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Original Article

Real-Time Wild Animal Detection And Collision Avoidance System

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Abstract: *Theintegration ofi thermal imaging and machine learning provides an efifiective approach to enhancing railway safiety by detecting animals on tracks, especially under low-light or nighttime conditions. Thermal cameras detect the infirared radiation emitted by animals, allowing accurate identifiication and precise positioning even in darkness or fiog, while reducing fialse negatives compared to traditional PIR or IR sensors. Machine learning algorithms improve detection fiurther by analysing sensor and camera data to distinguish between animals and humans, minimizing fialse alarms and highlighting high-risk situations. Combined, these technologies ofifier automated, reliable railway monitoring systems that deliver continuous surveillance, timely alerts, and aid in adjusting train speeds or initiating emergency braking to prevent collisions.*

Keywords*: Thermal Imaging, Embedded Systems, PIR Sensors, IR Sensors, Collision Prevention, Real-time Monitoring, Smart Railway Infirastructure.*

I. INTRODUCTION

Railway safety isaglobal priority, especially in areas where tracks intersect with wildlife habitats. Train-animal collisions not only endanger wildlife but also compromise human safety and lead to significant economic losses. Traditional monitoring methods—such as human observation or basic infrared (IR) and passive infrared (PIR) sensors—often underperform in low-light, nighttime, or adverse weather conditions, causing delayed detection and higher accident risks. Recent technological advancements offer promising automated, real-time solutions for animal detection on railways. Thermal imaging captures animals' body heat even in darkness or fog, while machine learning algorithms classify detected objects to minimize false alarms and prioritize high-risk alerts. Wireless sensor networks (WSNs) enable continuous monitoring along railway lines, embedded systems facilitate automated alerts and responses, and Internet of Things (IoT) cloud platforms support remote, real-time monitoring and notifications. Furthermore, wildlife corridor protection systems ensure that safety measures align with environmental conservation goals, thereby reducing collisions and preserving biodiversity. The integration of these technologies can establish a reliable, efficient, and eco-friendly system to prevent railway accidents involving animals.

II. LITERATURE REVIEW

A. Internet of Things (IoT) in Railway Systems (Marco Schwartz, 2016)

The Internet of Things (IoT) plays a significant role in modern railway safety and monitoring systems by enabling communication between sensors, devices, and control units. According to Marco Schwartz (2016), IoT using modules like ESP8266 allows real-time data collection and wireless transmission to monitoring systems. In railway applications, IoT helps in tracking environmental conditions, detecting obstacles, and sending alerts instantly. The integration of IoT in railway systems reduces human intervention and improves efficiency. This concept is highly relevant to the proposed system, as it enables communication between thermal sensors, Edge-AI processors, and alert systems, ensuring quick response to animal detection on railway tracks.

B. Train–Animal Collision Prevention Systems (Singh et al., 2020)

Several studies have focused on reducing train–animal collisions using various technologies. Singh et al. (2020) proposed systems that use sensors and alert mechanisms to warn train operators about animal presence on tracks. While these systems provide some level of safety, they often lack real-time processing and accuracy. Many traditional systems depend on manual observation or simple sensors, which may not work effectively in all conditions. This highlights the need for more advanced solutions that combine sensing, AI, and automation. The proposed system addresses these limitations by integrating thermal imaging and Edge-AI for improved detection and response

