Designing Agricultural Fertilizer Drone for Surveillance with Optimized Spraying Mechanism

A project thesis submitted in partial fulfillment of the award of the degree of Bachelor of Electrical engineering

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Author's Declaration

We hereby declare that we are the sole authors of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. It is further declared, that I have fulfilled all the requirements in line with the Quality Assurance guidelines of the HEC/PEC.

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Abstract

Agricultural spraying drone is an innovative method of modern agriculture that has many advantages for farmers. Precise application of insecticides, herbicides, and fertilizers is made possible by these drones' specialized sprayers, resulting in a more effective use of chemicals and lower costs for farmers. Drones used for agricultural spraying can quickly cover large areas of farmland, saving time and labour over more traditional spraying techniques. Drones used for agricultural spraying are beneficial to the surrounding environment. These drones target certain crop areas, lowering the quantity of chemicals required for treatment and lowering pollutants and runoff that could impact around water sources and aquatic life. Drones used for agricultural spraying may help in lowering greenhouse gas emissions and soil compaction caused by conventional agricultural practices. However, there are a number of issues that need to be resolved when using drones for agricultural spraying. Cost, regulation, safety issues, limited time during flights, technical skills, weather, and data handling are a few of these difficulties.

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Table of Contents

List of Figures

List of Tables

List of Acronyms

UAV: Unmanned Aerial Vehicle

IMU: Inertial Measurement Units

GPS: Global Positioning System

CW: Clock Wise

CCW: Counter Clock Wise

BLDC: Brushless DC

ESC: Electronic Speed Controllers

IOC: Intelligent Orientation Control

RTH: Return-To-Home

CNC: Computer Numerical Control

LCD: Liquid crystal display

MTOW: Maximum Takeoff Weight

LIDAR: Light Detection and Ranging

AI: Artificial Intelligence

LiPo: Lithium-polymer

NDVI: Normalized Difference Vegetation Index

DJI: Da-Jiang Innovation

Chapter 1 Introduction

1.1 Background

An unmanned aerial vehicle used for this purpose is the agricultural product spraying drone, often known as a crop sprayer drone or an agricultural UAV. For spraying crops with fertilizers, pesticides, and other chemicals, these drones contain tanks and spray nozzles. Compared to traditional crop spraying methods, using drones for agricultural spraying has a variety of advantages, including increased efficiency, accuracy, and safety. They can more accurately distribute chemicals, cover huge areas of ground quickly, and get too hard-to-reach spots while producing less waste and having no negative environmental effects. By eliminating the need for pilots to fly low over fields, they also reduce the risk of mistakes and improve worker safety.

The use of drones for agricultural spraying has several benefits. It reduces the need for manual labour, reduces the exposure to pesticides for humans, and increases worker safety. Additionally, it allows for precise application, reduces waste, and has a minimal negative environmental impact.

In countries with important agricultural businesses including the United States, China, and Brazil, drones for agricultural spraying are becoming more and more prevalent. As technology advances, it may fundamentally alter how crops are looked after for and sprayed, opening up new opportunities for the agricultural sector's growth and expansion.

Japan was the first nation in using drones for agricultural spraying in the early 1990s, concentrating on rice fields. This was the first step in the development of drones for agricultural spraying. Drone technology has greatly advanced over time, becoming more complex and high-tech. Modern agricultural spraying drones have modern sensors and algorithms that enable them to scan fields, identify problem areas, and apply pesticides precisely where they are needed. Commercial UAVs were developed in the 1990s for environmental and agricultural applications, but consumer drones weren't readily accessible for both commercial and private use until the 2010s. Drones are widely used in a variety of industries, including agricultural, environmental monitoring, surveying and mapping, search and rescue, photography, and more, because to their accessibility and affordability. The increase in drone usage has been a major factor in the development of the drone business. [9]

Future applications of drone technology are predicted to grow more inventive and useful as they develop. Drones are likely to find unique applications in many industries, including agricultural, with continued study and development. Drones have the ability to revolutionize farming techniques including precision farming and focused crop spraying, which has the potential to boost productivity, minimize negative environmental effects, and increase efficiency.

1.2 Problem Statement

Future uses of drones are anticipated to become increasingly more inventive and useful as the technology develops. Drones are likely to find advanced uses in a variety of industries, including agriculture, as long as research and development continue. Precision farming and targeted crop spraying are two farming techniques that drone technology has the potential to modernize. This has the potential to boost efficiency, limit environmental impact, and boost overall agricultural yield.

One of the main concerns is the potential environmental impact of spraying herbicides on crops using drones. Pesticide pollution of nearby water sources, runoff, and non-target animals like bees and other pollinators is a potential concern. The high cost of purchasing and employing drones for agricultural spraying is another problem. Despite the fact that these drones have the potential to significantly reduce chemical use and boost crop yields, many farmers, particularly those operating small farms, may find it too costly to purchase a drone, maintain it, and use it continuously. There are additional regulatory barriers associated with the use of agricultural spraying drones because many countries have severe regulations regulating the use of drones for commercial purposes.

1.3 Objectives

The goal of this project is to construct a quadrotor-style unmanned aerial vehicle (UAV) with a camera and wireless communication system to enable immediate environment surveillance. The following goals are listed.

- Design and build an Agricultural Spraying Drone with a 2-liter spraying capacity for efficient application of pesticides and fertilizers with 3kg weight of vehicle.
- Integrate a live video transmission system to enable monitoring of drone operations from a ground station.
- Assemble the UAV using necessary components.
- To design a mechanism for controlling the spraying system.

1.4 Thesis Organization

The thesis is organized as follows:

Chapter 1: Introduction

The background of the research topic is discussed in this chapter, giving context and emphasizing the significance of the investigation. The exact problem or topic that the research is intended to address is explicitly mentioned in the problem statement. To provide the research a clear direction, the goals of the study are specified. The structure and flow of the following chapters are examined as well in relation to the thesis organization. The study's boundaries and restrictions are outlined in the research's established scope.

Chapter 2: Literature Review

This chapter focuses on performing an in-depth assessment of the relevant literature. It entails a critical analysis of already published scholarly works, including books, journal articles, and other pertinent sources. The literature review identifies gaps, issues, and trends in the body of knowledge and offers a theoretical framework for the study. It helps in laying the groundwork for the research and emphasizes the importance of the study in relation to earlier research in the topic.

Chapter 3: System Architecture

The system architecture for the quadcopter is thoroughly covered in this chapter. It starts off by going through the quadcopter frame, including its design and the benefits of employing carbon fiber. The chapter then looks into the parts of the quadcopter system, including the flight controller, electronic speed controllers, propellers, and brushless DC motors. The global positioning system (GPS), inertial measurement unit (IMU), power management unit (PMU), and DJI A2 flight controller are described in detail. The chapter also discusses the quadcopter calibration and the addition of water pumps and spray tank. The LiPo battery and the transmitter and receiver for the quadcopter system are also covered.

Chapter 4: Methodology

An outline of the research technique is provided in this chapter. It describes the overall strategy and offers a block diagram that shows the procedures and steps taken during the study.

Chapter 5: Quadcopter Design and Development

The design and development of the quadcopter are thoroughly covered in this chapter. It discusses topics including the quadcopter weight, payload capacity calculation, and the choice of suitable motors. The chapter also looks at factors to take into account while trying to get the quadcopter flying time to be as long as possible.

Chapter 6: Results and Discussion

This chapter discusses the research findings and offers a comprehensive analysis and explanation of them. It comprises charts, tables, and any other relevant information. The findings are then explained in relation to the study's goals, compared to previous research, and any shortcomings or unexpected results are addressed.

Chapter 7: Conclusion and Future Work

The thesis's concluding chapter presents an overview of the study's key results and formulates recommendations based on those findings. Additionally, it highlights the research's contributions, explores its implications, and proposes possible directions for additional study and advancement in the area.

References

A complete list of all the sources used to support the thesis is provided in this part, following a predetermined citation structure. The references give readers the knowledge they need to find and check the sources used in the study.

1.5 Scope

There are many applications for drone technology in agriculture spraying, and it is advancing swiftly. Farmers have been compelled to increase agricultural yields and efficiency since there will be more than 9.7 billion people on the planet by the year 2050, which would result in a rise in food consumption. Farmers can solve these challenges by using drones for agricultural spraying, which give them a precise and efficient means to monitor and spray crops. The scope of agricultural spraying drone technology includes the creation of modern drone hardware and software to improve flight performance, cargo capacity, and camera capabilities. There is a growing market for data analytics tools that can examine the data collected by agricultural spraying drones and provide farmers with perceptions on the health, development, and production potential of their crops.

Future applications of agricultural spraying drone technology are expected to increase the benefits to precision agriculture, environmental monitoring, and disaster relief efforts. As technology develops, the agricultural sector will have more opportunities for innovation and expansion, which will benefit both farmers and consumers.

Chapter 2 Literature Review

2.1 Literature Review

Agricultural spraying drones got more attention in recent years as a result of their effectiveness and precision in applying insecticides, herbicides, and other chemicals to crops.

