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Design and Development of Quadcopter for Agro-Chemical Spray in Agricultural Field

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Abstract

The advent of Agricultural Drones promises to revolutionize modern farming practices by employing autonomous drones for crop surveillance and pesticide application. Outfitting quadcopters with spraying mechanisms presents numerous advantages over traditional methods. Firstly, it facilitates precise and targeted application of agro-chemicals, thereby minimizing wastage and environmental pollution. Furthermore, quadcopters exhibit the capability to effortlessly navigate challenging terrains, accessing areas previously unreachable by conventional spraying equipment and ensuring comprehensive crop coverage. Additionally, their autonomous operation or remote human supervision enhances operational efficiency, resulting in reduced labor costs. This initiative explores the integration of unmanned aerial vehicles (UAVs) into agricultural practices, specifically emphasizing their role in precisely spraying agro-chemicals. The project encompasses the entire development cycle, from design and development to the deployment of customized agricultural drones capable of autonomous flight and accurate pesticide distribution. The incorporation of quadcopters for precise agro-chemical spraying marks a significant advancement in agricultural technology, offering precision, efficiency, and sustainability. Ongoing research, development, and collaboration play a crucial role in realizing the transformative benefits of this innovative approach, ultimately enhancing agricultural productivity and environmental stewardship.

Keywords: *DJI Naza-M Lite Flight Controller; Brushless DC Motors; GPS Module; ESC.*

1. Introduction

Modern agriculture encounters a range of difficulties such as labor shortages, limited resources, and environmental issues. Conventional farming practices heavily depend on manual labor and sometimes excessive pesticide use, resulting in inefficiencies and harm to the environment. Agricultural drones present a viable solution by facilitating precision farming methods that enhance resource efficiency and reduce environmental harm. The Agricultural Drone project is dedicated to leveraging drone technology's potential to tackle these challenges and revolutionize agricultural methods. Modern agriculture faces the dual challenge of meeting increasing food demand while minimizing environmental impact and resource consumption. To address these challenges, innovative technologies are being explored, and one such promising advancement is the utilization of quadcopters for agro-chemical spraying in agricultural fields. Quadcopters, or unmanned aerial vehicles (UAVs), equipped with spraying mechanisms offer a novel approach to precision agriculture, promising precise application of agro-chemicals while reducing wastage and environmental contamination [1]. The integration of quadcopters into agricultural practices heralds a new era of precision agriculture, where chemicals can be applied with unprecedented accuracy, minimizing environmental impact and maximizing crop yield. Furthermore, the autonomous operation capabilities of quadcopters or their remote human supervision offer opportunities for increased operational efficiency and reduced labor costs.

2. Literature Survey

The primary purpose of a literature review is to define the research issue, which includes evaluating the existing knowledge on the subject, identifying knowledge gaps, and formulating research questions that need resolution. This process also involves examining various methodologies for studying the problem and choosing the most promising approach. This section outlines the optimal techniques drawn from diverse research studies that are well-suited for the proposed design. Prof. Aleksandar Icezic et al, in this study, the utilization of the DJI Matrice 100 drone and UAV imaging for efficient crop monitoring over large expanses is emphasized. [1] Prof. Ravindra Shende et al, the work discusses the adaptation of drones for efficient pesticide application, incorporating elements such as the HJ450 Frame and Electronic Speed Controller in quadcopter setups. [2] Joshua Anthony Fernandes et al, the paper presents the advantages of a lightweight, economical quadcopter in enhancing crop yield and quality. [3] Prof. Chern Han Sean Lee et al, details the refinement of spraying mechanisms in agricultural UAVs using advanced technologies and MATLAB for drone parameter assessment. [4] Prof. Laura García et al, focuses on drones equipped with thermal and remote sensors, along with Wi-Fi capabilities, for effective data communication between sensor nodes and for monitoring crops. [5] Sanad S, explores a mechanism for disinfectant spraying and UV light emission, utilizing multi-motor LCD flight control boards and UV lighting. [6] P.S. Mhetre et al, assesses drone efficiency in fertilizer application, using the ATMEGA 644PA microcontroller for drone control and navigation. [7] S R Kurkute et al, investigates the time-efficiency and health safety improvements provided by pesticide-spraying drones, managed with an 8051 microcontroller. [8] Prof. B. Balaji et al, stresses the advantages of lower noise pollution and reduced chemical exposure, using equipment like the L293D motor, power distribution board, and Raspberry Pi 3B in drone designs. [9] Yallappa D et al, examines spray parameters such as discharge rate, droplet size, density, swath width, and distribution uniformity in a hexacopter setup. [10].

