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ADVANCEMENTS IN PRECISION AGRICULTURE: PESTICIDE SPRAYING DRONES

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ABSTRACT

The integration of unmanned aerial vehicles (UAVs) in agriculture has ushered in a new era of precision farming. Among the various applications of UAVs in agriculture, pesticide spraying drones have gained significant attention due to their potential to revolutionize crop protection practices. This abstract provides a concise overview of the key aspects of pesticide spraying drones and their impact on modern agriculture. Pesticide spraying drones are equipped with advanced technologies, including GPS navigation, multispectral imaging, and precision spraying systems. These drones offer several advantages over traditional pesticide application methods, such as reduced chemical usage, increased efficiency, and minimized environmental impact. Additionally, they provide farmers with real-time data on crop health, allowing for targeted and timely pesticide applications. This abstract reviews recent developments in pesticide spraying drone technology, including improvements in flight stability, autonomous operation, and payload capacity. Furthermore, it discusses the regulatory challenges and safety considerations associated with the deployment of drones in agriculture, highlighting the need for standardized guidelines and training programs.

By promoting sustainability and cost-effectiveness while ensuring crop health and food security. This abstract underscore the importance of continued research and development. The adoption of pesticide spraying drones has the potential to transform agriculture in this field to unlock the full potential of UAVs in modern farming practices.

Keywords: Pesticide Spraying Drones, Precision Agriculture, UAV Technology, Crop Protection, Sustainable Farming And Agriculture Automation.

I. INTRODUCTION

Globally, intelligent agriculture is the newest trend. Furthermore, the intelligent drone plays a crucial part in this global scheme. The conventional pesticide sprayer may be replaced with an agricultural spraying drone, which has a speed 25 times faster than the conventional sprayer. 90% less water and 30%–40% less insecticide will be used. It will take 7 to 10 minute per acre. If we spray manually then per acre it will take 4 hours. It will reduce time. Spraying pesticide manually it must be affecting human body. Due to pesticide, it may cause different type of disease. Because this pesticide is a one type of chemical. This chemical harmful for health. By using technology, we can save time, cost also we can protect farmer health from disease which occur due to this chemical. Small droplet diameter makes the pesticide more well-distribute and improve the effect. At the same time, it will make the people far away from the pesticide and reduce the pesticide remain of the crop. Drones are used in the agricultural industry for a wide range of tasks, including surveillance, mapping, land inspection, monitoring, applying fertilizer, searching for harmed or rotting crops, and much more. Many different drone kinds are being looked at in order to identify the most innovative sector of farming, horticulture, and farming. Fixed-wing drones are suitable for fertilizing crops, despite their massive structure demanding a big field for takeoff and landing.

In order to ensure food security, one has to tackle the population's fast rise. The Food and Agriculture Organization (FAO) of the United Nations estimates that over 815 million people worldwide—of whom 64% are in Asia—are chronically hungry. Due to the rapid rise of the population, guaranteeing food security is a challenging task. The Food and Agriculture Organization (FAO) of the United Nations estimates that over 815 million people worldwide suffer from chronic hunger, with 64% of those individuals living in Asia. By 2050, the world's food supply would need to increase by over 50% in order to feed a population of nine billion people. However, the availability of land and water, two resources that are crucial for agricultural production, is running out every day. A 2018 poll found that 9.2% of people worldwide experienced serious problems with food supply. Another cut to the food supply will result in a very awful state of affairs. In addition, there was a problem with moderate food insecurity, which indicated that they weren't always able to get enough and healthful food. About 26.4% of the entire population has food supply issues in both severe and extreme forms. The use of drone monitoring systems by farmers allows them to see aerial views of the harvest. This provides details on the water system, different types of soil, pests, and fungus infestations.

II. USES OF PESTICIDE SPRAYING DRONES

2.1 Mapping:

Pesticide spraying drones have several uses, and mapping is just one of them. These drones are becoming increasingly popular in agriculture and pest control due to their efficiency and precision. Drones are equipped with GPS and navigation systems, allowing them to precisely determine their position and orientation during flight. This data is crucial for accurately georeferencing the captured imagery. Drones equipped with cameras and sensors can be used to create high-resolution maps and surveys of agricultural fields. This data can help farmers identify areas that require pesticide application, monitor crop health, and assess the effectiveness of treatments. Mapping through pesticide spraying drones is a powerful tool for precision agriculture, enabling farmers to make data-driven decisions, reduce the environmental impact of farming, and optimize crop yields.

2.2 Spraying:

Spraying through drones is a cutting-edge agricultural practice that utilizes unmanned aerial vehicles to efficiently and precisely apply pesticides, herbicides, and other chemicals to crops and fields. By automating the spraying process, these drones can cover large areas in a short amount of time, reducing the need for manual labor and minimizing human exposure to chemicals. Their precise targeting capabilities help minimize chemical drift and over-application, which, in turn, reduces the environmental impact and ensures that agricultural chemicals are used more efficiently. This technology not only enhances the productivity of farming operations but also offers a more sustainable and eco-friendly approach to pest and weed control in modern agriculture.

III. EQUIPMENTS

- ✓ Frame
- ✓ Flight Controller
- ✓ Battery
- ✓ BLDC Motor
- ✓ Electronic Speed Controller
- ✓ Power Module
- ✓ Propellers
- ✓ Power Distribution Board
- ✓ Global Positioning System
- ✓ Landing Gear
- ✓ Transmitter & Receiver
- ✓ Telemetry
- ✓ Pump Motor
- ✓ Nozzles
- ✓ Tank

3.1 Frame

It is usually some kind of enclosure or outline of the drone that provide a physical support. The framework serves as the foundation upon which the remainder of the construction is constructed. It is regarded as the UAV's backbone. Nowadays, carbon fiber composites are used to make practically all UAV constructions. Compared to piloted aircraft, where a substantial portion of the structure is automated. It has basically 2 main parts like the body, the arm. The body part used to protect all electronics components and the arm part use for installing the motor.

