International Journal on Advanced Computer Engineering and Communication Technology

ISSN: 2278-5140

Volume 15 Issue 2 (2026) | Pages: 245-250

Real-Time Surveillance and Early Warning System Using IoT and Machine Learning for Critical Environmental Zones

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Peer Review Information

Type: *Article*
Received: *02 June 2026*
Revised: *08 July 2026*
Accepted: *11 Aug 2026*
Published: *04 Sept 2026*

Abstract

Natural ecosystems often face serious challenges due to the interaction between wild animals and human living spaces. Animals sometimes move outside their natural regions, which creates risks for both humans and wildlife. Farmers lose crops, travellers face danger, and in many cases, conflicts lead to harm on both sides. This project focuses on building an intelligent monitoring system that can observe animal movement in real time and respond immediately when required. The system uses advanced camera technology along with embedded processing to continuously monitor forest boundary areas. A trained machine learning model running on an embedded device identifies whether the detected object is a wild animal, a domestic animal, or any other movement. Based on this identification, the system takes automatic action without human intervention. If a wild animal is detected crossing into a human-inhabited area, the system immediately sends alerts to a control center and nearby people. At the same time, it produces a specific sound designed to scare the animal and guide it back to its natural zone. This reduces direct human-animal conflict and helps protect both sides. The system also supports continuous monitoring and can detect illegal activities, unauthorized entry, and environmental disturbances. Overall, this project provides a smart and automated solution for wildlife protection and human safety.

Keywords: IoT; Machine Learning; Real-Time Monitoring; Wildlife Detection; Embedded Systems; Image Processing; Object Classification; Alert System; Smart Surveillance; Edge Computing

How to Cite This Article

Pon Kiruthika, T., Anton Joshila, J. A., Siva Senthil, D., Sindhuja, S., & Hepsi Bai, P. (2026). Real-time surveillance and early warning system using IoT and machine learning for critical environmental zones. *International Journal on Advanced Computer Engineering and Communication Technology,* 15(2), 245-250.

Introduction

In many regions, natural boundaries between wildlife areas and human settlements are becoming unclear due to urban expansion and environmental changes. This leads to frequent movement of animals into living spaces, causing damage to crops and sometimes dangerous encounters between humans and animals. Traditional monitoring methods depend on manual observation or limited camera surveillance, which is not enough to handle real-time situations effectively. Human monitoring also takes time, and by the time action is taken, damage may already occur. To solve this issue, an automated intelligent system is needed that can continuously observe movement, understand what is happening, and respond immediately. With the help of machine learning and embedded systems, it is possible to create a system that can recognize animals and react accordingly. This project aims to reduce conflicts, protect crops, improve traveler safety, and ensure wildlife is not harmed unnecessarily. It also removes the need for constant human monitoring in forest control centers.

Problem Statement

In many natural and semi-protected outdoor regions, there is a continuous conflict between human activities and wildlife movement. Wild animals often move out of their natural habitats due to changes in environment, food scarcity, or habitat disturbance. When this happens, they enter nearby human settlements or agricultural areas, which leads to serious problems. Farmers suffer crop damage, travelers face unexpected dangers on roads near these regions, and in some cases, both humans and animals get injured or even lose their lives during such encounters. These situations create fear and imbalance between wildlife protection and human safety. At present, most monitoring methods depend on manual observation or basic surveillance cameras. These methods are not capable of reacting immediately to sudden events. They also require continuous human attention, which is not practical for large and remote areas. Because of this limitation, many incidents are noticed only after damage has already occurred. Another major issue is the inability of existing systems to correctly identify what is actually happening in real time. Most systems only detect movement but cannot understand whether the movement is caused by a wild animal, a domestic animal, or any other object. This leads to false alerts and reduces system reliability. Therefore, there is a strong need for an intelligent and automated system that can continuously monitor such regions, understand the type of movement, and respond immediately without depending on human supervision. The system should also be able to reduce false alarms and ensure quick communication during critical situations.

Objectives

- To continuously monitor animal movement in boundary regions using intelligent vision systems
- To identify whether the detected object is a wild animal, domestic animal, or unknown movement using machine learning
- To automatically generate alerts when a wild animal enters human-inhabited zones
- To produce sound-based deterrents that guide animals back without harming them
- To reduce human-animal conflicts and protect agricultural land from damage
- To minimize manual monitoring in control centers by automating detection and alert systems

Literature Review

Earlier monitoring systems for wildlife and environmental safety mainly depended on manual observation and basic camera setups. In many cases, fixed cameras were installed at forest boundaries or sensitive regions, but these systems only recorded video without intelligent analysis. Because of this, human operators had to continuously watch the footage, which was time-consuming and often led to delayed responses. Some systems introduced motion detection using simple sensors. These systems could detect movement but could not understand what was moving. For example, they could not distinguish between animals, humans, or vehicles. This limitation often caused false alarms and reduced trust in the system. Later, researchers started using image processing techniques combined with basic machine learning models. These approaches improved detection accuracy, but most of them required powerful computing systems and were not suitable for real-time embedded environments. Recent advancements show that lightweight machine learning models can be deployed on embedded devices like Raspberry Pi. These models can process video frames in real time and classify objects more efficiently. However, many existing systems still lack immediate response mechanisms such as alert generation and active deterrent actions. This project improves upon existing methods by combining real-time vision processing, embedded AI, automatic alert systems, and active sound-based response, making the system more practical and responsive.

