Emulation of Multi-Rotor Functionalities in Fixed Wing Airplane for Farm Based Land Surveillance with Controlled Fluid Dispersion System

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Abstract- The World is emerging with Technologies in every discipline, and India plays a vital role in the export of agricultural products. Since it has a huge amount of manifestation, it requires a lot of manpower. The Lack of skilled labour can also cause depletion of crops production rate. So the use of Technologies in agriculture reduces manpower drastically and increases efficiency. The production rate of crops in agriculture is based on various parameters like temperature, humidity, rain, etc., which are natural factors and are not controlled by farmers. The field of agriculture also depends on some factors like pests, disease, fertilizers, etc., which can be controlled by giving proper treatment to crops. Even though the use of pesticides can protect the crop, it may also have harmful effects on human health. So usage of technologies like quadcopter is an efficient process. But as it involves a huge amount of Initial and Operational cost, the quadcopters are replaced with Fixed Wing Drones. This paper depicts about the design and development of Fixed Wing Airplane known as AGRIWING, which combines all the desirable features of a conventional agricultural fixed wing such as mapping of farm, gathering heat signatures, etc., with the added capabilities of the autonomous fluid dispensing system, as in the Drone Spraying System with the advantages of Fixed Wing Airplane including reduced cost, improved flight time, robustness and more.

1. Introduction
India plays a major role in the field of agriculture. It requires a lot of manpower to increase the crop production rate. So there is a need to employ various technologies which can maintain the production rate with less manpower and thus resulting in increased efficiency. There is a high need for these systems and they form an integral part for Precision farming. In this rising population, the need to produce food as equally important as the need to produce quality foods, because the use of large number of pesticides and chemicals can damage the crops. The World Health Organization (WHO) estimates that more than three lakh people die from the toxic exposure of pesticides per year across the world [1]. Various pesticides used in agriculture causes health effects like skin allergies, asthma, and it also leads to a serious effect on fetal growth [2]. Some pesticides even contain carcinogenic substances. Many side effects of using these pesticides mostly occurs in developing countries because they need to fulfill their rising demand for food and it majorly affects the growing generations like children, Teenager and even adults by reducing the visual ability and resulting in lots of neurological problems. To reduce these effects, the amount of pesticides and other chemicals that are used for
cultivation are to be controlled. To achieve this, Precision farming is desired and for implementing this concept various technologies are required. Various technologies which has been currently employed for this operation are the Unmanned Aerial Vehicles (UAV), which comprises of a multirotor with sensors for guidance and mapping along with a dispersion system which can be used for fertilizers, pesticides and even seeds. But all these systems incurs huge cost and it is not well suited for developing countries like India and it is probably one of the major reasons which explains why India is not a pioneer in the use of Agriculture technologies and various researches are done to rectify the issue.

2. Related Works
There have been many works previously done in the field of spraying pesticide for plants. One such work describes the use of Hexacopter UAV for pesticide spraying for crop protection [3]. There is also another work which states the design of blimp with a quadcopter for automatic aerial spraying system [4] and there is another paper which makes use of the Atmega 328 for controlling the drone and sprayer system [5]. But the problem with all these systems is that it uses a form of multirotor system and high-end sensors which is not only expensive and but also difficult to obtain.

3. Solution
Technological development on autonomous flight system has been developed to a level, when there is sudden change in Mission planning, decision problem involving obstacles decision [17] are no longer a hurdle. The reason that it is been considered as a problem because most of the solutions provided by others authors, who try to eliminate human from the process by incorporating more technologies, thus increasing the overall cost of the system [20]. This may be suitable for a farming system in developed nations where the majority of the farms are big and owned by a company, producing a specific type of crops. But this is not the case in India where most of the farmers own a relatively small strip of land and cultivate seasonal crops, which indeed depends on the monsoon of that year. Also in most of the farms, surveillance mapping is done by either a fixed wing aircraft or a multirotor but pesticide spraying is done only by a multirotor [14]. So all the works done earlier are harder to replicate and economically not viable to replace the damaged part. To eliminate these problems and to create a solution which can emulate the function of an agricultural multirotor, we have designed a Fixed wing UAV which is named as AGRIWING, whose purpose is to act as Farm Surveillance system along with a Pesticide sprayer system. The design choice mainly relies upon the fact that cost including capital cost, running cost and maintenance cost, for a multirotor is more when compared to a Fixed Wing Aircraft.

4. Proposed Methodology
For reducing the use of pesticides in crop production, it has to be sprayed in the areas where it is actually needed because increasing the time of spraying increases the rate at which it gets mixed with air and thus increases chances of falling on the wrong plants which affects the production rate. Therefore our design needs to be robust with minimal parts which can detect the areas needed for pesticides and can spray the right amount of fluid on the areas detected in the previous step.

