PACE Conclave 2025 | iCEST 2025 INTERNATIONAL CONCLAVE ON ENGINEERING SCIENCES & TECHNOLOGY | SEMI-COMM TECH SUMMIT INTERNATIONAL CONFERENCE ON EMERGING TRENDS IN ELECTRONICS & COMMUNICATION

AUTOMATED ANIMAL AND BIRD INTRUSION DETECTION SYSTEM USING IOT AND MACHINE LEARNING FOR AGRICULTURAL PROTECTION

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Abstract

The Automated Animal and Bird Intrusion Detection System addresses the growing need for efficient wildlife management in agricultural and restricted areas by providing a smart, cost-effective alternative to traditional methods like fencing or manual monitoring. Using sensors, cameras, microphones, and machine learning, the system autonomously detects intrusions and triggers immediate responses, ensuring real-time monitoring and protection. Its integration of PIR and ultrasonic sensors with advanced algorithms minimize false alarms, improves accuracy, and adapts to diverse environments. This system reduces human intervention, enhances efficiency, and prevents damage to crops and property, offering a scalable, non-invasive, and sustainable solution for wildlife control while protecting valuable resources.

ISBN:97881-19905-39-3

1 Introduction:

Human-wildlife conflicts pose significant challenges to agricultural productivity, causing substantial economic losses due to crop damage. Traditional methods, such as fencing, scarecrows, or manual patrols, are labor-intensive, costly, and often ineffective due to animals' adaptability. Recent advancements in Internet of Things (IoT), machine learning, and sensor technologies provide opportunities to develop automated, non-invasive solutions for wildlife management.

This work introduces an Automated Animal and Bird Intrusion Detection System designed to monitor agricultural fields and deter wildlife intrusions. The system integrates multiple sensors, including PIR for motion detection, ultrasonic for proximity sensing, cameras for visual data, and microphones for audio capture. These inputs are processed by machine learning models to identify specific animals or birds, triggering tailored deterrent responses. The system's IoT connectivity enables real-time monitoring and remote alerts, enhancing its practicality for farmers.

Unlike conventional methods, this system minimizes false positives through multimodal data analysis and adapts to diverse environments via continuous learning. It offers a sustainable alternative by using non-lethal deterrents, aligning with conservation goals. The proposed system is cost-effective, scalable, and suitable for both small and large agricultural settings, addressing the limitations of traditional wildlife management techniques.

2 Experimental Procedure

The system was tested in a controlled agricultural field over 30 days. Sensors were deployed to monitor a 50-square-meter area, with the Raspberry Pi processing data in real-time. The system was exposed to various animals (e.g., dogs, birds, cows) and environmental conditions (e.g., rain, wind). Detection accuracy, response time, and false positive rates were recorded.

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2.1 Sensor Calibration

PIR sensors were tuned to detect infrared signatures of animals larger than 10 cm. Ultrasonic sensors were set to a 5-meter range to avoid false triggers from distant objects. The camera operated at 1080p resolution, and the microphone captured audio at 44.1 kHz.

2.2 Deterrent Mechanism

Upon detection, the system identified the species and triggered a corresponding deterrent sound (e.g., high-frequency tones for elephants, barking for dogs). Alerts were sent via SMS using a GSM module integrated with the Raspberry Pi.

3 System Requirement Analysis and Specification

3.1 Functional Requirements

Functional requirements define the specific actions and behaviors a system must perform to meet user needs. They outline what the system should do, focusing on its core functionalities, without specifying implementation details.

3.2 Obstacle Sensing

This function is responsible for detecting any obstacles that might be in the system's environment. It ensures that the detection system is aware of the space around it. This could include physical objects like trees, fences, or other structures within the square meter area. Obstacle sensing is crucial for ensuring that the system can differentiate between actual intruders (animals or birds) and other environmental features that might trigger false alarms. The system needs sensors (such as ultrasonic or infrared) to detect these obstacles and allow the system to focus only on movement indicative of animal or bird intrusion.

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3.3 Machine Learning

Machine learning plays a critical role in making the system intelligent and adaptable. By using algorithms like deep learning, the system can be trained to recognize various animals and birds based on their sound and visual characteristics. This enables the system to improve its accuracy over time as it encounters more examples. For instance, the system could learn to distinguish between different types of birds and animals, enabling it to respond with tailored deterrent sounds. It also allows the system to handle new types of intruders by integrating new datasets of sounds or images that represent unfamiliar animals.

3.4 Animal and Bird Detection

The core of our project, this functionality is about accurately detecting the presence of animals and birds in the monitored area. It uses a combination of sensors for sound and vision, such as microphones to capture animal sounds and cameras or other imaging systems to detect visual movements. The detection process involves analyzing these inputs to identify whether the detected movement or sound corresponds to a known animal or bird. Once the system identifies an intruder, it can trigger a response, such as activating deterrent sounds or alerting the user with the sounds specifically stored in database.