Many studies have compared the effectiveness of agricultural spraying drones to more traditional spraying methods like human spraying or sprayers mounted on tractors.

In the study on the applications, requirements, and challenges of UAVs (drones) in smart agriculture, Maddikunta Reddy P.K. et al (2021) highlight the use of fixed-wing and multi-rotor UAVs as the primary types of drones employed in agricultural settings. While fixed-wing UAVs are better suited for long-distance operations and prolonged flight times, multi-rotor UAVs are very simple to produce and cost-effective. A number of possible uses for UAVs in smart agriculture are identified by the researchers as they investigate various agricultural sensors, such as optical, temperature-based, and location-based sensors. Aerial mustering, irrigation monitoring, artificial pollination, and the use of UAVs as "sky farmers" for obtaining a bird's eye view of farmland or livestock herds are some of these applications. Precision agriculture uses hyper spectral and multispectral cameras to capture high-quality images and derive vegetation indices like NDVI. The report emphasizes the significance of UAV enabling criteria for smart agriculture, including network accessibility, data storage capacity, farmer acceptance of the technology, result accuracy, and regulatory frameworks governing UAV use. [3]

In their comparative study on the application of UAV systems in agriculture, Rahman M.F.F et al. (2021) highlight the potential of UAVs to drive economic prosperity in developing countries by reducing health risks and labor requirements associated with manual pesticide spraying. UAVs, especially quadcopters, are ideal for agricultural uses since they are affordable, small, and have outstanding maneuverability. These airborne devices allow for precise fertilizer and pesticide application, reducing waste and improving laborers' working conditions. Nevertheless, difficulties including precise data interpretation, privacy problems, and complex spraying environments must be overcome. [2]

In their review on the impact of drone technology in agriculture, Rana V. and Mahima.et al. (2020) explore the diverse applications of drones and other technologies in the agricultural sector. Drones used to assess plant health are one of the main applications covered. Drones can quickly and effectively evaluate the general health of plants using specialized sensors and imaging technology. These sensors are able to pick up small changes in plant physiology, such as differences in chlorophyll concentrations or heat signatures, which can be signs of stress or illness. Drones can be used to constantly monitor crops, allowing farmers to spot possible problems early and take prompt action to stop additional damage, such as introducing tailored treatments or interventions. With the use of this technology, farmers may better allocate their resources, cut costs, and protect the general health of their crops, increasing yields and lowering losses. [8]

The research conducted by Beck et al. (2020) provides valuable insights into the use of drones for delivering adrenaline auto-injectors during anaphylaxis episodes. The study emphasizes the significance of surveying medical professionals about their impressions in order to gain their insightful opinions, as well as their acceptance of and objections to the use of drones for healthcare delivery, which can substantially aid in the planning and assessment of future missions. The study also emphasizes how important it is to keep pharmacopoeia recommendations for drugs quality and safety standards in mind throughout the entire delivery process. The most crucial factor that should be given priority when using drone technology in healthcare is patient safety. Future research into the use of healthcare drones will benefit greatly from the framework provided by this study, which encourages cooperation, adherence to regulations, and the best possible patient care. [10]

Prof. P. P. Mone, Chavhan Priyanka Shivaji, Jagtap Komal Tanaji, Nimbalkar Aishwarya Satish has published a paper in (2017) entitled “Agriculture Drone for Spraying fertilizer and Pesticides”. The authors of this publication go into great depth concerning the use of agricultural drones for autonomous spraying systems. The World Health Organization estimates that there are 3 million cases of pesticide poisoning each year, with up to 220,000 deaths, mostly in developing nations, according to the problem statement provided in this publication. They also discuss cost-effective technology that uses PIC microcontrollers to drive agricultural robots, as well as the precautions that farmers should take to prevent the damaging effects of pesticides and fertilizers. [7]

In their review on the application of drone systems in precision agriculture, Mogili U.M.R. and Deepak B.B.V.L. (2018) highlight the advantages of using drones for pesticide spraying, particularly in avoiding health risks associated with manual spraying. Drones have the potential to operate in hazardous environments where human intervention might be challenging. The use of multispectral cameras placed on drones for crop monitoring is described by the authors. These cameras take pictures during a single trip, and image analysis makes it simple to spot regions that need to be sprayed with pesticides. The autonomous navigation of the drone's sprinkler system then precisely directs the pesticides to the sick areas identified by the NDVI analysis of the plants. The research comes to the conclusion that these discoveries constitute the early days of drone applications in precision agriculture, with room for future technological and agricultural advancements. [4]

Overall, the study shows that agricultural spraying drones have a significant potential to improve the efficacy and efficiency of applying pesticides and other chemicals to crops. But there are problems with their possible environmental effects and regulatory issues that need to be fixed.

2.2 Challenges

The use of drones for agricultural spraying faces a variety of challenges that must be overcome. Several of these challenges are as follows:

- **Price**: Agricultural spraying drones may not be as affordable for smaller farms or farmers with limited resources due to their high maintenance and purchasing prices.
- **Regulation:** A number of countries have regulations and limits on the use of drones for agricultural spraying, so farmers may need to obtain permits or licenses in order to use them. This may increase the cost of adoption and create logistical difficulties.

- **Safety issues:** The use of drones in agricultural settings presents safety concerns, particularly in light of the possibility of collisions with other aircraft, wires, and other obstructions. It's critical to consider any potential issues related to the spraying chemicals.
- **Limited flight time**: Agricultural spraying drones frequently have a brief flight time, forcing multiple flights to cover larger fields. The cost and time of spraying operations can go up as a result.
- **Technical training and expertise:** The use and maintenance of agricultural spraying drones require technical training and knowledge, which may not be readily available to all farmers.

Chapter 3 System Architecture

Selecting quadcopter parts for agricultural spraying involves a lot of considerations**.**

3.1 Frame

The physical structure that holds and connects all of the quadcopter parts, including the motors, propellers, flight controller, battery, and other electronic devices, is referred to as the quadcopter frame, also known as the quadcopter architecture or frame structure. It gives the system as a whole rigidity, strength, and stability.

Typically, quadcopters feature four arms, one motor and propeller on each arm to ensure even weight distribution. Motor mounts provide a stable connection by fastening the motors to the arms. Landing gear, which are additional components attached to the bottom of the frame and serve as support, safety during takeoff and landing, and stability when the quadcopter is at rest on the ground, may be found on some quadcopters. The battery is safely stored in the battery section, which is normally found in the middle of the frame. By keeping the battery close to the centre of gravity, this maintains stability. The frame also has mounting holes, which are pre-drilled openings that provide the installation of various parts, including the GPS unit, camera, and other accessories.

Table 1: Frame Discription

Description	Specification
Frame Type	Quadcopter frame
Material Selection	Strong and lightweight materials, such as carbon fibre
Frame Shape	H-shaped frame (X- Configuration)
Dimension	Length: 610mm, Width: 460mm
Mounting Points	Mounting holes for components that are placed in a strategic manner
Payload Capacity	Total 5 kg with drone weight

3.1.1 Quadcopters Frame Configuration

Quadcopters and quadrotors are terms used to describe unmanned aerial vehicles (UAVs) with four rotors. They are frequently used for a variety of functions, including social interactions, surveillance, inspection, and aerial photography. A quadcopter configuration refers to the position and orientation of its four rotors.

The quadcopter "+" configuration is the most popular. The four rotors are organized in the shape of a plus sign (+), with two rotors placed in the front and two in the back. With this configuration, the quadcopter is stable and flexible enough to hover, travel in any direction, and rotate.

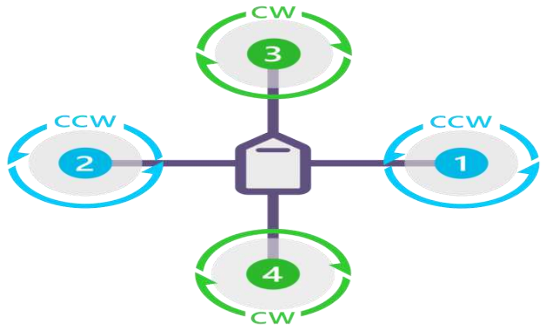

Figure 1: "+" Configuration

Another common layout is the "X" shape. With two front rotors set and two rear rotors inclined in the opposite direction, the quadcopters' four rotors are arranged in the shape of an X. The flight qualities of the "+" configuration are similar to those of the "X" configuration, however stability and responsiveness may vary significantly.

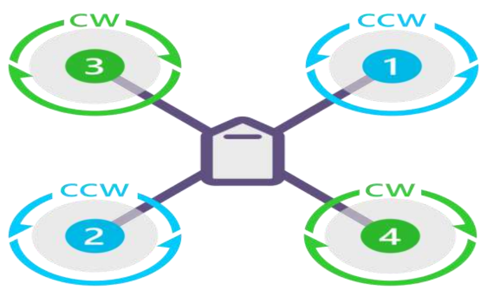

Figure 2: "X" Configuration

Other unusual configurations include the "H" and "V" configurations. In the "H" layout, the front and back rotors are arranged horizontally, while the two side rotors are arranged vertically. The "V" configuration, on the other hand, has two front rotors mounted vertically and two rear rotors mounted horizontally. These configurations are more popular in certain applications but less common overall.

