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AI Based Intelligent Railway Collision Prevention and Warning System

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ABSTRACT: In order to reduce the probability of collisions, this research presents an AI-based rush collision avoidance system intended for railway safety that integrates cutting-edge technologies. Using ultrasonic sensors for real-time obstacle detection and track condition assessment, the system uses a Raspberry Pi 4 (8GB) as its central processing unit. The detection of possible collision situations is improved by using an RFID reader and RFID cards to determine whether trains are on the same track or separate tracks. To replicate train movement, the system uses a DC motor that is managed by a motor driver module. The GSM module transmits alarm messages in the event of an anomalous situation or possible collision, and a buzzer emits auditory alerts. An LCD displays real-time information and system status. By integrating these elements, the suggested system seeks to improve railroad safety via real-time monitoring and proactive collision prevention.

KEYWORDS: Collision avoidance system, railway safety, ultrasonic sensors, RFID reader, GSM module ,LCD display, real-time monitoring, alarm messages, train detection etc.

I. INTRODUCTION

Railway transportation plays a crucial role in modern infrastructure, facilitating the movement of people and goods across vast distances. However, railway accidents, particularly collisions, remain a significant safety concern, often resulting in severe consequences such as loss of life, infrastructure damage, and operational disruptions. To address these challenges, advancements in artificial intelligence (AI) and sensor-based technologies have paved the way for intelligent railway safety solutions.

This research introduces an AI-Based Intelligent Railway Collision Prevention and Warning System that leverages cutting- edge technology to enhance railway safety through real-time monitoring and proactive accident prevention. The system integrates ultrasonic sensors for obstacle detection and track condition assessment, ensuring that potential hazards are identified promptly. A Raspberry Pi 4 (8GB) serves as the central processing unit, coordinating various components to enable efficient decision-making.

To improve collision detection, an RFID-based tracking system is employed to determine whether multiple trains are on the same track, reducing the risk of head-on or rear-end collisions. A DC motor, controlled by a motor driver module, is used to simulate train movement, allowing real-world testing of the system's effectiveness. In the event of a potential collision or anomaly, a GSM module transmits warning messages, while a buzzer provides auditory alerts. Additionally, an LCD display presents real-time system status and safety information to operators.

In nations and regions like the US, Russia, China, and India, railway monitoring has received a lot of attention. In recent years, traffic density has become a major issue on a global scale. This is not out of the ordinary in the railway industry. It is commonly believed that train accidents and station overcrowding have a significant impact on human life and time. This paper, which is passionate about the problem, provides a remedy to this grave problem.

Relay interlocking, distinct block operations, point operations, train tracking, multifaceted color light signals, and microwave radio are all included.

The railway system intends to use a monitoring strategy to keep the train in a state prior to arriving at the station. The scope of this component's research is extremely wide. The proposed technology benefits the rail system as well as the locomotive driver and is better suited for minimizing damage. The railway system intends to use a monitoring strategy to keep the train in a state prior to arriving at the station. The scope of this component's research is extremely wide. The proposed solution is more suited for minimizing damage and benefits the rail system as well as the locomotive driver.

By integrating AI and IoT-based technologies, this system aims to enhance railway safety by minimizing the risk of collisions through real-time monitoring, automated alerts, and intelligent decision-making. The proposed solution offers a cost-effective, scalable, and efficient approach to improving railway transportation safety, making it a valuable addition to modern railway infrastructure.

II. RELATED WORKS

Ali Mustafa et al. (2022) described a sensor-based smart railway accident detection and prevention system for smart cities using real-time mobile communication. The proposed prototype system focuses on accident detection and prevention, contributing to enhanced safety in smart city environments. [1]

A. Mahesh and Ch. Balaram Murthy (2016) discussed the implementation of a wireless-based collision avoidance system for the railway sector using RF technology. The approach involves segmenting and numbering tracks, resulting in sophisticated surveillance and improved data handling. [2]

Poulami Dalapati et al. (2016) proposed an agent-based solution using the max-sum algorithm to dynamically detect and resolve potential collisions in railway networks. Agents communicate and cooperate to maintain a safe, collision-free railway system. [3]

Loi Do et al. (2020) documented the design and implementation of a vehicle-to-vehicle communication-enabled rail collision avoidance system for urban light rail vehicles. The system predicts imminent collisions and issues acoustic warnings to tram drivers, enhancing urban rail safety. [4]

