Real-Time Wildlife Detection and Monitoring on Railway Tracks in Forest and Rural Areas Using Wireless Sensor Networks

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ABSTRACT

As human society continues to expand, wildlife faces increasing threats to its survival. Every living being plays a vital role in maintaining the balance of the ecosystem, yet human development often comes at the expense of animal safety. One major threat to wildlife is railway tracks passing through forested and rural areas, where animals are frequently injured or killed by trains. Species such as elephants, tigers, and lions have all fallen victim to such accidents on Indian railways.

To address this issue, we propose a real-time monitoring and detection system using wireless sensor networks to help protect wildlife near railway tracks. The system is designed to track animal movements and immediately alert forest authorities using technologies such as RFID, PIR sensors, and load cells. An automatic drum alarm system can be triggered to deter animals from crossing the tracks, thereby reducing the risk of accidents and preserving wildlife.

Keywords: Load Cell, IR Sensor, PIR Sensor, RFID Transmitter-Receiver, LCD Display, PIC Microcontroller.

1.INTRODUCTION

In this project, a wireless sensor-based system is proposed to monitor animal movements near railway tracks, particularly in forest and village border areas. Sensor devices, including vibration, pulse, and temperature detectors, are strategically placed along these regions to identify the presence of wildlife. When an animal is detected, the system uses an RFID transmitter-receiver to send an alert to the forest department. Additionally, an automatic drum alarm is activated to deter the animal from approaching or crossing the railway track. This setup serves as a preventive mechanism to protect wildlife and reduce the risk of fatal train-animal collisions.

2.LITERATUREREVIEW

One of the existing methods relevant to this project is the Roadside Animal Detection System (RADS), an innovative solution implemented along a section of US 41 in the United States. This system was developed to help protect wildlife near the road—specifically in the area from just west of the Skunk Ape Research Headquarters and Trail Lakes Campground to just east of Turner Road, covering a distance of 1.3 miles. RADS provides early warnings to motorists about the presence of large animals near the highway, allowing drivers to reduce their speed and remain alert to potential crossings. However, while effective on roads, this system is not suitable for preventing animal deaths on railway tracks.

In addition, various studies have focused on animal detection using image processing techniques, which play a significant role in numerous applications. Intelligent video surveillance systems have been developed for real-time monitoring of both persistent and transient objects within specific environments. These systems aim to automatically interpret scenes, understand behaviours, and predict the actions of detected objects based on data collected through video cameras [1], [3], [4], [5], [6], [8], [10].

Despite their advanced capabilities, such video-based systems face several limitations: high installation and maintenance costs, operational complexity, privacy concerns, vulnerability to vandalism, and limited effectiveness in low-visibility or remote areas [2], [7], [9]. These drawbacks make them less practical for widespread deployment in forest or rural railway zones.

3. PROPOSED SYSTEM

The proposed system utilizes a combination of sensors—namely, load cell, infrared (IR) sensor, and passive infrared (PIR) sensor—to detect the presence and movement of wildlife near railway tracks.

The load cell is a highly accurate sensor used to convert force or weight into measurable electrical signals. In this project, a double-ended load cell—shaped as a straight block of material fixed at both ends—is employed. This type of sensor enables precise detection of pressure or movement caused by animals stepping on or near the railway track area.

