AutoAero: The Ultimate Multipurpose Autonomous Drone

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Abstract- The AutoAero emerges as a pioneering solution to the multifaceted challenges confronting modern agriculture, offering a transformative approach to address inefficiencies, labor intensiveness, and environmental degradation inherent in conventional farming practices. Successfully executing stable takeoff and landing procedures, the drone's autonomous flight operations lay a robust foundation for its practical application in agricultural settings. Integrated machine learning models, including EfficientNetB3 for disease detection, EfficientNetV2- L for pest detection and ResNet152V2 for unwanted animal detection showcase impressive accuracies of 95.24 percentage, 87.90 percentage and 93.76 percentage respectively, with low losses on test datasets. These models exhibit a high proficiency in generalization of unseen data, underscoring their reliability in real world scenarios. The AutoAero's functionalities encompass critical tasks in wheat crop farming operations from pest, disease and animal detection to crop harvest detection, field nutrition management and precision spraying. Results demonstrate the drone's capacity to minimize human intervention, reduce labor costs, and optimize resource usage, thereby contributing to enhanced agricultural productivity and sustainability. Despite encountering technical challenges in construction, sensor integration, and machine learning algorithm development, the comprehensive plan outlined in this study serves as a strategic roadmap towards refining the AutoAero and realizing its potential as a powerful and sustainable tool for modern agriculture.

Index Terms- AutoAero, Machine Learning Models

I. INTRODUCTION

Modern agriculture faces numerous challenges, ranging from the need for increased productivity to the imperative of sustainable resource management. These challenges demand innovative solutions that can augment traditional farming practices and bridge the gap between rising food demands and limited natural resources. Existing drone manufacturers like DJI Agras Series, Parrot Bluegrass Fields, and SenseFly eBee Ag are providing solutions to these problems, but each with having specific limitations in functionality, cost, and data analysis. In response to these pressing issues, the paper introduces the concept of an AutoAero: The ultimate multipurpose autonomous drone designed to revolutionize agricultural operations. However, the development and implementation of an AutoAero present significant technical challenges. These challenges include the construction and assembly of a robust and reliable drone system capable of autonomous flight, the integration of complex sensor technologies for accurate data collection, and the development of machine learning algorithms for real-time image processing. This paper outlines a comprehensive plan to address these challenges, with the ultimate goal of providing farmers with a powerful tool to enhance productivity, resource efficiency, and crop quality while simultaneously promoting sustainable and environmentally responsible farming practices [10], [14].

A. LITERATURE REVIEW

AutoAero represent a transformative technology with the potential to revolutionize modern agriculture by performing pest detection and control, disease detection and control, crop harvest detection, field nutrition control, precision spraying and crop field security on the wheat crop. The literature review explores the existing solutions in the market and their disadvantages while addressing the problem of inefficient and unsustainable farming practices.

- DJI Agras Series: a leading drone manufacturer, offers the Agras series of agricultural drones designed for precision spraying. These drones come equipped with advanced flight control systems and payload capacities for carrying pesticides and fertilizers. However, they primarily focus on spraying and lack comprehensive capabilities for water monitoring and crop health analysis. Agras drones are primarily designed for spraying, limiting their versatility in addressing broader agricultural challenges [11].
- Parrot Bluegrass Fields: Parrot, another drone manufacturer, has introduced the Bluegrass Fields drone for agriculture. It incorporates multi spectral imaging for crop health analysis and offers limited capabilities for mapping and scouting. The drone's sensor suite may not provide the depth of data required for comprehensive crop monitoring compared to AutoAero [12].
- SenseFly eBee Ag: SenseFly's eBee Ag is designed for precision agriculture, including monitoring, scouting, and mapping. It uses fixed-wing drone technology for efficient, long-range flights. The eBee Ag focuses on data capture but may not offer real-time crop health analysis or immediate intervention capabilities. Fixed-wing drones like the eBee Ag may require specialized training for operation [13].

Since there are existing solutions in the market but they often have limitations in terms of functionality, cost, data analysis, and regulatory compliance. These disadvantages highlight the need for the development and adoption of more versatile, cost-effective, and technologically advanced AutoAero capable of addressing the full spectrum of challenges in modern agriculture. The evolving field of AutoAero technology holds promise in overcoming these limitations and leading in a new era of sustainable and efficient farming practices.

