Integrating Aerial Electric Vehicles for Sustainable Agriculture and to Optimize the Overhead Cost of Farming

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Abstract. India is a country whose roots are buried deep in agriculture. The livelihood of about 58% of the population depends on farming. Yet technological progress in the country's agricultural practices is lacking. The growing technology and increased demand for agriculture calls for the incorporation of technology into sustainable agriculture. The proposed work, therefore aimed at building a drone to serve this purpose. The rapid growth of the Electric Vehicle (EV) market and India's aim to shift to the complete use of EVs by the year 2023 demand a paradigm shift in the agriculture sector. The use of aerial electric vehicles would be an impeccable execution of EVs in agriculture, serving a vast set of functions. The proposed work focuses on one specific application: remote spraying of pesticides in an efficient way so that the overhead costs of farming are reduced. The harmful effects of exposure to pesticides are eminent. Farmers who take it upon themselves to spray these pesticides are at risk of contracting a wide range of health adversities and deadly chronic diseases. As a solution to this imminent need, it is proposed to design a drone to spray pesticides according to the requirement, as directed by the farmer. The Agriculture Drone has a hexagonal structure controlled using BLDC motors and Electronic Speed Controllers (ESCs). For flight control, Pixhawk 2.4.6 is used. It is equipped with a GPS module that can track the location of the drone and plan its mission. The drone operates on autopilot and requires no manual control for flight. Specific coordinates are given to the Drone so that it moves along the given coordinates for its flight using the software 'Mission Planner.' The designed drone has a removable tank for the storage of pesticides, which is placed under the landing gear. The tank has a spraying system that operates on the instructions of the farmer, which are given to the drone using a Radio transmitter.

1. Introduction

Modern agriculture ceaselessly requires the use of pesticides to protect crops and increase yield. Traditional methods of pesticide spraying, although efficient to satisfy the need of the crop, are time-consuming, involve a lot of pesticide wastage, even labor-intensive, restrict access to hard-to-reach areas such as steep slopes, areas with dense vegetation, lack uniformity in spraying, and poses a variety of health threats to the farmers. Since the complete elimination of the use of pesticides is a far-off goal, it tried to eliminate the direct exposure of these harmful chemicals on the farmers and reduce the overhead costs of farming in this proposed model. The usage of unmanned aerial electric vehicles provides a solution to these challenges. This paper implores the design and development of a drone that provides a solution to these challenges. The indirect expenses incurred in farming, such as equipment, utilities, insurance, administration, etc., which are independent of the production of crops are known as overhead costs. This paper proposes to optimize these costs by using aerial electric vehicles for sustainable agriculture.

The cotton crop is commonly farmed in Telangana, India. This drone is designed to accommodate the pesticide requirement of 1-acre farmland of cotton crop, with an estimation of the payload carried by the drone, which is the most important factor to assess the capacity and coverage of pesticide carried by the drone. The spraying system on this drone is designed to reduce pesticide wastage, cover large areas of land in a small amount of time, ensure uniformity in spraying, and can reach every nook and cranny of the farmland. Furthermore, adopting drone technology would require farmers to learn how to maneuver and operate the drone, this would be a taxing process. Hence, for easy serviceability, the drone is designed to operate on autopilot, with simple commands to launch the vehicle and control the pesticide spray, reducing the workload and labor costs even further.

1.1. Literature Survey

Huang et al. (2015) [2] constructed a low-capacity sprayer that can be fashioned into unmanned aircraft. The helicopter's primary rotor has a diameter of 3 meters, and its top payload is 22.7 kilograms. In the past, every 45 minutes needed at least one gallon

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of petroleum. This research cleared the way for the creation of UAV aerial application systems with a higher target rate and larger VMD droplet size for crop production.

Dongyan et al. (2015) [3] experimented with efficient swath width and droplet distribution uniformity using M-18B and Thrush 510G aerial spraying devices. They concluded from this experiment that the disparity in swath width for the M-18B & Thrush 510G is caused by the different flight heights of the agricultural aircraft, which were 5 meters and 4 meters, respectively.