3.5 Alert System

The alert system is designed to notify the user or relevant parties when an animal or bird is detected in the area. This could involve sending notifications via text messages, emails, or app alerts. The alert system helps the user take timely action to handle the intrusion. Additionally, the system might be designed to trigger specific deterrent sounds aimed at the detected animal or bird, ensuring that the intruder is driven away. This could be linked to the machine learning model to tailor the alert or response based on the type of animal detected.

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4 Non-Functional Requirements

Non-functional requirements (NFRs) specify how a system should perform rather than what it should do. They encompass aspects such as reliability, performance, usability, security, scalability, maintainability, availability, portability, interoperability, and compliance. These requirements are essential for ensuring the overall quality and effectiveness of a system, guiding decisions throughout the development lifecycle.

- Refers to the system's ability to consistently perform its intended functions without failure over a specified period and under normal operating conditions.
- Ensures that the system operates in a manner that minimizes the risk of harm to users, property, or the environment. Safety requirements include measures to prevent accidents, mitigate hazards, and respond to emergencies.
- Defines the degree to which the system produces correct and precise results. Accuracy requirements ensure that the system's outputs are reliable and trustworthy, particularly in critical tasks or decision-making processes.
- Indicates the system's capability to handle increasing workloads, users, or data volumes without sacrificing performance or functionality. Scalability requirements address the system's ability to grow or adapt to changing demands while maintaining efficiency and responsiveness.

5 Hardware Requirement

5.1 Raspberry Pi 5

Specifies the requirement for a Raspberry Pi microcomputer, with a specific model or version indicated, to serve as the central processing unit and control hub for the Animal and Bird Intrusion System.

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Figure 1:

5.2 Raspberry pi 5 module

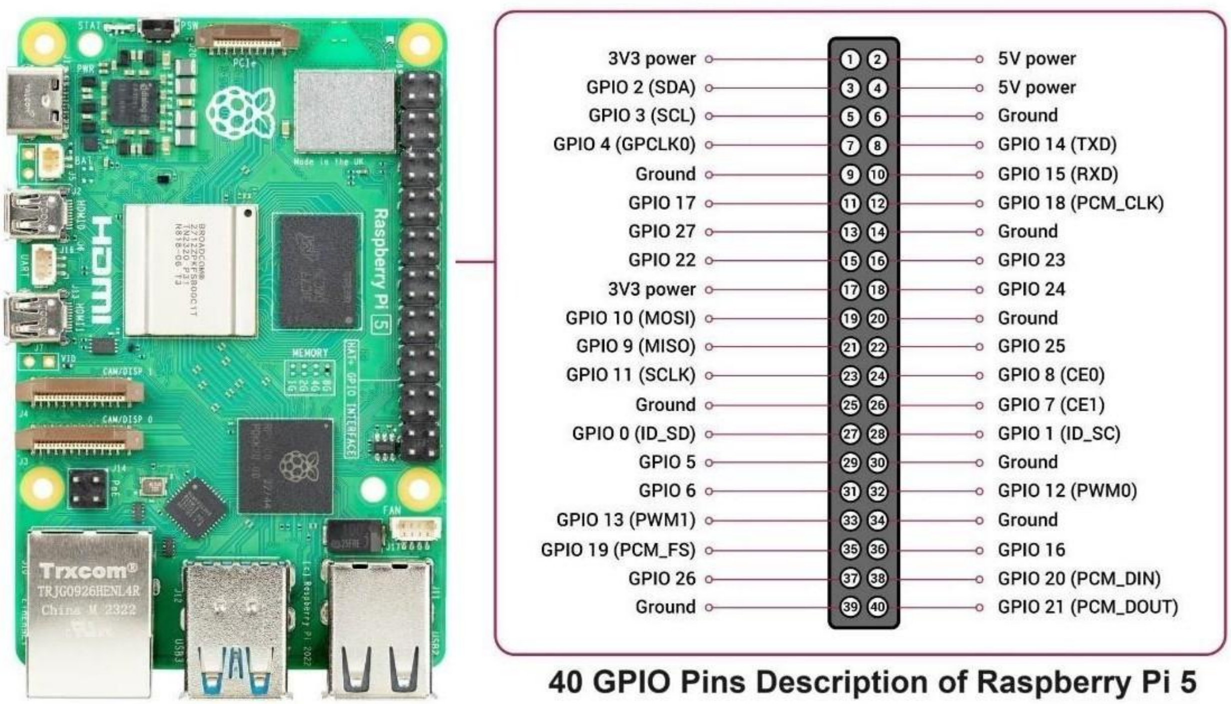

Figure 2:

