually applied. Individuals may experience moderate skin irritation, birth deformities, tumors, genetic alterations, blood and nerve diseases, endocrine disruption, unconsciousness, or even death due to exposure. The World Health Organization (WHO) calculated that one million people will be negatively impacted by manually applying pesticides to agricultural fields. This paved the way to develop a drone mounted with a spraying mechanism having a 12 V pump, 6 Litre storage capacity tank, 4 nozzles to atomize in a fine spray, an octocopter configuration frame, a suitable obtaining frame, 8 Brushless Direct Current (BLDC) motors with suitable propellers to produce the required thrust of approximately 38.2 kg (at 100% revolution per minute), and a suitable Lithium Polymer (LI-PO) battery with a current capacity of 22000 mAh and 22.2 V to meet the necessary current and voltage requirements. The drone can also be equipped with a First-Person View (FPV) camera and transmitter to monitor the spraying process and detect pest attacks on the plants. The application of pesticides reduces the amount of time, labor, and money required to apply pesticides.

By adjusting the pump’s flow discharge, this type of drone can also be used to spray disinfectant substances over structures, water bodies, and densely populated regions.

Industries such as entertainment, sports, and security, which depend on real-time dynamic camera angles, are being revolutionized by aerial cinematography. Nonetheless, it takes a lot of effort to operate a drone securely while recording a moving object during obstructions, frequently needing several skilled human operators. As a result, there is a need for an autonomous cinematographer who can make decisions in real time in terms of geometry and scene context. Not all aspects of this problem are addressed by existing approaches; for example, they rely on pre-existing maps of the environment, plan for short time horizons, or only adhere to fixed artistic guidelines specified prior to flight. The payload estimation is presented in Table 1.

LITERATURE SURVEY

Shaw and Vimalkumar (2020) [1] developed drones for spraying pesticides, fertilizers, and disinfectants. They also used FPV cameras for surveillance. Debangshi (2021) [2] published a paper titled drone Applications in agriculture in which various applications of drones are mentioned in the paper, such as Soil and Field analysis, planting seeds from air, spraying operations in agriculture, and crop health assessment.

Ganesh P. Borkar, Chaitanya Gharat, and Sachin R. Deshmukh (2022) [3] published a paper titled Application of Drone Systems for Spraying Pesticides in Advanced Agriculture in which they mentioned types of drones, their working spraying drone, featuring the EMAX motor, F450 frame, and 9-inch propellers [4].

Taking a comprehensive approach to this issue, Bonatti et al. proposed a system that integrates the following aspects of real-time aerial cinematography for the first time: (a) vision-based target estimation, (b) 3D signed-distance mapping for occlusion estimation, (c) effective trajectory optimization for long time-horizon camera motion, and (d) learning-based artistic shot selection. They performed a thorough simulation and field experiment evaluation of their system by recording dynamic targets moving through unstructured surroundings. They showed that their system can function dependably in the real world without making limiting assumptions. They also offered comprehensive analysis and debates for every module, to generalize our design tradeoffs to other relevant applications [5].

Table 1. Payload estimation.

Parts	Weight (grams)
0.5-litre liquid	500
Liquid tank	100
Pump	200
Nozzle	300
Total	1100
Estimation	E1

Peterson et al. reported the findings of an observational study conducted at the Savannah River National Laboratory to examine the performance of numerous algorithms for the localization of radioactive compounds. Data from two radioactive source configurations were collected in this multi-robot system using a UAV, a customized hexacopter, and an unmanned ground vehicle (UGV), the ClearPath Jackal, which was outfitted with γ-ray spectrometers. The gathered datasets were used to test the Laplacian Eigenmaps and Fourier scattering transform techniques for source detection [6].

Talaeizadeh et al. provided a model for the velocity limits that the quadcopter needs to meet to stay outside of these areas. Subsequently, the issue of creating ideal time-descent paths that steer clear of the VRS and WBS areas is addressed. Ultimately, ideal paths were executed on a quadcopter. The flying tests demonstrated that the quadcopter may descend significantly faster by adhering to the intended trajectories than by using only vertical routes, which also avoids the VRS and WBS [7].

