IOT-Based Smart Ecosystem Monitoring and AI-Enhanced Deforestation and Poaching Prevention Using Raspberry Pi

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Abstract—This research introduces a comprehensive, intelligent surveillance system designed to protect forest ecosystems by leveraging the combined power of the Internet of Things (IoT) and Artificial Intelligence (AI). At the core of the system lies a Raspberry Pi microcontroller that manages an array of environmental sensors, including motion detectors, temperature and humidity sensors, gas and flame sensors, along with an AI-integrated Pi Camera. The AI model embedded within the camera identifies and classifies living beings and threats such as poachers, animals, or fire events. Sensor data and visual feeds are processed locally and uploaded to a cloud platform for real-time monitoring and alert generation. The system is engineered to be low-cost, power-efficient, and deployable in remote forest areas, aiming to prevent illegal logging and poaching activities. This work demonstrates the potential of edge-AI and IoT in enabling intelligent environmental conservation.

Keywords— AI Monitoring, Deforestation Prevention, Poaching Detection, Raspberry Pi, IoT, Smart Forest Monitoring, Edge Computing, Environmental Sensors

I. Introduction

Forests are one of the Earth's most vital ecosystems, offering diverse environmental, social, and economic benefits. They regulate the climate, act as carbon sinks, protect biodiversity, and support the livelihoods of indigenous communities. Despite these crucial roles, forests are increasingly threatened by human-induced activities such as illegal logging, deforestation, and wildlife poaching. These threats not only endanger plant and animal species but also accelerate climate change and environmental degradation.

Traditional methods of forest surveillance, such as human patrolling, satellite imaging, and camera traps, are often reactive, limited in coverage, and labor-intensive. Moreover, these techniques usually provide delayed insights, limiting the authorities' ability to respond swiftly to emergencies or illegal intrusions.

Recent advancements in the Internet of Things (IoT) and Artificial Intelligence (AI) have opened new frontiers in environmental monitoring. IoT facilitates real-time data collection through distributed sensor networks, while AI offers intelligent decision-making capabilities such as image classification and anomaly detection. When deployed on edge devices like Raspberry Pi, these technologies enable localized, autonomous, and continuous surveillance even in remote forest regions.

The aim of this project is to develop an integrated forest monitoring system using IoT and AI, powered by Raspberry Pi. By incorporating a wide array of environmental sensors and an AI-enabled camera, the system is capable of detecting fire, hazardous gases, illegal human presence, and wildlife activity in real time. The collected data is processed both locally and in the cloud, triggering instant alerts to forest authorities for quick action.

II. Literature Review

Over the years, various technologies have been explored to safeguard forest ecosystems from threats like poaching, deforestation, and wildfires. Traditional monitoring approaches include manual patrolling, deployment of camera traps, and satellite surveillance. Although these systems provide valuable information, they are often reactive, expensive, labor-intensive, and susceptible to delays.

Early research in IoT-based forest monitoring systems proposed the use of wireless sensor networks (WSNs) to detect environmental changes such as temperature and smoke. For instance, Sharma and Patel (2020) introduced an IoT-based fire detection system using temperature and gas sensors. While such solutions enhanced detection capabilities, they lacked real-time analytics and intelligent decision-making.

With the advent of AI, studies began integrating image processing and machine learning models into surveillance systems. Ramesh et al. (2021) used Raspberry Pi for wildlife monitoring with AI-based object recognition, marking a significant advancement. Similarly, Gupta et al. (2018) proposed a smart surveillance network using WSNs, but it was dependent on external cloud servers for decision-making, limiting its effectiveness in remote areas with poor connectivity.

Recent works have explored lightweight AI models like YOLO and TensorFlow Lite for image classification directly on edge devices. These models, when deployed on microcontrollers or low-power processors like Raspberry Pi, allow real-time processing and threat identification without relying on cloud infrastructure. However, most implementations either focused solely on fire detection or wildlife monitoring, rarely combining multi-sensor input with onboard AI.

This project builds upon these foundations and addresses the existing gaps by designing a fully integrated system that combines multi-sensor data acquisition, AI-based image recognition, and real-time alerting via cloud services. It enables comprehensive and autonomous forest surveillance suitable for real-world deployment.