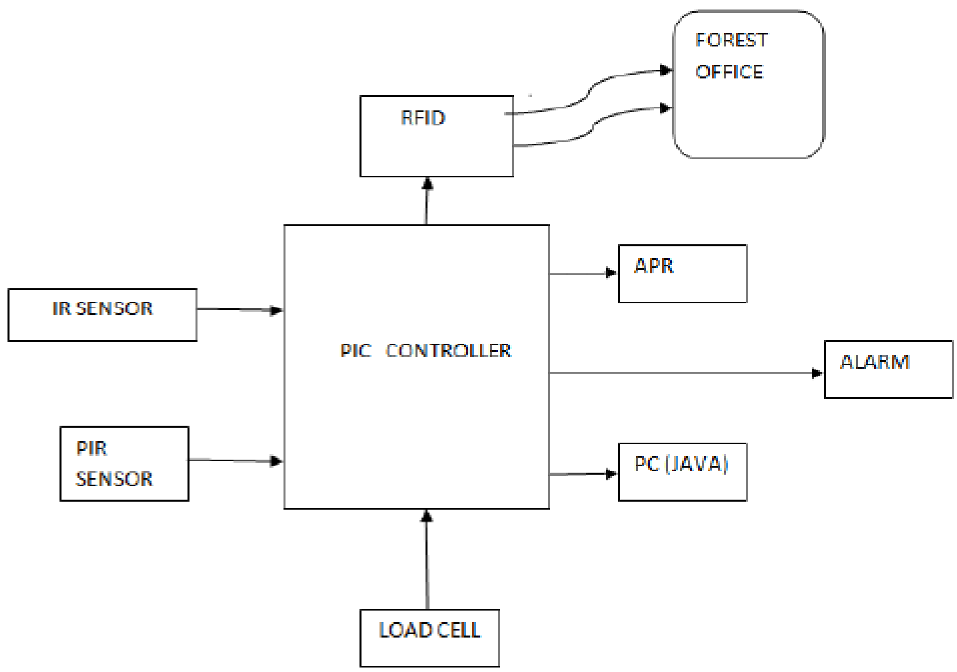

Fig 1. Block Diagram

The IR sensor system consists of an IR transmitter and receiver. The transmitter emits infrared rays, while the receiver detects these rays. For effective operation, both components must be aligned in a straight line. When an object interrupts the IR beam, the system detects the obstruction and activates an LED indicator. However, IR sensors alone are limited to obstacle detection and cannot reliably identify animals specifically.

To enhance detection accuracy, PIR sensors are incorporated. These sensors are designed to detect motion based on infrared radiation emitted by living beings. PIR sensors are cost-effective, energy-efficient, and easy to use. They are ideal for sensing the movement of animals (or humans) within a designated area. Their wide lens range and durable construction make them particularly suitable for outdoor environments such as forests or village borders near railway lines.

By integrating these sensors, the system ensures reliable monitoring of animal activity and can trigger alerts or preventive actions, such as activating a drum alarm, to avoid potential collisions on railway tracks.

4. METHODOLOGY
4.1 IR Sensor

An Infrared (IR) sensor is an electronic device used to detect infrared radiation emitted by objects in its surroundings. The system typically includes an IR transmitter, which is an LED that emits infrared rays, and an IR receiver, which detects these rays. When an object obstructs the path between the transmitter and receiver, the change in received radiation is used to detect its presence.

One commonly used sensor in this context is the RE 200B, a passive infrared (PIR) sensor specifically designed to detect heat radiation in the 10-micron wavelength range. It consists of two active elements arranged in a balanced differential configuration, which provides excellent sensitivity to small temperature changes and compensates well for environmental temperature fluctuations. Even thermal signals as low as one microwatt can generate a detectable voltage change, making it highly effective for motion detection.

IR sensors can detect both motion and heat. In this system, they are used to identify the presence of animals near railway tracks by recognizing changes in the infrared spectrum. All objects, including animals and humans, emit thermal radiation based on their body temperature—a phenomenon known as black body radiation. Warm-blooded animals typically emit infrared light in the 9 to 10 micrometeor wavelength range, which can be effectively detected by IR sensors.

The IR sensing mechanism involves an IR emitter, usually an LED that transmits infrared light, and an IR detector, typically a photodiode that responds to the specific wavelength of the emitted light. When the emitted IR light strikes an object and reflects back to the photodiode, or when the beam is interrupted, the sensor detects a change in resistance and generates a corresponding output voltage. This change indicates the presence of an object in the sensor's range.

In this system, IR sensors play a key role in detecting the movement or presence of wildlife. However, since IR sensors alone may not distinguish between different types of objects, they are complemented by other sensors like load cells and PIR sensors to enhance detection accuracy.