4.1. Design of Fixed Wing
Our design of fixed wing is based on a Blunt Nose Ft Versa with modification for various attachments. The reason that the Blunt nose design was chosen because it has an extra compartment for the storage of the other electronic components and also provides protection for the flight controller (Omnibus F2) and Global Positioning System (GPS) module. The Figure. 1 shows the actual AGRIWING without the winglets and sprayer system. Also availability of the flat base gives us the place to mount mapping and spraying modules in a custom designed enclosure which can speed up the insertion of the module in the flight. The module in Figure. 2 shows the quick insertion attached to flight bottom which is designed for the mapping and spraying system containing the Raspberry Pi Zero board, Pi Camera and an extendable microphone array. All these parts are separately powered, removing the dependency of the battery in plane and thus ensuring longer flight time. Also the Figure. 2 shows the Mapping and
Spraying module that has a nozzle with a valve, a liquid storage section and a pump. The flow is controlled by a Raspberry Pi that adjusts the valve which is actuated by a servo motor connected to the valve. All these parts can be removed, replaced and easily upgraded.

**Figure 1.** The black and orange colour gives better contrast to sky and makes it easy to spot

**Figure 2.** 3D model of quick insertion design and Mapping and Spraying System

### 4.2. Crop Monitoring Systems

Monitoring of the crops is the important step because it determines the areas of the field which needs to be sprayed with pesticide and also determines the amount of spraying needed for that particular area. Plants are monitored based on two ways, one is Vegetation Index and another is through the detection of pests in the field.

#### 4.2.1. Vegetation Index

A Vegetation Index (VI) is a method used to analyze the vegetation properties of the plants by enhancing the terrestrial photosynthetic activity and canopy structural variations [6]. There are various types of Vegetation Index used for agriculture. But some crop require a multispectral camera [19] which is expensive and the returns for that investment is considerable only for large farms. But in India, most of the farm land are small and the rate of return is low. Therefore, other Vegetation index like the Visible Atmospheric Resistant Index (VARI) [7] and Green Leaf Index (GLI) [8] are used because both of them can be measured by RGB spectrum camera. The formula for Indices are,

\[
VARI = (C_{GREEN} - C_{RED}) \times (C_{GREEN} - C_{BLUE})^{-1} \\
GLI = (2 \times C_{GREEN} - C_{RED} - C_{BLUE}) \times (2 \times C_{GREEN} + C_{RED} + C_{BLUE})^{-1}
\]

where \(C_{xxx}\) is the color reflected by the plant. Using (1) and (2), plant growth can be monitored and areas where growth is depleted due to external factors are marked and thus allowing the system to spray fluids in only those affected areas.
4.2.2. Detection of Pests. A Vegetation Index can give details of the plant growth and health, indicating whether the plant is growing or depleting. But it doesn’t give details about the type of pests affecting the plant. This identification of pests is important because it enables the system to localize the spraying of different types of pesticides for various types of pests because spraying all kinds of pesticides for unaffected areas affects the vegetation and also increases the cost. For detection of pests, the audio is recorded and it is processed after the flight. The recorded audio is compared with the insect’s sound to create a heat map. By using both mapping techniques the areas of pesticide spraying is decided and it is stored in Raspberry Pi whilst it can be overwritten by the user if they want to.

4.3. Control Systems for Mapping and Spraying
Control system for sprayer uses information from the heat maps formed by the combined monitoring systems.

![Figure 3. Block Diagram of Crop Monitoring System](image)

![Figure 4. Block Diagram showing Liquid Spraying System](image)
Flight paths are needed to be designed in a way such that multiple flights can take place simultaneously for large farms [13]. Since flight path determination for the AGRIWING is same as that for Drone, existing method is adopted. In Figure 3 the block diagram shows the monitoring systems which has the Raspberry Pi Zero which processes the data and acts as storage system. Once the Flight Mission is planned and the route is set using Flight Controller Software, the Raspberry Pi takes images using a Pi camera for land patches and embeds that image with GPS data from the GPS Module. In addition to that the Microphone data is also stored along with the agricultural land images. After completing the mission, the flight lands and all the data metrics is viewed using SSH in the main computer field.

During the manual inspection, the user can change the amount of liquid spraying or pesticide spraying by colouring the heat maps appropriately. After inspection, the spraying mode sets the same mission route and Raspberry Pi will spray the plants based on the Heat maps which is generated during the mapping stage. Based on the data values stored in the heat maps in their respective GPS locations, the spraying system can vary the amount of liquid sprayed and this can be done by using two controls methods. The Figure 4 shows the sprayer system consisting of a pump controlled by the Raspberry Pi, that takes liquid from the storage tank and pumps it to the valve which is actuated by a servo motor. By manipulating the valve position and flow rate of the pump using Raspberry Pi, the amount of liquid sprayed is controlled. Finally, the liquid is sprayed using a fan nozzle as it provides more coverage and better spread even in the presence of drift wind [3]. Spraying system is designed based on the modified and simplified version of Variable Spraying Actuator [9].