3.2 Flight Controller

A flight controller in a drone is the central component responsible for managing and orchestrating the aircraft's flight. It combines data from various sensors, such as accelerometers, gyroscopes, and GPS, to stabilize the drone's position, orientation, and altitude. Through this data fusion process, the flight controller ensures the drone remains level, maintains stability, and responds to user commands via a remote control or transmitter. It plays a crucial role in executing flight maneuvers, following flight paths, and enabling autonomous features like return-to-home and waypoint navigation. Ultimately, the flight controller acts as the drone's "brain," making real-time decisions that govern its flight, safety, and overall performance. The flight controller is entrusted with the pivotal role of stabilizing the drone. To accomplish this, it continuously monitors data from onboard sensors, including accelerometers and gyroscopes. These sensors provide information about the drone's orientation, rotation, and acceleration. By interpreting and analyzing this data, the flight controller adjusts the speed and power of the drone's motors and propellers. This fine-tuned motor control is crucial for maintaining the drone's stability, ensuring it remains level in the air, and countering any unwanted movements or disturbances Advanced flight controllers offer autopilot capabilities, taking drone flight to a whole new level of automation. These autopilot features enable the drone to operate autonomously, executing specific flight modes or missions. For example, "follow-me" mode allows the drone to track a moving object or operator, while "orbit" mode enables the UAV to circle a designated point of interest. Object tracking, surveying, and aerial photography missions are all achievable through the intricate automation provided by the flight controller. These advanced functions rely on the controller's ability to process sensor data and GPS information, ensuring that the drone can navigate and perform complex tasks with precision.

Advantage of K++ flight controller:

Stability and Control: Advanced flight controllers, in general, provide precise stability and control for drones and UAVs. They use various sensors and algorithms to maintain the desired orientation and position, which is crucial for capturing stable aerial footage or performing specific tasks.

Autonomous Flight: Many advanced flight controllers support autonomous flight modes, enabling features like waypoint navigation, follow-me mode, and return-to-home functionality. This makes the operation of drones more user-friendly and versatile.

Safety Features: These controllers often include safety features such as geofencing, low battery return-to-home, and obstacle avoidance systems, which help prevent accidents and collisions during flight.

GPS Integration: GPS is a key component of advanced flight controllers, providing accurate positioning and allowing for functions like waypoint navigation and precise return-to-home capabilities.

Compatibility: They are usually compatible with a wide range of drone platforms, making it easier for drone manufacturers to integrate them into their designs and for users to upgrade their existing drones.

Type of Flight Controller In Agriculture Drone:

- ✓ K++, K++pro
- ✓ K++V2
- ✓ K3, K3Apro
- ✓ DJI N3 AG
- ✓ TopXGun TIA.

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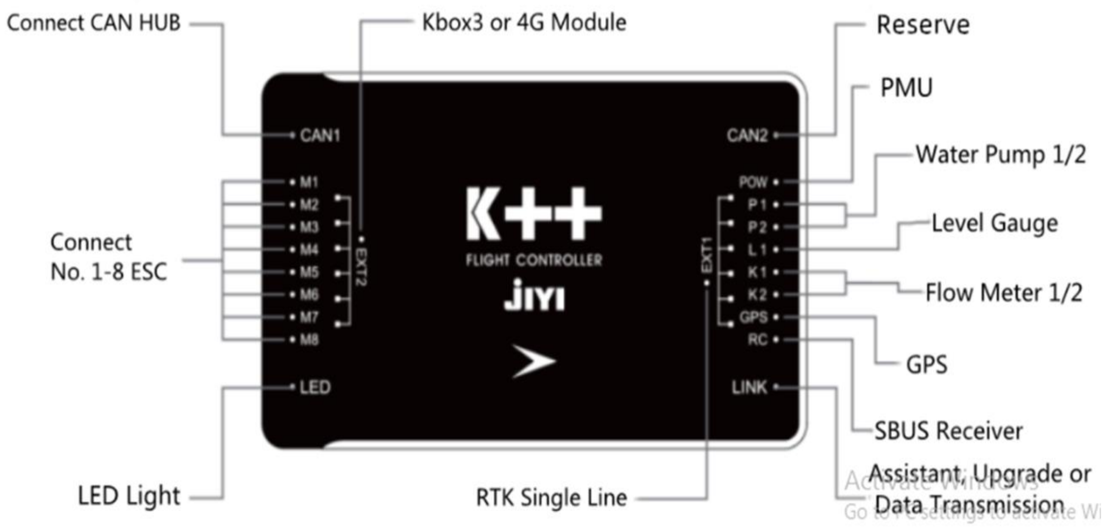

Figure 1. K++ Flight Controller

3.3 Battery

Commonly nickel based and lithium-based batteries are known. Lithium based batteries are mostly used due to best performance.

A lithium battery has two most commonly used batteries are:

✓ Lithium-ion battery (e.g., Mobile batteries etc.)
✓ Lithium polymer battery (e.g., Quadcopter, helicopter etc.)