Yallappa et al. (2017) [7] created a hexacopter with two 8000mAh LiPo batteries. In addition to the performance assessment of spray liquid discharge and pressure, spray liquid loss, and determination of droplet size and density are all included in their study. They succeeded in developing a drone through research that can transport 5.5 L of liquid and has a 16-minute endurance.

Kurkute et al. (2018) [8] labored on a quadcopter unmanned aerial vehicle's spraying system using basic, inexpensive equipment. Both liquid and solid contents are sprayed using the universal sprayer device. They have also compared various controllers required for agricultural applications in their study, and they have concluded that the quadcopter system with Atmega644PA is the most appropriate due to its successful deployment.

Prof. B. Balaji et al. (2018) [9] devised a hexacopter UAV using a raspberry pi running the Python programming language to spray pesticides and monitor crops and the environment. Additionally, their UAV has a variety of instruments, including DH11, LDR, and Water Level Monitoring sensors. They came to the ultimate verdict from this experiment that the correct use of UAVs in agricultural fields can result in savings of 20% to 90% in labor, water, and chemical abuse.

Rahul Desale et al. (2019) [10] described a UAV-based architecture suitable for agricultural uses. In addition to being used for spraying, their UAV was also built with GPS and cameras for watching farmland. Cost and weight calculations contributed to their construction. They employed a firmware-equipped microprocessor, model KK 2.1.5.

2. DESIGN AND DEVELOPMENT

The drone is premeditated around the payload it is required to carry. Based on the payload required, the specifications of primary components such as motors, propellers, battery, are curated. Specifications of secondary components such as the pump, nozzles, and pesticide tank are then estimated according to the overall weight of the drone. Lastly, the chassis of the drone is chosen to accommodate the above components, ensuring it is lightweight but strong enough to withstand the flight and payload. For instance, the pesticide required for a cotton farm of 1 acre is about 3 liters. Hence, the drone must carry a 3-kilogram pesticide tank, along with the weight of the remaining components, according to which the specifications of the components were chosen.

2.1. Construction

2.1.1. Drone Mainframe:

The brain of the drone is the flight controller, PIXHAWK 2.4.6. Pixhawk is an ergonomic flight controller which can be configured using the software "Mission Planner." The software facilitates the calibration of the accelerometer, gyroscope, and compasses present in the flight controller, the radio channels, and the ESCs connected to it. The drone has a configuration of 6 arms, each mounted with a BLDC motor coupled with its propeller, and its respective ESC, giving it the name 'Hexa-copter'. The arms are connected between the main frame consisting of an upper mounting board and the lower power distribution board. The arms are made from ultra-durable polyamide nylon and the main frame to which these arms are connected is made of a glass fibre material. The ESCs have their output end connected to the motor, in a pattern that determines the direction of rotation of the motor, one input end drawing power from the power distribution board, and the other input connected to the flight controller's 'main output pins.' The flight controller, an external GPS, and the receiver are placed atop the upper mounting board.

