Efficient Field Monitoring Autonomous Drone (FMAD) with pesticide sprayer and anomaly detection in crops

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Abstract - *Agricultural production is one of the key factors in the stability of the global economy. Correct and timely use of pesticides and proper observation of the crops provides an additional favorable atmosphere for crops to grow that eventually results in good agricultural production. FMAD is a system that is capable of spraying pesticides automatically over the agricultural land and also collect images and record videos of the field for further monitoring using various spectral imaging techniques. FMAD as a system is very low cost and has very little maintenance as compared to the other systems available. FMAD increases the efficiency and also minimizes the manual work of the farmer to spray pesticides and monitor the field which indeed becomes very beneficial for the farmer.*

Key Words: **Agriculture, Drones, Pesticides, Spectral Imaging, Smart Agriculture, Autonomous Drone.**

1. INTRODUCTION

Agriculture is a key aspect of the whole country. It plays a very vital role in the global economy. So, it is very important to look to boost up agricultural production and it can be boosted by using smart techniques which will help to detect and monitor diseases in plants and spraying pesticides and medicines at the proper time.

Identification of plant diseases is the key to preventing the losses in the yield and quantity of the agricultural product. The studies of plant diseases mean the studies of visually observable patterns seen on the plant. Health monitoring and disease detection on the plant are very critical for sustainable agriculture. It is very difficult to monitor plant diseases manually. It requires a tremendous amount of work, expertise in plant diseases and also requires excessive processing time. Hence, image processing is used for the detection of plant health. Disease detection involves steps like image acquisition, image pre-processing, image segmentation, feature extraction, and classification. This paper discussed the methods used for the detection of plant diseases using their images. This paper also discussed some segmentation and feature extraction algorithm used in plant disease detection.

The proposed system here allows the farmer to see the aerial view of the field while spraying pesticides over the field. The aerial view of the field helps the farmer to monitor the field and to get the appropriate data. The proposed system uses the multispectral image processing technique to monitor the health of the crops. This technique can differentiate between the healthy crop and the infected crop. It sends the data of the infected crops to the farmer, and then the farmer can take the appropriate action on it. The spraying mechanism installed in the proposed system can be controlled remotely. This variable spraying speed mechanism helps to increase accuracy and efficiency. This reduces the time and efforts of the farmer.

The next section explains the literature survey of the existing systems. Section III explains the problem definition of the FMAD system while the proposed system explanation is mentioned in Section IV. Ariel, feature extraction and cost analysis of the system is given in Section V followed by results and conclusion in Section VI and VII respectively.

2. LITERATURE SURVEY

In construction and infrastructure inspection applications, unmanned aerial vehicles (UAVs) can be used for real-time monitoring construction project sites [1]. The project managers can monitor the construction site using UAVs with better visibility about the project progress without any need to access the site [2]. Moreover, UAVs can also be utilized for high voltage inspection of the power transmission lines. In the papers [3]–[4], the authors used UAVs to perform autonomous navigation for the power lines inspection. The UAVs were deployed to detect, inspect and diagnose the defects of the power line infrastructure.

In paper [5], the authors designed and implemented a fully automated UAV-based system for real-time power line inspection. More specifically, multiple images and data from UAVs were processed to identify the locations of trees and buildings near the power lines, as well as to calculate the distance between trees, buildings, and power lines. Furthermore, the Thermal infrared camera was employed for poor conductivity detection in the power lines. Drones can also be used to monitor the various facilities and infrastructure, including gas, oil, and water pipelines. In paper [6], it was suggested by the authors that the development of a small drone enabled with a gas controller system will be capable of detecting air and gas content.

3. PROBLEM DEFINITION

As India is a fast-growing country and to fulfill the food requirements of the growing population it is very much important to make the agricultural sector strong by using smart technologies and without causing any damage to the environment. The agricultural sector plays a really important role in the economy of the country. Drones can have multiple uses in agriculture, from mapping to spraying. Drones are an important tool in smart agriculture, as they permit farmers to constantly monitor crop and livestock conditions by air.

With new drone models, the user only needs to draw around the area he must cover as drones come equipped with flight planning software allowing them to follow an automated flight path. The drone automatically takes pictures using onboard sensors and the built-in camera and uses GPS to determine when to take each shot.

