IRJCS: International Research Journal of Computer Science ISSN: 2393-9842
Volume 12, Issue 12, December 2025 https://www.irjcs.com/archives
https://doi.org/10.26562/irjcs.2025.v1212.04

Autonomous Animal Intrusion Detection and Repelling Drone

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Publication History
Manuscript Reference: IRJCS/RS/Vol.12/Issue12/DCCS10083
Research Article | Open Access | Double-Blind Peer Reviewed Article ID: IRJCS/RS/Vol.12/Issue12/DCCS10083
Received:12,November 2025,Revised: 20,November 2025,Accepted: 30 November 2025 Published Online:18 December 2025 https://www.irjcs.com/volumes/Vol12/iss-12/04.DCCS10083.pdf
Article Citation:Dr.Poonghuzhali,Sathiya,Ponmudi,Supritha,Srinivas(2025),Autonomous Animal Intrusion Detection and Repelling Drone, IRJCS: International Research Journal of Computer Science, Volume 12, Issue 12 of 2025 pages 700-702 **Doi:>**https://doi.org/10.26562/irjcs.2025.v1212.04
BibTeX Key Dr.Poonghuzhali@2025Autonomous
IRJCS papers should be cited as IRJCS (International Research Journal of Computer Science, AM Publications, India 2025, ISSN 2393-9842, https://doi.org/10.26562/ijrcs.2025.v1212.04 The journal's official abbreviation is IRJCS.
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Abstract: This work proposes an intelligent and low-cost solution to detect and respond to wild animal intrusions, particularly by elephants, in agricultural regions, addressing significant threats to crops, livelihoods, and human safety. The system utilizes a ground-based detection unit featuring an ESP32-CAM module equipped with Infrared (IR) night vision to continuously monitor the field day and night. Upon detecting an animal, the system sends location information to an autonomous drone which navigates to the spot. The drone is equipped with bright flashing lights and a sound device for effective, non-lethal repelling. Simultaneously, a GSM module (SIM800L) makes an automated phone call alert to the farmer, ensuring immediate awareness even on keypad mobile phones. This affordable, efficient, and reliable IoT-based solution operates with minimal human intervention, aiming to significantly reduce crop damage and increase safety in rural farming communities through real time animal detection and response.
Keywords: Animal Intrusion Detection, Drone, ESP32-CAM, IoT, GSM, Non-lethal Repelling, Sustainable Agriculture.

I. INTRODUCTION

Wild animal intrusion, primarily by elephants, presents a persistent and destructive threat to farmlands in agricultural regions, resulting in massive crop damage, financial losses, and risks to human life. Traditional methods like manual patrolling, scarecrows, and basic fences are often labor- intensive, inconsistent, or ethically/environmentally problematic. While modern solutions such as thermal imaging systems and electric fences exist, their high costs and infrastructure requirements make them in accessible to small and medium-scale farmers, and many systems lack reliable night time detection. The proposed solution addresses this gap by developing a smart, affordable, and autonomous system that ensures $24/7$ monitoring and immediate response using modern, cost-effective components.

II. LITERATURE REVIEW

A. Autonomous Drone Surveillance System

First, this work employed a drone equipped with a thermal camera, GPS, and an on board Raspberry Pi for autonomous Movement. Animal detection relied on thermal imaging, and upon intrusion, a GSM module sent SMS alerts to the farmer while the drone deployed sound and flashing LED deterrents. The primary limitation of this system was its dependence on expensive thermal cameras, making it unaffordable for small-scale farmers and unsuitable for wide spread adoption.

B. IoT-Based Forest Monitoring and Intrusion Detection

This approach utilized a simple setup involving a Passive Infrared (PIR) sensor and an Arduino Uno to detect motion. An alert was sent via a GSM module to the farmer, and a basic sound system was activated. The system's drawbacks included a complete lack of night vision capability and the limited range of PIR sensors, which could only detect large animals when they were already close to the crops.

III. SYSTEM ARCHITECTURE

The system's structural design is based on five interconnected operational layers: Detection, Communication, Response, Deterrent, and Power Management

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A. Detection Layer (Ground-Based Unit)

This unit monitors the farm land continuously, identifying and verifying animal intrusion.

ESP32-CAM Module: Serves as the primary detection unit, capturing images via its OV2640 camera and processing data.

IR Night Vision LEDs: Ensures the system's efficiency in low-light and darkness by providing invisible illumination, allowing $24/7$ operation.

PIR Motion Sensor: Works as a secondary verification tool, detecting changes in infrared heat signatures to confirm animal presence and reduce false alerts.

B. Communication Layer (Wireless Data Transmission)

This layer establishes are liable link to alert both the response unit and the farmer.

LoRa/Wi-Fi Module: Transmits the detection alert and GPS location coordinates from the ESP32-CAM to the autonomous drone system.

SIM 800L GSM Module: Provides a fail-safe, non- internet-dependent communication channel by sending emergency alerts via an automated phone call to the farmer's mobile number.

C. Response and Deterrent Layers (Drone-Based)

Upon receiving coordinates, the drone autonomously navigates to the target location and deploys deterrents.

Quad copter Drone & Flight Controller (Pixhawk/STM32): Provides autonomous mobility and manages stability using Ardu Pilot/PX4 firmware, processing GPS navigation commands.

