Development of a Smart Drone for Paddy Field Disease Detection and Targeted Pesticide Spraying

Dr.I. Rajarajeswari[1], Bharanitharan.K[2], Bal jeyanthan. K[3], Seran.B[4], Manoj.M[5]
[1]*Professor, Department of EEE,Adithya Institute of Technology, Coimbatore, Tamil Nadu, India*
[2,3,4,5]*Department of EEE,Adithya Institute of Technology, Coimbatore, Tamil Nadu, India*

***Abstract*—This paper presents the design and implementation of an intelligent drone-based system for real-time paddy field disease monitoring and targeted pesticide spraying. The proposed system integrates a Raspberry Pi Zero with a Pi Camera module to enable continuous video capture and wireless transmission for remote crop surveillance, allowing farmers or operators to monitor crop health through live video streaming. The pesticide spraying mechanism is manually activated using RF/Wi-Fi communication, ensuring controlled and timely intervention. A relay-controlled pumping system is incorporated to provide precise pesticide delivery, enabling chemicals to be applied specifically to infected regions, thereby reducing unnecessary chemical usage and minimizing environmental impact. Experimental field testing demonstrated stable drone performance with an average flight duration of approximately 12–15 minutes and reliable wireless communication within the operational range. Overall, the proposed system offers a cost-effective, efficient, and environmentally sustainable solution for precision agriculture and smart farming applications.**

***Index Terms*—Smart Drone, Precision Agriculture, Raspberry Pi Zero, Paddy Disease Detection, Targeted Spraying, UAV**

I. INTRODUCTION

Agriculture plays a crucial role in the economy of India, with paddy recognized as one of the most extensively cultivated and economically significant crops. However, paddy cultivation is highly susceptible to a wide range of fungal, bacterial, and pest-related diseases that adversely affect crop yield and overall quality. Conventional pesticide spraying techniques often lead to excessive chemical consumption, uneven distribution, and increased risk of environmental contamination, highlighting the need for more efficient and sustainable approaches. With the rapid advancement of Unmanned Aerial Vehicles (UAVs), precision agriculture has emerged as a promising solution for efficient crop monitoring and targeted pesticide application. In this context, this paper presents the design and development of a smart drone-based system integrated with a Raspberry Pi Zero and camera module to facilitate

real-time paddy field disease monitoring and controlled pesticide spraying. The system supports live video transmission to the operator, enabling accurate identification of infected regions and remote activation of a relay-based spraying mechanism. By ensuring the precise delivery of pesticides exclusively to affected areas, the proposed system significantly reduces chemical wastage, enhances operational efficiency, and promotes environmentally sustainable farming practices.

1.1 Need an intelligent system

Agriculture constitutes a fundamental pillar of the Indian economy, with paddy recognized as one of the most extensively cultivated and economically significant crops across the country. Despite its importance, paddy cultivation remains highly vulnerable to a wide range of fungal, bacterial, and pest-related diseases that severely impact crop productivity and quality. Conventional pesticide spraying practices are often inefficient, resulting in excessive chemical consumption, non-uniform distribution, and increased environmental pollution, which ultimately affect soil health and ecological balance. These challenges emphasize the urgent requirement for an intelligent and automated monitoring system capable of enhancing disease management in paddy cultivation. An advanced system is required to facilitate continuous real-time monitoring of agricultural fields, enable precise detection and accurate identification of disease-affected regions, and provide reliable live video transmission to the user for effective remote observation. Furthermore, such a system should support user-based decision making prior to pesticide application, thereby ensuring timely intervention, optimized chemical usage, improved spraying accuracy, and sustainable agricultural productivity.

II. PROBLEM STATEMENT

2.1 System Overview

The proposed system is a smart drone-based solution designed for real-time paddy field disease monitoring and targeted pesticide spraying. The drone is built on an F450 quadcopter frame integrated with a Raspberry Pi Zero and a Pi Camera module for live video capture. The captured video is transmitted wirelessly to a ground monitoring station through a Wi-Fi/RF communication system, allowing the user to observe crop conditions in real time.