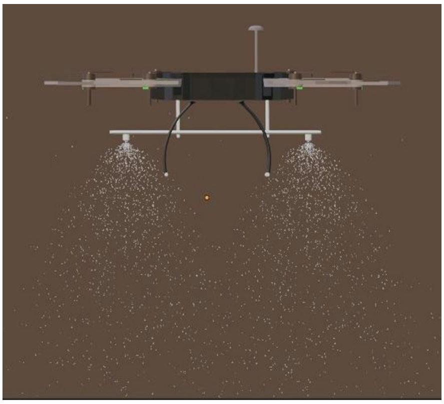

Fig. 1. Simulation of Drone Construction with Spray Nozzles

2.1.2. **Spraying System:**

The designed spraying system encompasses a pressurized 12V (Volts) DC water pump, two sprinkler nozzles, and a lightweight fiber container for the storage of pesticides. The whole system is placed in the space between the landing gear. Power supply to the pump is given from the power distribution board and instructions for operations are communicated from the flight controller. The pressurized pump has its inlet pipe submerged in the pesticide tank and its outlet connected to an expandable tube, whose ends have nozzles attached to it. The expandable tube is placed perpendicular to the flight direction of the drone (Fig.1.). Each nozzle produces a maximum of a 0.9m (meters) spray diameter. Thus, the nozzles are placed at a minimum distance of 1.8m apart so there is no aliasing of the pesticide spray. The diameter of each cotton crop is no more than 0.7m in diameter, hence the drone is capable of spraying two rows of the crop at the same time. The pressurized pump is connected to the flight controller via a relay through the 'auxiliary outputs pins', which can be operated by the transmitter. The block diagram visualizes the components that embody the drone.

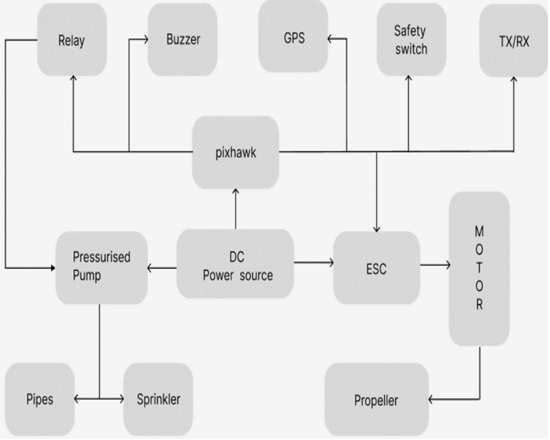

Fig. 2. Block Diagram of the proposed model

2.1.3. **Automation**

To make the drone intelligible and sustainable, its entire operation is automated. The outset of automating the drone relies on the vehicle's ability to fly without manual control. This is achieved by programming the flight controller to have various flight modes. The flight modes are configured to be controlled by one of the 6 channels of the radio, via a transmitter switch. A 3-position switch on the transmitter is used to set up the flight modes, one for Auto, another for Stabilise, and the last for Land. The Auto flight mode requires a 'flight plan' that serves as the instruction set for the drone. A flight plan is unique for every piece of land.

The image (Fig. 3) shows the flight plan for particular farmland. Points 1 to 13, are organized for the drone to pursue that path. Commands are given to be performed at each point on that path as shown in the image (Fig. 4). Point 1 is given the take-off command. The drone placed at this point takes off to embark upon the laid-out path. The last command, at point 13 (Fig. 5), is to return to launch. Here, the drone returns to point 1 and lands, from the last designated point 12. Another important factor is the altitude (Alt), specified in meters. It is given as 2 since cotton crops grow up to a maximum height of 1.5m, giving the spraying system enough space to cover the entire crop as well as reduce any wastage due to winds. The path can also be directed by mentioning the latitudinal and longitudinal coordinates of the land.

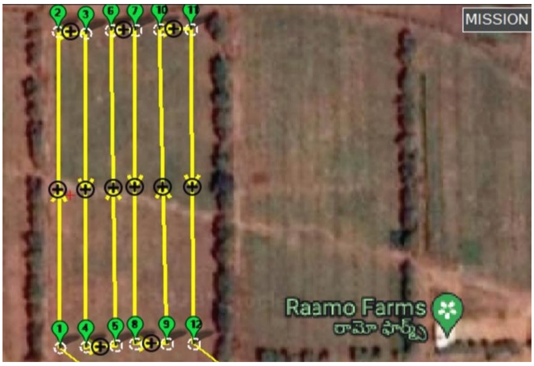

Fig. 3. Flight Plan

	Command	Delay	Lat	Long	Alt
1.	Takeoff	0	17.7565800	78.0597818	2
2.	Waypoint	0	17.7576120	78.0597764	2
3.	Waypoint	0	17.7576069	78.0598676	2
4.	Waypoint	0	17.7565851	78.0598676	2
5.	Waypoint	0	1737565902	78.0599642	2