LI-PO BATTERY IN AGRI DRONE

✓ 12 cell battery
✓ Each Cell has minimum of 3.7 volt and maximum of 4.2V capacity
✓ 12 cell battery contains 44.4V
✓ 12 cell battery 22000MAh

Figure 2. 22000 Mah Lipo battery

Benefit of using LiPo battery in drone:

✓ High Energy Density: LiPo batteries is crucial for drones, as they need to be as light as possible to achieve longer flight times and better performance.

✓ High Discharge Rates: LiPo batteries can provide high discharge rates, which are essential for drones that require bursts of power for takeoff, acceleration, and maneuvering. This enables drones to perform acrobatic maneuvers and maintain stability.

✓ Lightweight: LiPo batteries are lightweight compared to other types of batteries like NiMH or Li-ion, making them ideal for drones, where weight directly impacts performance and flight time.

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✓ Compact Size: LiPo batteries are available in various shapes and sizes, allowing drone manufacturers to design and integrate batteries into the drone's frame efficiently.

✓ Fast Charging: LiPo batteries can be charged relatively quickly, reducing downtime between flights and enabling more flight opportunities in a single day.

✓ Rechargeable: LiPo batteries are rechargeable, which means you can use them for multiple flights, reducing the cost and waste associated with disposable batteries.

3.4 BRUSHLESS DC MOTOR

Brushless DC (BLDC) motors are the go-to choose for powering drones due to their exceptional combination of efficiency, reliability, and performance. These motors are designed to deliver high levels of thrust with minimal energy loss, resulting in longer flight times, improved battery life, and reduced maintenance requirements. Their brushless design ensures longevity and durability, making them well-suited for the demands of drone applications. With a high power-to-weight ratio, BLDC motors provide the necessary thrust for agile flight and the carriage of payloads. Precise control, variable speed capabilities, and low noise production make these motors essential for stabilizing drones in flight, executing complex maneuvers, and ensuring minimal noise disturbance. The low electromagnetic interference they produce reduces the risk of interference with other onboard electronics. As a result, BLDC motors contribute to longer flight times, enhancing a drone's capacity for extended missions, be it in the realm of aerial photography, surveillance, or any other application where drones have become indispensable.

Advantage Brushless DC motor for drone

✓ **High Efficiency:** BLDC motors are more efficient than brushed motors because they eliminate the need for brushes and commutators, which can cause friction and heat generation. This increased efficiency results in longer flight times and reduced power consumption.

✓ **Longer Lifespan:** Due to the absence of brushes that wear out over time, BLDC motors tend to have a significantly longer lifespan. This means less maintenance and replacement, reducing the operational costs of the drone.

✓ **Higher Power-to-Weight Ratio:** BLDC motors are typically lighter than their brushed counterparts while offering higher power output. This results in drones that can carry more payload or achieve better performance, such as faster speeds and greater maneuverability.

✓ **Smoother Operation:** BLDC motors provide smoother and more precise control of the drone's movement. This is essential for tasks that require stable and precise hovering, like aerial photography and videography.

✓ **Reduced Electromagnetic Interference (EMI):** BLDC motors generate less electromagnetic interference, which can be crucial for maintaining stable communication between the drone and its remote controller or other electronic equipment on board.

✓ **Low Maintenance:** BLDC motors require minimal maintenance since there are no brushes to replace or commutators to clean. This reduces the downtime and costs associated with motor maintenance.

✓ **Quick Response and High RPM:** BLDC motors can respond to control inputs rapidly, allowing drones to change speed and direction quickly. They can also achieve higher RPM (rotations per minute) levels, providing the necessary thrust for various flight maneuvers.

✓ **Regenerative Braking:** BLDC motors can act as generators when power is reduced, which enables regenerative braking. This feature can help recover energy during descent and increase overall efficiency.

✓ **Enhanced Durability:** BLDC motors are less susceptible to wear and tear due to the absence of physical brushes. This makes them more durable and reliable in challenging operating conditions.

✓ **Reduced Noise:** BLDC motors are generally quieter than brushed motors, which is advantageous for applications where noise pollution is a concern, such as aerial filming in quiet environments.

Figure 3. Brushless DC Motor

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Out Runner BLDC motor:

An Outrunner Brushless DC (BLDC) motor is a distinctive and versatile electric motor widely employed in a range of applications, particularly in the realms of drones, radio-controlled aircraft, and robotics. What sets Outrunner motors apart is their unique external rotor design, where the motor's rotating component is situated on the outer side of the motor housing. This design offers several advantages, including the generation of high torque at low rotational speeds, making Outrunner motors highly efficient for applications requiring precise, slow movements or the lifting of heavy loads. Their durability and impact resistance are notable, making them a preferred choice for applications that may face physical stress or collisions. Furthermore, the external rotor design enhances heat dissipation, preventing overheating during extended usage, and is particularly valuable in applications requiring a built-in cooling fan, such as radio-controlled aircraft. While they may be less precise in RPM control compared to inrunner motors, Outrunner BLDC motors find their niche in scenarios where torque and resilience are paramount, making them indispensable components in a diverse array of electromechanical systems.

3.5 Electronic Speed Controller

An Electronic Speed Controller (ESC) for drones is a critical component that acts as the intermediary between the drone's flight controller and the electric motors. Its primary function is to regulate the speed and direction of the motors, translating commands from the flight controller into precise control of the drone's movement. The ESC achieves this by modulating the power supplied to the motors through pulse-width modulation (PWM) signals. This allows for rapid adjustments in motor speed, which are essential for stabilizing the drone, controlling its direction, and executing maneuvers. ESCs designed for drones are typically lightweight, compact, and optimized for high-speed rotations, ensuring the drone's responsiveness and agility. Advanced drone ESCs may also offer programmable features that allow users to fine-tune acceleration, braking, and other parameters to suit specific flight requirements. Ultimately, the ESC is a vital component in the world of drone technology, enabling the smooth and precise control of electric motors that powers these aerial vehicles.