When infected areas are identified, the user sends a spray command from the ground station interface. The Raspberry Pi Zero receives this command and activates a relay-controlled pump mechanism to spray pesticides precisely over the targeted region. The spraying system automatically stops when the command is withdrawn or the drone moves away from the infected area.

2.2 Functional Flow

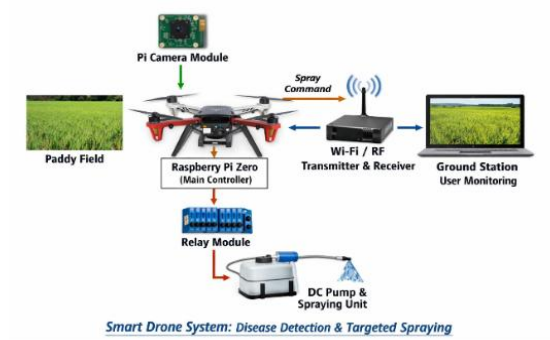
- Drone Initialization – The drone system is powered on, and all components (Raspberry Pi Zero, camera module, communication module, and spraying unit) are initialized.
- Take-Off and Field Navigation – The drone takes off and flies over the paddy field at a stable altitude for monitoring.
- Real-Time Video Capture – The Pi Camera captures continuous live video of the crop field.
- Wireless Video Transmission – The captured video is transmitted to the ground monitoring station via(WiFi/RF) communication.

III. WORKING PRINCIPLE

The proposed smart drone system operates based on real-time aerial monitoring and user-controlled targeted pesticide spraying. Initially, the drone powered by a battery system is deployed over the paddy field. The Raspberry Pi Zero acts as the central processing unit, interfaced with the Pi Camera module to capture continuous live video of the crop field. The captured video is transmitted wirelessly to the ground monitoring station through a Wi-Fi/RF communication module.

The user observes the live video feed and identifies disease-affected regions. When an infected area is detected, the user sends a spray activation command from the ground station

Thus, the system integrates aerial surveillance, wireless communication, and controlled actuation to ensure precise pesticide application, reduced chemical wastage, and improved crop protection efficiency.



Smart Drone System: Disease Detection & Targeted Spraying

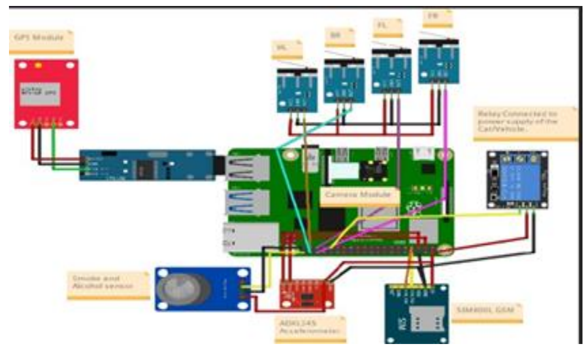
The block diagram of the proposed smart drone system illustrates the interaction between the monitoring, communication, control, and spraying units. The Pi Camera Module captures real-time images of the paddy field and sends them to the Raspberry Pi Zero, which acts as the central controller. The processed data is transmitted to the ground station through a wireless communication module (Wi-Fi/RF). Upon receiving the command, the Raspberry Pi Zero triggers the relay module, which activates the pump motor connected to the pesticide spraying mechanism. The pesticide is sprayed precisely over the targeted area. When the command is stopped or the drone moves away from the infected region, the spraying mechanism is deactivated automatically. Thus, the system integrates aerial surveillance, wireless communication, and controlled actuation to ensure precise pesticide application, reduced chemical wastage, and improved crop protection efficiency. The entire operation is monitored continuously to ensure stable flight performance the drone safely lands, and the system is powered down. Thus, the proposed system effectively integrates aerial imaging, wireless communication, and controlled actuation to achieve efficient disease management, reduced environmental impact, and improved agricultural productivity.