Fig. 4. Waypoint Commands

Steps that follow in automating the drone is the control of pesticide spray. To carry out this step, the pressurized pump is controlled using a relay to turn it on and off on command. The relay is connected to one of the 'auxiliary output pins' on the flight controller. A radio channel is allocated to operate the relay via the transmitter switch. A 2-position switch is used here, one for turning on the pressurized pump to release the spray and the other to turn it off. Furthermore, the speed of the drone can also be regulated (between 1 meter/second to 13 meters/second) in the mission planner to optimize the pesticide spray to reduce product wastage, battery usage, and operating time.

3. PAYLOAD ANALYSIS

A drone's efficiency is directly reflected by the payload it carries. Excessive load on the drone will result in faster battery drain, reduced altitude and speed, and propeller fatigue. Hence, payload estimation is essential to draw the highest potential of the drone. The total weight of the drone and the thrust produced by the propellers is taken into account for calculating the payload.

TABLE 1. Weight roundup

Component	**Weight (kilograms)**
Drone mainframe	0.880
Motors and propellers	0.530
Battery	0.650
Pesticide tank	3.200
Pressurized pump	0.480
Total	**5.740**

Here, the pesticide tank and the pump make up the payload which is equal to 3.680 kilograms. The remaining weight belongs to the drone alone.

The thrust produced by 1 motor and propeller = 2.870 kilograms.

The thrust produced by 6 motors and propellers = 2.870 x 6 = 17.220 kilograms.

The thrust produced at 100 percent throttle must always be maintained to be three times the overall weight of the drone. That is the thrust-to-weight ratio much be 3:1.

Thrust : weight = 17.220 : 5.740 = 3 : 1

Thus, the ratio is maintained and the payload is adequate for maximum efficiency.

4. OPERATION

The initial setup of the drone requires the mapping of the flight plan for a given plot of the farm. With the flight plan remaining unaltered and saved in the flight controller's memory, the farmer can operate the drone using the transmitter. The drone is placed at the take-off point of the flight plan. The farmer now transmits the instruction to set the flight mode to Auto using the transmitter's 3-position switch. The drone then takes off from that point and pursues the path laid out. Upon take-off, the farmer is also required to turn on the pesticide spray using the 2-position switch on the transmitter. After completion of the flight path, the drone returns to the take-off point. During unanticipated conditions of the flight, PIXHAWK activates a fail-safe condition and the drone lands where it is.

5. RESULT

The designed drone model exhibited the following results:

Overall flight time is approximately 11 minutes, during which the pesticide tank is fully drained, covering 1 acre of farmland. The speed of the drone per this time duration is 2 meters/second. Hence, the time consumption of spraying is reduced significantly as compared to manual spraying methods. A fully charged battery of the specified rating lasts the entire flight duration. Since the Li-Po battery used is rechargeable, it significantly reduces fuel costs, proving that an electric power source is much more efficient in agricultural practices to reduce overhead costs. The convenient automation of the drone makes it straightforward for a farmer to operate without the help of a professional, evading additional labor costs for drone operation. Overhead costs of farming are reduced since purchasing the drone is a one-time investment with little to no maintenance costs. Lastly, exposure to harmful pesticides is eliminated, protecting the farmers from the adversities inflicted by these chemicals.

Fig. 5. Resulting Drone Model

6. CONCLUSION

In this paper, the design and development of an aerial electric vehicle for sustainable agriculture are discussed. The design specifications and component details are composed to adhere to the payload requirement. Drone automation is enabled to ease efficacy. The analysis of payload capacity is carried out for the resourceful functioning of the drone. The pesticide drain is estimated based on the flow rate of the nozzles, and flight time and battery drain are approximated based on in-field testing of the drone.

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