It should be mentioned that each rotor speed needs to be properly managed for quadcopters to be stable and under control. By changing the rotor's speed, the quadcopter can change its altitude, position, and direction of flight. The rotor speeds are controlled by advanced flight control systems that continuously track the quadcopter position and make necessary modifications to maintain stability.

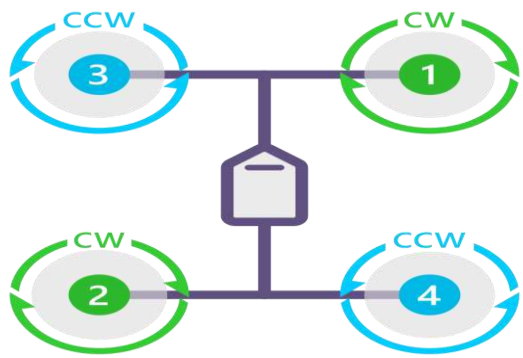

Figure 3: "H" configuration

A brushless DC motor with a fixed-pitch propeller is mounted to each arm in Fig. 3 so that the rotor may direct the air flow downward and generate the lift force. Two rotors rotate in the clockwise direction (CW) and two more rotate in the anticlockwise direction (anticlockwise; CCW). Thus, it is clear that the rate of motor rotation alone determines the quadcopter dynamic motion.

3.1.2 Advantages of Carbon Fiber frame:

- **Strength:** The strength of carbon fiber is well known, especially when compared to other materials. It can support the weight of the payload and withstand potential impacts while in flight because to its high tensile strength.
- **Lightweight:** Carbon fiber is much lighter than a few other materials that are typically used for frames, such aluminum or steel. The aircraft's reduced weight allows it to travel farther and carry a heavier payload without losing structural integrity.
- **Rigidity:** Flight stability is made possible by the strong elasticity and rigidity of carbon fiber frames. This rigidity allows precise control over the drone's movements and reduces the risk of spraying equipment damage by minimizing flexing and vibration.

- **Corrosion resistance**: Carbon fiber is naturally resistant to corrosion, unlike materials like steel or aluminum that may rust or degrade over time. When working with chemicals regularly utilized in spraying applications, this resistance helps to extend the frame's lifespan and is very helpful.

Overall, a well-designed frame for an agricultural spraying drone combines structural integrity, lightweight construction, and thoughtful features to ensure stability, durability, and safe operation throughout the drone's lifespan.

3.2 Brushless DC motors

Electric motors that run on direct current (DC) and use electronic commutation to control rotation are known as brushless DC (BLDC) motors. BLDC motors, in contrast to conventional brushed motors, have a more sophisticated design that includes numerous stationary coils (windings) on the stator and permanent magnets on the rotor. The permanent magnets interact with the spinning magnetic field produced by the sequentially energized stator windings to produce continuous rotation.

Compared to brushed motors, BLDC motors have a number of advantages. Their improved efficiency is a key benefit. BLDC motors endure less friction and electrical losses due to the lack of brushes and commutators, which increases efficiency and decreases heat generation. Longer battery life and better performance are results of this greater efficiency. The increased power-to-weight ratio of BLDC motors provides an additional advantage. They are frequently smaller and lighter than brushed motors of comparable power, which makes them ideal for applications where weight and size are crucial considerations, including in drones and electric vehicles. Better flexibility and enhanced push are made possible by the higher power-to-weight ratio. BLDC motors are known for their quickness and precision speed regulation. Electric vehicles, robotics, and industrial automation are just a few examples of applications that can benefit from precise control of motor speed and direction thanks to the usage of electronic commutation. Smooth acceleration, deceleration, and precise placement are all possible with this level of control.

Table 2: Motor specification

Motors	Specification:
RPM/V:	400KV
Stator size:	35 *15mm
Motor Dimension:	42.5 * 34.5mm
Maximum Current:	26.8A
Motor Weight:	150g
Wire:	Winding extended 150mm
Degree of Protection:	Rain resistant

The stator winding layout in a BLDC motor typically has a distributed three-phase structure. Each winding is connected between a phase and the shared neutral point in a "Y" or "Wye" arrangement, which is the most common way to connect three phases. An alternative name for this configuration is "three-phase star connection." A BLDC motor's winding architecture is designed to deliver balanced torque and effective performance over a wide speed range. To provide the appropriate speed and torque characteristics, the motor controller electronically modulates the stator windings' sequence of energization. [11]

3.2.1 Application of BLDC motors

- BLDC (Brushless DC) motors are utilized in a wide range of goods and industries due to their many advantages. Here are a few typical uses for BLDC motors:
- **Drones and unmanned aerial vehicles (UAVs):** Drones and UAVs frequently use BLDC motors to generate thrust for lift and control. They have a high power-to-weight ratio, precise control, and efficiency, making them ideal for establishing stable flying and mobility.
- **Electric Vehicles (EVs):** BLDC motors are essential parts of all electric vehicles, such as motorbikes, scooters, bicycles, and cars. They convert electrical energy from batteries

into mechanical energy for propulsion, enabling efficient and environmentally friendly mobility.

- **Robotics:** Robotics regularly uses BLDC motors for a number of purposes, such as mobility, joint action and arms. Due to their high torque and small size, they are the perfect choice for robotic systems that require quick movements and precise control.
- **Industrial Automation**: BLDC motors are utilized in industrial automation systems for things like conveyor belt drives, robotics, CNC machines, and pumps. Their dependable and efficient operation allows for precise control and mobility in manufacturing and assembly processes.

3.3 Electronic Speed Controller

The Electronic Speed Controller (ESC) is an essential component for a drone to function properly. Its main responsibility is to regulate and manage the power supply to the drone's motors. The flight controller, which regulates the motors' rotational speed and direction, sends signals to the ESC, which then alters the voltage and current supplied to the motors. This precise control allows the drone to travel easily, change directions, and hover at different altitudes. The ESC's quickness and ability to maintain steady motor speeds are crucial for stable flying performance and precise control inputs from the pilot. ESC technology has substantially improved with features including motor and motor timing adjustment to improve performance. Many ESCs also have built-in safety features like overheat prevention, overcurrent protection, and low voltage cutoff to prevent damage to the motors and batteries. The drone's specifications and the motors' power requirements influence the ESC's dimensions and weight.

Table 3: ESCs Specification

ESCs	Specification
Input Voltage	2~6S LiPo 26V
Continuous Output current	40A
Instantaneous current (10s)	55A

Size (LxWxH)	78mmx34mmx17.5mm
Weight	68g

A typical ESC used in drones will often have four or more wires. The typical wire connections in a drone ESC are discussed as follows:

Power Input Wires: The main battery of the drone is connected by these lines. They transport the high current and voltage needed to power the motors. Typically, thicker power input wires are used to handle the power demand.

Motor Output Wires: These wires connect to the drone's motors. The number of motor output wires will depend on the number of motors the ESC is designed to control. There will normally be four motor output cables for a quadcopter, one for each motor.

Signal Wire: The control signals that determine the motor speed and direction are carried along this wire, which is connected to the flight controller or receiver. The PWM (Pulse Width Modulation) signal is sent from the flight controller to the ESC over the signal wire.

Ground Wire: The ground wire provides the reference ground connection for the ESC and is usually connected to the drone's common ground.

3.4 Propellers

Quadcopter drones and other types of aircraft require propellers as essential parts. They are rotating objects with two or more blades that generate the propulsion required to lift and move the drone through the air. Aerodynamic design principles are used in the development of propellers in order to maximize efficiency and lift. A propeller's blades are often formed with an airfoil profile that is curved, much like an aero plane wing. By establishing a pressure difference between the upper and bottom surfaces of the blades as they rotate, this design enables the propeller to produce lift. The amount of thrust produced and the propeller's efficiency are both determined by the pitch, or angle, of the blades. Various materials, including as plastic, carbon fiber, or composites, can be used to make propellers. These materials are chosen for their strength, durability, and lightweight properties. To accomplish desirable flight characteristics, such as stability, maneuverability, and efficient power usage, proper propeller selection is essential.

In order to achieve optimal performance, the propellers' size and pitch must match those of the engine and the drone, respectively. Overall, propellers are crucial parts that provide quadcopter drones the lift and propulsion they need to fly.

Table 4: Propellers Specification

Propellers	**Specification**
Diameter	15 inch
Pitch	5.5mm
Weight	21 g ± 2 g per Prop
Circular Diameter	12mm
Props	1 x CW; 1 x CCW

3.5 Flight Controller

A quadcopter or other multirotor drone cannot operate without a flight controller. The flight controller serves as the drone's main processing unit and serves as the "brain" of the aircraft, managing and controlling all aspects of flight. The flight controller gathers information regarding the orientation, altitude, and movement of the drone using sensors like accelerometers, gyroscopes, and barometers. After analyzing the data, it instructs the motors to change their speeds in order to stabilize the drone and keep it in the correct flight position.