Components used in ESC:

- ✓ Solder pads for the 3-BLDC motor phases
- ✓ Negative (-) LIPO connections
- ✓ Positive (+) LIPO Connection
- ✓ Servo signal or input of the PWM signal
- ✓ GND reference of PWM Signal
- ✓ Solder jumper, for altering the direction of Rotation (CW/CCW)
- ✓ Solder jumper, for varying the type of the PWM input signal
- ✓ State LED

Here we use Brushless ESC because Brushless ESC is the modern advancement in technology once it comes to Electronic Speed Controls. It is also a bit more costly. Connected to a brushless motor, it carries more power higher performance as compared to the brushed ones. It can also last a longer period.

ESC design mainly includes the following features:

- ✓ direction control
- ✓ speed control
- ✓ PWM
- ✓ battery compatibility
- ✓ thermal protection
- ✓ current limiting
- ✓ brake functionality
- ✓ BEC, programmability
- ✓ compatibility
- ✓ communication protocols
- ✓ firmware updates.

3.6 Power Module:

A power module in a drone is an essential component responsible for managing and distributing electrical power within the UAV (Unmanned Aerial Vehicle). Drones require precise control over power sources, voltages, and currents to operate efficiently and safely. The power module receives power from the drone's main battery source, typically a lithium-polymer (LiPo) or lithium-ion (Li-ion) battery. It then distributes this power to various components of the drone, including the flight controller, electronic speed controllers (ESCs), motors, servos (if applicable), and other onboard electronics. Power modules play a critical role in drone operations, as they ensure a consistent and controlled supply of power to all components, contributing to stable flight, safety, and the efficient use of battery resources. The design and capabilities of power modules can vary based on the specific drone's requirements, its payload, and intended use, whether for recreational flying, aerial photography, surveying, or professional applications.

Specification:

Below are typical limits, but it is best to confirm directly with vendor:

- ✓ Maximum input voltage of 18V (4s LIPO)
- ✓ Maximum of 90Amps (but only capable of measuring up to 60 Amps)
- ✓ Provides 5.37V and 2.25Amp power supply to the Autopilot

3.7 Propellers:

The large size of 19-inch propellers means they are typically used on heavy-lift drones and specialized applications where significant thrust is necessary. When configuring 19-inch propellers, it's essential to choose the right pitch and material to match the specific requirements of the drone. The pitch, which determines how the propeller interacts with the air, should be chosen based on whether the goal is maximum thrust or optimized efficiency. In heavy-lift applications such as industrial drones, high pitch propellers may be preferred to generate substantial lift. Materials, including carbon fiber or reinforced plastics, are chosen for durability and resistance to wear and tear. It's crucial to ensure that the drone's motors and frame are compatible with 19-inch propellers, as the propellers' dimensions have a direct impact on the drone's stability and flight performance. Overall, configuring 19-inch propellers is about achieving the right balance of power, efficiency, and stability to meet the specific demands of the drone's intended use, whether it's for aerial photography, agriculture, or industrial tasks.

Materials used for propellers:

- ✓ Carbon fiber
- ✓ Plastic

Purpose of using carbon Fiber:

Carbon fiber is chosen as a material for various applications, including drone propellers, for several compelling purposes. Its exceptional strength-to-weight ratio endows it with remarkable durability and structural integrity, making it ideal for withstanding the stresses and forces encountered during drone flight. This strength, combined with its lightweight nature, results in propellers that are not only robust but also efficient, contributing to extended flight times. Carbon fiber's stiffness ensures that the propellers maintain their shape, providing stable thrust and enhancing flight stability and maneuverability. Precision-balanced carbon fiber propellers reduce vibration, a crucial factor for applications like aerial photography where smooth, shake-free footage is paramount. Additionally, carbon fiber's resistance to environmental factors, corrosion, and heat, along with its aerodynamic flexibility, makes it the choice for high-performance drones. Its longevity and resistance to wear and tear make carbon fiber propellers a cost-effective and durable solution for drones operating in demanding conditions.

3.8 Power Distribution Board:

PDB's essentially distribute the power from the battery to the ESC.

- ✓ **Centralized Power Management:** The PDB acts as a central hub for distributing power to all the essential components of the drone, such as the flight controller, motors, propulsion systems, and payload systems (e.g., pesticide sprayers).

✓ **Improved Safety:** By providing a structured and organized power distribution system, a PDB helps prevent electrical shorts, overloading, and other electrical issues, enhancing the safety of the drone's operation.

✓ **Redundancy:** Some advanced PDBs are designed with redundancy in mind. They can have multiple power inputs or circuits, ensuring that the drone can continue to operate even if one power source fails.

✓ **Voltage Regulation:** PDBs often incorporate voltage regulation or filtering to ensure that the voltage supplied to critical components remains stable, preventing voltage fluctuations that could disrupt the drone's performance.

✓ **Integration of Additional Electronics:** Pesticide spraying drones often require various additional electronics, such as GPS modules, telemetry systems, and communication devices. The PDB can provide the necessary power connections for these components.

✓ **Ease of Maintenance:** With a PDB, it's easier to diagnose and repair electrical issues. It simplifies the process of troubleshooting, making it more convenient to identify and address problems in the power distribution system.

✓ **Customization:** PDBs can be designed and configured to suit the specific needs and requirements of the drone, allowing for easy integration of various components and sensors.