3. Methodology

The design methodology for the Quadcopter system for Agro-Chemical Spray in Agricultural Fields is outlined below. Figure 1 illustrates the block diagram depicting the working process of the system. The proposed system comprises both hardware and software components. The hardware components include a Lithium-Ion Battery rated at 1000KV, BLDC Motors operating at 11.2V, a DJI (Da-Jiang Innovations) NAZA Flight Controller operating at 2.4GHz, a 6CH Remote, and a 12V DC Pump for spraying purposes. The design of the quadcopter frame takes into account factors such as weight distribution, stability, and payload capacity. The system incorporates four Electronic Speed Controllers, each paired with its respective BLDC Motor. The DJI NAZA controller plays a central role in this system by utilizing GPS signals for navigation. Additionally, the compass provides directional information to the controller. Signals from the DJI NAZA flight controller are transmitted to the Electronic Speed Controllers, which monitor and control the quadcopter's speed. The Electronic Speed Controllers regulate the rpm of the BLDC motors accordingly. The Lithium-Ion Battery serves as the primary power source for both the quadcopter and the DC pump used for spraying. Upon powering up the system, the LED indicators activate, signaling the propellers to begin rotating. This setup ensures the efficient operation of the quadcopter system for agro-chemical spraying in agricultural fields.

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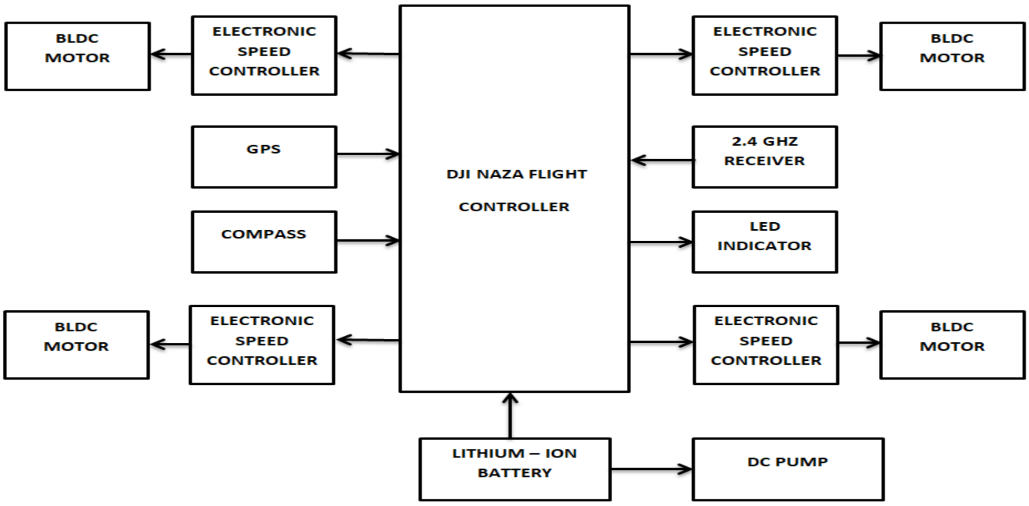

Figure 1 Block Diagram of Quadcopter for Agro-Chemical Spray

The below Figure 2 depicts the block diagram illustrating the operational flow of the Sprayer Module. The pump is integral to pressurizing the liquid designated for spraying, while the tank securely contains the liquid until it is needed for application. Controlled liquid release is managed by the spray nozzle, which dispenses the liquid in a targeted manner, often as a fine mist, ensuring precise coverage. The GPS module tracks the sprayer's location, enabling accurate positioning during operations, which is particularly valuable for large-scale agricultural applications. An actuator is employed to move specific parts within the system in response to received signals. The antenna functions as the communication interface, facilitating signal transmission and reception with external devices or systems. The decoder plays a crucial role in interpreting and translating coded information embedded within signals, ensuring seamless communication and operation. Furthermore, the RF receiver is vital for capturing radio waves and converting them into electrical signals that the system can process and act upon. Together, these components form a cohesive system that enables precise and efficient liquid spraying operations, enhancing productivity and effectiveness in agricultural tasks.