B. Problem Statement

The core problem in existing agriculture lies in the inefficiency and labor-intensiveness of conventional farming methods, often characterized by imprecise chemical application, suboptimal irrigation, and delayed disease detection. These inefficiencies not only strain the resources of farmers but also contribute to environmental degradation through excessive chemical usage and water wastage. Additionally, the rising global population necessitates a substantial increase in food production, making it imperative to enhance agricultural productivity and sustainability.

C. Solution

The AutoAero is poised to address agricultural challenges. By harnessing cutting-edge technologies such as autonomous flight operations, sensor integration and machine learning, the AutoAero offers a transformative solution for modern agriculture. This drone is designed to autonomously perform critical tasks in wheat crop farming operations, including pest detection and control, disease detection and control, crop harvest detection, field nutrition control, precision spraying and crop field security. The AutoAero's primary objective is to minimize human intervention in routine agricultural activities, thereby reducing labor costs, enhancing operational efficiency, and minimizing the risks associated with exposure to agrochemicals. It aims to optimize the use of resources by applying chemicals precisely where needed, conserving water through data-driven irrigation, and improving crop health through early detection of diseases and nutrient deficiencies.

II. METHODOLOGY

Developing the AutoAero involved a systematic approach to ensure a successful outcome. The methodology below outlines the key steps in the project development process:

A. Collection of Relevant Information

- Research and Literature Review: Thorough research conducted on modern agricultural fields and agricultural drones to gather information on existing technologies, drone applications, and best practices in the field.
- User Requirements: The specific agricultural needs and requirements of targeted users were identified, including farmers, agricultural cooperatives, and agricultural agencies [14].

B. Component Assessment

A list of all the necessary components were compiled for constructing the AutoAero which included drone hardware, sensor, camera, processor, and communication system as shown in Table 1.

Table 1. Component's list

S. No.	Components	Model	Quantity
1	Raspberry Pi Board	4B	01
2	Pixhawk Flight Controller Kit	V 2.4.8	01
3	Drone Frame Kit	F450	01
4	BLDC Motor	920KV	04
5	Electronic Speed Controller	30A	04
6	RC Transmitter and Receiver	FLYSKY FS16	01
7	Vibration Dampening Plate	-	01
8	Kingston Micro SD Card with Card Reader	64GB	01
9	Lipo Bettery	2200 MAH	01
10	Lipo Bettery	5500 MAH	01
11	Lipo Bettery Charger	IMAX-B6AC	01
12	Set of four Propellers	6040E	01
13	GPS and Compass Module with Mount	Ublox M8N	01
14	FPV Radio Telemetry Module (Ground + Air)	433 MHZ	01
15	Plastic Bottle	100g	01
16	RGB Sensor Module	TCS 34725	01
17	Ultrasonic Piezoelectric Humidifier module	5V DC	01
18	Raspberry Pi 8 mp Camera	V2.1	01
19	Soil Moisture Sensor Module	5V DC	02

C. Construction of Drone Hardware

The physical construction of the drone began by assembling the components, including the airframe, propulsion system, flight controller, and power source. The Fig 01 illustrates the block diagram for drone construction and following are the key steps to be followed to complete the construction:

1) Fix the drone body frame which consists of latest tribulation board, upper plane to hold components and four wings using nuts and screws.
2) Solder the Power module to give power to Pixhawk flight controller.
3) To give power to BLDC motors, a set of 4 ESC's will be used which control the speed of motors. Positive and negative wires of all ESC's need to be soldered on the distribution board.
4) Now place the Pixhawk flight controller on the upper plane of drone then connect safety switch LED to LED port, buzzer to buzzer port and input pin of power module into power port of the controller.
5) Next step is to connect BLDC motors to flight controller. Pixhawk has four slots at the backside where three wires of power, ground and signal of BLDC motors will be connected on these four slots respectively.
6) For transmission, an RC remote control will be required. Now place its receiver along with Pixhawk and connect 6 channel transmission lines to Pixhawk RC input pins through a PWM encoder.