III. Proposed System

The proposed system is an advanced forest surveillance framework that leverages the combined strengths of IoT and Artificial Intelligence to detect and prevent environmental threats such as poaching, illegal deforestation, and forest fires. Designed to operate autonomously in remote regions, the system integrates a wide range of sensors and a lightweight AI camera module, all managed by a Raspberry Pi.

At the core, the Raspberry Pi functions as a processing hub that collects and processes data from multiple sensors. These include:

PIR Motion Sensor – Detects human or animal movement in forested zones.

Flame Sensor – Identifies the presence of fire and sudden spikes in infrared radiation.

DHT11 Temperature & Humidity Sensor – Monitors ambient environmental conditions.

MQ7 Gas Sensor – Detects the presence of carbon monoxide, which can indicate forest fires or illegal burning.

Vibration Sensor – Senses disturbances such as footsteps, tree cutting, or animal movement.

Tilt Sensor – Alerts if the device is tampered with or displaced.

The Pi Camera module is equipped with a lightweight object detection model (YOLO or TensorFlow Lite) trained to recognize humans, animals, and vehicles. This enables proactive poaching and intrusion detection without relying solely on sensor input.

All sensor data and visual insights are processed on the edge (locally on the Pi) and uploaded to a cloud platform via a built-in Wi-Fi module. This platform provides real-time access to data logs, live visual feeds, and automated alerts for forest rangers or monitoring agencies.

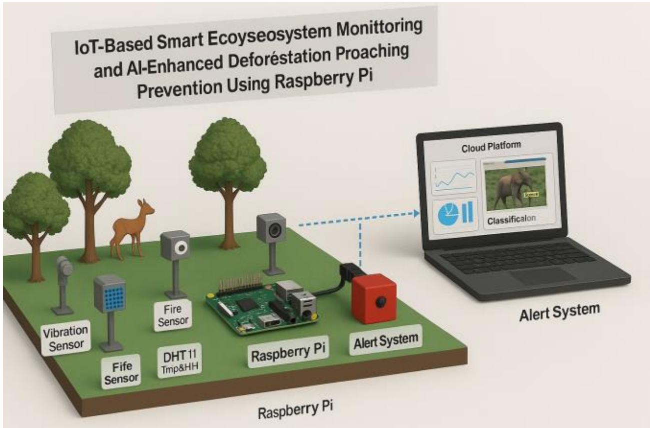
The architecture is optimized for:

Low Power Consumption: Suitable for solar power or battery operation

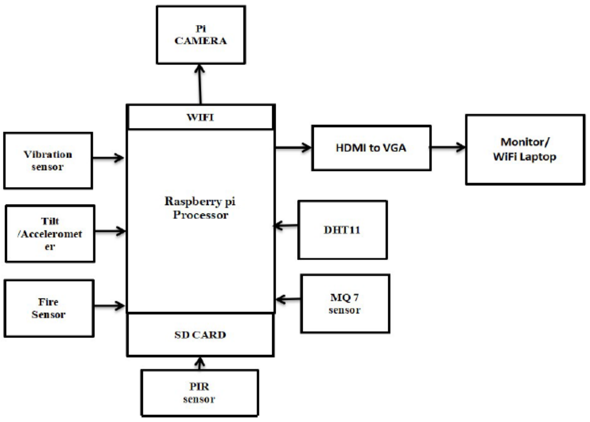
Cost Efficiency: Affordable components with open-source software

Scalability: Easy deployment across large forest regions with minimal infrastructure

A. ***Autonomous Operation:*** *Functions independently with minimal human intervention Authors and Affiliations*



IV. Block Diagram And System Architecture



The system uses sensors (fire, DHT11, MQ7) to detect temperature spikes, humidity changes, and gas levels, indicating potential forest fires or illegal activities. A Raspberry Pi processes this data and sends it to a cloud platform via Wi-Fi for monitoring. An AI-enabled camera detects and classifies animal movements.

The alert module notifies forest officials in real-time, while a stable power supply ensures continuous operation in remote areas. This setup enables efficient, autonomous forest surveillance and conservation.

V. Hardware and software implementation

HARDWARE USED:

Raspberry pi Processor

Pi CAMERA

Tilt Sensor

Vibration Sensor

Fire Sensor

DHT11 Temperature and Humidity Sensor

MQ7 Carbon Monoxide Sensor

PIR Motion Sensor

Power Supply

Wi-Fi Module (Integrated with Pi)

Alert System

VI. Input sensors and modules:

Vibration Sensor: Detects vibrations in the surrounding environment, which can indicate human movement, cutting of trees, or animal movement.