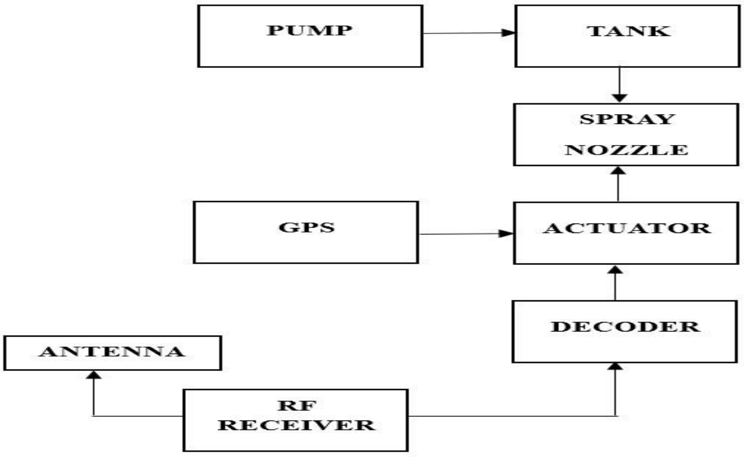

Figure 2 Block Diagram of Sprayer Module

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4. Flowchart

The algorithm for the proposed Design and Development of Quadcopter for Agro-Chemical Spray in Agricultural Field, as illustrated in Figure 3, outlines a series of sequential steps involved in its operation. It begins with initializing the quadcopter for takeoff. Subsequently, the quadcopter navigates towards predetermined waypoints, typically representing the designated spraying area. The system then checks if the quadcopter has reached these designated waypoints. If not, the quadcopter continues its flight path towards the waypoints. Conversely, if the quadcopter has reached the waypoints, the system verifies if all waypoints have been reached to ensure complete coverage of the spraying area.

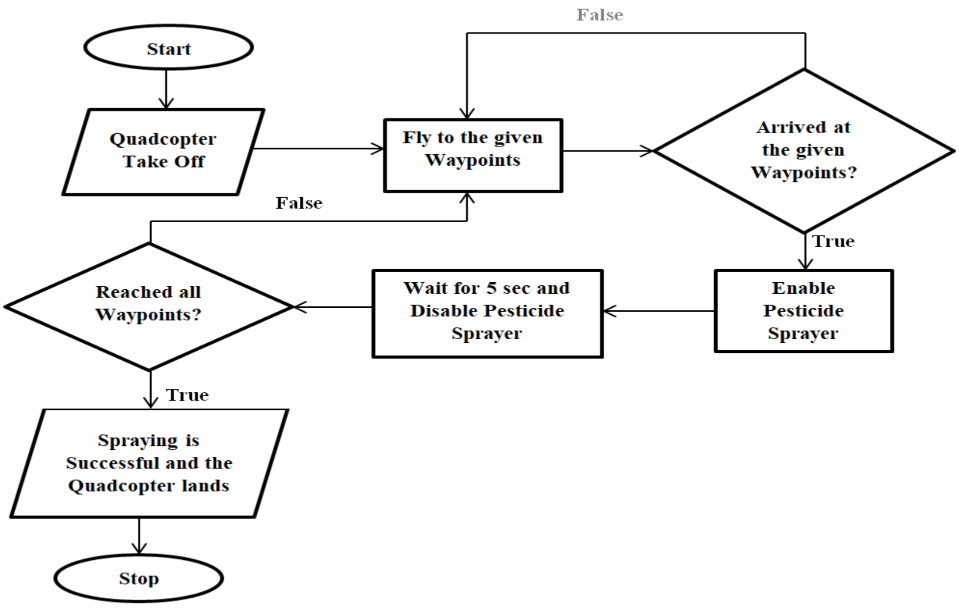

Figure 3 Flowchart of Quadcopter for Agro-Chemical Spray

Once all waypoints have been reached, the system activates the pesticide sprayer for a predefined duration, typically five seconds, before deactivating it. Following the completion of spraying, the quadcopter executes a successful landing, indicating the conclusion of the process. This systematic approach ensures precise and efficient spraying operations in agricultural fields using the quadcopter system.

5. Hardware Description

The main hardware components used in this work are DJI Naza Flight Controller, ESC, DJI F450 Quad Copter Frame, BLDC Motors, Propellers, Li-Po Battery, Radio Controller, Nozzle, Submersible Pump, GPS and Compass.

5.1. DJI (Da-Jiang Innovations) NAZA-M Flight Controller

Figure 4 DJI Naza-M Flight Controller

The DJI Naza-M is a flight controller from Da-Jiang Innovations (DJI), recognized for its contributions to drone technology and aerial

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imaging. The Naza-M incorporates features such as intelligent orientation control and voltage protection. The hardware interface of the system is depicted in Figure 4.

