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Object Detection and Train Disaster Avoidance on Railway Track Using AI-Based Wireless Sensor Network

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Abstract

The system integrates Artificial Intelligence (AI) with embedded hardware to detect obstacles or objects present on the railway track and respond in real time to prevent accidents. An AI-based object detection model, developed using Python and implemented in PyCharm, processes live video or image data from a connected camera or PC. When the model identifies an object on the track, it sends a detection signal to the ESP32 microcontroller through serial communication or Wi-Fi. Upon receiving this signal, the ESP32 immediately turns off the relay, stopping the DC motor that represents the train movement. Simultaneously, a 16×2 LCD display connected to the ESP32 shows the system status such as "Object Detected – Train Stopped." Current railway safety mechanisms often rely on manual inspection or fixed track sensors, which are insufficient for preventing accidents caused by unpredictable foreign objects, debris, or unauthorized presence on the track in real time. Additionally, the system can be scaled for real-world deployment by integrating high-resolution cameras and cloud-based data analysis for continuous monitoring. Future enhancements may include automatic alert notifications to railway authorities through GSM or IoT platforms. Overall, this approach contributes to safer, smarter, and more reliable railway transportation systems.

Keywords: *Train Disaster Avoidance, Railway Track Monitoring, Artificial Intelligence (AI).*

1. Introduction

Railway transportation is one of the most widely used and cost-effective modes of transport, playing a vital role in economic growth and public mobility. However, railway systems are highly vulnerable to accidents caused by obstacles on tracks, track failures, human errors, and environmental conditions such as fog, rain, and poor visibility [1]. Train disasters not only result in significant loss of life and property but also disrupt transportation networks and public confidence. Hence, ensuring railway safety has become a critical challenge for modern transportation systems [2]. Recent advancements in Artificial Intelligence (AI) and Wireless Sensor Networks (WSN) have opened new possibilities for intelligent and automated railway safety solutions. AI-based object detection techniques enable real-time identification of obstacles such as humans, animals, vehicles, and fallen objects on railway tracks using image processing and machine learning algorithms [3]. When combined with WSN, which consists of distributed sensor nodes capable of sensing, processing, and wireless communication, continuous monitoring of railway tracks can be achieved over long distances with high reliability. The proposed system contributes to safer railway operations, enhanced situational awareness, and improved reliability of railway infrastructure, making it highly suitable for modern smart transportation systems [4].

2. Literature Review

2.1. Ramesh, K., Et al. (2021) – "Automation of Railway Platform Gate System Using IR Sensors and Microcontroller".

This paper presents an automated railway gate control system using IR sensors and a microcontroller to detect train movement and control barriers. The

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system reduces human intervention and improves operational safety. This study supports the use of low-cost sensors and embedded controllers for reliable train detection and automated safety mechanisms.

2.2. Ahmed, M. R., Et al. (2020) – "Wireless Sensor Network Based Railway Track Monitoring System".

The authors proposed a wireless sensor network for continuous monitoring of railway tracks. Distributed sensor nodes detect vibrations, obstacles, and track abnormalities, transmitting data wirelessly to a central monitoring unit. This work demonstrates that WSN improves real-time monitoring and early fault detection, supporting its application in large-scale railway safety systems.

2.3. Sharma, P., and Kumar, R. (2021) – "Intelligent Railway Accident Prevention System Using IoT and Machine Learning".

This study integrates IoT sensors with machine learning algorithms to identify obstacles on railway tracks. Sensor data is analyzed to predict potential hazards and generate alerts. The system enhances decision-making accuracy and supports proactive accident prevention, highlighting the importance of AI-based data processing in railway safety.

2.4. Li, Y., Et al. (2022) – "Real-Time Object Detection for Railway Safety Using Deep Learning".

This paper presents a deep learning-based object detection system using convolutional neural networks for identifying humans, animals, and vehicles on railway tracks. The model achieves high detection accuracy in real-time environments. The study supports the use of AI and computer vision for reliable obstacle detection in train disaster avoidance systems.

2.5. Thakur, S., and Chandra, M. (2021) – "Deep Learning Approach for Railway Track Intrusion Detection".

The authors developed a deep learning framework to detect intrusions on railway tracks and classify objects based on threat levels. The system reduces false alarms and improves response time. This work emphasizes the need for intelligent intrusion detection and automated alert mechanisms for effective train disaster avoidance.

3. Existing System

In the existing railway safety system, accident prevention mainly relies on manual monitoring, traditional signaling systems, and basic sensor-based mechanisms. Railway tracks and crossings are often supervised by human operators who depend on visual observation and fixed timetable-based signaling to manage train movements [5]. These systems are effective only under normal operating conditions and are highly prone to human error, delayed response, and communication failures, especially in remote or high-risk areas. Conventional systems use track circuits, relay-based signaling, and simple IR or proximity sensors to detect train presence [6]. While these methods can identify whether a train is occupying a particular section of track, they cannot detect unexpected obstacles such as humans, animals, vehicles, or fallen objects on the railway track [7]. Moreover, these systems lack intelligence and are unable to classify the type of obstacle or assess the level of risk involved. Overall, the existing system lacks intelligent object detection, real-time wireless communication, automated disaster avoidance mechanisms, and scalability, which necessitates the development of an AI-based wireless sensor network for effective object detection and train disaster avoidance [8].