3.5.1 DJI A2 Flight Controller

A complex flight control system specifically created for professional aerial platforms, such as multi-rotor drones, is the DJI A2 Flight Controller. The A2 Flight Controller was created by DJI, a prominent producer of drone technology, and has a variety of features and capabilities to improve flight performance and stability.

The DJI A2 Flight Controller's incredibly effective and dependable flight control technology is one of its primary features. A powerful flight control algorithm used by the controller ensures accurate control and stability during flight. The A2 Flight Controller delivers exact positioning and attitude information by integrating various sensors, including accelerometers, gyroscopes, and GPS, enabling fluid and accurate flight maneuvers.

The A2 Flight Controller has an IMU (Inertial Measurement Unit) system to ensure safety and redundancy. This redundant system ensures greater flying reliability and safety by serving as a fallback in the event that one of the IMUs experiences issues. By providing stable flight control even in the case of a sensor failure, the multiple IMUs give the pilot additional assurance. Professional drone pilots will find the DJI A2 Flight Controller's Intelligent Orientation Control (IOC) to be a useful tool. Regardless of the drone's orientation, IOC enables pilots to maintain steady flight control. As a result, the drone's orientation in the air can be less of a concern for the pilot and more of a focus on managing the drone in relation to their own position. This makes it easier to do flight maneuvers, particularly when the drone is far away or in complicated flight situations, allowing the pilot to maintain accurate and natural control.

The A2 flight control system's essential element is the Controller Unit:

- The aircraft's ESCs are connected using the MI-M8 connector.
- The CANI and CAN2 ports should be connected to different modules because they operate independently.
- Four separate, programmable outputs.
- It works with external Receivers, such as the DSM2 satellite Receiver.
- To support the conventional receiver, use the DJI DBUS Adapter, which is optional.

3.5.2 IMU (Inertial Measurement Unit)

Inertial measurement unit is known as IMU. The IMU is a sensor system that includes accelerometers, gyroscopes, and occasionally magnetometers in the context of a DJI flight controller. It is in charge of calculating the orientation, velocity, and acceleration of the drone and delivering the resulting data. The capacity of the flight controller to retain stability, control, and precise placement during flight depends heavily on the IMU. It enables the flight controller to do calculations and real-time changes to ensure precise and fluid flight maneuvers.

Accelerometers: Accelerometers track changes in velocity or speed along a certain axis, or "linear acceleration." They identify changes in motion and forces causing acceleration on the sensor. When used to drones, accelerometers offer data on the drone's acceleration, enabling the flight controller to modify motor speeds and maintain flight stability.

Gyroscopes: Gyroscopes detect rotational motion or angular rate around one or more axes. Changes in the drone's orientation and rotational speed are picked up by them. The flight controller needs a gyroscope to determine the drone's attitude (roll, pitch, and yaw) and to help stabilize and control the drone's motions. The flight controller can maintain a desired flight path by making exact modifications by continuously monitoring the angle rate.

3.5.3 PMU (Power Management Unit)

An essential part of DJI flight controllers, the PMU (Power Management Unit) is responsible for regulating the power supply and distribution. It carries out a number of crucial tasks to ensure the proper operation and effectiveness of the flight controller system.

Power regulation is one of the PMU's main responsibilities. It adjusts the incoming power supply to make sure that the voltage is within the range that is appropriate for the flight controller and its related components. The PMU delivers a clean and dependable power source by stabilizing the voltage, avoiding potential harm or performance problems brought on by voltage fluctuations. The PMU is in charge of power distribution as well. It distributes the main supply's electricity to the different parts of the flight controlling system. The processor, sensors, communication components, and other peripherals are included in this. The PMU makes sure that each component receives the proper voltage and current in accordance with its unique requirements by carefully allocating power.

The PMU has the ability to monitor batteries as well. It regularly checks the connected battery's voltage and current levels. Calculating the battery's remaining capacity and remaining flying duration requires this information. The PMU may also activate low battery alarms to inform the pilot when the battery is running low, enabling them to safely land the drone or take the necessary actions.

3.5.4 GPS (Global Positioning System)

Accurate location and navigational capabilities for drones are made possible by the GPS (Global location System) functionality in DJI flight controllers. The GPS receiver in the flight controller can determine the exact latitude, longitude, and altitude of the drone by receiving signals from several satellites in orbit. For many different flight modes and operations, this positioning data is essential.

Drones can create a Home Point using GPS at takeoff, which serves as an indicator for the drone's original location. The drone can use GPS to start a Return-to-Home (RTH) function in the event of signal loss or other urgent circumstances, such as low battery. To ensure a secure and controlled landing, the drone uses RTH to autonomously navigate back to its Home Point. Furthermore, because GPS gives precise altitude readings, it helps pilots maintain stable flight at particular heights. In flight modes like altitude hold, where the drone can maintain a consistent height without the need for frequent manual modifications, this functionality is very helpful.

3.5.5 Configuration of DJI Flight Controller

A DJI flight controller must be configured by setting up a number of parameters and settings that correspond to a unique drone and flight preferences. The following are the standard procedures for setting up a DJI flight controller:

Power on your drone: Press the power button on the drone's body or battery compartment to turn it on.

Connect the drone to computer: Depending on the capabilities of our drone and device, we either use a USB cable or a wireless connection to link our drone to our computer. Connect one end of the USB cable to the drone and the other end to the computer if the drone allows USB connectivity. Ensure that the drone and computer are linked to the same Wi-Fi network if the drone allows wireless connectivity.

Launch the DJI Assistant software or DJI app: We need to launch the proper programed based on the DJI flight controller model we have. We must utilize the DJI Assistant program, which can be downloaded and installed on a computer, for older DJI flight controllers or more complex configurations. We can utilize the DJI mobile app, which can be downloaded from the appropriate app store for device, for newer DJI flight controllers or simpler configurations.

Connect to the drone: Once the DJI Assistant software or DJI app has been launched, follow the on-screen directions to connect to the drone. The linked drone should be automatically detected by the software or app. If not, make sure the wireless or USB connection is correctly established and try again.

Select the X configuration mode: Navigate to the flight controller configuration option in the DJI Assistant program or DJI app. The X configuration should be available if we look for an option that lets to choose the drone configuration mode. The motor arrangement for this configuration option, which is generally offered for quadcopters, is where the motors are grouped in a "X" pattern.

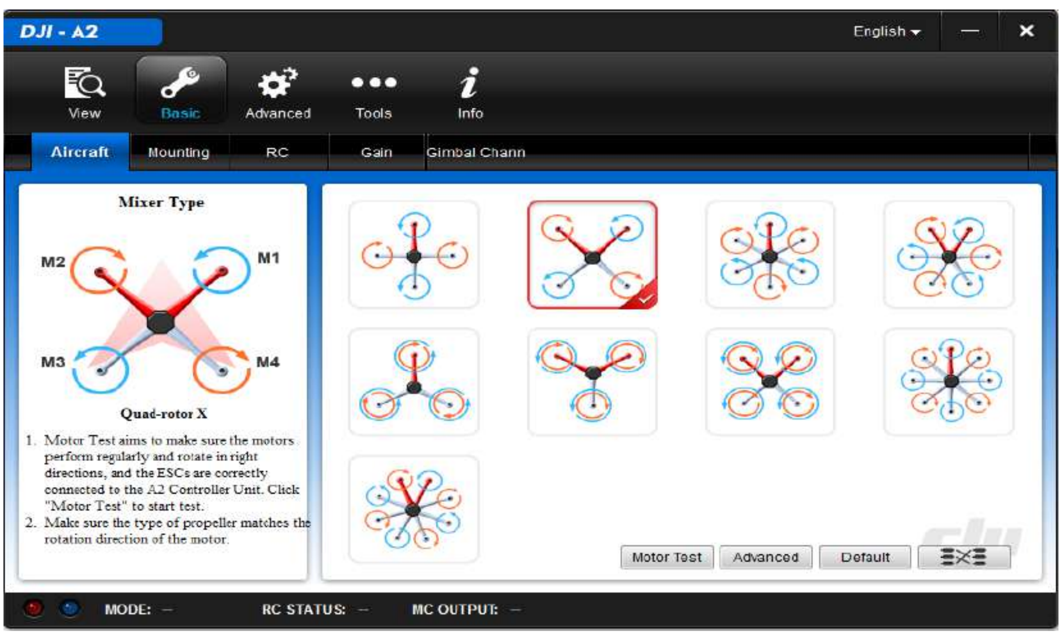

Figure 4: Mode Selection in A2 Software

Save and apply the configuration: Make sure to save the adjustments and apply them to the drone after choosing the X configuration mode. By doing this, we can be confident that the flight controller will recognize the arrangement of the motors and change the flight control signals to match.

3.5.6 Upgrade IMU, PMU and GPS module

Start the firmware upgrade process: A separate firmware upgrade for the GPS, IMU, and PMU may be available. To start the upgrading process, choose the appropriate firmware update option and follow the on-screen directions. Choosing the firmware file that was downloaded and accepting the upgrade are typically required.