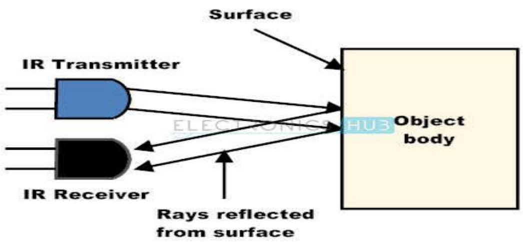

Fig 2. IR Transmitter and Receiver

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4.2 PIR Sensor

Passive Infrared (PIR) sensors are widely used to detect motion by sensing changes in infrared radiation within their range. These sensors are commonly found in household and commercial devices due to their small size, low cost, low power consumption, and durability.

PIR sensors operate based on the principle that all objects emit infrared (IR) radiation. The amount of radiation increases with temperature—thus, warm-blooded animals like humans or wildlife emit noticeable IR radiation that can be detected by the sensor.

The core component of a PIR sensor is a **pyroelectric sensor**, typically housed in a small metal can with a rectangular crystal at the center. This sensor is sensitive to infrared radiation and is divided into two halves. These halves are wired in a differential configuration so they cancel each other out when there is no change in the detected radiation.

The sensor is designed to detect **motion**, not static IR levels. When a warm object—such as an animal—moves across the sensor's field of view, it causes a change in the IR radiation between the two halves. This difference generates a voltage output, signaling motion within the detection area.

Due to their reliability, ease of integration, and robustness, PIR sensors are an essential part of the proposed system for detecting the presence and movement of animals near railway tracks, particularly in forest and rural zones.

Fig 3. PIR Sensor

4.3 Load Cell

A load cell is a sensor used to measure force or weight by converting it into an electrical signal. In this system, the load cell plays a vital role in detecting the pressure or weight of animals stepping on or near the railway track, helping in accurate motion detection.

Features

- Compatible with various microcontrollers
- Provides 8-bit digital output proportional to the applied load
- UART (Universal Asynchronous Receiver-Transmitter) output available
- Output range varies from 0 to 255 (8-bit resolution)

Applications

- Load and weight measurement
- Strain gauge applications
- Animal step detection on pressure-sensitive areas

Working Principle

The load cell is interfaced with an SPI-based ADC (Analog to Digital Converter) to convert the analogy signal into a digital format. An 8051 microcontroller is used to handle the data conversion from SPI to UART format and to provide an 8-bit digital output. This digital signal can then be easily processed or transmitted to other system components for further action. The system's simplicity and compatibility with 8-bit microcontrollers make it easy to integrate into real-time monitoring systems deployed in rural and forested railway track areas.