✓ **Weight and Space Savings:** By centralizing power management, a PDB can help reduce the number of cables and connectors required, leading to weight savings and a more compact design, which is essential for drone applications.

✓ **Efficient Power Distribution:** PDBs are designed to efficiently distribute power, reducing energy losses and ensuring that the drone's systems receive the necessary power without wastage.

✓ **Scalability:** As the requirements of the drone change or as additional systems are integrated, a PDB can be designed to accommodate these changes, making it a scalable solution for future upgrades and improvements.

In summary, a Power Distribution Board in a pesticide spraying drone offers a centralized and efficient solution for managing electrical power, enhancing safety, and facilitating the integration of various electronic components. It is a critical component in the overall design and functionality of the drone, ensuring reliable and efficient operation during pesticide application and other tasks.

3.9 Global Positioning System (GPS):

The Global Positioning System (GPS) is a satellite-based navigation system that provides precise location and time information to users anywhere on or near the Earth. It is a network of orbiting satellites, ground stations, and user devices that work together to enable various applications, including navigation, mapping, surveying, and timing synchronization.

✓ **Precise Navigation:** GPS enables the drone to accurately determine its position in real-time, allowing it to follow predetermined flight paths with high precision. This precise navigation is essential for ensuring that the pesticide is applied evenly and accurately across the target area.

✓ **Waypoint Navigation:** Drone operators can program specific waypoints and flight routes using GPS coordinates. The drone can then autonomously follow these waypoints, ensuring consistent coverage of the entire field or area being treated.

✓ **Overlap Control:** GPS technology can be used to control the overlap of pesticide spray patterns. This ensures that there are no gaps or excessive spraying in adjacent swaths, leading to efficient pesticide distribution.

✓ **Return to Home (RTH):** In case of unexpected events or low battery levels, GPS enables the drone to safely return to its launch point. This feature helps prevent the loss of the drone and its valuable payload.

✓ **Data Logging and Mapping:** GPS-equipped drones can log data on the precise location of pesticide applications. This data can be used to create maps and reports that show where pesticides were applied and in what quantities. This information is valuable for compliance, record-keeping, and optimizing future applications.

✓ **Remote Sensing Integration:** GPS coordinates are essential for correlating drone-acquired remote sensing data (e.g., NDVI imagery) with the specific locations within the target area. This enables farmers and operators to identify areas of concern and tailor pesticide application accordingly.

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✓ **Real-time Monitoring:** GPS data can be transmitted in real-time to the operator, allowing them to monitor the drone's position and progress during the spraying operation. This real-time feedback can help ensure that the mission is going as planned.

✓ **Integration with Ground-Based Systems:** GPS data from the drone can be integrated with other agricultural management software and systems, enabling farmers to track and manage pesticide application alongside other farming operations.

In summary, GPS technology is a fundamental component in modern pesticide spraying drones, enabling precise navigation, data collection, and efficient and environmentally responsible pesticide application. It enhances the accuracy and effectiveness of pest control while reducing the overall environmental impact.

3.10 Landing Gears:

Landing gear, also known as undercarriage, is a fundamental component of drones (UAVs or Unmanned Aerial Vehicles). It serves the crucial purpose of supporting the drone during takeoff and landing, protecting the payload and delicate electronics on board, and providing stability during ground operations. Landing gear is a critical component of drones, providing support, stability, and protection during takeoff, landing, and ground operations. The design and type of landing gear can vary based on the drone's purpose, size, and the specific needs of its missions, whether for photography, surveying, surveillance, or other applications.

✓ **Stability:** The primary purpose of the landing gear is to provide stability to the drone during takeoff and landing. It should keep the drone level and prevent it from tipping over, especially in uneven or rough terrain.

✓ **Ground Clearance:** The landing gear should provide sufficient ground clearance to ensure that the drone's propellers and other components do not touch the ground or vegetation during takeoff, landing, and while hovering close to the ground.

✓ **Retractable vs. Fixed:** Some drones have retractable landing gear, which can be raised after takeoff to reduce air resistance and improve flight efficiency. Retractable landing gear can be useful for maximizing flight time, but it adds complexity to the design.

✓ **Shock Absorption:** A good landing gear system should have some level of shock absorption or damping to cushion the impact of landings, reducing stress on the drone's structure and payload. This is particularly important in agricultural settings where the drone may land on uneven terrain.

✓ **Material and Durability:** The landing gear is typically made from lightweight, durable materials like carbon fiber or aluminum to withstand the rigors of repeated takeoffs and landings. It should be able to withstand the weight of the drone and any additional payload.

✓ **Weight Considerations:** Landing gear contributes to the overall weight of the drone, and excess weight can reduce flight time. Therefore, it's important to strike a balance between durability and weight, depending on the specific requirements of the drone and the payload.

✓ **Visibility and Ground Clearance Sensors:** In some cases, landing gear may be equipped with sensors or markers that help the drone's operator judge ground clearance and alignment during landings.

✓ **Maintenance and Replacement:** Landing gear should be designed for ease of maintenance and, if necessary, replacement. Since they are subject to wear and tear, it's important to have a system in place for quick and cost-effective maintenance or replacement.

The design and characteristics of the landing gear should align with the specific needs and operational conditions of the pesticide spraying drone, taking into account factors like the drone's size, weight, payload capacity, and the types of terrains it will operate in. Properly designed landing gear enhances the safety and effectiveness of drone operations in agriculture.