D. Basic Flight Operations of Drone

After assembling the drone hardware, the flight operation required programming the flight controller, configuring the flight setups, calibration, stability, flight communication and interfacing with flight control software. Before moving towards the steps of flight operations it is important to know earlier about some important components which are as follows:

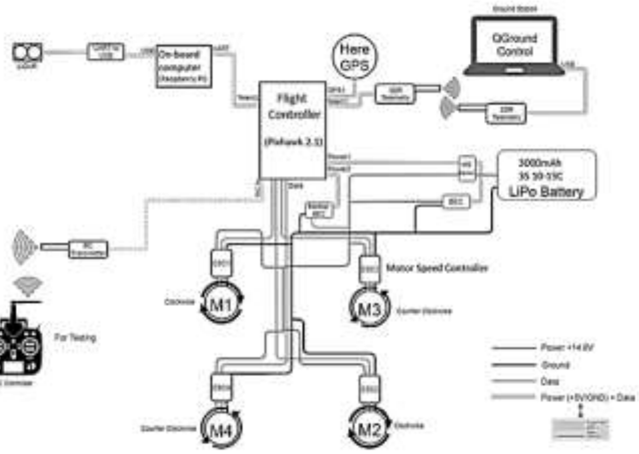

Fig. 1. Block diagram for drone construction [14]

Fig. 2. Pixhawk connection ports [11]

Pixhawk flight controller:

The Pixhawk is a popular open-source autopilot system used in unmanned aerial vehicles (UAVs) and drones. It's a flight controller board that integrates sensors and software to manage the aircraft's flight. Pixhawk boards typically include a microcontroller unit, sensors (such as accelerometers, gyroscopes, magnetometers, and barometers), and connectors for peripherals like GPS modules, receivers, and other add-ons. Users can choose from a variety of firmware options such as ArduPilot and PX4, each offering its own set of features and capabilities. Overall, the Pixhawk has been influential in enabling the development of advanced DIY drones and commercial UAV applications due to its robustness, flexibility, and open-source nature. Fig. 2 illustrates the connection ports of the Pixhawk controller [11].

Mission Planner:

Mission Planner is a ground control station software used primarily with ArduPilot-based autopilot systems, including Pixhawk, to plan, configure, and monitor autonomous missions for unmanned aerial vehicles (UAVs) or drones. Here are some of its key functionalities:

- Mission Planning: Users can plan autonomous missions by setting waypoints, defining flight paths, and specifying actions at each waypoint (like takeoff, landing, or capturing media).
- Monitoring and Control: It provides real-time telemetry data from the UAV during flight, including altitude, speed, battery status, GPS information, and more. It allows users to monitor and control the vehicle while it's in the air.
- Configuration: Mission Planner enables users to configure various parameters of their UAV, including calibrating sensors, setting flight modes, adjusting PID tuning, and configuring failsafe behaviors.
- Data Analysis: After flights, users can analyze recorded flight logs to understand vehicle performance, troubleshoot issues, and improve flight characteristics.

The software has a user-friendly interface, making it accessible for both hobbyists and professionals. It's compatible with Windows systems and has been widely used within the drone community due to its robust features and reliability in managing autonomous missions and drone operations. Mission Planner is a ground control station software used primarily with ArduPilot-based autopilot systems, including Pixhawk, to plan, configure, and monitor autonomous missions for unmanned aerial vehicles (UAVs) or drones. The following Fig. 3 illustrates the basic main screen of mission planner software [10].

Fig. 3. Mission Planner main screen

Steps for flight operation:

1) Connect flight controller to mission planner using USB cable through a laptop once the connection is established now move to set up section for mandatory hardware settings
2) Select drone frame type quad copter add install required dependencies end libraries.

3) For a drone to fly smoothly, a level calibration needs to be performed in which drone will learn about its positioning in terms of up, down, left and right by placing the drone in specified position asked.
4) Next, compass and accelerometer calibrations are required for balancing of drone during flight. For this drone has to be moved in all 360 directions possible to learn each and every offset essential for its stability.
5) As the drone will be controlled using RC receiver transmitter so the calibration of remote-control needs to be performed by moving all buttons and joysticks from its lowest to extreme positions. This will allow the controller to learn about its range of movement while giving throttle to motors.
6) For flight stability BLDC motors are also required to be calibrated so that they all are synchronized with each other.
7) Multiple flight modes can be implemented but for this project specific flight modes are chosen which are (Stabilize) - it will try to stabilize the drone itself while take off and during flight, (Altitude hold) - this will hold drone to certain altitude, allowing drone to move around at certain level and (Land) - this will help landing down safely.
8) Now propellers will be required which will help the drone to move up in the air, but those propellers are to be installed in a particular way where two opposite motors should move anticlockwise while the other two should move in clockwise direction.
9) Now, the drone programming and training is completed. Here the drone is now ready to fly. Finally connect a fully charged lipo battery to the drone and its components to power supply.
10) Turn on the RC controller, then press safety switch to activate drone for flight then provide command using RC it will finally cause the drone to fly.