![Diagram of Spray Control System](image-url)

**Figure 5.** Illustration showing Spray Control System
4.4 Valve Position Control System

The Servo Valve Control System, also known as Valve Position Control System, whose main purpose is to spray the fluid based on the spray pattern measured by Vegetation Index. Servo Valve Control is built up on the image processing to calculate the movement of servo in correspondence to plants health measured using vegetation index [10]. Servo valve control provides the output signal for the servo to alter the position which controls the amount of pesticide to be sprayed. Servo Valve Control gets the input form the Modified VARI (MVARI) image from farmers, in which farmer marks the areas of affected crops based on his expertise. This input is passed on to the Servo Control’s subsystems. The overall working of the AGRIWING and parameters used for calculation is shown in Figure 5. This input is unrolled based on the flight path and effective length distance which can be covered by spray nozzle in single pass.

4.4.1 Unrolling of the MVARI Image. The input MVARI is unrolled based on the flight path and effective length which can be covered by spray nozzle in one pass which is Spray Distance also known as row count “rc”. For getting optimal Spray Distance (rc) without overlapping the spray, the flight path and length of the Field (r) is used. The spray distance is calculated using the following formula,

\[ \text{Spray Distance, } rc = r/nop \]  

Where, \(nop\) or \(Number of Passes\) denotes the number of times the plane crosses the field before reaching its end point, which is based on the factor of turning radius of plane. Based on this value, the MVARI is unrolled into a strip which proceeds to the normalizing of the strip image.

4.4.2 Normalizing Unrolled Image. The Unrolled MVARI image strip consists of \(rc\) number of Pixels in each row (along the flight path) and individual pixels are made up of 24 Bit Colour data, with 8 bit for Red, Green and Blue each. These data has to be converted into a form of an image showing the amount pesticide required based on the MVARI image which can be turned into a Signal for Valve Servo. As each pixel is having 3 Colour channel, each colour channel is assigned a coefficient which is based on the notation from VARI image, i.e., Red pixels should have more coefficient value as it needs more amount of pesticides. Due to this process, 3D Matrix (3 Channel) is linearly transformed into 2D Matrix (1 Channel). The normalizing formula used is,

\[ \text{Norm} = (R_{COEFF} * C_{RED} / 255) + (G_{COEFF} * C_{GREEN} / 255) + (B_{COEFF} * C_{BLUE} / 255) \]  

Where \(C_{yyy}\) is the colour value in \(yyy\) channel. The coefficients are chosen in a way that give optimal angle based on the sunlight falling on the field at the time of measurement.

4.4.3 Valve Opening Angle or Servo Signal. From the normalized image strip the average sum of pixel values at each row is calculated and it is mapped to the Servo Valve operating range of angles from 0° to 180° degrees. Dimensionality reduction of 2D Matrix to 1D array is done by the formula,

\[ SA(i) = \sum_{i=0}^{l} \sum_{j=0}^{re} N(i,j) * 180 \]  

Where, \(l\) is the length of flight path and \(SA\) is an array containing Servo angles in degrees. From equation 5, the angles are calculated and these angles are plotted on the graph in Y-Axis with respect to time for completing the flight in x-axis as shown in the Figure 6. Due to Light disturbance and cloud movements there will be light differences in field which affects the processing of VARI image and thus introduces noise in the Servo angle output signal. Some of these noises can also be caused by wind [11]. So in order to reduce noise, the Kalman filter is used, which reduces the external noise without actually losing the data [18]. This filtering application is limited due to its highly computational intensive process and for small farms it provides less advantage, as lighting changes across the field is minimum. The overall process flow chart is shown in Figure 6, where a specific
image is converted into VARI image which is then Modified, Unrolled and converted to normalized image from which the servo signal is generated and filtered using Kalman filter.

**Figure 6.** Process Flowchart of Valve position Control System
5. Conclusion
The Fixed Wing drone system with selective spraying method was developed and tested for agricultural purposes like Vegetation Mapping and Pesticide Spraying. Based on the development and experimental investigation the following points are concluded,

- The method of spraying is designed for the Fixed wing, which allows it to spray the right amount of pesticide to affected plants while travelling in the normal flight path.
- Mapping of the Agricultural Field is done using RGB Camera, which calculates VARI index and based on that value, amount of pesticides to be sprayed is calculated.
- The developed system can fly at a maximum speed of 60 km/hr in no load condition, which allows it to map the field faster than the conventional drones.
- Due to the emulation of multirotor functionalities in fixed wing, the development cost, running cost and maintenance cost of this system is cheaper than the existing multirotor system [21].

The future scope of our system is to detect multiple crop vegetation and use machine learning to make more accurate pest detection and to increase the wide usage of the system in other terrestrial areas like river banks [12]. Using a custom flight controller powered by smartphones [16] or the one built on Raspberry Pi Zero [15] can further reduce the cost. Also, in future we will develop additional modules like seeding system and weed removal system.

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