3.11 Types of Telemetry:

Telemetry systems on drones collect a wide range of data, including altitude, airspeed, GPS location, battery voltage and capacity, motor RPM, temperature, and other vital parameters. Some advanced drones may also capture additional data, such as camera settings and sensor readings. The collected data is transmitted in real-time to a ground control station, typically via radio waves or a wireless connection. This real-time monitoring allows operators to have up-to-the-second information about the drone's status while it is in flight. Telemetry data is instrumental in controlling the drone during its flight. Operators can use this data to make real-time decisions, such as adjusting the flight path, managing power consumption, or responding to emergencies like low battery warnings or motor failures. Telemetry data can alert operators to potential issues or emergencies, such as loss of GPS signal, adverse weather conditions, or obstacles in the flight path. This information allows for quick and informed responses to ensure the drone's safety. Telemetry systems usually enable two-way communication between the ground station and the drone. This can be used for sending control commands, receiving flight instructions, and maintaining a communication link in case the drone goes out of range. Telemetry in drones provides a critical link between the unmanned aircraft and the remote operator, enabling real-time monitoring, control, and data collection. This data is invaluable for ensuring the safe and effective operation of drones in various applications, including agriculture, aerial photography, surveillance, and more.

Basically, there are two types of telemetry.

- ✓ FPV Telemetry
- ✓ Marine & Subsea Telemetry

FPV Telemetry:

FPV telemetry (First-Person View telemetry) is a technology used in the field of unmanned aerial vehicles (UAVs), particularly in the context of drones and remote-controlled aircraft. It is designed to provide real-time data and information to the operator or pilot of the UAV, enhancing situational awareness and control during flight. FPV telemetry is often used in conjunction with FPV systems that provide live video feeds from the UAV's onboard camera to the operator.

Marine & Subsea Telemetry:

Marine and subsea telemetry is a specialized field of telemetry that involves the collection and transmission of data and information from underwater or marine environments to a remote location. This technology is essential for various applications, including oceanography, marine biology, offshore exploration, underwater monitoring, and navigation.

3.12 Transmitter & Receiver:

In the context of a drone, the transmitter and receiver serve as the vital communication link between the operator and the unmanned aircraft. The transmitter, typically held by the drone pilot or operator, is the device that sends control commands and other essential data to the drone. It generates signals, often in the radio frequency range, which are then transmitted wirelessly to the drone. On the drone's end, the receiver captures these signals using an antenna and processes them to interpret the pilot's commands. It ensures that the drone responds accurately to control inputs, such as those for movement, altitude, and orientation. This real-time, two-way communication between the transmitter and receiver is crucial for safe and precise drone operation, allowing operators to navigate the drone, capture aerial footage, and execute various tasks with control and finesse.

Basic commands in Transmitter:

An FPV Drone Radio Transmitter transmits commands via channels. Each channel is an individual action being sent to the aircraft.

- ✓ **Roll:** Moves your drone left or right in the air, literally “rolling” your drone.
- ✓ **Pitch:** Tilts your drone forward or backward.
- ✓ **Yaw:** Rotates your drone clockwise or counterclockwise, allowing you to make circles or patterns in the air.
- ✓ **Throttle:** To increase, push the left stick forwards. To decrease, pull the left stick backward. This adjusts the altitude, or height, of the drone.

3.13 Nozzles:

The nozzle in a pesticide spraying drone is a critical component that plays a significant role in the effective and efficient application of pesticides. Nozzles are responsible for creating and controlling the spray pattern, droplet size, and spray distribution. Here are some key considerations regarding nozzles in pesticide spraying drones:

✓ **Droplet Size**: Nozzles are designed to produce droplets of specific sizes. The choice of droplet size is crucial because it affects the coverage and penetration of the pesticide. Smaller droplets can drift with the wind, while larger droplets may not cover the target area adequately. The selection of the appropriate droplet size depends on the type of pesticide, the target crop, and environmental conditions.

✓ **Spray Pattern:** Nozzles can create different spray patterns, such as flat-fan, cone, or even air-induced. The choice of spray pattern should be based on the shape and size of the crop, the height and speed of the drone, and the need for uniform coverage.

✓ **Flow Rate:** Nozzles have different flow rates, which determine the volume of liquid sprayed per unit of time. The flow rate needs to be calibrated according to the drone's speed and the desired application rate for the pesticide.

✓ **Nozzle Material:** The material of the nozzle can affect its durability and resistance to corrosion from the chemicals in the pesticide. Stainless steel and ceramic nozzles are commonly used for their durability.

✓ **Nozzle Placement:** The placement of the nozzles on the drone's spray boom is essential to ensure even coverage. Proper spacing and alignment of the nozzles help prevent over-application or under-application of pesticides.

✓ **Pressure Control:** Maintaining the correct pressure in the spraying system is critical to achieve the desired droplet size and spray pattern. Pressure control systems are often integrated into the drone's pesticide spraying system to regulate the pressure at the nozzles.

✓ **Calibration:** Nozzles need to be calibrated regularly to ensure that they are operating within the desired specifications. Calibration involves checking the flow rate, droplet size, and spray pattern.

Overall, the choice of the right nozzle is a crucial factor in optimizing the effectiveness and efficiency of pesticide application in agriculture. Properly selected and maintained nozzles can help reduce pesticide wastage, improve crop protection, and minimize environmental impact. It's important to consult with experts or manufacturers to select the most suitable nozzles for a specific drone and application scenario.