Wait for the upgrade to complete: The process of updating the firmware could take some time. Make sure your drone is plugged into a reliable power source, and refrain from pausing the upgrading procedure. Till the upgrade is finished, adhere to the directions or progress indicators given by the software or app.

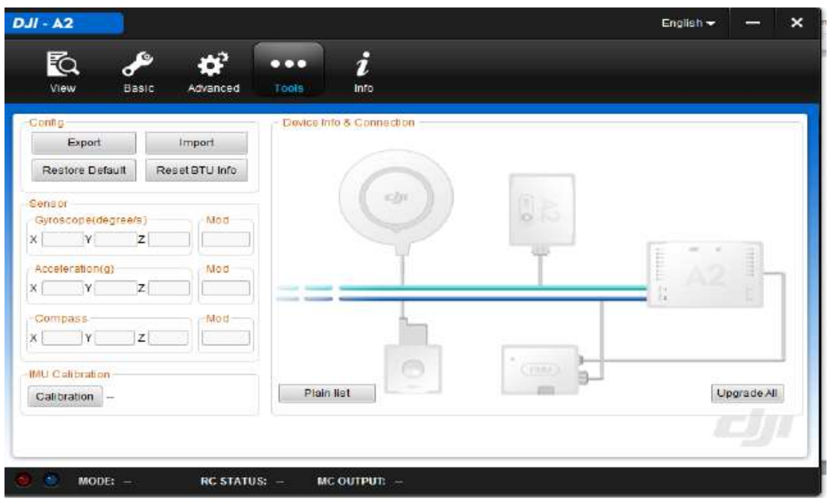

Figure 5: Upgradation of GPS, IMU and PMU Module

Verify the upgrade: Perform a power cycle on our drone by turning it off and back on after the firmware upgrade is complete. To make sure that the GPS, IMU, and PMU firmware versions have been updated successfully, connect it to the DJI Assistant program or DJI app.

3.5.7 Configuration of RC

The procedures below should be followed to configure the RC (Remote Controller) in the DJI Assistant software:

Connect drone and RC: Ensure that the drone and the remote control are both turned on and within each other's range. As previously mentioned, connect the drone to the DJI Assistant program in PC or the DJI app on our mobile device.

Navigate to the RC configuration: Locate the menu or section that allows us to customize the RC settings in the DJI Assistant software or DJI app. Depending on the program or app version, the precise position and labeling may vary, but it is normally found in the remote control or controller settings.

Select the RC configuration mode: Find a choice that enables us to choose the RC configuration mode. Depending on the drone and RC model, there could be a variety of configuration settings available. Select the setting mode that best meets our needs.

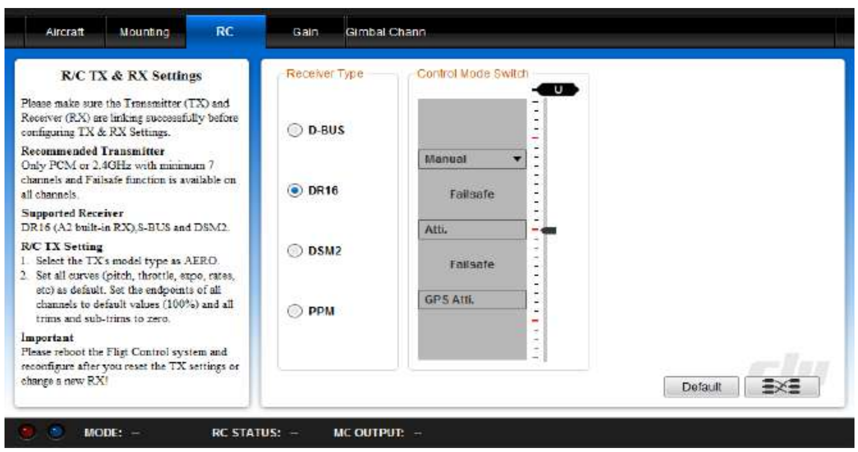

Figure 6: Configuration of RC

Customize RC settings: As we choose the configuration mode, we may change RC settings such control sensitivity, control stick assignments, channel mapping, and other factors. We can change these parameters to suit our preferences or stick with DJI's suggested settings.

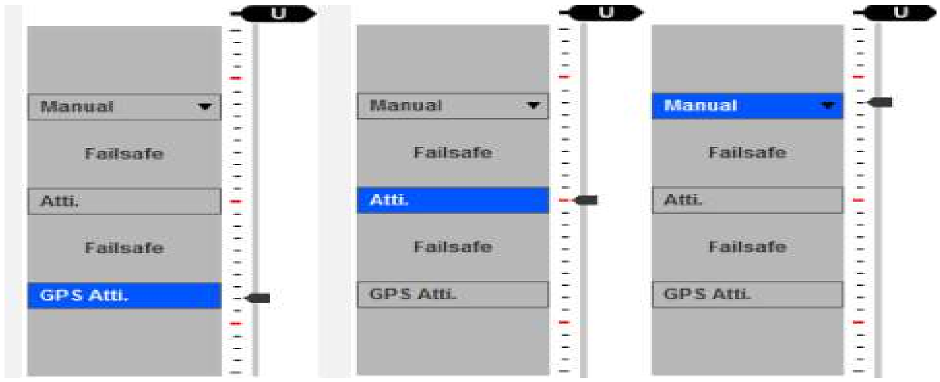

Figure 7: Different Modes of RC

Save and apply the configuration: Save the configuration settings after making the required adjustments, and then apply them to RC. By doing this step, you may be sure that the RC will recognize and use the defined values.

3.6 Calibration of Quadcopter

The following actions are often required to calibrate a quadcopter:

Find a suitable location: Pick a place that is wide open and level, ideally outside, free from any barriers or people. Make sure the quadcopter has sufficient space to fly without restriction while being calibrated.

Power on the quadcopter and remote controller: Connect the battery to the quadcopter, and then turn on the remote control. Make that the pairing is successful on both devices.

Level the quadcopter: Set the quadcopter down on a flat, level surface like the ground or a table. For precise calibration, a level reference must be used right away.

Steps for Horizontal and Vertical Calibration:

1) Quickly Flip the Control mode switch

From position 3 to 1, rotate 6 to 10 times.

2) **Now rotate the aircraft 360° horizontally**

The quadcopter indicator light becoming green usually means that the process of horizontal calibration has been accomplished. This denotes that the quadcopter horizontal position has been successfully calibrated, together with the aircraft's leveling and the motor output's adjustment for stability.

3) Now for Vertical Calibration, Flip the control mode switch

From position 3 to 1, rotate 6 to 10 times.

4) **Now rotate the aircraft 360° Vertically**

The quadcopter indicator light becoming green usually means that the vertical calibration procedure has been successful. The quadcopter is now prepared for flight after properly calibrating its vertical position. On the other hand, if the indication light turns red during the calibration procedure, it typically indicates that the calibration was flawed.

3.6.1 Calibration Precautions:

- To reduce risk, do calibration outside whenever possible. Make sure the location is open and safe, free from people, animals, and other impediments.
- To ensure correct calibration and avoid accidental movements or disruptions, place the quadcopter on a level, stable surface.
- Ensure that the quadcopter and remote controller have enough battery life to finish the calibration process and prevent unexpected power outages.
- Give the calibration procedure enough time to finish and avoid stopping it early. Follow any on-screen instructions and wait for completion signals.
- While calibrating, pay attention to indicator lights or on-screen indicators, interpreting various colours or patterns as successful calibration or mistakes that need to be corrected.
- Consider repeating the procedure while carefully following the directions to ensure accurate results if problems or inconsistent results continue after calibration.

Table 5:Flight Controller Specification

DJI Flight Controller	**Specification**
Power Consumption	MAX 5W (Typical Value: 0.3A@12.5V)
Recommended Battery	2S ~ 6S LiPo
Weight	224g (overall)
Max Yaw Angular Velocity	150deg/s

Table 6: Flight Controller Dimension

DJI Flight Controller	**Dimensions**
Flight Controller	54mm x 39mm x 14.9mm
IMU	41.3mm x 30.5mm x 26.3mm
GPS-Compass Pro	62mm (diameter) x 14.3mm
LED-BTU-I	30mm x 30mm x 7.9mm
PMU	39.5mm x 27.6mm x 9.8mm

3.7 Water Pump with Spray Tank

It's important to take into account the particular needs of aerial spraying when integrating a water pump into a drone for spraying applications. The water pump needs to be small, light, and able to support the drone's cargo. For effective spraying, it should deliver the necessary flow rate and sustain the required pressure. The effectiveness of the electric pumps, which are often supplied by the drone's onboard battery, is crucial to maximizing flying time.

Table 7: Water Pump and Nozzles Specification

Water Pump	Specification
Rated voltage	DC 12V
DC 12V	300mA
Applicable voltage	DC8-12V
Weight	150g
Spray Tank Capacity	2 Liters
Nozzles	Flat Jet Nozzles (Spray Angle 30 TO 120) and Pressure (3-6 bar) Nozzle Size: 0.1 mm Flow rate: 0.5 liters per minute (LPM), maximum spray distance: 2 meters

3.8 Transmitter and Receiver

A small wireless device called a transmitter or remote control is used to wirelessly operate a drone. It uses a radio link to communicate with the drone's receiver and gives the pilot control over the drone's movements and functionality. The drone's throttle, pitch, roll, and yaw may all be adjusted by the pilot via the transmitter's control inputs, which include control sticks, switches, buttons, and knobs. From simple models to sophisticated versions with programmable settings and many flight modes, they range in complexity and features. The transmitter, which is battery-operated and essential to the operation of a drone, gives the pilot access to the features and operations of the aircraft as well as control over it.