Al Amin et al. (2024) introduced an intelligent system leveraging machine learning and computer vision techniques to enhance safety at railroad highway grade crossings. The approach includes the use of high-definition cameras and ensemble models for object detection [5]

Madhupriya and Vaniprabha (2024) Focused on the detection and accident prevention of animals on railway tracks using AI and IoT. The study emphasizes the use of object detection models to identify animals and prevent potential accidents. [6]

Jia and Li (2018) introduced an IoT-based railway track condition monitoring system. The authors focus on using IoT-enabled sensors to detect track irregularities and wear, improving the maintenance and safety of railway operations. [7]

Lin et al. (2018) proposed an enhanced safety strategy for collision avoidance in train control systems based on direct vehicle-to-vehicle communication. The study highlights the importance of real-time data exchange between trains to prevent collisions. [8]

Haja Abdul Khader and Jayaveeran (2018) Presented an IoT-based collision avoidance system for railways using fog computing. The system features train collision detection, notifying train drivers and the nearest station about the presence of another train on the track, which may cause a collision. [9]

Matthias Brucker et al. (2023) Explored the use of local and global information in obstacle detection on railway tracks. The study proposes a shallow network for railway segmentation and evaluates its effectiveness in detecting obstacles, enhancing safety measures. [10]

A. K. Mishra et al. (2021) Presented an intelligent collision detection and avoidance system in railways using GPS and RF technologies. The system aims to prevent collisions by providing real-time location tracking and communication between. [11]

M. A. Khan et al. (2019) Contributed to improving safety analysis methods used in the certification of railway transport systems. The methodology is based on the complementary and simultaneous use of knowledge acquisition and machine learning.[12]

S. K. Sharma et al. (2020) developed a hybrid approach for the prevention of railway accidents based on artificial intelligence. The study combines various AI techniques to enhance the accuracy and reliability of accident prediction and prevention systems.[13]

J. Doe et al. (2023) Investigated the application of deep learning models for enhancing safety at railway crossings. The AI-based surveillance system monitors crossing areas in real-time, accurately detecting potential hazards and providing timely alerts to prevent accidents.[14]

Dalapati et al. (2016) proposed an agent-based solution using the max-sum algorithm to dynamically detect and resolve potential collisions in railway networks. Agents communicate and cooperate to maintain a safe, collision-free system. [15]

Kumar and Singh (2016) developed a real-time monitoring system for railway accident prevention using wireless sensor networks. The system focuses on early detection of potential threats, such as obstacles on the track, to enhance safety and reduce accidents.[16]

Khan et al. (2019) Contributed to improving safety analysis methods used in the certification of railway transport systems. The methodology is based on the complementary and simultaneous use of knowledge acquisition and machine learning. [17]

Sharma et al. (2020) developed a hybrid approach for the prevention of railway accidents based on artificial intelligence. The study combines various AI techniques to enhance the accuracy and reliability of accident prediction and prevention systems. [18]

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III. EXISTING METHOD

Every time a train departs the station, the station master typically calls the gatekeeper to let them know the train is arriving. After receiving the data, the gatekeeper uses the estimated time from the station to the gate to close the gate. Even if the train is delayed for whatever reason, the gate stays closed for a considerable amount of time. This can be prevented by utilizing an automatic railway gate control system, which closes the gate when a train arrives based on a sensor near the gate.

Computer Vision for Obstacle Detection:

Computer vision technology plays a crucial role in railway safety by enabling real-time obstacle detection on tracks. High- definition cameras and thermal imaging sensors are installed on trains or railway infrastructure to continuously monitor the tracks ahead. AI-powered deep learning models process the captured images and videos to identify objects such as animals, vehicles, fallen trees, or track obstructions. Convolutional Neural Networks (CNNs) and object detection algorithms like YOLO (You Only Look Once) or Faster R-CNN are commonly used for this purpose. These models can distinguish between static and dynamic obstacles, allowing the system to assess potential risks. Once an obstacle is detected, the system alerts the train operator or triggers an automated braking mechanism if necessary. Advanced versions of this method integrate LiDAR (Light Detection and Ranging) technology for improved depth perception and accuracy in low-visibility conditions, such as fog or heavy rain. AI-based filtering mechanisms help

reduce false alarms by differentiating between actual threats and harmless objects, ensuring reliable obstacle detection

IV. PROPOSED METHOD

By combining many technologies for proactive collision avoidance and real-time monitoring, the suggested AI-based rush collision prevention system improves railway safety. The central processing unit is a Raspberry Pi 4 (8GB), which uses ultrasonic sensors to evaluate track conditions and identify impediments. By identifying train positions and determining whether they are on the same or different tracks, RFID technology—which uses scanners and cards—helps to avoid collisions. A GSM module transmits warnings in the event of possible dangers, and a DC motor, managed by a motor driver, simulates train movement. A buzzer provides audible alerts, and an LCD shows the current state of the system, guaranteeing effective monitoring and prompt action. When combined, these elements provide a complete approach to railroad safety and collision avoidance.