Drones can carry tanks of fertilizers and pesticides to spray crops with far more precision than a tractor. This helps reduce costs and potential pesticide exposure to workers who would have needed to spray those crops manually. Previous works have investigated the use of UAVs to improve the quality and amount of crop production in several agricultural activities. One of the most important of these activities is pesticide spraying for pest control. This activity has had a great influence on the quality and yield of cultivated crops since pesticides are used to create a near-optimum environment and their inappropriate use can cause environmental and economic damage and lead to health problems. To deal with the previously mentioned problem, the UAV is developed with a spraying element equipped with a programmable trigger system.

Fig -1: Problem Statement (Courtesy: Shutter stock)

4. PROPOSED SYSTEM

The proposed system is a completely autonomous embedded system that will be able to fly over the field as per the coordinates set on the remote controller as it is GPS enabled. As the proposed system is spraying over the field the user will get a live video feed regarding the crops and the fields so that if the user sees any kind of uncertainty over the field, he can resolve it and click images of the particular section for further examination. The system comprises sensors, Analog to Digital Converter, microcontroller, camera, and actuators. When any of the sensors fails or there is an error in the system it automatically detects the error and sends feedback to the user so that the user can bring back the drone. If the user uses autopilot mode then the drone will automatically return to the starting point if there is an error in the working of the drone. Since a microcontroller is used as the heart of the system, it makes the set-up low-cost and effective nevertheless. As the proposed system can be controlled via a mobile handset it becomes very user-friendly. The signal is received from the Microcontroller Processing Unit (MPU) encoder and then it is passed to the microcontroller. The microcontroller unit processes this signal from the MPU encoder according to user-selected firmware and passes the control signal to Electronic Speed Control (ESC). This signal instructs to make a fine adjustment to the motor speed which in turn balances the multi rotorcraft. The installed control board uses the signal from the radio system and passes the signal to the microcontroller, throttle, and radar unit. Once everything has been processed, the microcontroller will send analog signals to ESC which in turn will adjust the speed of each motor to induce controlled flight.

Fig -2: The proposed system (Hex copter with computer interface)

Fig -3: A prototype of the hex copter system

Fig. 2 and fig. 3 shows the proposed hex copter system with a computer interface. Fig.4 shows the technical hardware specifications used in the proposed system.

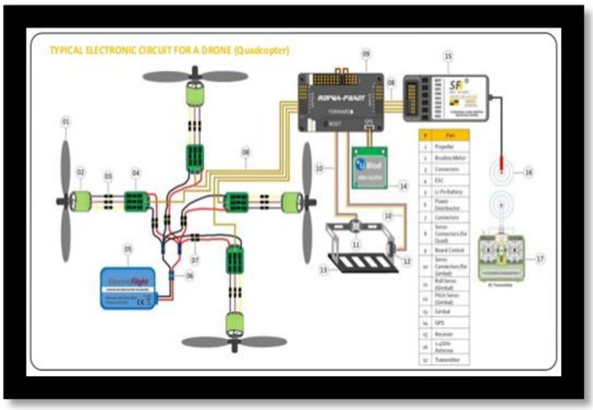

Fig -4: Hardware Specifications (Courtesy: Shutter Stock)

TABLE -1: Hardware Specifications of Agriculture Drone

Component Name	Specifications
Brushless DC Motors (out runners)	1000KV
Transmitter and Receiver	2.4GHz
Frame	Length: Width: 450mm: 450mm Height:55mm
Electronic Speed Controllers (ESC)	20 Amp
Propellers	1045R,1045 Diameter: 10 inches, Pitch: 4.5 inch
Li-Po Battery	11.1(nominal) 12.6V(max), 5200 mAh 30C

5. ANALYSIS OF PROPOSED SYSTEM

5.1 Ariel Analysis

The FMAD was primarily controlled by the 9-channel remote controller. When real-time performance analysis was carried out, we measured the take-off speed, which varied from 40–55 kilometers/hour. The cruise speed of the drone was varied from 35–65 kilometers/hour. The minimum altitude of the drone was ground level and the maximum altitude achieved was 40 meters or 131.23 feet. We were able to control the agricultural drone 6 km far from the starting point or the base station. When the agricultural drone flew with a cruise speed of 42 kilometers/hour, the pesticide spraying rate was approximately 0.1 liters/sec, which was controllable by changing the diameter of the nozzle. During the experiment, the radius of the nozzle is 0.0625 meters, and the altitude (h) is 5 meters. We obtained the pesticides coverage area for a static drone which comes to be 1.25 m2. At a cruise speed of V is 13 m/s (42 km/hour), the maximum covered distance R is 0.62 m. As a result, the dynamic pesticides spreading area (A) becomes,

$$A=13\times2\times0.62 = 16.12 \text{ m2/sec}$$

The test flight path is shown in fig.5. The flight time of the drone was approximately 15 minutes, which can further be increased by adding a high current rating battery. When the battery voltage reduces down to a predefined level, the communication between the drone and the controller is broken, or the pesticides are finished, the drone automatically returns to the starting point. Table II summarizes various parameters of the agricultural drone.