Along with the transmitter, the receiver is an essential component of the drone's control system. It receives signals from the transmitter and transmits them to the flight controller of the drone, enabling the operator to operate the aircraft from a distance. The receiver creates a wireless communication link between the emitter and itself by using the same radio frequency as the transmitter. The pilot can direct the drone's flight and activate numerous features because it supports many channels that correspond to various control inputs. The drone's main power source powers the lightweight, small receiver, which is essential for providing responsive and accurate control of the aircraft while in flight.

Table 8: RC Specification

Transmitter & Receiver	**Specification**
Item	fs-i6x RC transmitter
Channel	6-10
RF range	2.408-2.475GHz
Power	6V DC

3.8.1 Parts of RC

Like other remote controllers, the Flysky remote transmitter is made up of a number of parts that work together to control the quadcopter. A Flysky remote transmitter's exact components could be:

- **Antennas:** One or two antennas are commonly present on the Flysky remote transmitter to enable wireless communication with the quadcopter.
- **Power Switch**: You can turn on or off the remote transmitter using the power switch.
- **LCD Display**: Many Flysky remote transmitters have an LCD display that shows data like battery life, signal quality, flying mode, adjustment settings, and other useful data.
- **Control Sticks**: To control the quadcopter movement, two control sticks are usually used. The left sticks normally control the roll (sideways movement) and pitch (forward/backward movement), while the right stick often controls the throttle (vertical movement) and yaw (rotation).
- **Mode Switch:** The operator can change between various flying modes or control profiles using the mode switch, which is frequently found on top of the remote transmitter.

- **Auxiliary Switches:** The mode switch, which is often located on top of the remote transmitter, allows the operator to choose between different flying modes or control settings.
- **Battery Compartment:** The batteries that power the device are normally stored in a section on the remote transmitter. Depending on the particular model of the Flysky remote transmitter, the kind and quantity of batteries needed may change.

3.9 LiPo Battery

A drone's battery, which powers the motors and electronic systems, is an essential component. Due to their high energy density and lightweight construction, lithium-polymer (LiPo) batteries are frequently used. The size of the drone, the amount of flight time needed, and the power requirements all influence the battery choice. Flight time is influenced by battery capacity, expressed in milliampere-hours (mAh), whereas overall voltage output is determined by voltage rating. When handling LiPo batteries, safety must always come first. Correct charging, storing, and monitoring procedures must be followed. Protection circuits or battery management systems (BMS) aid in ensuring safe functioning. Battery technology is always improving, leading to better performance and dependability.

LiPo (Lithium Polymer) battery performance and attributes are defined by certain specifications. The following are some typical details that are going to observe while discussing a LiPo battery:

- **Voltage:** The nominal voltage rating of LiPo batteries is often given in volts (V). LiPo batteries typically have voltage ratings of 3.7V (single cell), 7.4V (2S), 11.1V (3S), 14.8V (4S), and so forth. The number of cells connected in series within the battery pack determines the voltage rating.
- **Capacity:** The amount of charge a LiPo battery can hold is referred to as its capacity, which is commonly expressed in milliampere-hours (mAh). Longer periods of time can

be powered by batteries with a higher capacity. Common capacity ratings for small devices and bigger applications range from a few hundred mAh to several thousand mAh.

- **Discharge Rate:** How quickly the battery can produce power is determined by the discharge rate, which is sometimes represented as a multiple of the battery capacity (C-rating). For instance, a battery can provide its entire capacity over an hour at a 1C discharge rate. Higher C-ratings indicate the ability to discharge more quickly.
- **Maximum Continuous Discharge Rate**: The maximum continuous discharge rate of LiPo batteries denotes the continuous current level that the battery can deliver without going above its safe operating parameters. Overdoing the maximum continuous discharge rate might cause the battery to lose power, perform worse, or even get damaged.
- **Dimensions and Weight:** To ensure that a LiPo battery fits inside the available space and follows to the size and weight restrictions of the device or application, its physical dimensions and weight must be taken into account.
- **Connector Type**: For appropriate compatibility and connectivity, LiPo batteries often come with specified connector types, such as XT60, XT30, EC3, or JST, which must match the connectors on the device or charger.

Table 9: LiPo Battery Specification

LiPo Battery	Specification
Capacity	5200mAh
Voltage	6-10
Max Continuous Discharge	25C
Weight	875g
Dimensions	190*45*50 mm

3.10 Camera

The COOAU Action Camera is a good option to take into account for drones used for agricultural spraying. COOAU offers a selection of action cameras appropriate for drone applications that are known for their low cost and good performance. Following are some characteristics and advantages of the COOAU Action Camera:

Video Quality: COOAU cameras often have Full HD or 4K video recording capabilities, enabling us to take high-definition pictures of the agricultural fields while spraying activities are taking place.

Compact Size: The COOAU versions are made to be small and light, similar to other action cameras, making them appropriate for use on drones without adding too much weight or harming flying stability.

Durable and Waterproof: Many COOAU Action Cameras include a waterproof case that enables us to use them in damp or humid environments without worrying about damage. When using drones in agricultural settings, this function is extremely helpful.

Wi-Fi Connectivity: A few COOAU action cameras come equipped with built-in Wi-Fi, allowing us to link the camera to a smartphone or tablet. With the remote control, you can witness your live action from a distance of 20 meters. To change settings or sample the live video feed while in flight, this capability can be useful.

SD Card Storage: SD cards can be used with COOAU cameras to store recorded media. This enables us to record video directly to the camera and preserves it there, making it simple to access and transfer the files for additional research or documentation.

3.10.1 Working of Camera

The COOAU Action Camera is a flexible tool made to record high-quality images and films in a variety of action-packed situations. Make sure the camera's battery is completely charged before turning it on by pushing and holding the power button, which may be found on the front or side of the device. Once the camera is turned on, choose from the many shooting modes, including photo, video and slow motion. With a few simple configuration changes, we can alter the resolution, frame rate, white balance, exposure, and other aspects of our shooting experience. Simply hit the record button to begin recording video or the capture button to take a picture when we are ready. The camera makes it clear when it is actively recording media.

Application that we use for live transmission is **iSmart DV.**

Figure 8: App for Camera

Chapter 4 Methodology

4.1 Overview

A simplified technique is used in the mechanism of the agricultural spraying drone, which was created exclusively for spraying operations with live streaming capabilities. The drone is equipped with the tools required to carry out accurate and efficient spraying operations while transmitting live footage for monitoring. The drone platform, which houses all the crucial systems and parts, serves as the building block. It has propulsion systems, including rotors or motors that let it to fly steadily and move over the field with ease. For controlled and stable flight during the operation, the platform also includes the appropriate power source, flight controllers, and stabilization algorithms.

There are various procedures involved in starting the drone and the spraying system. First, the drone operator makes sure that it is set up for flight, including checking the battery level and securing any necessary parts, such as propellers and supplies. The operator turns on the drone after it is prepared. The operator verifies the GPS lock and signal stability while the flight controller initializes and does system checks. The spraying parameters, such as flow rate and spray pattern, are the following. Armed, the drone is slowly lifted off the ground by the operator, who may then either manually steer it or switch on autonomous mode to begin the flight. The operator automatically turns on the spraying mechanism using an on/off switch as soon as the drone reaches the appropriate spraying zones established by the predefined waypoints. This switch activates the pump, allowing the liquid solution to be released onto the crops. The pilot keeps a careful eye on the spraying process during the flight by watching the live video feed on the Ground Control System (GCS). In order to provide enough coverage and maximize the efficacy of the spraying, changes can be made to the flight path or the spraying settings as needed.

The operator carefully lands the drone after the spraying job is over to ensure a secure and controlled fall. After landing, the drone's operator checks it for damage or other abnormalities, carries out maintenance, and cleans the spraying system's parts. By doing this, the drone will be prepared for subsequent spraying missions.

By using this technique, operators may successfully launch the drone, configure the spraying parameters, regulate the spraying systems on/off function automatically, and guarantee a successful flight for effective agricultural spraying.

The flight controller, which manages the drone's flight and controls its various systems, operates at a lower voltage. The battery supplies 5V to the flight controller, ensuring a stable power source for its operation. The flight controller, consisting of microprocessors, sensors, and other electronic components, requires a lower voltage to function properly and process the incoming signals from the receiver.

The battery supplies 12V to the spraying motor, which is responsible for activating the spraying mechanism and releasing pesticides or chemicals. The higher voltage is typically required to provide sufficient power for the motor to operate effectively. The spraying motor draws power from the battery at 12V to perform its designated function.