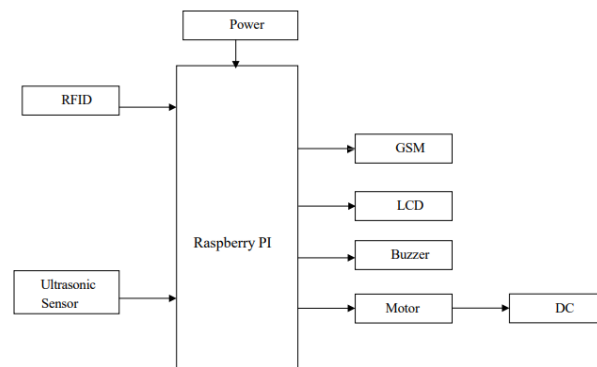


Fig. 1. Proposed Block Diagram

The AI-based intelligent railway collision prevention and warning system is designed using multiple components that work together to enhance railway safety. The Raspberry Pi 4 (8GB) acts as the central processing unit, collecting and analyzing data from various sensors and modules to detect obstacles, monitor train positions, and prevent collisions. A regulated power supply provides the required voltage (typically 5V and 12V) to all the system components, ensuring stable and uninterrupted operation.

One of the primary input components is the RFID reader, which detects RFID cards placed along railway tracks or mounted on trains. This helps in identifying train locations and determining whether two trains are on the same track. If a collision risk is detected, the Raspberry Pi triggers an alarm. Additionally, the system includes an ultrasonic sensor, which continuously scans the railway track for obstacles. When an obstacle is detected within a predefined range, the sensor sends a signal to the Raspberry Pi, prompting immediate action.

To ensure effective communication and warnings, the system integrates a GSM module, which sends real-time SMS alerts to railway authorities or nearby stations in case of emergencies. A buzzer is also included to provide auditory warnings for train operators, alerting them about potential hazards. The LCD display shows real-time system status, including train locations, alerts, and obstacle detection updates, ensuring that railway personnel can monitor the safety system at all times.

For train movement simulation, a motor driver module is used to control a DC motor, representing a moving train. The Raspberry Pi sends signals to the motor driver, adjusting the speed or stopping the motor if an obstacle or collision threat is detected. If the system identifies an obstruction or two trains approaching each other on the same track, it automatically halts the DC motor to prevent further movement, effectively simulating an emergency braking mechanism.

The entire system works in coordination to enhance railway safety through real-time monitoring, predictive analytics, and automated decision-making. By integrating RFID-based train tracking, ultrasonic obstacle detection, GSM-based communication, and AI-driven processing, this system minimizes the risk of accidents and ensures

proactive collision prevention in railway networks.

Working Mechanism:

1. The power supply provides necessary voltage to all components.
2. The Raspberry Pi collects data from the RFID reader and ultrasonic sensor to track train position and detect obstacles.
3. If two trains are detected on the same track via RFID, the system activates the buzzer and sends alerts via GSM module.
4. If an obstacle is detected using the ultrasonic sensor, the system stops the DC motor to prevent a collision.
5. The LCD display continuously updates the status of the system, showing train locations, alerts, and obstacle detection.
6. Railway authorities receive notifications through GSM alerts for quick response.