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5.3 Raspberry pi pins

	Raspberry Pi 4	Raspberry Pi 5	
CPU	Broadcom BCM2711, Cortex-A72 (ARM v8) 64-bit SOC @ 1.8 GHz	**Broadcom BCN12712, quad-core Cortex-A76 (ARM v8), 64-bit SOC @ 2.4 GHz**	**2-3x performance**
RAM	1 GB, 2 GB, 4 GB, 8 GB	**1 GB, 2 GB, 4 GB, 8 GB**	
Connectivity	2.4 GHz and 5.0 GHz 802.11 ac wireless Bluetooth 5.0, BLE Gigabit Ethemet n/a 2x USB 3.0, 2x USB 2.0 ports Standard 40-pin GPIO header 2x Micro HMDI Ports (up to 4K 60p) 2-lane MIPI DSI, 2-lane MIPI CSI 4-pole stereo audio and composite video	2.4 GHz and 5.0GHz 802.11 ac wireless Bluetooth 5.0, BLE Gigabit Ethemet **1x PCIe 2.0 interface** **2x USB 3.0 (5 Gbit/s),** **2x USB 2.0 ports** Standard 40-pin GPIO header 2x Micro HDMI ports (up to 4K 60p) **2x 4-lane MIPI (DSI/CSI) n/a**	**High-speed peripheral interface (for SSDs, etc.)**
OS and data storage	microSD card slot	**microSD card slot with support for high-speed SDR104 mode**	**2x interface speed**
Input power	5 V DC @ 3 A (via USB-C connector or GPIO)	**5 V DC @ 5 A DC (PD-enabled)**	**New Raspberry Pi power supply**
PoE	Via separate PoE HAT	**Via (new) separate PoE HAT**	**Fully PoE 802.3at-compliant**
Real-time clock (RTC)	n/a	**RTC and RTC battery connector**	

Figure 3:

5.4 Difference among different version raspberry pi modules

PIR Sensor

PIR sensor

5.5 Android Application for Data Display and Classiftcation

The Android application serves as the main interface for diagnostic analysis and respiratory monitoring. Designed to communicate with the microcontroller via Bluetooth, the app collects respiratory data and computes critical pulmonary function parameters such as Forced Expiratory Volume in one second (FEV_1), Forced Vital Capacity (FVC), and Peak Expiratory Flow (PEF). Additionally, it generates both the flow-volume curve and the flow-time graph, offering real-time visualization and classification of the breathing effort.

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Figure 4:

Developed using Android Studio, the application has been tested on devices running Android 7.1 (Nougat). It includes a zoom feature to allow detailed inspection of plotted curves, enhancing usability and accuracy in interpreting respiratory patterns.

- The app workflow includes the following steps (refer to Fig. 5 for the visual flow):
- Select the appropriate Bluetooth device from the available list.
- Fully inhale, then tap the “Begin Recording” button to start the test and exhale forcefully.
- Once the maneuver is completed, tap the “Stop Recording” button.
- The calculated results—FEV_1, FVC, FEV_1/FVC ratio, and PEF—are then displayed on-screen.
- Users can tap “View Plot” to see the flow-volume and flow-time graphs.
- Pressing the “Classify” button initiates the algorithm to assess the respiratory condition as either ’Normal’ or ’Abnormal’.
- Finally, selecting “Save” stores the measured values, including the FEV_1, FVC,

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FEV_1/FVC (%), and PEF, for future reference.

Camera Module

Figure 5:

Camera module

Microphone Sensor

The **microphone sensor** in your project would be used to capture sounds from the environment, including animal and bird noises. It helps in identifying intrusions by analyzing sound patterns, allowing the system to distinguish between different species based on their unique vocalizations, and triggering appropriate responses such as deterrent sounds.

Buzzer or alarm module

Represents the audio alert system integrated into the robot to emit audible signals, such as alarms or warning sounds.

5.5.1 Power Supply Unit

SG90 Servo Motor

An **SG90 Servo Motor** in our project helps Rotate the Web Camera to left and right. It turns the camera when a motion is detected in PIR Sensor and rotate towards the side of PIR which had the motion detection.