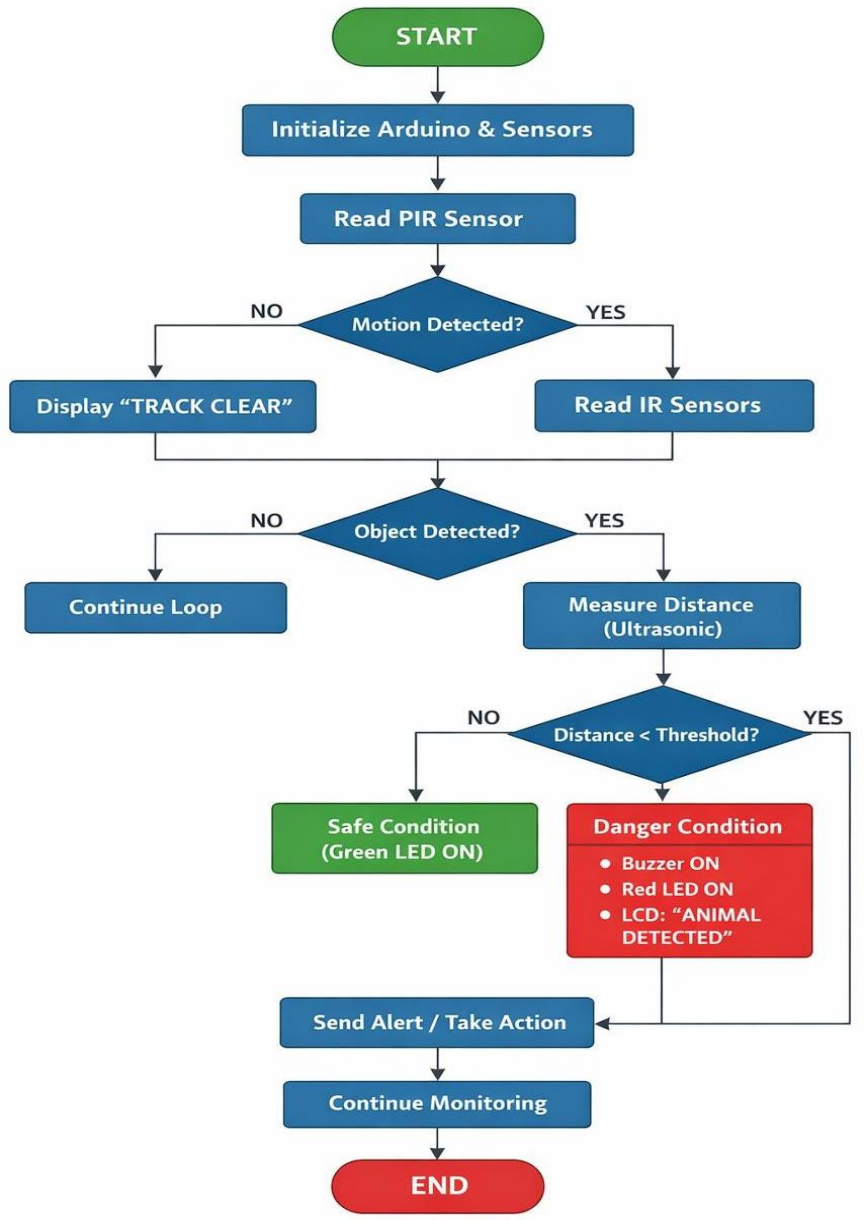
C. Artificial Intelligence in Object Detection (Joseph Redmon et al., 2016 – OLO)

Artificial Intelligence (AI), particularly deep learning techniques, has significantly improved object detection capabilities. Joseph Redmon et al. (2016) introduced the YOLO (You Only Look Once) algorithm, which is widely used for real-time object detection. YOLO processes images quickly and identifies objects with high accuracy, making it suitable for time-sensitive applications. In wildlife detection systems, AI models can be trained to recognize different animal species from thermal images. This allows the system to differentiate between animals and other objects, reducing false alarms. The use of AI in the proposed system enhances detection accuracy and ensures reliable performance in real-time scenarios.

D. Edge-AI Processing in Real-Time Systems (Wei Yu et al., 2018)

Edge-AI refers to the implementation of artificial intelligence algorithms on local devices rather than relying on cloud computing. Wei Yu et al. (2018) highlight that edge computing reduces latency and improves response time by processing data near the source. This is especially important in safety-critical applications such as railway systems, where quick decision-making is essential. By integrating Edge-AI, the system can analyse thermal
images instantly and generate alerts without delay. This reduces dependency on internet connectivity and ensures continuous operation even in remote forest areas. Edge-AI is therefore a key component in achieving real-time performance in the proposed system.

III. METHODOLOGY



IV. WORKING PROCESS

Sensor Detection:

- PIR (Passive Infrared) Sensor: Detects motion by sensing infrared radiation emitted by living beings, signalling when an animal moves near the track.
- IR (Infrared) Sensors: Monitor infrared beam interruptions to confirm the presence of an animal crossing the track area.
- Ultrasonic Sensor: Measures the distance between the animal and the train or track, helping assess if immediate action is necessary.

Data Processing:

- Sensor signals are transmitted to a microcontroller (Arduino).
- The microcontroller processes this data to identify animal presence and evaluate collision risk.

Decision Making:

- Real-time data is compared against predefined safety thresholds.
- If an animal is detected within the danger zone, alerts are triggered.