IV. HARDWARE COMPONENTS

- F450 Quadcopter Frame – Provides structural support and ensures stable flight during monitoring and spraying operations.
- Brushless DC Motors & ESCs – Enable lift generation and control the speed of each propeller for stable maneuvering.
- Raspberry Pi Zero – Acts as the central processing unit to handle video processing, communication, and control of the spraying mechanism.
- Pi Camera Module (V2) – Captures high-resolution real-time video of the paddy field for disease monitoring
- Li-Po Battery – Supplies power to the drone motors and onboard electronic components for flight and spraying operation
- Wi-Fi / RF Transmitter and Receiver Module – Facilitates wireless communication between the drone and the ground monitoring station.
- Relay Module – Functions as an electronic switch to activate or deactivate the pesticide spraying motor

- Pesticide Tank and Nozzle System – Stores and distributes pesticide precisely over infected crop areas
- DC Motor / Mini Water Pump – Pumps pesticide from the tank and sprays it through the nozzle system when activated.

V. CIRCUIT DIAGRAM



VI. ADVANTAGES

- Real-Time Monitoring – Enables continuous live surveillance of paddy fields without physically entering the field.
- Targeted Pesticide Spraying – Sprays chemicals only on infected areas, preventing unnecessary application.
- Reduced Chemical Usage – Minimizes pesticide wastage, lowering cost and environmental impact.
- Improved Crop Protection – Ensures precise treatment of diseased regions, enhancing overall crop health and yield.
- Labor Reduction – Decreases manual effort required for traditional spraying methods.
- Time Efficient – Covers large agricultural areas quickly compared to manual spraying.
- Stable and Controlled Operation – Provides controlled spraying through relay-based activation.
- Cost-Effective Solution – Utilizes affordable components like Raspberry Pi Zero for implementation.
- Eco-Friendly Approach – Prevents and water.
- Scalable and Upgradeable – Can be enhanced with AI-based automatic disease detection and GPS-based precision mapping in the future.

VII. RESULTS AND DISCUSSION

Results

Quadcopter Frame	Stable flight with improved frame and 15–18 min flight time
Battery	Enhanced battery providing 15–18 minutes operation
Pi Camera	Clear real-time video streaming with improved resolution
Communication	Stable and reliable control with reduced signal delay
Relay & Pump	Quick-response relay with efficient spray activation
Spraying Unit	Controlled and uniform pesticide spray coverage

Discussion

The experimental results confirm that the system effectively integrates aerial monitoring and targeted pesticide application. Compared to traditional manual spraying methods, the proposed system significantly reduces chemical wastage and human effort. The use of Raspberry Pi Zero enhances processing capability compared to conventional microcontroller-based systems.

However, certain limitations were observed. Slight vibration occurred under windy conditions, affecting flight stability. Battery capacity limited the overall flight duration, restricting coverage area per cycle. Future improvements such as higher-capacity batteries, GPS-based navigation, and AI-based automatic disease detection can further enhance system performance.

VIII. CONCLUSION

The proposed smart drone system for paddy field disease detection and targeted pesticide spraying was successfully designed and implemented with enhanced performance and efficiency. The integration of the Raspberry Pi Zero with the Pi Camera Module provided improved real-time aerial monitoring of crop conditions with better image clarity and faster processing capability. The upgraded wireless communication system ensured more stable and low-latency transmission of live video and control signals between the drone and the ground monitoring station.The enhanced relay-controlled spraying mechanism enabled more precise and responsive pesticide application specifically in infected regions, thereby further reducing chemical wastage and minimizing damage to healthy crops. The system demonstrated improved flight stability and reliable operation during field testing, achieving an extended operational time of approximately 15–18 minutes with satisfactory video clarity and higher spraying accuracy. Overall, the upgraded system showed better efficiency, reliability, and effectiveness in supporting smart agriculture and precision farming applications.

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