3.14 Pump Motor:

A pump motor is a crucial component in a pesticide spraying drone's agricultural payload system. This motor is responsible for pressurizing and pumping the pesticide or liquid solution from the drone's onboard tank to the spray nozzles, enabling the precise and controlled application of pesticides or other agricultural chemicals. The mechanical configuration of a pump motor in a pesticide spraying drone is meticulously designed to facilitate the efficient and precise application of agricultural chemicals. Typically situated near the liquid reservoir, the pump motor features inlet and outlet ports for the controlled flow of liquid. It is equipped with an electric motor powered by the drone's onboard battery, and its pump head, often utilizing diaphragm technology, ensures a consistent and unidirectional flow of liquid. Check valves prevent backflow, and pressure regulation mechanisms maintain an even spraying pressure. Flow rate adjustments are provided to fine-tune the application volume. A hose connects the pump motor to the nozzle system, which atomizes the liquid into fine droplets for uniform distribution over crops. To mitigate mechanical stress and vibrations, suitable mounting and vibration isolation mechanisms are often integrated. This configuration guarantees reliable and accurate liquid application, a fundamental component in the drone's role as a precise and effective tool in modern agriculture.

3.15 Tanks:

✓ Tanks are usually equipped in drones for pesticide spraying and sanitization purposes.

✓ Hence, they are fixed at the bottom of the drones for easy discharge using mechanical

✓ The tanks are integrated with nozzles that spray the liquid with proper precision.

✓ This unit also consists of a pump that discharges the fluid from the tank through the nozzles at a fixed pressure and velocity.

✓ The capacity of tank is about 10 Liters

Loss of power:

✓ Loss of power in drone occurs when the battery level of the drone becomes too low and all the control shut down.

✓ When this happens, the drone may just fall from the sky like a rock.

✓ This loss of power condition can be avoided using the Return to Home (RTH) switch available in modern day drones

IV. THE BASICS OF ROUTINE DRONE MAINTENANCE

4.1 Pre-flight Check:

Before every flight, conduct a pre-flight check to ensure everything is in order. This check should include the following:

- ✓ Ensure all components are securely attached and in good condition.
- ✓ Check the propellers for damage or wear.
- ✓ Inspect the battery for any visible damage or swelling.
- ✓ Verify that the camera and gimbal are clean and functioning correctly.
- ✓ Ensure the firmware and software are up to date.

4.2 Battery Care:

Properly maintain your drone's batteries to maximize their lifespan and ensure safe flights.

- ✓ Store batteries at room temperature and avoid extreme temperatures.
- ✓ Charge and discharge the batteries regularly, following manufacturer recommendations.
- ✓ Always use the manufacturer-recommended charger.
- ✓ Inspect the battery connectors for damage or dirt before every flight.

4.3 Propeller Maintenance:

Propellers are crucial for flight stability and should be well-maintained.

- ✓ Inspect propellers for cracks, chips, or other damage.
- ✓ Tighten propellers securely.
- ✓ Replace damaged or worn propellers.

4.4 Cleaning and Protection:

Drones can accumulate dirt, dust, and debris during flights, which can affect performance.

- ✓ Clean the drone's body and components with a microfiber cloth.
- ✓ Use compressed air to blow away dust and debris.
- ✓ Protect the drone from water, moisture, and extreme environmental conditions.

4.5 Gimbal and Camera Care:

If your drone has a gimbal and camera, it's essential to take care of them.

- ✓ Keep the gimbal and camera lens clean and free from debris.
- ✓ Calibrate the gimbal if necessary.
- ✓ Check for loose or damaged gimbal components.

4.6 Software and Firmware Updates:

Regularly check for software and firmware updates for both your drone and its controller. These updates often include bug fixes, new features, and improved performance.

4.7 Storage and Transportation:

- ✓ Properly store and transport your drone to prevent damage.
- ✓ Use a protective case or bag designed for your drone.
- ✓ Remove the battery during long-term storage to prevent over-discharge.

4.8 Motor and System Checks:

Periodically inspect the drone's motors, wires, and electronic components for any signs of wear, damage, or loose connections. Address any issues promptly.

4.9 Record Keeping:

Keep a maintenance log to track the date of each maintenance task, any repairs or replacements, and any issues you encounter during flight. This record can help identify patterns and potential problems.

4.10 Training and Knowledge:

Stay informed about your specific drone model, its features, and any known issues. Consider taking a maintenance and repair course to increase your knowledge and skills.

4.11 Overall Checklist:

- ✓ Arms, Motors, GPS, Landing Gear and pump should be tightly mounted. No shake in landing gear
- ✓ Propellers should be correctly mounted in their appropriate motors.
- ✓ Propellers should not be tightly and loosely mounted.
- ✓ While connecting batteries to the drone, transmitter should ON.
- ✓ Home point of drone, drone location and transmitter location should be in appropriate location.

V. DRONE CONTROL APPROACH

The drone control approach encompasses the methods, technologies, and strategies employed to manage and direct the operation of unmanned aerial vehicles (UAVs), commonly known as drones. Many drones are operated through remote control systems, where a human pilot uses a handheld controller or a software interface on a computer or mobile device to send commands to the drone. These commands control aspects like flight path, altitude, and camera functions. Drones are often equipped with autonomous features and technologies, such as GPS, obstacle avoidance, and waypoint navigation. These allow the drone to operate semi-independently, following pre-programmed routes or responding to situational cues. The different flight controllers with their controlling approaches are given in the table below (Table 1).