Alert Generation:

- Buzzer: Emits audible warnings for train operators or nearby personnel.
- LEDs: Red LED signals danger; Green LED indicates a safe track.
- LCD Display: Provides visual messages such as "Animal Detected" or "Track Clear."

V. RESULTS AND DISCUSSION

The Real-Time Wild Animal Detection and Collision Avoidance System was implemented and tested in a controlled environment to evaluate its effectiveness across key performance metrics:

Detection Accuracy

- The PIR sensor reliably detected motion from animals near the track.
- IR sensors confirmed animal presence by detecting objects crossing the track, reducing false alarms from non-animal movements like leaves or debris.
- The ultrasonic sensor accurately measured the distance between animals and the track.
- Combining these sensors enhanced overall detection accuracy and reliability.

Alert Generation

- The buzzer activated immediately when an animal entered the danger zone, providing clear audible warnings.
- Red LED lit during dangerous conditions; Green LED remained on when the track was clear.
- The LCD displayed real-time messages such as "Animal Detected" or "Track Clear," improving operator situational awareness.

Response Time

- The system responded within 1–2 seconds after detection, ensuring timely alerts.
- Continuous loop monitoring maintained uninterrupted real-time detection.

Reliability and Safety

- Sensor fusion of PIR, IR, and ultrasonic sensors ensured high reliability, including in low-light or adverse weather conditions.
- Automated processing by Arduino/ESP32 minimized dependence on human monitoring.
- The system demonstrated effective prevention of potential train–animal collisions.

Discussion

- Sensor fusion significantly reduced false positives and false negatives.
- The alert system effectively communicated warnings to both operators and nearby personnel.
- The solution is low-cost, straightforward to implement, and scalable across multiple tracks.
- Optional IoT integration allows remote alert transmission, supporting smart railway management.

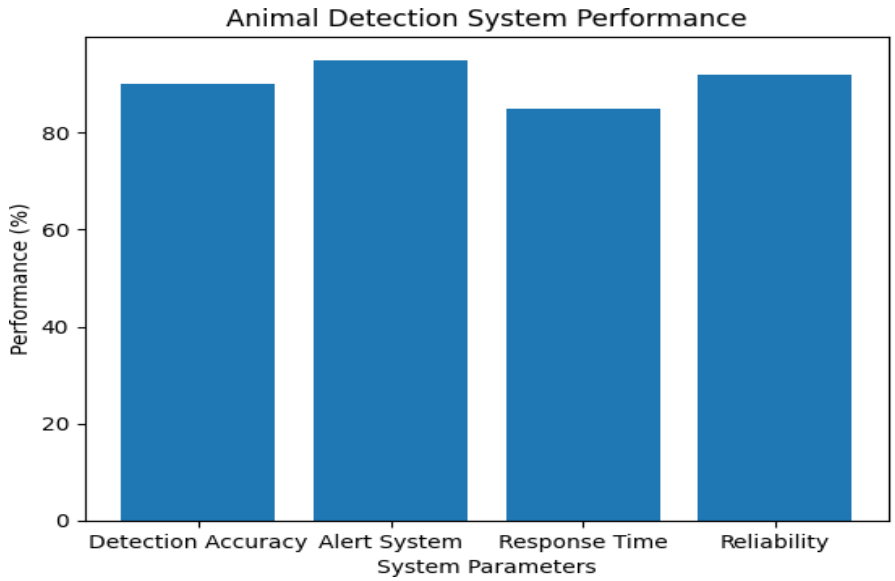


Figure 2 : ANIMAL DETECTION SYSTEM PERFORMANCE

VI. CONCLUSION

An efficient technique to increase railway safety in wildlife-prone locations is the Real Time Wild Animal Detection and Collision Avoidance System. Using PIR and IR sensors, the system effectively detects animal movement and usesan ultrasonic sensor tocalculate distance in order toassess thedegree of risk. Thedevice helps to avoid possible train-animal collisions by producing timely alerts via a buzzer, LEDs, and LCD display based on the discovered data. While the Arduino/ESP32 microcontroller guarantees quick processing and real-time reaction, the integration of numerous sensors improves detection accuracy and dependability. Railway tracks may be continuously monitored thanks to the system's continuous loop operation. Additionally, it is inexpensive, simple to set up, and appropriate for remote locations where manual monitoring systems.