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AUTONOMOUS AERIAL SURVEILLANCE AND ANALYSIS SYSTEM FOR INTEGRATED PEST AND PREDATOR MONITORING IN PRECISION AGRICULTURE

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ABSTRACT- An innovative method for enhancing crop safety and agricultural output is the Autonomous Aerial Surveillance and Analysis System for Integrated Pest and Predator Monitoring in Precision Agriculture. The system monitors agricultural fields autonomously using a quadcopter drone fitted with a GPS module, an ESP32-CAM, and wireless communication technologies. The drone takes pictures and videos of crops in real time while adhering to predetermined flying routes. In order to identify insect infestations, crop stress, and predator activity that might impair crop development and productivity, these photos are examined utilizing image-processing algorithms. When a danger is detected, the system logs the GPS location and sends notifications farmers or monitoring stations for immediate action. The collected data is processed to generate useful reports for crop management and resource planning. By providing continuous aerial surveillance and early threat detection, the system reduces manual inspection efforts, minimizes crop losses, decreases unnecessary pesticide usage, and supports sustainable precision agriculture. Overall, it offers a cost-effective, reliable, and intelligent approach to modern smart farming.

***Keywords*:** Precision Agriculture, UAV, Drone Surveillance, Pest Detection, Predatorr Monitoring, Integrated Pest Management (IPM), Artificial Intelligence, Machine Learning, Crop Health Monitoring, Image Processing, Smart Farming, Agricultural Automation.

I. INTRODUCTION

By fusing aerial robotics, cognitive sensing, and data-driven decision-making, the Autonomous Aerial Surveillance and Analysis System for Integrated Pest and Predator Monitoring in Precision

Agriculture offers a revolutionary approach to contemporary farming. Traditional pest monitoring techniques, such manual field inspection, are becoming ineffective, labor-intensive, and inefficient due to the growing worldwide need for increased agricultural output and sustainable practices. often inaccurate. This project introduces an automated solution that leverages unmanned aerial vehicles (UAVs), commonly known as drones, to monitor crop health, detect pest infestations, and analyze Predator activity in real time. Precision agriculture focuses on optimizing inputs such as water, fertilizers, and pesticides by using advanced technologies. In this context, aerial surveillance systems provide a significant advantage by offering rapid, high-resolution coverage of large agricultural areas. The proposed system integrates multispectral or high-definition cameras mounted on autonomous drones to capture detailed images of crop fields. These images are then processed using advanced algorithms, including machine learning and image processing techniques, to identify early signs of pest attacks, disease spread, or beneficial Predator presence.

II. OBJECTIVES

- To Create an Autonomous Aerial Surveillance System
- To Make Early Pest Infestation Detection Possible
- To include cutting-edge imaging technologies
- To Encourage Precision Farming Methods
- Reduce the Use of Chemical Pesticides

III. SYSTEM OVERVIEW

A drone-based smart farming system called the Autonomous Aerial Surveillance and Analysis System for Integrated Pest and Predator Monitoring in Precision Agriculture is intended to monitor agricultural fields, identify pests and predators, and offer farmers immediate assistance. The system makes use of a UAV with an ESP32-CAM, wireless communication modules, algorithms for analyzing images, and a laser deterrent. In order to enable the drone to independently scan the whole agricultural area, mission planning is carried out prior to operation by establishing field boundaries, flight routes, and waypoints. The ESP32-CAM takes pictures and movies of crops in real time while in flight. The processing unit receives these photos and uses image analysis algorithms to detect crop damage, insect infestations, and predator activity. The system produces useful information after assessing the seriousness of threats. can be activated automatically or manually to deter pests in specific locations, reducing the need for excessive pesticide application. The communication system provides wireless transmission of live video, GPS data, pest alerts, and drone status information to a mobile application. Farmers can monitor field conditions, view pest locations, and control the system remotely. The control center further analyzes collected data and generates reports for decision-making. Overall, the system improves crop protection, reduces chemical usage, enhances productivity, and supports sustainable precision agriculture through intelligent aerial monitoring and targeted intervention.