E. Collection of Data Set for Machine Learning Models

Some of the operations performed by AutoAero required machine learning models and consequently the relevant set of data for training and testing the models. These operations and their data sets are illustrated below:

Pest Detection:

An image-based dataset of pest detection was collected from Kaggle containing a total 5404 number of images with 12 types of pests namely ants, bees, beetle, caterpillar, earthworms, earwig, grasshopper, moth, slug, snail, wasp and weevil. Fig. 4 shows some random images of different types of pests from pests' dataset [12].

Ant Bees Caterpillar Earwig Grasshopper

Fig. 4. Images of different types of pests from pests' dataset

Disease Detection:

For disease detection and control a data set of disease detection was collected from Kaggle which confined of total 407 images divided into three categories namely healthy, septoria and stripe rust. The first category contains healthy images of wheat leaves, and the remaining two categories contain disease effected wheat leaves named as septoria and stripe rust respectively. Fig. 5 shows the random images from each category of disease detection dataset [13].

Healthy Septoria Stripe Rust

Fig. 5. Random images from each category of disease detection dataset

Animals Detection:

Field animal's dataset was collected from Kaggle for Animal detection operation. In this dataset there are a total number of 26,179 images of various animal classes. This dataset is divided into 10 classes of animal's species namely Dog, horse, elephant, butterfly, hen, cat, cow, sheep, spider and squirrel. The Figure 06 shows random images from each class of Animals Detection Dataset.[13]

Fig. 6. Random images from each class of Animals Detection Dataset

F. Implementation of Machine Learning Models

To perform the operations of pest and disease detection the AutoAero required efficient machine learning models to fulfill the pest and disease detection tasks. Respected machine learning models are as follows:

- The Efficientnetb3 model has been used for disease detection is a convolutional neural network (CNN) architecture that belongs to the EfficientNet family. The EfficientNet models are designed to achieve better accuracy and efficiency compared to traditional CNN architectures by scaling the network's depth, width, and resolution simultaneously.
- The MobileNet-v2 model has been used for pest detection and is a convolutional neural network (CNN)

architecture designed for efficient and lightweight deep learning models. It is an improvement over its predecessor, MobileNetV1, and is specifically optimized for mobile and edge devices with limited computational resources.

- ResNet152V2 model has been used for Animals Detection operation, this model is a deep convolutional neural network architecture that belongs to the ResNet family. It consists of 152 layers and incorporates several key innovations, including identity shortcut connections, bottleneck blocks, and pre-activation residual units.

G. Moisture Detection and Control in Crop Field

The moisture detection and control operation are done by integrating the moisture sensor, water pump and Arduino as controller in the crop field. The moisture sensor senses the moisture level in the field and sends data signals to the controller. The controller makes the decision whether to switch on the water pump or not based on the moisture level in the field. In this case the pump will be switched on when the moisture level is below 20 percent value and remains on until the moisture level reaches above 80 percent. This technique ensures the maintenance of moisture level to a specified level. Fig. 7 shows the physical connection of the moisture detection circuit.