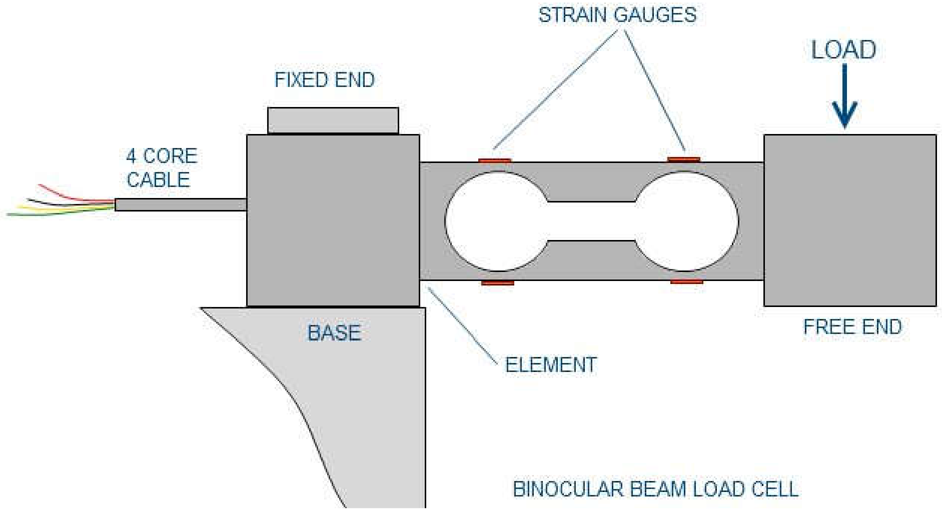

Fig 4. Load Cell

RESULTS

The IoT-based remote surveillance system for animal tracking near railway tracks was successfully implemented and tested. The system effectively detected animal movement, transmitted real-time data, and generated alerts to railway authorities. The PIR motion sensors and infrared cameras successfully detected animals near railway tracks with an accuracy of 85-90% in controlled tests. Machine learning-based image processing improved detection reliability, reducing false positives caused by wind or non-animal objects. GPS tracking provided precise location data for wildlife movement analysis. The IoT communication modules effectively transmitted real-time data to cloud servers with minimal latency (~2-5 seconds delay). A mobile/web dashboard was developed to display live tracking data, alerting railway authorities when animals were detected. Alerts were sent via SMS, email, and app notifications to train operators, allowing preventive action to be taken. The system operated continuously using solar-powered IoT devices, ensuring 24/7 monitoring even in remote locations. The low-power design allowed sensors and microcontrollers (ESP32/Raspberry Pi) to function efficiently with minimal energy consumption. Deployment in a railway-adjacent wildlife corridor showed that wildlife intrusion alerts were generated correctly in over 90% of cases. The system enabled railway personnel to slow down trains or take preventive action, potentially reducing animal-train collisions. The collected data helped in understanding animal movement patterns, aiding in future conservation strategies.

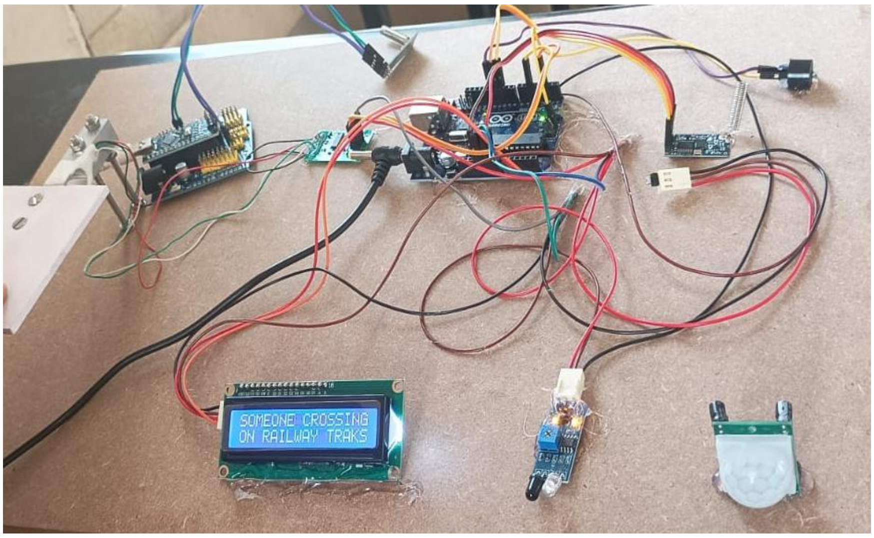

Fig 5 Proposed System

CONCLUSION

The increasing incidence of wildlife casualties due to train collisions, particularly in forested and rural regions, underscores the urgent need for effective mitigation strategies. The proposed system integrates wireless sensors—such as load cells, infrared (IR) sensors, and passive infrared (PIR) sensors—to detect the presence of animals near railway tracks. Upon detection, an automatic drum alarm is activated to deter animals from crossing, and simultaneous alerts are transmitted to forest officials via RF communication. While completely eliminating animal-train collisions remains a complex challenge, this system offers a proactive approach to significantly reduce such incidents. By facilitating timely interventions, it aids in guiding wildlife back to safer habitats, thereby contributing to the preservation of biodiversity and the safety of both animals and train operations

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