Solution

The solution proposed in this project is to develop an intelligent and automated monitoring system that can observe real-time movement in sensitive outdoor regions and respond immediately without human involvement. Instead of depending on manual surveillance or traditional camera systems that only record and display footage, this approach focuses on making the system capable of understanding what is happening in the environment. The system continuously captures live video from the surrounding area and processes it using an embedded computing device. The captured information is analyzed using a trained machine learning model that helps in identifying and classifying different types of movement. This allows the system to understand whether the detected activity is normal or requires attention. Once a potentially risky situation is identified, the system automatically generates an alert and sends it to a remote monitoring center through wireless communication. At the same time, a local response mechanism is activated to handle the situation immediately in a safe and controlled manner. By combining real-time monitoring, intelligent classification, and automatic response, the system provides a complete solution for reducing conflicts, improving safety, and ensuring faster reaction during critical situations. This removes the need for continuous human monitoring and makes the overall process more efficient, reliable, and practical for real-world deployment.

Proposed System

The system is designed to continuously monitor movement in boundary regions where human and wildlife interaction is highly possible. It uses a wide-angle camera system that captures a complete view of the surroundings without missing movement from any direction. The captured video is processed using an embedded computing unit that runs a trained machine learning model. This model analyzes each frame and identifies whether the detected object is a wild animal, domestic animal, human, or unknown movement. Instead of only detecting, the system also reacts intelligently. When a wild animal is detected moving toward a restricted or human area, the system immediately triggers two actions. First, it sends a real-time alert to the control center. Second, it activates a sound-based deterrent system designed to gently scare the animal and redirect it back to its natural environment. This dual-action approach ensures both safety and non-harmful guidance. The system is designed to operate continuously without manual intervention, making it suitable for remote and high-risk areas.

Working Model

The working of the system can be understood in a simple sequence:

- The system starts and activates all hardware components including camera, processor, and communication modules.
- The camera continuously captures real-time video of the monitored area.
- Video is broken into frames and sent to the embedded processing unit.
- Each frame is analyzed using a trained machine learning model.
- The model identifies whether the object is a wild animal or other movement.
- If normal activity is detected, monitoring continues without interruption.
- If a wild animal is detected near restricted zones, the system reacts immediately.
- Alerts are sent to the control room through wireless communication.
- A sound-based deterrent system is activated to guide the animal away safely.
- The system continues this cycle continuously for real-time monitoring.