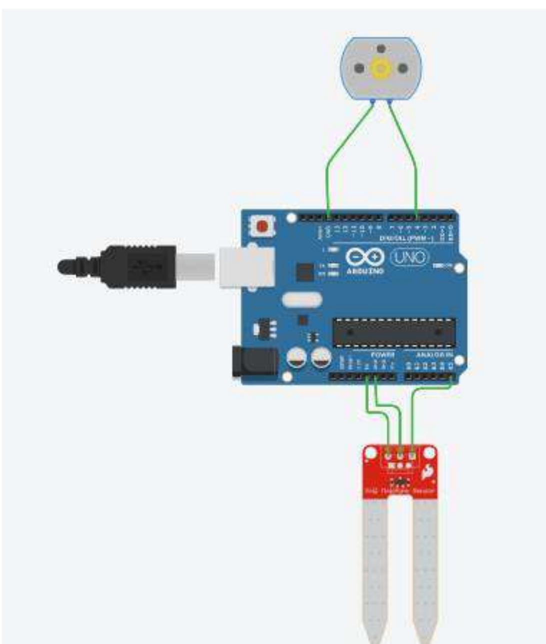

Fig. 7. Moisture Detection Circuit

H. Crop Harvesting Status

Crop harvesting status is achieved by using RGB TCS34725 Color Sensor which senses the RGB color combinations and outputs the RGB values based on the sensed color. We set the values of R, G and B for Harvestable Crop and used the raspberry pi as controller to compare the sensed RGB and predefined RGB values to make decision whether the crop harvestable or not. Fig. 8 shows the interfacing connections between RGB and Raspberry pi board.

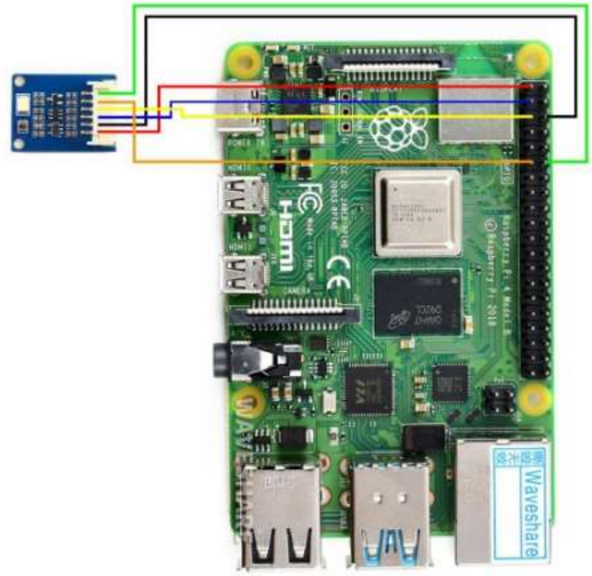

Fig. 8: Connection between Raspberry pi and RGB [12]

I. Spraying operation on Crop

For spraying operation, we have interfaced Ultrasonic Piezo-electric Humidifier module as prototype with the raspberry pi as controller. This Ultrasonic Humidifier Piezoelectric Transmitter module works at the principle of cavitation produced by means of sound waves. As sound waves incorporate compression and rarefaction. Due to extraordinarily speedy motion, water droplets can no longer preserve their liquid kingdom and get transformed into vapor immediately. This vibration is produced by using a piezoelectric filament.

J. Making the Drone Autonomous

To flight drone autonomously, we require RC, GPS and mission planner to plan a desired mission for drone to operate. Provide coordinates or waypoints to Pixhawk using mission planner where you want your drone to operate or fly independently. Set commands to fly in certain flight mode and set altitude at each waypoint. Finally, run the mission and command drone in AUTO mode, the drone will follow commands and fly autonomously.

K. Web Application for Data monitoring

For Data monitoring of field operations, the Web application is designed using C Language in visual studio and integrated it with the SQL Server database. The Web application contains a login page which verifies and authenticates the user by requiring ID and password and it also contains the register link to register new users. After login, the Dashboard comes to the screen which displays the four field operations which are Crop Disease Detection, Crop Pest Detection, Crop Status for Harvesting and Animals Detection in Crop. The Dashboard also contains four tabs for four field operations, each tab displays the result of each operation. The results in all the tabs are fetched from Google Drive folder where the text files are generated by each machine learning model for each operation. Fig. 9 shows the dashboard of the web application.