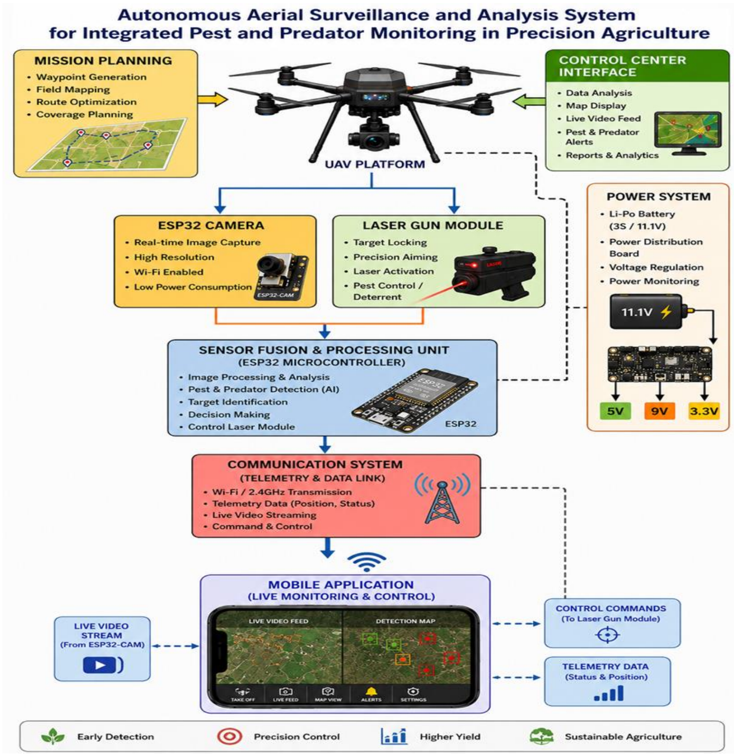

Fig.1- Proposed System

IV. HARDWARE COMPONENTS

F450 Quadcopter Drone Frame

Fig.2- ESP 8266 Nodemcu

The F450 frame operates on a quadcopter configuration, consisting of four arms arranged in an “X” shape. Each arm holds a brushless DC motor connected to a propeller. Two propellers rotate

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clockwise and the other two counterclockwise to maintain balance and eliminate torque. The flight controller continuously adjusts motor speeds based on sensor inputs (GPS, IMU), enabling stable hovering, navigation, and autonomous path tracking. In Pest and Predator detection, the drone follows predefined waypoints and maintains altitude.

1000KV BLDC Motor for Drones

Fig.3- 1000KV BLDC Motor for Drones

The 1000KV BLDC motor (A2212/13T) shown in the image is a commonly used propulsion unit in quadcopters designed for applications such as an Aerial Surveillance and Analysis System for Integrated Pest and Predator Monitoring in Precision Agriculture. This motor operates on the principle of electronic commutation, where the Electronic Speed Controller (ESC) rapidly switches current through the stator windings to generate a rotating magnetic field. This field interacts with permanent magnets in the rotor, producing smooth and efficient rotation. The motor speed is controlled by varying the input signal from the flight controller, enabling precise thrust adjustment for lift, hovering, and navigation.

Simonk 30 A speed controller

Fig.4- Simonk 30 A speed controller

The ESC acts as an interface between the flight controller and the brushless DC motor. It receives PWM (Pulse Width Modulation) signals from the flight controller and converts them into high-frequency switching signals using MOSFETs. These signals energize the motor windings in sequence, creating a rotating magnetic field that drives the motor. The SimonK firmware enables a fast response rate (~490 Hz), ensuring quick throttle changes and smooth maneuvering, which is essential for obstacle avoidance and precise navigation in Pest and Predator detection missions

Ardupilot Flight Controller

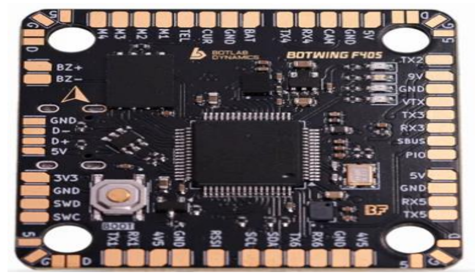


Fig.5- Ardupilot flight controller

ArduPilot processes real-time data from onboard sensors such as the IMU (accelerometer and gyroscope), GPS module, barometer, and compass. It uses advanced control algorithms (PID control) to maintain stable flight by continuously adjusting motor speeds through the ESCs. The system supports autonomous waypoint navigation, allowing the drone to follow pre-programmed paths for systematic Pest and Predatorr scanning. It also integrates payload sensors and performs sensor fusion to improve accuracy. Telemetry modules enable real-time communication with the ground control station for monitoring and decision-making.