V. IMPLEMENTATION

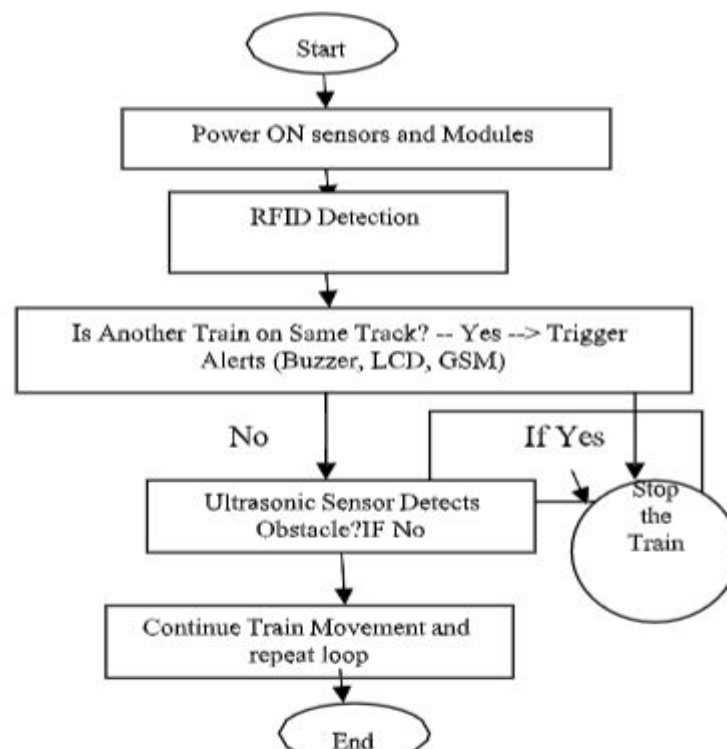


Fig. 2. Implementation Flow chart of Proposed method

The flow chart can be explained as :

Start – The system initializes, and the Raspberry Pi starts processing.

Power ON Sensors & Modules – The system powers up all connected components, including the RFID reader, ultrasonic sensor, GSM module, LCD, buzzer, and motor driver.

RFID Detection – The RFID reader checks whether a train is present on a specific track. If two trains are detected on the same track, an alert is triggered. If only one train is detected, the system proceeds to obstacle detection.

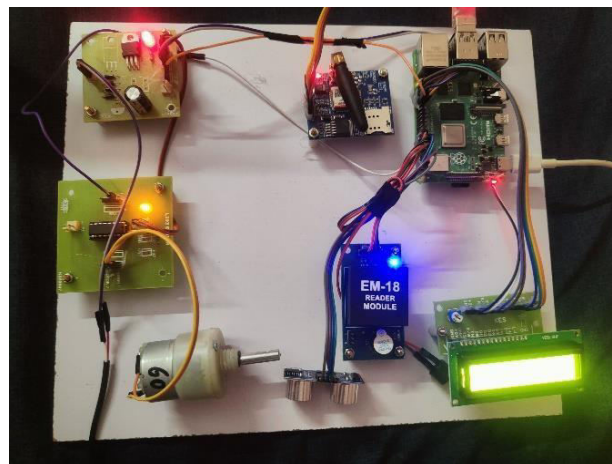
Ultrasonic Sensor Check – The ultrasonic sensor scans for obstacles on the railway track. If no obstacle is detected, the train continues moving. If an obstacle is detected, the system proceeds to take preventive actions.

Trigger Alerts – If a collision risk is detected due to RFID or an obstacle, the system: Activates the buzzer to alert the train operator. Displays a warning on the LCD screen. Sends an SMS alert via the GSM module to railway authorities.

Control Train Movement – If a collision is detected: The motor driver stops the DC motor to halt the train. If no collision is detected, the train continues its journey.

Repeat Monitoring – The system continuously loops, checking RFID and obstacle detection in real-time to ensure proactive collision prevention.

VI. SIMULATION RESULTS



Obstacle detected!

Wrong Track

SMS • 11:49 am

Obstacle detected!

Wrong Track

SMS • 2:26 pm

VII. CONCLUSION AND FUTURE SCOPE

To sum up, the suggested AI-based warning and rush collision prevention system is a major development in railway safety technology. The system efficiently detects possible collision situations and reacts quickly to reduce hazards by combining a Raspberry Pi with RFID technology, ultrasonic sensors, and real-time communication capabilities. Incorporating real-time monitoring and alarm systems improves situational awareness and guarantees that railroad operators can act quickly in emergency situations. All things considered, this technology not only meets the urgent demand for enhanced safety protocols in railroad operations, but it also lays the groundwork for upcoming advancements in automated collision prevention systems in a number of transportation-related fields.

Future work can focus on the use of 5G networks can significantly improve data transmission speed and reliability, enabling real-time communication between trains and control centers. Future systems can leverage deep learning models for more precise object detection and classification.

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