4.2 Block Diagram:

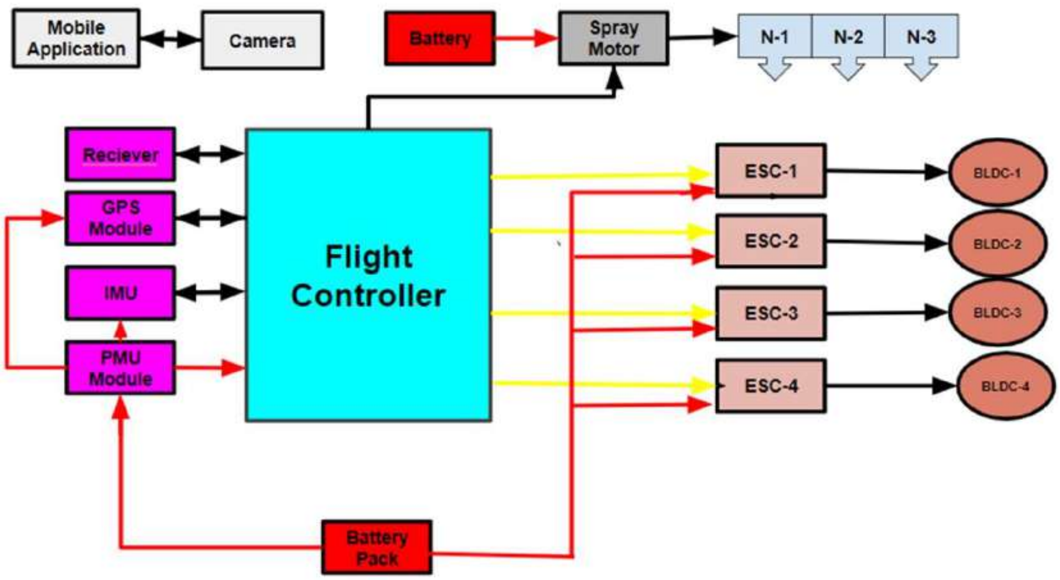

Figure 9: Block Diagram

ESC: Electronic Speed Controller

BLDC: Brushless DC Motor

N-1: Nozzelles-1

IMU: Inertial Measurement Unit

PMU: Power Management Unit

The essential parts and how they link are shown in high-level detail in the block diagram of a drone used for agricultural spraying. The main building blocks of the block diagram are explained as follows:

Flight Controller:

The drone's flight controller, which is in charge of managing flight operations, gets data from a variety of sensors and converts that information into commands for the propulsion and stabilization systems. Stable flight, accurate navigation, and height control are all provided by the flight controller.

Propulsion System:

The drone's propulsion system is made up of motors or rotors that produce the thrust required to lift and move the drone. It gets commands from the flight controller to change the propellers' speed and direction for accurate flight control.

GPS and Navigation System:

The drone can identify its position, altitude, and direction due to its GPS and navigation system, which also uses satellite signals to offer precise location information for flight planning, waypoint navigation, and position holding.

Spraying System:

The tanks, pumps, valves, and nozzles in the spraying system are used to apply pesticides or fertilizers. The liquid solution is kept in the tanks under pressure provided by the pumps. Nozzles distribute the liquid in a chosen pattern for efficient spraying, while valves regulate flow rate and on/off operation.

Camera and Transmission:

The camera records live video of the fields while they are being sprayed, and it may have image stability and other capabilities to ensure that the video is transmitted clearly and steadily.

Power Supply:

The power supply block, which includes batteries or other power sources and distribution circuits to guarantee a consistent and dependable power supply, provides electricity to all of the drone's components.

Chapter 5 Quadcopter Design and Development

5.1 Weight of the Quadcopter

The drone's components alone, empty of any payload or additional equipment, make up the drone's overall weight, also known as the dry weight or empty weight. The size, design, and materials used in the drone's construction, as well as other elements, can all affect how much it weighs. Depending on the particular model and setup, the dry weight of a quadcopter agricultural spraying drone normally ranges in 2 kilograms. The frame, motors, flight controller, power management system, batteries, and other important parts are included in this weight.

It's crucial to remember that the weight of the drone's payload, which may include chemicals, a spraying system, or other sensors or equipment, is not included in the weight of the drone itself. To make sure that the drone runs within its planned parameters and maintains stable flying performance, it's crucial to take both the dry weight of the drone and the weight of the payload being carried into account when estimating the overall weight of the drone for operational purposes.

Table 10: Weight Estimation of Quadcopter

Quadcopter Parts	Weight (Grams)
Frame	500 (Approx.)
Battery	940
Motor (4)	600
ESC (4)	150
Propeller (4)	100
Flight controller	220
Other Wires and tools	100
TOTAL	2560 Or 2.56kg

5.2 Payload Estimation

A drone for agricultural spraying must be designed with payload estimation as a priority because it establishes the drone's maximum weight capacity while ensuring stable flying. Several elements must be taken into account in order to evaluate the payload capacity.

First, the drone's Maximum Takeoff Weight (MTOW) needs to be established. This includes the drone's overall weight, which takes into account the frame, motors, flight controller, batteries, and other essential parts. The weight of the spraying system, including the spraying tank, pump, switches, and related hardware, should also be taken into consideration. Additionally, any extra drone sensors, communication systems, or security measures should be taken into account.

Table 11: Payload Estimation of Quadcopter

PARTS	WEIGHT (grams)
2-litre liquid	2000
2-litre liquid tank	150
Pump	200
Nozzles	100
Total	2450 grams (approximately) Or 2.4 KG

Total weight = Payload + Weight of Quadcopter

= 2450 grams + 2560 grams

= **5.10 Kg** (approx.)

5.3 Selection of Motors:

- **Determine the Total Weight:** The total weight of quadcopter, including the frame, motors, battery, payload, and any other components (in kg), including the 2.450 kg payload are **5.10 Kg** (approx.)
- **Calculate Thrust Requirement**: To achieve steady flying, the motor thrust must be equal to or greater than the quadcopter overall weight. If the total weight of the drone, including the payload, is 5 kg, then the thrust requirement to achieve stable flight would also be **5 kgf** (approx.)
- **Determine Lift-to-Thrust Ratio**: For quadcopters, the lift-to-thrust ratio is around 2:1. Accordingly, the quadcopter overall thrust should be close to twice its total weight. The required thrust in this situation should be 2 * W (in kg). [5]

  Desired Thrust = 2 * Weight of the Drone (including payload)

  Desired Thrust = 2 * 5 kgf

  Desired Thrust = 10 kgf

- **Find Motor Thrust**: Look for the motor specifications that manufacturers or suppliers have provided. We must locate motors that can provide our quadcopter the necessary thrust. Take note of the thrust information for various voltages and propeller diameters.
- The motor's maximum thrust is 3.529 kg. It's easy to immediately compare this result to the desired thrust requirement to get an idea of the motor's ability to generate thrust.

$$Total\ Thrust = \frac{Total\ weight * 2}{Number\ of\ Motors}$$

Total Weight of the Drone (including payload) = 5 kg

Number of Motors = 4

Total Thrust per Motor = (5 kg * 2) / 4

Total Thrust per Motor = 10 kg / 4

Total Thrust per Motor = 2.5 kgf

The quadcopter should be able to fly if the combined thrust produced by the motors is more than the desired thrust. The quadcopter will have enough power to take off and maintain steady flight if the motor thrust is more than the target thrust.

In this case, the motor's maximum thrust of 3.527 kilogram-force is larger than the required 10 kilogram-force, proving that the motor's thrust is actually stronger. This indicates that the motor is capable of producing enough push to allow the quadcopter to fly.

Note: Typically, the unit of thrust is given in kilogram-force (kgf) or Newton (N). The kilogram-force is a unit frequently used in the fields of aerospace engineering and aviation, whereas the newton is the standard unit of force in the International System of Units (SI). It is important to remember that 1 kgf equals the force produced by 1 kilogram at the Earth's standard gravity level (9.80665 m/s2). As a result, the units of measurement used to determine the thrust needs for a drone are often either Newton or kilogram-force.

Chapter 6 Results and Discussion

6.1 Results

A quadcopter used for agricultural spraying can produce results that can be evaluated using a number of different factors, including spray dispersion, coverage and application rate. These findings provide the efficiency and performance of the quadcopter in distributing pesticides or fertilizers to the desired locations.

Spray Distribution: The most important aspect of a quadcopter is its capacity for consistent spray application. By examining the spray pattern and making sure that the spray material is evenly spread throughout the crops or designated regions, the outcomes may be evaluated.

Spray Tank Capacity and Distribution Mechanism:

A tank with a 2 liters capacity is built into the agricultural spraying quadcopter to hold the agricultural solution or pesticide. To have the least amount of an impact on the quadcopters' ability to fly, the tank is made to be both lightweight and sturdy. Typically, corrosion- and chemical-resistant materials are used in its construction.