Transmitter FS-i6

The FS-i6 operates on 2.4 GHz AFHDS 2A (Automatic Frequency Hopping Digital System) technology, which minimizes interference and ensures stable signal transmission. The transmitter sends control commands (throttle, pitch, roll, yaw) to the receiver connected to the flight controller. These commands are converted into PWM or PPM signals, allowing precise control of the drone's motors via the flight controller and ESCs. In autonomous missions, the transmitter acts as a manual override system, enabling the operator to take control during emergencies or unexpected obstacles in Pest and Predator environments. This transmitter provides stable communication, low latency, and reliable manual control, ensuring safety and flexibility in hazardous reconnaissance operations.

Fig.6- Transmitter FS-i6

ESP 32 Cameras

Fig.7- ESP 32 Camera

As the drone follows a predefined path using GPS navigation, the ESP32-CAM records visual information from different sections of the farm. The integrated OV2640 camera sensor captures detailed images of crop leaves, stems, and surrounding areas. These images are used to identify signs of pest infestation, plant stress, disease symptoms, leaf discoloration, and the presence of harmful predators such as birds or insects that may damage crops. The captured images are converted into digital data and processed either locally or transmitted wirelessly through the ESP32-CAM's built-in Wi-Fi capability. The data is sent to a ground monitoring station, cloud server, or mobile application where image-processing and machine-learning algorithms analyze the crop conditions.

Laser Gun

Fig.8- Laser Gun

During surveillance flights, the drone continuously captures images of the agricultural field using the ESP32-CAM. These images are analyzed to identify the presence of predators such as birds that may damage crops. When the system detects a predator in a specified monitoring zone, a control signal is sent to activate the laser gun. The laser diode emits a focused beam toward the detected target area. The moving laser spot creates a visual disturbance that birds and other animals perceive as a potential threat. As a result, they move away from the protected crop region without physical contact or harm. The laser can be directed manually by the operator or automatically through programmed control mechanisms.

V. SYSTEM DESIGN OVERVIEW

A comprehensive drone-based smart farming platform is represented by the PCB circuit diagram of the Autonomous Aerial Surveillance and Analysis System for Integrated Pest and Predator Monitoring in Precision Agriculture. The ESP32-WROOM microcontroller, which manages flight control, image processing, communication, navigation, and pest detection, is the main component. To take pictures and movies of crop fields in real time, the controller is linked to an ESP32-CAM module. To find insect infestations, crop damage, and predator activity, these photos are examined. Accurate mapping of impacted regions and autonomous flying along predetermined paths are made possible by a GPS module that gives position, altitude, and navigation data. By acting as a targeted pest deterrence device, the laser gun module—which is controlled by ESP32 GPIO pins—helps lower the use of pesticides. connected to four motors, allowing stable flight, hovering, and navigation.

Wireless communication is achieved through a dedicated telemetry module that transmits live video, GPS coordinates, alerts, and system status to a mobile application. Power is supplied by an 11.1 V Li-Po battery, while voltage regulators generate stable 5 V and 3.3 V outputs for different components. A current sensor monitors battery consumption and system load conditions. Additional components such as buzzers and status LEDs provide operational alerts and system indications. Through real-time monitoring and communication, farmers can access pest detection information and control functions remotely. Overall, the PCB integrates image acquisition, GPS navigation, wireless communication, flight control, power management, and laser-based pest deterrence into a single intelligent platform, enabling efficient crop monitoring, early threat detection, improved productivity, and sustainable precision agriculture.