5.2. Electronic Speed Controller

Figure 5 Electronic Speed Controller

An Electronic Speed Controller (ESC) is crucial for the operation of drones, mainly controlling the motors' speed and direction as shown in Figure 5. It transforms the DC electricity from the battery into a three-phase AC signal that energizes the motor windings, enabling precise regulation of motor speed.

5.3. DJI F450 Quad Copter Frame

Figure 6 DJI F450 Quad Copter Frame

The DJI F450 is a popular quadcopter frame extensively utilized by both hobbyists and professionals for drone construction and customization. Created by DJI Innovations, the F450 is durable and has a lightweight design, crafted primarily from high-strength polymer materials as depicted in Figure 6.

5.4. BLDC Motors

Figure 7 BLDC Motor

BLDC (Brushless DC) motors are fundamental to drone technology, providing significant improvements over traditional brushed motors. These motors drive the propulsion systems of drones, powering the propellers necessary for flight as shown in Figure 7.

5.5. Propellers

Figure 8 Propeller

The propellers transform the rotational energy from the drone's motors into aerodynamic lift by pushing air downward, thus generating an upward force that elevates the drone. The specific design and dimensions of the propellers significantly influence the drone's efficiency, stability, and performance, as illustrated in Figure 8.

5.6. Radio Controller

The controllers generally use radio frequencies, often in the 2.4 GHz spectrum, which provides a strong mix of range and interference resistance.

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Figure 9 Radio Controller

The system includes a transmitter, which the pilot uses to send commands like direction changes, throttle settings, and mode switches as depicted in Figure 9.

5.7. Lithium Polymer Battery

Figure 10 LiPo Battery

Lithium Polymer (LiPo) batteries are favored in contemporary drone technology for their high energy density and ability to support high discharge rates. Comprising multiple cells with a standard nominal voltage of 3.7 volts each, these cells can be configured in series to provide the higher voltages required by various drone models as shown in Figure 10.

5.8. GPS and Compass

Figure 11 GPS and Compass

The GPS (Global Positioning System) module supplies real-time geographic positioning, enabling the drone to pinpoint its exact location relative to the ground as depicted in Figure 11.

5.9. Nozzle

Figure 12 Nozzle

Nozzles are used for aerial spraying tasks such as pesticide and fertilizer distribution in agricultural settings. Modern nozzles may also feature adjustable spray rates and droplet size adjustments, which can be dynamically regulated by the drone's flight control system, as illustrated in Figure 12.

5.10. Submersible Pump

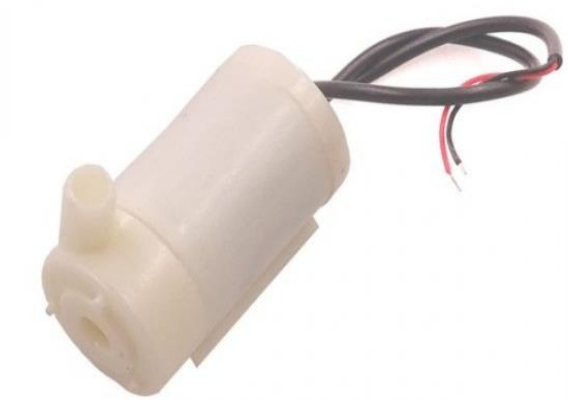

Figure 13 Submersible Pump

A submersible pump is engineered to function while fully immersed in the fluid it is tasked with moving. This type of pump differs from surface pumps by pushing fluid to the surface rather than drawing it upward as depicted in Figure 13.

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6. Software Requirements

The software requirements for the system include embedded firmware for the drone's onboard systems and ground control software for overseeing mission planning and execution.

6.1. Embedded Firmware

Embedded firmware is essential for managing the drone's flight dynamics, processing sensor inputs, and overseeing autonomous operations. Key components of the embedded firmware include:

- Flight Controller Firmware: The software runs on the drone's flight controller which process data from sensors and implements flight algorithms.
- Sensor Drivers: It includes drivers for connecting with onboard sensors such as GPS and compass for processing navigational and environmental data.
- Communication Protocols: It implements protocols for sending telemetry data to ground control and receiving commands.