Methodology

Block Diagram

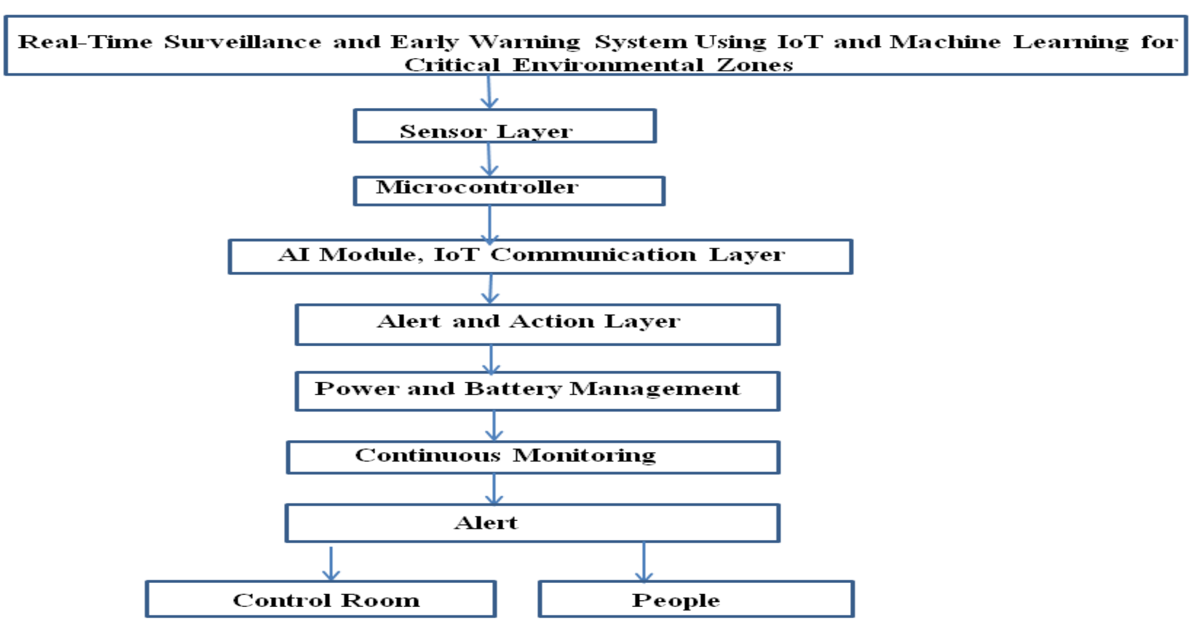

Fig. 1. *Work Flow*

The system works by continuously capturing live video using a camera module placed at strategic locations. This video feed is processed frame by frame using an embedded processing unit. Each frame is analyzed using a machine learning model that has been trained using animal and environment datasets. The model extracts patterns from the image and identifies the type of object present in the frame. Once classification is completed, the system evaluates whether the detected movement is normal or requires action. If no unusual activity is found, the system continues monitoring without interruption. If a wild animal is detected near human-inhabited areas, the system immediately generates an alert. At the same time, a sound module is activated to produce specific deterrent sounds that help redirect the animal safely. All detection results and alerts are simultaneously sent to a central monitoring station for record-keeping and quick response. The system works in a continuous loop to ensure real-time protection.

Algorithm

The proposed system begins by powering on all hardware components, including the camera, embedded processing unit, and communication modules, and checks whether they are functioning correctly. After the system is ready, the trained machine learning model is loaded to analyze the captured images. The camera continuously records the surrounding area, and the live video is divided into individual frames for processing. Each frame is cleaned and prepared to improve image quality before analysis. The embedded processor then extracts important features such as the shape, size, and movement of objects, and the machine learning model identifies whether an object is present. Based on the detected features, the system classifies the object as a wild animal, domestic animal, human, or unknown object. It then determines whether the detected object poses any risk by considering its location and movement. If no danger is identified, the system stores the information and continues monitoring. However, if a wild animal or suspicious movement is detected near human or restricted areas, the system immediately generates an alert and sends the detection details, including the location, object type, and time, to the monitoring authorities through a wireless communication module. At the same time, it activates an appropriate sound to safely scare the animal away and guide it back toward its natural habitat without causing harm. After completing these actions, the system automatically returns to monitoring mode and repeats the entire process continuously, providing uninterrupted real-time surveillance and rapid response whenever a potential threat is detected.

Implementation

The implementation of this project is done by combining embedded hardware, intelligent software, and real-time communication techniques into a single working system. The main idea is to continuously observe movement in sensitive areas and respond automatically when required. The system uses a wide-angle camera setup that continuously captures live video from the surrounding environment. This camera is placed in strategic locations so that it can cover a large area without missing movement. The captured video is then processed by an embedded computing device such as a Raspberry Pi, which acts as the central processing unit of the system. The video stream is broken into individual frames so that each frame can be analyzed separately. These frames are then passed to a trained machine learning model. This model has been developed using different images and patterns of animals and other movements so that it can understand and classify what it sees. The model processes each frame and identifies whether the detected object is a wild animal, a domestic animal, a human, or an unknown object. This classification step is very important because it decides how the system should respond. If the system detects normal activity such as domestic animals or non-threatening movement, it simply continues monitoring without any action. However, if a wild animal is detected moving toward a restricted or human-inhabited area, the system immediately triggers a response. This response includes sending real-time alerts to a control center through wireless communication modules. At the same time, a local sound-based system is activated. This sound is carefully designed to scare the animal in a non-harmful way and guide it back to its natural environment. The control center receives all details such as detection time, location, and type of object. This helps authorities take quick decisions if necessary. The entire system works continuously without human involvement, ensuring 24x7 monitoring and automatic response. To improve reliability, the system is designed to run in a loop where detection, analysis, and response happen repeatedly in real time. This makes the system suitable for remote and high-risk regions where manual monitoring is not possible.

Results And Discussion

The system shows strong performance in detecting and classifying movement in real time. It is able to identify different types of objects with good accuracy using the trained machine learning model. One of the major improvements observed is the system's ability to reduce false alerts. Since it uses intelligent classification instead of simple motion detection, it avoids unnecessary warnings and focuses only on meaningful events. The real-time alert mechanism ensures that any important activity is immediately communicated to the control center. This allows faster decision-making and quick response to potential risks. The sound-based deterrent system also shows effective results in guiding animals away without causing harm. This helps in maintaining a balance between safety and wildlife protection. Overall, the system performs efficiently in continuous monitoring, real-time detection, and automatic response, making it suitable for real-world deployment.