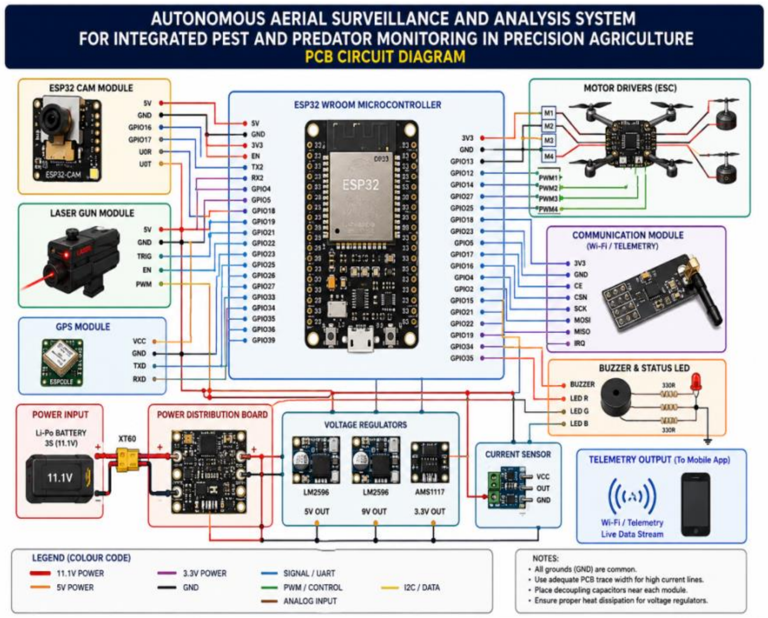
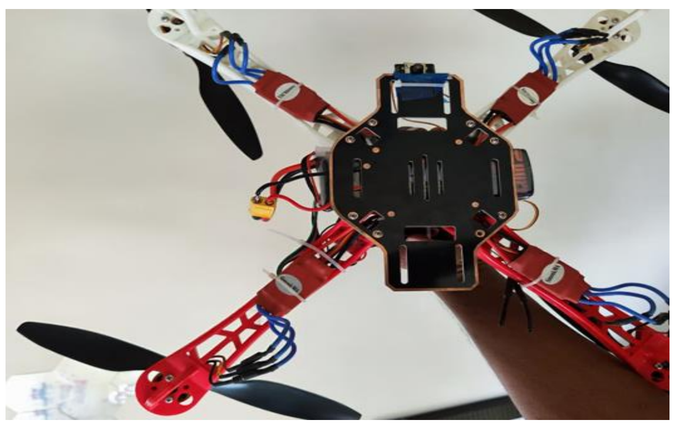


Fig.9- System Design Overview

VI. EXPERIMNTAL SETUP



VII. RESULT AND DISCUSSION

Parameter	Result
Project Name	Farm Guard using ESP32-CAM
Detection Method	Motion-based animal detection
Live Streaming	Successful
WiFi Mode	AP Mode

User Connection	Mobile/Laptop connected directly to ESP32-CAM
Animal Detection	Rabbit/Pig sized motion detected
Web UI Alert	Successful
Siren in UI	Successful

Table.1- Result Analysis

The Autonomous Aerial Surveillance and Analysis System for Integrated Pest and Predator Monitoring in Precision Agriculture successfully demonstrated real-time crop monitoring, threat detection, and crop protection. The ESP32-CAM captured and transmitted live video through Wi-Fi, allowing farmers to monitor fields using mobile devices. The motion-based detection system effectively identified pests and predators such as rabbits and wild pigs, generating instant alerts through a web interface. GPIO-controlled relay, laser deterrent, and buzzer modules operated successfully upon threat detection. The system achieved fast response with low memory usage and low cost. Overall, it provided reliable surveillance, automated alerts, predator deterrence, reduced crop losses, and improved agricultural productivity.

VIII. CONCLUSION

The study effectively combines wireless connection, GPS navigation, ESP32-CAM photography, drone technology, and image processing for agricultural monitoring in real time. It takes overhead photos, finds pests and predators, and notifies farmers so they may take prompt action. By facilitating focused treatment and lowering pesticide use, operating expenses, and environmental effect, the system promotes precision agriculture. Automated monitoring increases crop protection, increases output, and saves labor. The study shows the viability and efficiency of drone-based smart agricultural solutions in spite of obstacles like weather dependence and battery restrictions. Thermal imaging sensors, cloud-based analytics, sophisticated artificial intelligence algorithms, and autonomous spraying mechanisms for improved functionality and accuracy. The project contributes significantly to precision farming by enabling early threat detection, efficient resource utilization, improved crop protection, and enhanced agricultural productivity. It represents an important step toward the adoption of smart farming technologies and sustainable agricultural development in the future.

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