The quadcopter has a distribution device to disperse the herbicide during the spraying operation. In this instance, the quadcopter three strategically placed nozzles serve as the distribution mechanism. The quadcopter spraying system is controlled by a switch in the transmitter in the autonomous control configuration. The spraying mechanism can be turned on and off by the operator as required. A signal is delivered to the spraying system when the switch is switched to the "ON" position, starting the pesticide discharge. The distribution system, which consists of the designated nozzles, allows the pesticide to flow out of the tank. While the spraying system is still running, the user manually controls the quadcopter flight and location. During the spraying process, this type of hand control enables immediate operator engagement and decision-making. The spraying system is turned off and the flow of pesticide stops when the switch is flipped to the "OFF" position. Even while manual control might not provide automated systems with the same level of accuracy and consistency, it might still be an appropriate option for smaller-scale applications or circumstances where operator control is preferred or necessary owing to certain operational or regulatory requirements.

6.1 Flight Time:

A Quadcopter flying time is affected by a number of variables, such as the drone's weight, battery power, and component power consumption. The formula below can be used to determine a quadcopter flight time:

$$\text{Flight Time} = \frac{\text{Battery Capacity (mAh)} * \text{Battery Voltage}}{\text{Power Consumption}}$$

The battery voltage is measured in volts (V), and the battery capacity is measured in milliampere-hours (mAh). The total power used by the drone's parts including the motors, ESCs, flight controller, and any other accessories is the total power consumption of the drone. [7]

With a battery capacity of 5200mAh and a voltage of 22.4V, and an overall component power consumption of 870 watts, a quadcopters flight time can be computed as follows:

At 50% throttle,

$$\text{Flight Time} = \frac{5200(\text{mAh}) * 22.4\text{V}}{870\text{W}}$$

$$\text{Flight Time} = \frac{116.4\text{Wh}}{870\text{W}}$$

$$\mathbf{Flight\ time = 0.133\ hours/8.17\ minutes\ (approximately)}$$

6.2 Spraying Coverage

Another important consideration is the quadcopter coverage. It involves evaluating the degree to which the sprayed substances have covered the target locations. When a quadcopter has high coverage, it effectively reaches all of the target areas, including those that could be challenging to reach manually.

We need to account for the drone's ground speed and swath width when calculating the area that it covers when spraying. The area that is covered by the spray pattern created by a drone's spraying mechanism in a single pass is referred to as the swath width. It serves as a representation of the ground's actual spray coverage width.

Swath Width:

The angle of the spray emitted from the nozzles, which is 30 according to nozzle specifications, must be determined in order to determine the swath width.

Along the spraying rod, measure the distance as well between the centers of the three nozzles. The nozzles are spaced 30 centimeters apart.

To calculate the effective breadth covered by each nozzle, divide the spray angle by the quantity of nozzles. In this instance, each nozzle covers an effective breadth of

30 degrees / 3 = 10 degrees because there are three nozzles.

Divide the distance between the nozzles by the effective width per nozzle. The swath width in this scenario will be roughly 3 meters (10 degrees x 0.3 meters).

So, the swath width is 3 meters.

Speed of the drone

While spraying, the drone moves at an average speed of 2 meters per second.

Covered Area

To find out how much ground the drone covers in a given amount of time, multiply the swath width by ground speed.

$$\text{Area Covered} = \text{Swath Width} * \text{Ground Speed}$$

$\text{Area Covered} = 3 \text{ meters} * 2 \text{ meter per second}$

$\mathbf{Area\ Covered = 6\ square\ meter}$

Multiply the area covered by the total time to determine the area covered in a given amount of time. This will show the approximate area that the drone was flying over at that moment.

$\text{Total Area Covered} = \text{Area Covered} * \text{Time}$

$\text{Total Area Covered} = 6 \text{ square meter} * 600 \text{ second}$

$\mathbf{Total\ Area\ Covered = 3600\ square\ meter}$

To determine how much acreage the agricultural spraying drone will cover in a given amount of time with a speed of 2 m/s,

1 acre = 4,046.86 square meters

Area in Acres = Area in Square Meters / 4,046.86

Area in Acres = 3600 square meters / 4,046.86

Area in Acres ≈ **0.91 acres in 10 minutes**

Therefore, 3600 square meters is approximately equal to 0.91 acres.

As a result, drone spraying systems exhibit exceptional time efficiency, improving agricultural practices production and resource management.

6.3 Cost Analysis

Specification	Our Project	DJI Phantom 4 Pro
Payload Capacity	2 liters (spraying chemical)	Approximately 1 liters (Spraying Chemical)
Flight Time	10 minutes	Up to 15 minutes
Range	1.5 to 2km	Up to 2 km
Controller	DJI controller	DJI controller included
Price	**Rs.185,000**	**Rs. 370,000**

The cost of this project is Rs. 185,000, while the cost of the DJI Phantom 4 Pro is Rs. 370,000. Making a well-informed decision requires taking into account the capabilities and features of each option in relation to their costs. [12]

6.4 Discussion

We worked on a hexacopter in our previous project, a multirotor aircraft with six motors and a hexagonal structure. We used a strong hexa frame and tested various motors. Our hexacopter, however, crashed during the flying test, causing the frame to be harmed and the failure of two motors. After the crash, we made the decision to concentrate on a quadcopter, which is a more straightforward design with four motors and a quad frame. When choosing fresh motors and an appropriate frame for the quadcopter, we applied the lessons we learnt from the problems encountered during the hexacopter project.

We purchased new quadcopter motors to address the issue brought on by the crash, making sure they met our standards for quality and compatibility. A quad frame that provided strength and stability during flight was also acquired. We want to streamline the design and lessen the system's complexity by switching to a quadcopter. This modification will increase the aircraft's stability and maneuverability while also making it simpler to manage and maintain. Considering advantage of the lessons we've gained from our past endeavors, we are confident about the quadcopter project. We are certain that the new arrangement will enable us to overcome the difficulties encountered previously and complete successful flight tests.

The discussion focused on analyzing the outcomes of the quadcopter used for agricultural spraying. In terms of spray distribution, coverage, application rate, efficiency, and effectiveness, the quadcopter exceeded conventional approaches. It was able to distribute the spray evenly, ensuring constant coverage and lowering the possibility of applying too little or too much. The field was completely covered due to the quadcopter capacity to explore hard-to-reach locations. It maintained an accurate and consistent application rate, reducing waste and its negative effects on the environment. By covering more regions in less time, the quadcopter increased productivity and efficiency.

Chapter 7 Conclusion and Future work

7.1 Conclusion

In conclusion, drones for agricultural spraying are now recognized as an advanced and useful device in modern methods of farming. These drones have many advantages, including enhanced productivity, precise pesticide or fertilizer application, lower labour costs, and better crop health management. These drones can fly autonomously, optimize spraying patterns, and gather useful data for decision-making by using modern technologies like GPS, sensors, and intelligent software. The primary function of cameras in agricultural spraying drones is to give farmers an aerial viewpoint so they can locate and recognize their crops. These cameras help in navigation and movement enabling the drone pilot to accurately target the areas that will be sprayed. Farmers can optimize the spraying operation and ensure precise drone location by using the camera feed. Farming could be revolutionized by using agricultural spraying drones to increase productivity, sustainability, and overall yields while reducing environmental impact and enabling effective resource management.

7.2 Future Work

In future, The use of quadcopter drones for agricultural spraying that have cameras for surveillance purposes is anticipated to witness a number of improvements and innovations. Here are some future enhancements that could be made:

- **Enhanced Precision Agriculture**: Quadcopter drones for agricultural spraying that are fitted with cameras will continue to be essential for precision farming. These drones will become even more accurate and effective at detecting pests, determining agricultural health issues, and keeping track of general plant development. High-resolution images and real-time data will be made available via advanced cameras and sensors for better decision-making.
- **AI and Machine Learning Integration**: Future drones will use machine learning and artificial intelligence (AI) algorithms to analyze the data gathered by cameras. These algorithms will provide more accurate detection and classification of various pests,

illnesses, and weed species. Farmers will be able to use pesticides more effectively and apply targeted treatments as a result.

- **Autonomous Operation**: Agricultural drones will become more autonomous in the future. They will have autonomous navigation, flight planning, and obstacle avoidance capabilities, which will lessen the need for manual control. These drones will be able to make real-time judgments, altering their spraying patterns in response to the analyzed data from the cameras, due to the integration of AI and advanced computer vision technologies.
- **Improved Efficiency and Capacity**: Future quadcopter drones for agricultural spraying are likely to have improved battery technology, enabling longer flight durations and more spraying capacity. They will be able to spray more effectively and cover more regions in a single flight as a result.
- **Integration of Multiple Sensors**: Beyond cameras, drones will also include a variety of sensors to improve surveillance capabilities. These could include LIDAR (light detection and ranging) sensors for precise terrain mapping and obstacle identification, multispectral or hyper spectral sensors for detailed information about plant health, thermal sensors for early detection of stress or illness, and so on.
- **Environmental Considerations**: Future drone designs will place more emphasis on environmental sustainability. This includes the creation of more environmentally friendly spraying techniques, such as the use of insecticides derived from plants and precise application methods to use less harmful chemicals. Drones may include systems for catching and minimizing spray movement, which would further lessen their influence on the environment.

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