TABLE -2: Hardware Parameters of Agriculture Drone

Parameter	Type/Value
Construction Material	Fiber
Take-off Speed	40-55 kilometers/hour
Cruise Speed	35- 65 kilometers/hour
Empty Weight	2 kilograms
Maximum payload	8kg
Global Positioning System	Ublox Neo
Flight Controller	Autopilot Mega
Telemetry	RFD900 Radio Modem
Ground Control System	Mission Planner 1.2

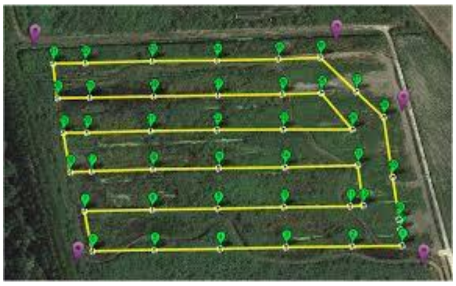

Fig -5 Test Flight Path

5.2 Feature Extraction

The images of the crops will be captured by the drone which will be an RGB image. This image will be transformed using the mean filter to remove the noise from the image. Once the noise is removed further smoothing will be done using the smoothing filter. This will help us to increase the contrast of the image for a more accurate result. After the above process, the image will be segmented using the Otsu Threshold algorithm and k means clustering approach. The flowchart of the image processing section of the proposed system is shown in fig.6.

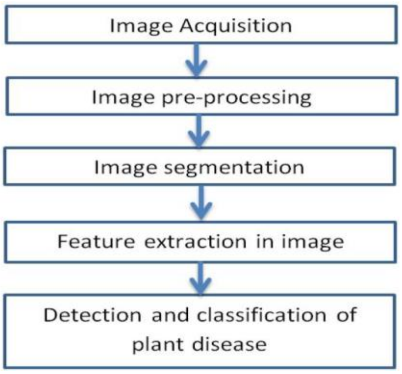

Fig -6 Flow Chart of Image Processing section of the proposed system

The leaves which are infected or have less nitrogen content show the symptoms of changing the color of the leaf as shown in fig.7. Hence the greenness of the leaves can be used for the detection of the infected portion of the leaf. Feature extraction plays an important role in the identification of an object. In many applications of image processing, feature extraction is used. Color, texture, morphology, edges, etc. are the features that can be used in plant disease detection. Further, the leaf color is extracted by using the anisotropic diffusion technique to preserve the information of the affected pixels before separating the color from the background.

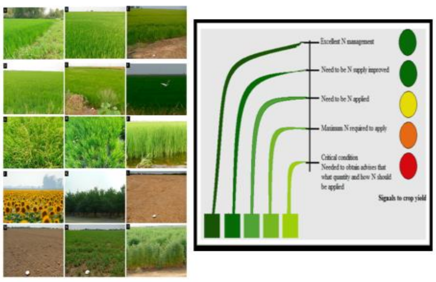

Fig -7 Nitrogen content analysis as per color (Courtesy: Krisijagran)

Fig -8 Potassium deficiency effect on the color of leaves (Courtesy: Grainsa)

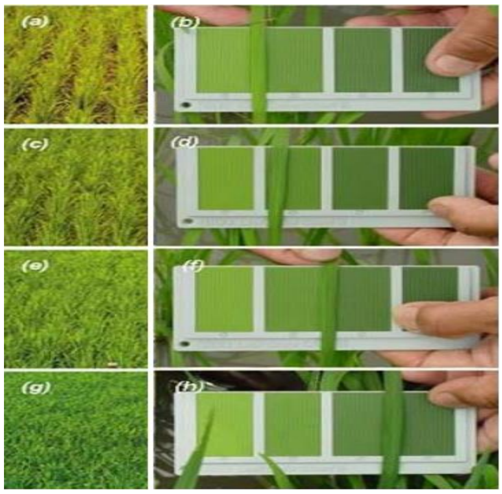

Fig -9 Nitrogen deficiency in agriculture plant (Courtesy: Krisijagran)

Fig.8 shows the potassium deficiency effect on the color of leaves. In Fig.9 photo (a) shows plants without nitrogen application are yellowish. Nitrogen deficiency is confirmed in photo (b) because the Leaf Colour Chart (LCC) reading is between panels 2 and 3. At low fertilizer nitrogen rates in photos (c) and (d) the plants look better, but the low LCC reading still indicates Nitrogen deficiency. At higher fertilizer nitrogen rates in photos (e) and (f) the plants look well developed and the canopy is closed. The LCC reading is between panels 3 and 4, which is the critical range for most transplanted rice. In photos (g) and (h) plants with a high Nitrogen rate are dark green. Leaf color is darker than the LCC panel no. 4 indicating a surplus of fertilizer nitrogen.