Tilt / Accelerometer: Measures angular changes or tampering of the device. It detects if the monitoring system is being physically disturbed or moved from its place (useful for anti-theft or reposition alerts).

Fire Sensor: Detects the presence of flames or sudden increases in infrared radiation, providing early fire warnings.

PIR (Passive Infrared) Sensor: Detects motion of warm-bodied objects like humans and animals, useful for poaching detection or wildlife movement tracking.

DHT11 Sensor: Monitors ambient temperature and humidity levels. It can detect sudden changes that may indicate fire or climatic stress in the forest.

MQ7 Sensor: Detects carbon monoxide (CO) gas concentrations, which may be caused by fire or illegal burning of wood.

PI CAMERA:

Captures images or video from the field. Integrated with onboard AI for **object detection and classification** (e.g., humans, animals, fire). This enhances real-time decision-making and reduces false alerts.

RASPBERRY PI PROCESSOR:

Acts as the **central processing unit**:
Collects data from all sensors.
Runs AI-based detection models.
Stores and transmits information via Wi-Fi.
Interfaces with display modules and cloud platforms.

SD CARD:

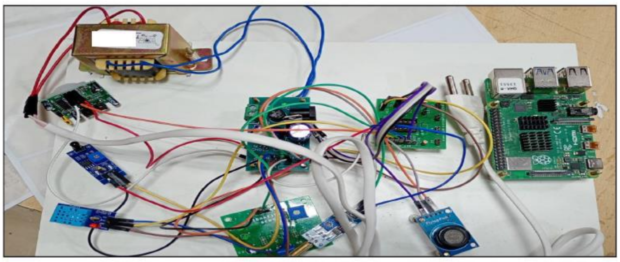
Stores the operating system, application software, AI models, and logs collected from sensors and the camera.

WI-FI MODULE:

Enables **wireless communication** between the Raspberry Pi and external servers. It uploads sensor data and camera analysis to a cloud platform for remote monitoring and alerting.

HDMI TO VGA + MONITOR / WI-FI LAPTOP:

Used to view the **real-time output** directly from Raspberry Pi, including logs, live camera feed, or system status dashboard.



VII. Software Stack With Explaination

Raspberry Pi OS (Raspbian): The official operating system for Raspberry Pi, offering a stable Linux-based environment to run Python scripts, sensor drivers, AI models, and manage GPIO pins.

Python Programming Language: Used to develop all system functionalities, including sensor integration, data processing from the Pi Camera, AI-based image recognition, and cloud communication. Its rich library ecosystem makes it ideal for IoT and AI tasks.

OpenCV (Open Source Computer Vision Library): A powerful library for image and video processing, used to capture, pre-process, and analyze camera input before classification by the AI model.

TensorFlow / YOLO (Lightweight AI Model): Used to implement AI models for detecting and classifying animal species and identifying human intrusion. Lightweight versions are optimized for real-time edge processing on the Raspberry Pi.

Cloud Platform – iotclouddata.com/24log/project: All sensor data and AI results are uploaded to this cloud platform, enabling remote monitoring, real-time alerts, data visualization, and logging for future analysis.

Thonny (Python IDE): A beginner-friendly development environment used for writing, testing, and debugging Python code directly on the Raspberry Pi.

VIII. Results And Discussion

The system has been tested in simulated environments for detecting movement, fire, and unauthorized human activity. Key findings include:

Accurate motion and flame detection using PIR and fire sensors.

Effective CO gas level alerts during controlled combustion testing.

Real-time wildlife identification (accuracy up to 80–90%) using camera and AI models.
Instant alert delivery to cloud platform with minimal delay (<3 seconds).

All components operated smoothly on a stable power supply in field-like conditions.

These results confirm the feasibility of deploying this system in real-world forest environments for proactive ecosystem monitoring.

IX. Conclusion

The proposed system offers a comprehensive solution for forest ecosystem monitoring by integrating AI, IoT, and edge computing. The use of Raspberry Pi ensures low cost and energy efficiency, while the cloud platform provides scalable data access and alerting. Future enhancements may include:

Solar-powered autonomous units for off-grid operation

Integration with drones for aerial surveillance
AI model training with larger datasets for improved accuracy

Extended support for species identification and ecological pattern analysis
This system has the potential to revolutionize forest protection through smart automation and real-time intelligence.

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