Table 1. Flight controller with control approach

Flight controller	Control Approach	References
NAZA M-lite flight controller	Radio Transmitter	[1]
ATmega328	Radio Transmitter	[3][18][28]
Arduino mega	Wi-Fi	[2]
APM Ardupilot controller	Radio Transmitter	[10]
Pixhawk controller	Autonomous	[22][23][32]
KK 2.1.5	Radio Transmitter	[25][26][31]
Raspberry Pi Model 3 B	Autonomous	[36]

VI. RECENT TRENDS AND CHALLENGES

In recent years, drone technology in pesticide spraying has witnessed significant advancements and notable challenges. Emerging trends include the integration of sophisticated sensors and imaging systems, such as multispectral cameras and LiDAR, which enhance the precision and efficiency of pesticide application. Drones equipped with AI and machine learning algorithms are being used to analyze crop health data and make real-time decisions on where and how much pesticide to apply, reducing chemical use and minimizing environmental impact. Additionally, swarm technology, where multiple drones work collaboratively, is gaining traction for large-scale agricultural operations. However, challenges persist, including regulatory frameworks that vary by region and evolving privacy concerns related to drone surveillance. Ensuring safe drone operation in complex and dynamic agricultural environments remains a priority, and addressing issues of battery life and payload capacity continues to be a challenge. As drone technology in pesticide spraying continues to evolve, it promises more sustainable and efficient agriculture practices but also demands ongoing adaptation to address regulatory, environmental, and operational challenges. Details of the drones used by various users in recent time for pesticides spraying along with their technical elements are listed below in Table 2.

Table 2. Existing drones for spraying pesticides in recent time

Exiting Drones	Volume of pesticide	Max. Flight time full load	Max. Speed	Discharge rate	No. of nozzles	Reference
DJI Agrus MG-1S	10 L	10 min	12 m/s	0.379 L/min	4	[38]
3WQF120-12	12 L	30 min	5 m/s	0.8 L/min	2	[39]
3CD-15	15 L	20 min	6 m/s	0.54 L/min	4	[39]

WSZ-0610	10 L	20 min	4 m/s	0.72 L/min	2	[39]
HY-B-15L	15 L	15 min	4.5 m/s	0.38 L/min	5	[39]
N-3 UAV	25L	-	4 m/s	0.85 L/min	2	[40]
Knapsack-type electric fog sprayer 3WBD	20L	-	1 m/s	1 L/min	1	[40]

VII. DRONE FOR CROP SPRAYING

The utilization of drones for crop spraying has ushered in a new era of precision agriculture. These unmanned aerial vehicles (UAVs) equipped with specialized crop spraying equipment are redefining the way farmers protect and manage their crops. The key advantage lies in their ability to precisely target specific areas of fields, delivering pesticides, fertilizers, or other treatments with unparalleled accuracy. Unlike traditional methods that can be wasteful and environmentally taxing, drones can significantly reduce resource consumption, costs, and the environmental impact of agricultural chemicals. Efficiency is another major driver of their adoption. Drones can cover vast areas of farmland with remarkable speed, making them particularly advantageous for large-scale agricultural operations. This efficiency not only saves costs but also allows for more effective crop management. Furthermore, the reduction in chemical usage is a major environmental boon, as it limits contamination of surrounding ecosystems, reduces chemical runoff, and minimizes potential harm to non-target organisms. Safety considerations also play a pivotal role, as drones eliminate the need for human operators to be in close proximity to potentially hazardous chemicals. Moreover, their accessibility to challenging terrain ensures no part of the field is left untreated, further enhancing overall effectiveness. As technology advances, drones for crop spraying are equipped with GPS guidance systems, sensors, and imaging technology, making them more efficient and capable of assessing crop health, soil conditions, and pest infestations. However, challenges such as battery life, weather conditions, and the need for regulatory compliance must also be addressed. Responsible choices regarding the chemicals and application methods used are essential to ensure the long-term sustainability of this technology. The synergy between data collection and precise treatment application exemplifies the power of precision agriculture, with drones offering a transformative approach that not only enhances crop yields but also reduces the environmental impact of conventional crop management practices. (Table 3).

Table 3. Various types of spraying systems used in drones

Tank capacity (liter)	Nozzle type	Pump discharge	Reference
5 litres	Flat fan	2.5 L/min	[17]
5.7 L	Micronair nozzles	100 mL/min	[19]
-	The Universal nozzl	1 L/min	[20]
10 L	XR11001	0.43 L/min	[21]
13.2 L	flat fan nozzles	46.8 L/ha	[24]
6 L	flat fan nozzles	2.5 L/min	[25]
250ml	-	250 mL/min	[31]
5 L	-	2.4 L/min	[35]

VIII. CONCLUSION

In conclusion, this study has explored the application of pesticide spraying drones in modern agriculture and has highlighted both their potential benefits and challenges. The findings from our research suggest that pesticide spraying drones offer a promising avenue for improving the efficiency and sustainability of pesticide application in agriculture. They have the capacity to enhance precision, reduce labor requirements, and minimize the environmental impact of pesticide use. However, the adoption of pesticide spraying drones is not without its hurdles. The initial costs associated with acquiring and maintaining the technology can be prohibitive for small-scale farmers. Additionally, navigating complex regulatory frameworks and ensuring compliance with safety and environmental standards can pose significant challenges. Training and skill development for drone operation and maintenance are also critical considerations. The success of pesticide spraying drones in agriculture will depend on a holistic approach that addresses these challenges while harnessing the technology's advantages. Further research and development efforts are needed to refine drone capabilities, improve payload capacities, and enhance their environmental performance. Policymakers and industry stakeholders should work together to streamline regulations and promote responsible drone use in agriculture. As we move forward, it is imperative that we continue to monitor and assess the evolving landscape of pesticide spraying drones in agriculture. By doing so, we can unlock the full potential of this technology and contribute to more sustainable and efficient farming practices. This journal article adds to the growing body of knowledge on the subject and underscores the need for continued exploration of pesticide spraying drones as a valuable tool for modern agriculture.

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