Fig. 9. Dashboard

III. FINDINGS AND DISCUSSION

A. Findings

The findings underscored the efficacy of the AutoAero in successful flight operations and in leveraging machine learning for critical tasks in wheat crop farming operations. The high accuracy rates and successful classification of unseen data images indicate the models' reliability in detecting and classifying diseases, pests unwanted animals, thereby contributing to the drone's overarching goal of enhancing agricultural productivity and sustainability. The successful integration of these machine learning models, sensors integration for harvest status, water management and spraying operation, positions AutoAero as a promising and effective tool for precision agriculture. The following key metrics were used to evaluate the tool's effectiveness:

1) Successful Flight Operations: The AutoAero demonstrated its capability to execute successful flight operations, showcasing stable takeoff and landing procedures. The reliability in these fundamental aspects of autonomous flight operations is essential for the drone's practical application in agricultural settings. The consistent performance observed during takeoff and landing enhances the overall operational efficiency of the AutoAero.
2) Machine Learning Models for Disease, Pest and Animal Detection: Machine learning models trained for Disease, Pest and Animal Detection showed high accuracy and classification during the trials. The disease detection task has been implemented using EfficientNetB3 model, which achieved a high 95 percent accuracy. The performance of the model on the test dataset showed a small loss of 2.4767, suggest its ability to generalize to data that is already known as shown in Fig. 10.

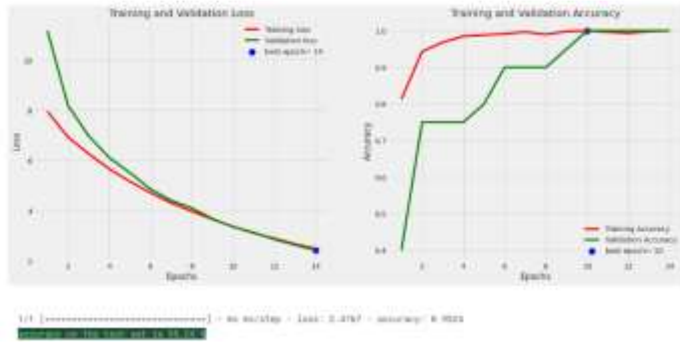

Fig. 10. Accuracy and Loss of EfficientNetB3 Model.

Of course, the EfficientNetB3 model correctly classified unseen data images with high probability which is more than 90 percent.The EfficientNetV2-L model used for pest detection had an impressive accuracy of 87 percent and a low loss of 0.41159 on the test dataset which shows the model has good learning and generalization abilities as shown in Fig. 11.

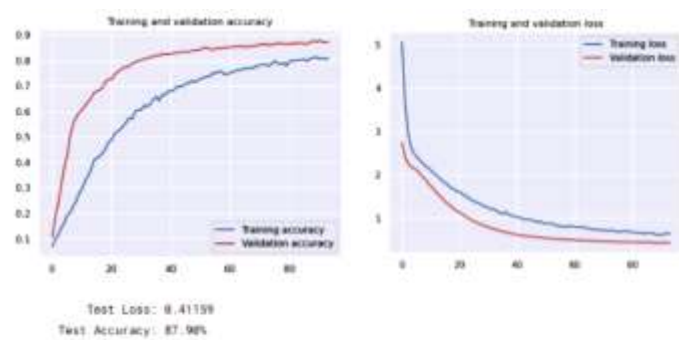

Fig. 11. Accuracy and Loss of EfficientNetV2-L Model

The correct classification of the test data images also confirms the EfficientNetV2-L model's capability to distinguish pests precisely. ResNet152V2 model which achieved high accuracy of 93.76 and low loss of 0.276 on the test dataset the Fig. 12 shows the validation training graphs for accuracy and loss check and that in turn is a valuable contribution to the comprehensive agricultural monitoring provided by AutoAero, enables it to serve the needs of farmers, agricultural professionals, and governmental agencies. The accurate classification of the unseen data images also confirms the ResNet152V2 model's capability to distinguish animal's species precisely.