4. Proposed System

The proposed system introduces an AI-based Wireless Sensor Network (WSN) for effective object detection and train disaster avoidance on railway tracks. This system is designed to overcome the limitations of conventional railway safety mechanisms by integrating intelligent sensing, real-time data processing, and automated response actions. In the proposed model, multiple sensor nodes are deployed along the railway track. These nodes consist of cameras, IR/ultrasonic sensors, and vibration sensors to continuously monitor the track environment. The collected data is transmitted wirelessly through a WSN to a central processing unit or edge device. This enables continuous and large-scale monitoring without the need for complex wired infrastructure. Artificial Intelligence techniques, particularly machine learning and deep learning algorithms, are used to analyze sensor and image data

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for real-time object detection and classification. The system can accurately identify obstacles such as humans, animals, vehicles, and track obstructions, even under challenging environmental conditions. By classifying the detected object, the system determines the severity of the threat (Figure 1).

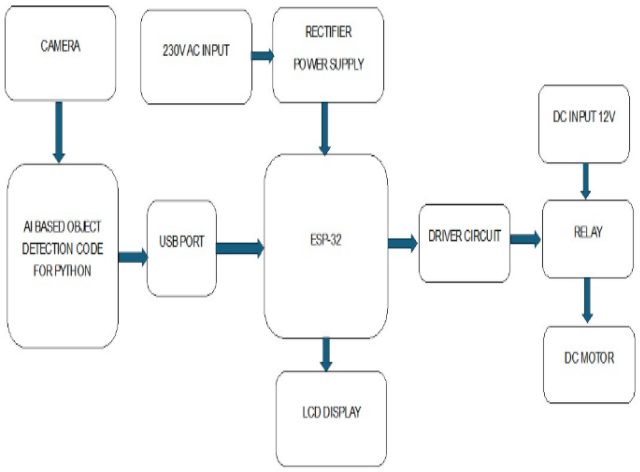

Figure 1 Proposed Diagram

5. Result

The AI-Based Object Detection in Railway System was successfully implemented and tested using a Python-trained AI model for object identification and an ESP32 microcontroller for real-time control. The system effectively detected objects such as humans, animals, and vehicles in front of the simulated railway track using a webcam or image feed processed in PyCharm. When an object was detected, the AI model transmitted a detection signal to the ESP32 via Wi-Fi or serial communication. The ESP32 immediately deactivated the relay, stopping the DC motor that represented the moving train. Simultaneously, a 16x2 LCD displayed the message "Object Detected – Train Stopped". Once the track was clear, the AI model sent a "no object" signal, and the ESP32 reactivated the relay to resume train movement, with the LCD displaying Track Clear – Train Running. The system performed consistently during testing, providing fast response times and reliable detection under various lighting conditions. The AI model demonstrated high detection accuracy (above 90%), ensuring precise identification of obstacles. The results confirm that combining AI-based object recognition with ESP32 automation can substantially improve railway safety. Future development can include cloud connectivity, automatic braking in real trains, and IoT-based monitoring dashboards for centralized railway management (Figures 2 and 3).

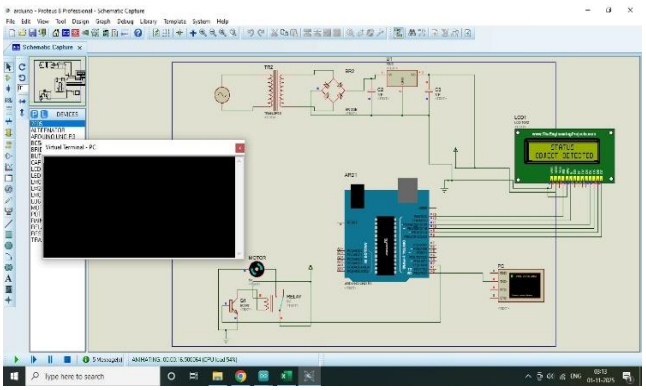

Figure 2 Detected Status

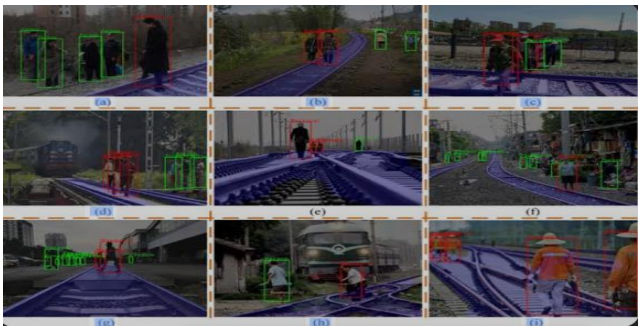

Figure 3 Object Detected

Conclusion

The project "AI-Based Object Detection in Railway Using ESP32 and Python" successfully demonstrates how Artificial Intelligence and embedded systems can be integrated to enhance railway safety. By using AI models for object detection and ESP32 for relay and motor control, the system achieves real-time, automated responses without human intervention. The model effectively identifies obstacles on the railway track, stops the train (DC motor) instantly, and provides continuous feedback through the LCD. The combination of AI precision, IoT communication, and embedded automation makes this approach more intelligent and efficient compared to conventional sensor-based systems. In conclusion,

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this project provides a smart, cost-effective, and scalable solution for modern railway safety applications. The proposed system demonstrates that AI-based object detection algorithms can accurately detect humans, animals, and foreign objects under varying environmental conditions. The use of an ESP32-based wireless sensor network enables efficient real-time communication, low power consumption, and rapid alert generation. Compared to traditional manual inspection and conventional sensor-only systems, the proposed AI-based solution improves detection accuracy, reduces response time, and enhances automation.

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