Chen and Meng investigated a method that adjusted pesticide spraying based on plant height. A depth sensor and spraying system with several nozzles positioned at various vertical heights were part of the system. The automated guided car has a complete system installed. For systems with fixed nozzle heights, plant recognition, and plant height calculations are essential for implementing precision spraying or autonomous targeting [8].

In the last ten years, Hafeez et al. conducted an examination of drone technology and how it has changed over time in the agricultural industry. It has been discussed how drones can be used in precision agriculture (PA) to spray pesticides and monitor crops. The development of various sensors, drone structures, and spot-area spraying innovations have been presented [9]. Abdullahi et al. discussed how the use of UAVs for photo collection, processing, and analysis is transforming agriculture into precision agriculture [10].

The market for precision agriculture, design and development of spray robot technologies, including those for terrestrial and aerial platforms, spray technologies and their application mechanisms, different spraying techniques catered to particular pests and vegetation, and evolution of sensor technologies for precision spraying were the main topics of discussion in Lochan et al.'s systematic overview of recent developments in precision delivery technology within agricultural robotics. In addition, they investigated state-of-the-art robotic technologies applied in precision agriculture [11].

Hanif et al. reviewed the research trends in the application of semi-automatic techniques and land-specific platforms for precision spraying. The use of an autonomous control system, coupled with a selection of hardware, such as microcontrollers, sensors, pumps, and nozzles, offers the performance necessary to accomplish spraying precision, UAV performance efficacy, and flexibility in meeting plant pesticide requirements. The consequences of the ongoing research are discussed in this study. To aid future research, a comparison of hardware, control system methodologies, and data collection from each study's parameters is provided [12].

Chen et al. pointed out that the majority of these characteristics may make the UASS drift unavoidable. However, by fine-tuning the structural layout of the rotor and spraying system, changing the operating settings, and creating a drift buffer zone, this drift may be efficiently minimized. To create drift models from typical models, crops, and climate conditions, explain common methods for assessing UASS drift, and properly characterize the drift features of UASS, further work remains [13].

WORKING

The transmission of signals in the drone entails their origin from the transmitter and subsequent reception by the drone receiver. Upon reception, the signals are processed within the flight controller, where both the accelerometer and gyroscope sensors contribute to the analytical procedures. Following processing, the signal is conveyed to the ESC, which, contingent on the received signal, regulates the current directed to the motor. This orchestrated process induces rotation in the propellers, generating the required thrust for the drone's propulsion.

Concurrently, the propulsion system involves a pump that draws electrical current from the Li-Po battery, facilitating the compression of the liquid stored in the reservoir, as shown in Figure 1. The pressurized liquid traverses a conduit, ultimately reaching a nozzle from which it is dispensed in a spray pattern. The pump's fluid displacement rate is subject to manipulation through the adjustment of the input current, a parameter conveniently regulated via the transmitter. This affords precise control over the liquid propulsion system, contributing to the versatility and adaptability of the operational dynamics of the drone [14].

MATERIAL FOR AGRICULTURAL SPRAYING DRONE

Motor

The Brushless Direct Current (BLDC) motor, specifically EMAX ECO 2, operates without brushes and incorporates a permanent magnet. The revolution per minute (RPM) of the motor was modulated by adjusting the input current. The motor is illustrated in Figure 2. This design eliminates the need for brushes, which contributes to increased efficiency and reduced wear. Furthermore, when paired with a propeller, the EMAX ECO 2 motor yields a maximum thrust of 2100 g, showing its robust performance in generating a propulsive force [7].

Propeller

The propeller measures 10 inches in length and is crafted from high-quality plastic, chosen for its notable strength-to-weight ratio, in contrast to propellers fashioned from plastics. The propeller is illustrated in Figure 3. This selection of material contributes to enhanced performance and durability in the context of propeller function [8].

Battery

For optimal performance in this configuration, the recommended battery is a Li-Po (Lithium Polymer) battery with a capacity of 2500 mAh and a voltage of 14.8 V. This specific Li-Po battery was structured with four cells connected in series, each possessing a nominal voltage of 3.7 V. The battery shown in Figure 4 shows the battery. The cumulative voltage of the four cells (4 × 3.7 V) resulted in an overall voltage of 14.8 V, which aligned precisely with the requirements of the system. This battery setup ensures compatibility and efficient power delivery to support the BLDC motor and associated component requirements.