5.3 Cost Analysis

5.3.1 Drone Cost

The cost of this system comes to be around INR 35000. While comparing this to the other system available in the Indian market we have reduced the price by 60% to 70% with all the features intact. Currently, DJI is the leading company that manufactures agricultural drones. The cost of the drones manufactured by DJI is ranging from 5 lakhs to 10 lakhs. The prize is the main factor that is creating a hurdle to use a drone for spraying pesticides in our country. We have managed to overcome this barrier by developing FMAD at a very minimal price. Also, FMAD can be used on a rental basis or a group of farmers can buy this together and use it collectively. Apart from the actual cost, the maintenance cost is also very less as all the parts are manufactured locally and more durable.

5.3.2 Manual Spraying

Spraying Pesticides manually includes labor cost per hour, pesticide cost, and equipment cost. When we sum up all these, the cost comes around INR 800-1000 per day. It takes around 1 to 2 days to spray 1 acre of land which eventually will cost thousands.

5.3.3 Ariel Spraying (Using Drone)

Normally a drone takes 1 to 2 days for spraying pesticides over 10 Acres of land so if we consider it for 1 acre it will take hardly 15 to 20 mins. If we sum up the cost of flying the drone for 15 to 20 mins it comes around INR 10 to 15 or even less. The charge for spraying using drones is very negligible as it only includes the electricity cost for charging the battery of the drone.

6. Results

The proposed system has the potential to improve agricultural production at a very low cost and with ease. Agriculture Drone can help farmers to transform the agriculture industry. Now a day's farmers use a hand pump for spraying pesticides. Human beings take a large amount of time to spray the crops and they don't uniformly spray the pesticides. FMAD will allow the farmers to choose Ariel spraying of pesticides which in turn will save them around INR 600 to 700 per day including all. The drone will uniformly spray the fertilizers hence; there is no possibility of damaging crops. The drone will save time for spraying pesticides and also it will reduce the diseases caused by fertilizer to the human body such as skin diseases as per the research of the World Health Organization (WHO). Hence, the drone will minimize the efforts of farmers for agriculture purposes. While designing the required circuitry it is very necessary to follow all the design and development steps for PCB designing.

Apart from spraying pesticides, we were able to fulfill the objective of disease detection as per the nitrogen content in the crops. As shown in fig 10 if the crops are having ideal green color then they are having balanced nitrogen content and thus the crops are healthy. If the shade of the crop moves towards a yellowish shade then the nitrogen content is less in the crops and thus it is considered that the plant is unhealthy and might have some disease or needs care. Similarly, Fig 11 shows a comparison of a segmented image with the original image taken from the drone.

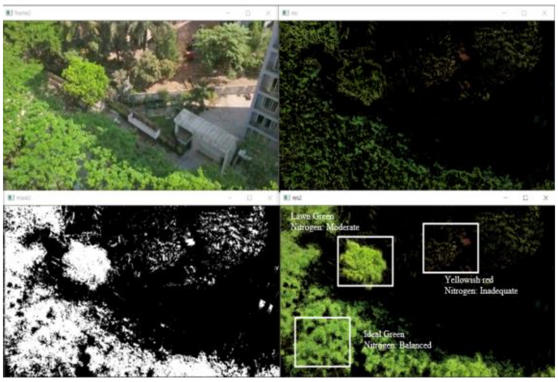

Fig -10 Real-Time Detection of (Image is taken from drone)

Fig -11 Original and segmented (Image is taken from drone)

7. Conclusion

This paper proposes an autonomous system that can spray pesticides over a field as per coordinates set by the user and can monitor the field with the camera installed on it. The results of the multiple tests showed a great performance. The aim of safe spraying of pesticides without harming the environment was achieved. Real-time disease detection was also achieved using the system. The cost of the proposed system is very low as compared to any other products available in the market. The proposed system has very low maintenance and can complete spraying within minutes. Thus, this system is highly efficient in comparison with all the existing systems in all terms possible.

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