GPS Module (UbloxNEO-6M): Ensures precise movement and accurate navigation to the detected intrusion points.

High-Intensity Flashing LEDs & Buzzer/Speaker System: Non-lethal deterrents activated at the site to disrupt animal behavior and scare them away.

III. PROPOSED METHODOLOGY

The methodology describes the sequential workflow, implementation steps, and software architecture necessary to achieve autonomous detection and repelling.

Working Principle (Sequential Workflow)

The operation follows a five-step process designed for minimal human intervention

Detection Initiation: The ESP32-CAM continuously monitors the area while the PIR sensor detects motion. The ESP32-CAM verifies the intrusion via image processing.

Alert Transmission: The system immediately sends alert data (GPS coordinates) to the drone via the LoRa/Wi-Fi Module. Simultaneously, the GSM Module initiates an automated call/SMS alert to the farmer.

Autonomous Deployment: The drone receives the GPS coordinates, and the Flight Controller processes the instructions, enabling stable, autonomous movement to the target location.

Deterrence Activation: Upon reaching the site, the drone activates the flashing LEDs and the buzzer/speaker, which scares the animal away non-lethally.

Power Continuity: The system is maintained by rechargeable batteries, with optional solar panels ensuring continuous operation in remote areas.

Software and Programming: The system relies on specialized firmwarefor both ground and aerial control.

Ground Unit Programming: Code for the ESP32-CAM is written using the Arduino IDE and ESP32 Core Libraries, enabling image processing, sensor integration, and communication functionality.

Drone Control Firmware: The drone utilizes ArduPilot or PX4 Firmware for stability and precise autonomous movement based on waypoints. This is configured using Mission Planner or Q Ground Control.

Communication Protocols: The MQTT protocol is implemented over LoRa/Wi-Fi for fast data exchange, and GSM AT Commands control the SIM800L for cellular alerts.

Testing and Validation

Initial testing confirmed that the system functions across all layers. The detection unit successfully validated image clarity and motion detection day and night. The communication layer delivered alerts reliably to the drone and to farmers via automated GSM calls. The drone's GPS navigation and activation of deterrents were successful, confirming smooth system integration.

RESULTS AND DISCUSSION

The system successfully implemented and validated the design objectives, providing an affordable, automated, and non-lethal defense against animal intrusion.

Performance Validation

Testing confirmed the system's operational efficiency across all layers.

24/7 Detection: The ESP32-CAM combined with IR Night Vision achieved reliable detection in all lighting conditions, overcoming prior system limitations. The PIR Sensor reduced false alerts by providing motion verification.

Response Reliability: The dual alert system proved robust. The LoRa/Wi-Fi Module transmitted coordinates for autonomous drone movement, while the SIM800L GSM Module guaranteedimmediatefarmer notification via call, independent of internet connectivity.

Autonomous Deterrence and Effectiveness

The drone response was validated for precision and efficacy.

Precise Navigation: The GPS Module and Flight Controller enabled the drone to autonomously reach the target location accurately.

Mitigation Success: Upon arrival, the drone successfully activated the Flashing LEDs and Buzzer/Speaker System, confirming the non-lethal deterrent mechanism is effective in scaring animals away and preventing crop damage.

Conclusion on Design Goals: The architecture's use of low-cost IoT components meets the goal of affordability for small farmers. Furthermore, its use of rechargeable batteries and design for solar integration confirms its sustainability and capability for continuous, unattended operation in remote environments. The system is a practical, technology-driven solution that minimizes human intervention.

CONCLUSION

In conclusion, this IoT-based animal intrusion detection and repelling system successfully implemented a practical and scalable approach to safeguarding agricultural lands from wildlife interference. By integrating essential low-cost components such as the ESP32-CAM with IR for $24/7$ detection, wireless communication via LoRa/Wi-Fi, and GSM for reliable call alerts, alongside an autonomous drone response equipped with non-lethal deterrents, the system ensures efficient, real-time protection for crops. The system's successful validation confirmed the precision of the drone's GPS navigation and the effectiveness of its non- lethal deterrents. Ultimately, the project delivers a sustainable, technology-driven solution that minimizes human intervention and maximizes farm security, proving reliable even in remote environments through its independent power (rechargeable battery/solar) and communication systems.

FUTURE SCOPE

Enhanced AI & Vision: Integrate advanced object detection algorithms with high-res cameras for accurate species identification and improved night vision.

Mobile App Alerts: Develop a real-time mobile application to replace GSM calls for interactive alerts and data display.

Multi-Drone Scaling: Expand the system to support coordinatedmulti-droneoperationsforcoverageoverlarge areas.

Sustainability: Fully implement solar-powered units for continuous, off-grid operation and enhance component durability/weatherproofing.

Custom Deterrents: Introduce customizable repelling strategies based on specific animal behavior for increased efficacy.

ACKNOWLEDGEMENT

The authors gratefully acknowledge Prof.Poonghulazhi, Head of Department of Electronics and Communication Engineering, Sri Sairam College of Engineering, for her valuable guidance and support throughout the project. The authors also thank the institution's laboratory staff for assistance during hardware testing and simulation.

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