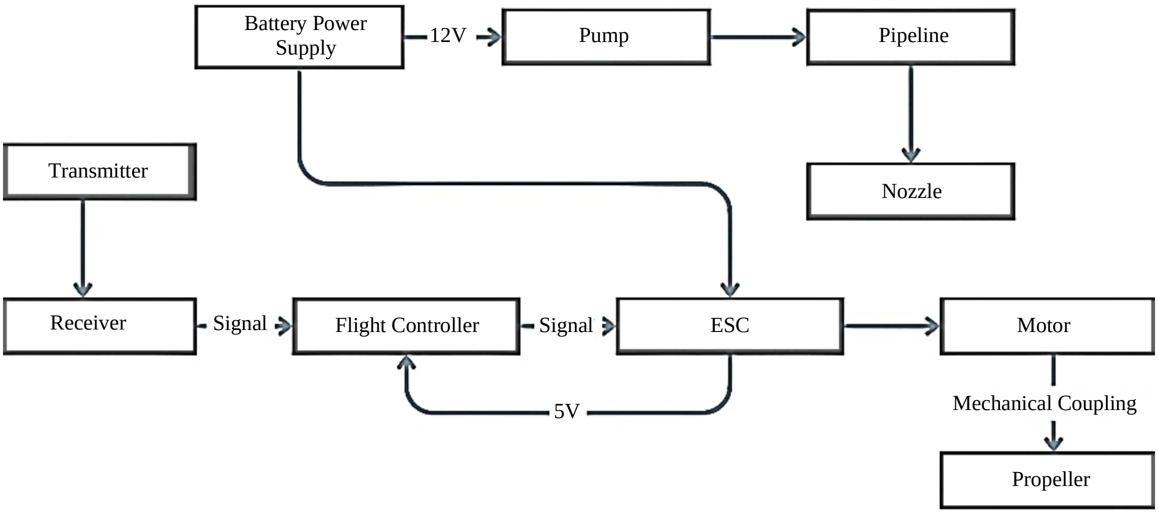

Figure 1. Block diagram of spraying drone.

Figure 2. BLDC motor.

Figure 3. Propeller.

Figure 4. Battery.

Figure 5. Electronic speed controller.

ESC

ESC stands for an electronic speed controller, a device used to modulate the RPM of an engine. ESC 40A was used in this project. ESC is shown in Figure 5. In accordance with the motor and battery specifications, a 40 A rated ESC was used to ensure optimal performance and compatibility within the system.

Flight Controller

The DJI Naza Multirotor V2 flight controller plays a pivotal role in the maneuvering operations of the drone, boasting an auto-level function for enhanced stability during flight. It efficiently processes signals from the receiver, accelerometer, and gyroscope sensors integrated into the system, as shown in Figure 6. The Naza V2 Flight Controller, renowned for its reliability, was selected for the drone because of its seamless integration with built-in firmware. This firmware ensures smooth operation and compatibility with the hardware components of drones. Moreover, the controller simplifies the calibration process, offering user-friendly features for precise sensor calibration. Powered by an advanced 32-bit microcontroller, DJI Naza V2 delivers robust performance in drone control and navigation tasks, providing pilots with a high level of confidence and control.

Radio Transmitter and Receiver

The transmitter and receiver employed in this system are the FlySky FS-i6S 2.4 GHz 6CH and FS-iA6B, respectively. This combination offers a communication range of approximately 1000 m. The FlySky FS-i6S transmitter and FS-iA6B receiver provide up to six channel options, allowing versatile and precise control over the drone’s functionalities. The radio transmitter and receiver are illustrated in Figure 7.

Pump and Nozzle

The system relies heavily on a 12 V DC water pump with a 2.5 L/min capacity to provide successful liquid pressurization. After pressurization, the fluid was directed into a flat jet nozzle that was specifically designed to disperse the material in an effective and focused manner. This flat jet nozzle is an improvement over the nozzle type chosen for its accuracy and efficiency. Four of these flat jet nozzles are part of the integration; they are carefully positioned at 45 cm intervals and delicately linked with ducting. The pump is shown in Figure 8. Careful planning guarantees that the liquid is distributed throughout the designated region efficiently and consistently.