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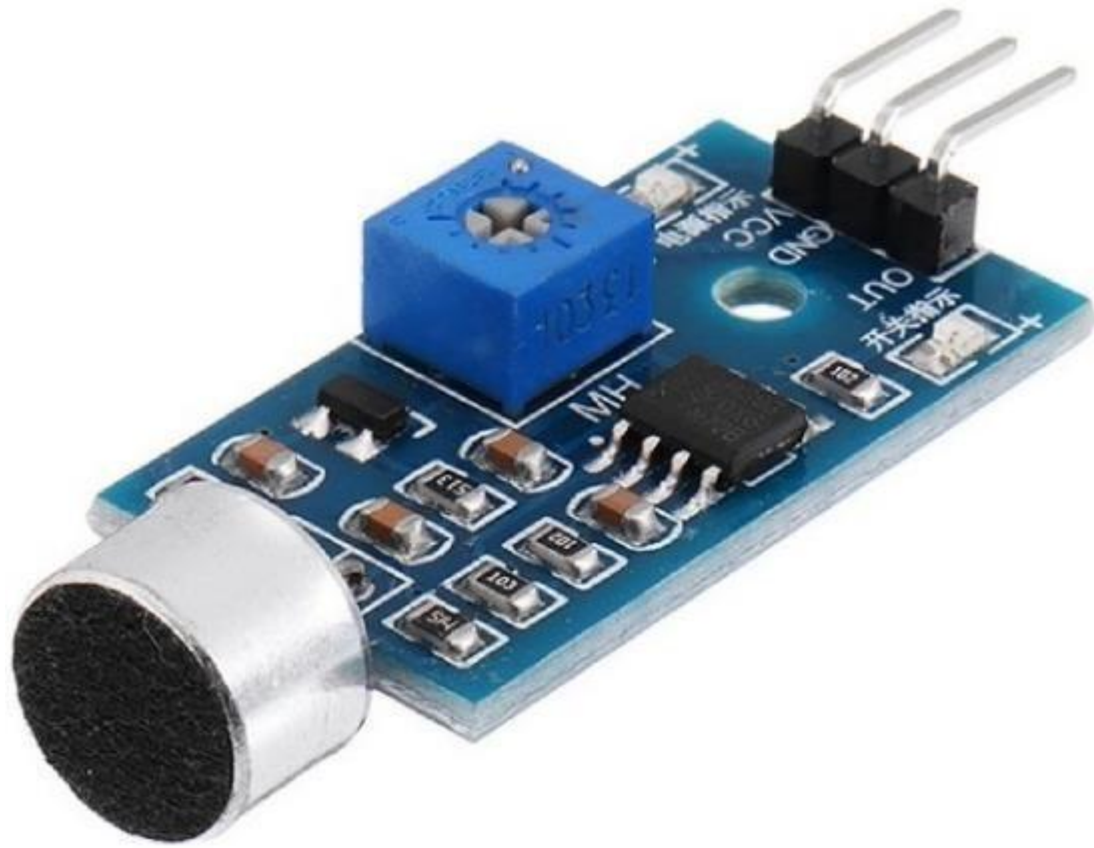

Figure 6:

Figure 7:

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Figure 8:

Ultrasonic Sensor

The ultrasonic sensor in your project is used to detect the distance between the sensor and objects or obstacles in the environment. It emits sound waves and measures the time it takes for the waves to bounce back, helping the system map the surroundings and detect movement or obstacles, which is crucial for avoiding false intrusions and ensuring the system's accuracy in animal or bird detection.

Software Components

- Raspbian OS: Provides the operating environment for the Raspberry Pi.
- Python 3: Used for developing data processing and machine learning algorithms.
- Libraries: OpenCV for image processing, PyAudio for audio analysis, RPi.GPIO for sensor control, and MobileNet-SSD for object detection.

6 Results and Discussion

Detection Accuracy

Field tests demonstrated an overall detection accuracy of 85%, with 90% accuracy for visual detection and 80% for audio-based classification. The system correctly identified species such as dogs, cows, and common birds (e.g., crows, sparrows). False positives were reduced to 5% through multi-sensor integration.

Response Time

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The average response time from detection to deterrent activation was 1.2 seconds, sufficient for real-time applications. IoT-based alerts were delivered within 5 seconds, ensuring timely user notification.

Environmental Robustness

The system-maintained performance in adverse conditions, such as rain and high temperatures, due to robust hardware design and active cooling. However, dense vegetation occasionally reduced ultrasonic sensor accuracy, suggesting a need for enhanced sensor placement strategies.

7 Conclusion

The Automated Animal and Bird Intrusion Detection System offers a reliable, cost-effective solution for protecting agricultural fields from wildlife intrusions. By integrating IoT, machine learning, and multi-sensor technologies, the system achieves high detection accuracy and rapid response times. Its non-invasive deterrents promote sustainable wildlife management, while IoT connectivity enables remote monitoring. Field tests confirmed its effectiveness, with an 85% detection accuracy and low false positive rates. Future enhancements include expanding the detection range, integrating solar power, and incorporating reinforcement learning for greater adaptability.

8 Acknowledgement

The authors thank the Department of Science and Technology, Karnataka, for providing research facilities (Grant No. DST/KAR/2023/789).

ISBN:97881-19905-39-3