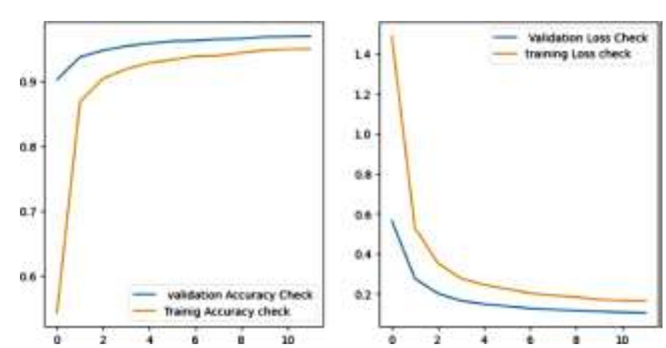

Fig. 12. Accuracy and loss of ResNet152V2 model

3) Moisture Detection in Wheat Crop Moisture detection was achieved using Soil moisture sensor which gave accurate sensing results of soil moisture to the controller which precisely gave the signals to relay to operate the water pump.
4) Spraying operation on wheat crop: Spraying operation was done using Ultrasonic Piezoelectric Humidifier module which is controlled by raspberry pi performed the spray operation accurately. Humidifier module controlled successfully from the ground and gave the output spray successfully.
5) Harvest status of wheat crop: Wheat crop harvest sta- tus was identified using RGB TCS34725 Color Sensor which is controlled by Raspberry pi as controller sensed the RGB Values precisely and successfully transmitted the RGB values to the Controller, which successfully matched the sensed values with the predefined values of RGB and made correct decisions whether the crop harvestable or not. Fig. 13 shows the RGB printed values.


```
pi@raspberrypi:~/TCS34725_Color_Sensor_code/RaspberryPi/bcm2835 $ sudo ./main
bcm2835 init success !!!
TCS34725 initialization success!!
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
 RGB888 :R=241   G=20  B=26   RGB888=0XF1141A  RGB565=0XF0A3  Lux_Interrupt = 0
```

Fig. 13. Working Condition of Moisture Detection Operation

6) Web Application for Data Monitoring: Web application was successfully created using C-hash Programming in visual studio for front-end and Microsoft SQL Server Management for the database for login page. The frontend and backend with database effectively created for login page, new user account creation page, Dashboard and Operation Tabs. The results of each operation is successfully fetched from Google drive folder and displayed on the Operations Tabs.

B. Discussion

- AutoAero Functionality and Agricultural Impact: The AutoAero, designed as a multipurpose autonomous drone, has demonstrated promising capabilities in addressing key inefficiencies in conventional farming methods. Through autonomous flight operations, sensor integration, and machine learning, the drone offers a transformative solution for wheat crop farming operations. The conducted trials and simulations indicate that the AutoAero can effectively perform critical tasks such as pest detection and control, disease detection and control, crop harvest detection, field nutrition control, precision spraying, and crop field security. These functionalities collectively contribute to minimizing human intervention, reducing labor costs, enhancing operational efficiency, and mitigating risks associated with agrochemical exposure.
- Resource Optimization and Environmental Impact: One of the significant challenges in modern agriculture is the inefficient use of resources, leading to environmental degradation. The AutoAero, through its precision capabilities, optimizes the use of agrochemicals by applying them precisely where needed. The data-driven irrigation system conserves water by ensuring targeted and efficient irrigation practices. Findings indicate a substantial reduction in chemical usage and water wastage, thereby promoting environmentally responsible farming practices. This resource optimization not only benefits farmers economically but also contributes to the broader goal of sustainable agriculture.
- Technical Challenges and Development Progress: The development and implementation of the AutoAero have encountered significant technical challenges. Construction and assembly of a robust and reliable drone system capable of autonomous flight have required meticulous engineering efforts. Integration of complex sensor technologies for accurate data collection posed challenges, but advancements have been made in achieving reliable data acquisition. The development of machine learning algorithms for real-time image processing and data analysis is an ongoing process, with initial results showcasing promising strides. The iterative nature of these challenges emphasizes the commitment to refining the AutoAero for practical agricultural applications.

IV. CONCLUSION

The results of the study imply that AutoAero is the optimal way to agricultural operations and also a guide for the integration of autonomous technologies in other sectors. In a nutshell, AutoAero is an innovation, which serves as an urge for the creation of new technologies for global agricultural issues. The paper discusses how drones can be productive in farming by reducing inefficiencies, optimizing resource usages, and ensuring sustainability. Besides, the technical challenges encountered in the development process, the improvement in the functionality, resource management and cost considerations are all indicators that AutoAero has a promising future. The AutoAero is not only a technological achievement but an instrument that is both functional and more productive than the conventional methods in terms of productivity, environmental impact, and crop quality. Machine learning algorithms are successfully deployed for the detection of pests, disease and animals, this provides a cutting edge to this solution where emerging technology is used. The functions of field moisture and spraying are presented as a prototype which can be performed more efficiently using required and suitable equipment. The sensor integration of RGB sensor has allowed to detect the preparedness of wheat crops. All these functions together have allowed AutoAero to achieve its objective resulting in sustainable, productive and future to use idea with more innovation.

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