Figure 6. Flight controller.

Figure 7. Radio transmitter and receiver.

Figure 8. Pump and nozzle.

WEIGHT OF DRONE

Current output from battery= 2500 mAh

Total current consumption of all components = 42.8 A (as calculated in Table 2)

The overall weight of the drone was calculated by adding the total weight of the components to the weight of the payload, as shown in Table 3.

Table 2. Current requirement table.

Component	**Current required (in Amperes)**
Motor	40
Receiver	0.1
Flight controller	0.1
ESC	0.1
Pump	2.5
Total	42.8

Table 3. Weight table.

Parts	**Weight (in grams)**
Frame	282
Battery	100
Motor (4)	133.6
ESC + Power distributor	174
Propeller	80
Flight controller	38
Total	867.6

Overall weight = Payload + Weight of components
= 1100 + 867.6
= 1967.6 grams (approx.)

THRUST CALCULATION

For enhanced maneuverability and the ability to ascend to higher altitudes at an increased climb rate, the thrust developed at 100% RPM is engineered to be three times greater than the total weight of the drone. This strategic design choice optimizes the performance capabilities of the drone, ensuring greater agility and capacity to navigate diverse terrains and altitudes with efficiency. Thrust produced by propeller with motor= 2100 g

Total thrust produced = 4 × 2100 = 8400 grams
To calculate the thrust-to-weight ratio, we consider a 50% thrust of the total thrust.

Thrust-to-weight ratio = Thrust produced/total weight of the drone
= 4200/1967.6
= 2.14:1

Battery Drain Time Calculation

To ensure comprehensive coverage and operational efficiency, the battery drain time was set to >10 min. This duration allows the drone to empty the storage tank during a single operation, providing subsequent refills for continued service. To account for safety measures, the calculation of the battery drain time considers the distance covered and the time required for the drone to return safely after completing its mission. This approach ensures a margin of safety, enabling the drone to fulfill its tasks effectively and return to the base securely. The proposed drone is shown in Figure 9.

Figure 9. Spraying drone model.

Battery endurance = current output from battery/total current consumption of all components
= 2500 mAh/42.8 A
= 2.5×60/42.8 A
= 03.50 mins (at 100% throttle)

CONCLUSION

This study outlines the design of a drone mounted spraying mechanism tailored for agricultural purposes and disinfectant applications. The proposed method significantly diminishes the need for manual labor, reduces time and costs, and mitigates the risks associated with personnel exposure during liquid spraying operations in agricultural fields. Moreover, the versatility of this drone extends to spraying disinfectant liquids, making it applicable to the disinfection of buildings, water bodies, and densely populated areas. The multifunctional capabilities of drones enhance efficiency and contribute to safer and more streamlined spraying processes in both agricultural and disinfection contexts.

Future Scope

The transition from manual to autonomous control is facilitated by integrating GPS technology and incorporating an auto-return-home option. This enhancement allows the drone to operate autonomously, leveraging GPS for precise navigation and ensuring a seamless return to its designated home point. The integration of these advanced features not only simplifies the control but also enhances the overall efficiency and reliability of the drone, enabling more sophisticated and automated operations.

By employing image processing techniques, drones can be effectively utilized in surveillance tasks to assess the extent of pest attacks on plants and monitor the conditions of ripening fruit. This application enhances the drone's capabilities beyond spraying, providing valuable insights into crop health and aiding timely interventions for pest management and harvesting. The integration of image processing technology adds a layer of intelligence to the drone's functions, contributing to more informed decision-making in agriculture.

Improving the energy efficiency of drones and advancements in battery technology can extend flight times and increase the overall operational range of agricultural spraying drones. This is crucial for covering larger farms and for reducing the need for frequent recharging.

Agricultural spraying drones can be integrated into precision agriculture systems, allowing for the targeted and precise application of fertilizers, pesticides, and herbicides. This innovative technology can enhance crop yields, reduce environmental impacts, optimize resource utilization, and revolutionize modern farming practices.

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