6.2. Ground Control Software

This software offers an intuitive interface for planning missions, monitoring the drone in real-time and controlling its operations. It enables users to set flight paths, designate waypoints and initiate autonomous flights while viewing telemetry data.

6.3. DJI Naza Assistant Software

A desktop application provided by DJI for the setup and calibration of their Naza-M Lite flight controllers. The key capabilities include Sensor Calibration, Parameter Configuration and Firmware Updates.

7. Results

The quadcopter is efficient and robust for the described application of spraying. The below given Figure 14 shows the calibration of Naza-M V2. The DJI Naza-M V2 software enables users to manage and adjust the settings of DJI Naza flight controllers, which are commonly used in drones for aerial photography and videography. This software facilitates the modification of flight settings, sensor calibration, selection of flight modes and firmware upgrades to maintain the drone's performance and stability.

Figure 14 Calibration of Naza-M V2

The below given Figure 15 is a SolidWorks model of agricultural quadcopter with a spraying mechanism. It is helpful in spraying fertilizers, pesticides and crop protection products while being controlled by a single person operating from a safe and secure location.

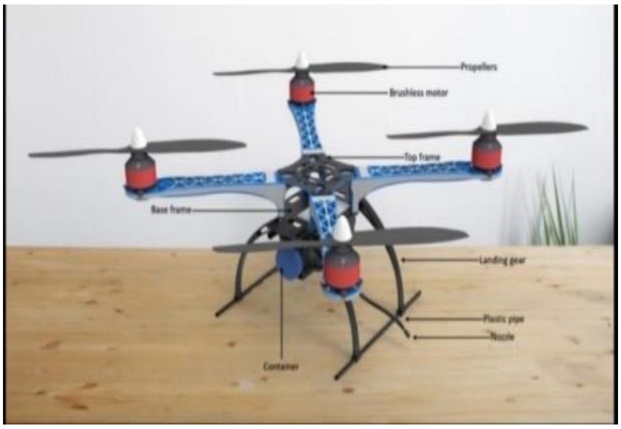

Figure 15 SolidWorks Model of Agricultural Quadcopter with Spraying Mechanism

The below Figure 16 and Figure 17 are the Side View and the Top View of the Quadcopter for Agro-Chemical Spray.

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Figure 16 **Side View of the Quadcopter**

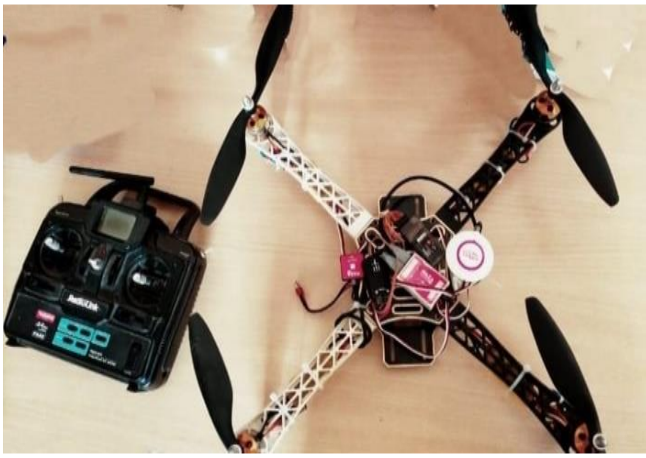

Figure 17 **Top View of the Quadcopter**

8. Future Scope

To enhance agricultural drone capabilities, integrating advanced sensing technologies like multispectral and hyper spectral cameras can significantly improve the monitoring of vital crop health metrics, including chlorophyll levels and pest presence. Leveraging artificial intelligence for the analysis of imagery data can deliver actionable insights in real-time, streamlining precision farming practices. These innovations aim to prolong flight times and lessen the agricultural sector's carbon footprint by reducing reliance on traditional energy sources.

Conclusion

This project encompasses the development of a fully operational agriculture drone designed to transport and spray water or pesticides across crops with precision. It offers meticulous control over flight patterns and spraying actions, ensuring consistent coverage and minimal wastage. Compared to traditional manual or tractor-mounted spraying techniques, this system delivers heightened efficiency and effectiveness. The implementation of this drone system promises notable reductions in labor expenses and environmental footprints through targeted and optimized spraying practices. By demonstrating the feasibility and practicality of employing drones in agricultural tasks, this project sets the stage for future innovations in farming technology. This advancement not only showcases the potential benefits of drone usage in agriculture but also emphasizes the importance of embracing technological solutions for sustainable and efficient farming practices.

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