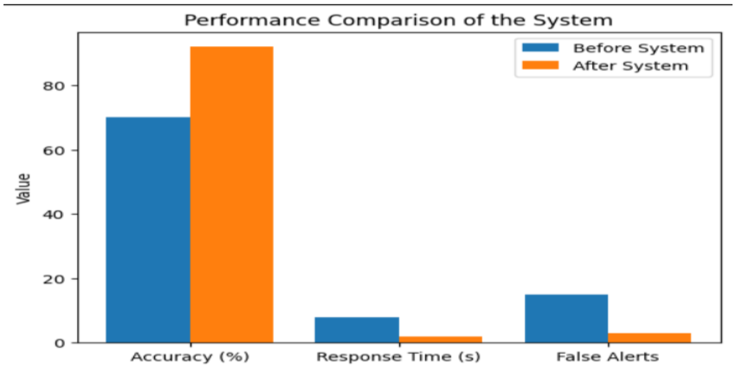

Fig. 2. *Graph analysis*

Advantages

- Real-time automatic monitoring: The system continuously observes movement without any manual control. This helps in tracking animal activity 24x7 and ensures no important event is missed even in remote areas.
- Reduces human-animal conflict: By detecting animal movement early and responding immediately, the system helps prevent direct encounters between humans and wild animals. This protects both farmers and animals from harm.
- Smart classification using machine learning: The system can intelligently identify whether the detected object is a wild animal or not. This reduces wrong alerts and makes the system more accurate and reliable in real-world situations.
- Automatic alert and response system: Whenever a risk is detected, alerts are sent instantly to control centers and nearby users. At the same time, sound-based deterrents are activated to guide animals safely back.
- No need for constant manual monitoring: Control room operators do not need to continuously watch screens. The system automatically handles detection and reporting, reducing workload and improving efficiency.

Future Scope

In future improvements, the system can be enhanced by integrating temperature-based monitoring to detect abnormal environmental conditions such as heat rise or fire risks. It can also be connected with satellite or drone systems for wider area coverage. Advanced deep learning models can be used to improve detection accuracy further, especially for rare or new animal species. Solar-powered modules can also be added to make the system energy independent for remote deployment. Additionally, mobile applications can be developed to send instant alerts directly to farmers and travellers, making the system more accessible and responsive.

Conclusion

This work presents a practical and intelligent solution for monitoring wildlife movement and preventing conflicts between humans and animals. The system combines real-time vision processing, embedded computing, and machine learning to achieve accurate detection and fast response. Unlike traditional monitoring methods, this approach does not depend on human observation. It automatically detects movement, analyzes it, and takes appropriate action when needed. This reduces workload and improves efficiency in monitoring operations. The system also focuses on safety by using non-harmful sound-based deterrents instead of physical intervention. This ensures that animals are guided back to their natural environment without injury. In addition, the real-time alert system improves communication between remote monitoring locations and control centers, enabling faster response during critical situations. Overall, the system provides an effective, scalable, and intelligent solution for real-time monitoring and protection of sensitive regions, while ensuring safety for both humans and wildlife.

References

1. A. Sharma, “IoT-based intelligent monitoring systems,” IEEE Systems Journal, 2023.
2. S. Patel, “AI applications in real-time surveillance systems,” IEEE AI Review, 2024.
3. M. Gupta, “Wireless sensor networks for remote monitoring,” Elsevier Networks Journal, 2022.
4. N. Kumar, “Machine learning in anomaly detection systems,” Springer AI Applications, 2023.
5. R. Singh, “Smart environmental sensing using IoT,” IEEE IoT Journal, 2023.
6. P. Verma, “Low-power communication systems for remote areas,” IEEE Communications Magazine, 2022.
7. S. Das, “Deep learning for sensor-based classification,” ACM Computing Surveys, 2024.
8. K. Rao, “LoRa-based long-range communication systems,” IEEE Access, 2023.
9. A. Mehta, “Smart monitoring using embedded systems,” Journal of Embedded Technology, 2022.
10. D. Jain, “Edge AI for real-time decision systems,” Nature Machine Intelligence, 2024.

11. T. Williams, “Intelligent IoT frameworks for automation,” IEEE Industrial Electronics, 2023.
12. S. Reddy, “Sensor fusion techniques in smart systems,” Springer Journal of Sensors, 2022.
13. L. Zhang, “Environmental monitoring using distributed networks,” Elsevier IoT Systems, 2023.
14. M. Ahmed, “AI-based real-time detection systems,” IEEE Smart Systems, 2024.
15. C. Brown, “Autonomous monitoring frameworks using IoT,” IEEE Future Technologies, 2023.