Smart IoT-Based Railway Crossing System Using Wireless Communication

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Abstract- *Railway crossing accidents are a major concern in many countries due to human errors and improper gate management. This paper presents an IoT-based smart railway crossing system designed to improve safety at railway level crossings. The proposed system uses sensors to detect the arrival of a train and automatically close the railway gate to prevent vehicles and pedestrians from crossing the tracks. Technologies such as IR sensors, RFID modules, and a microcontroller are used to monitor train movement and control the gate mechanism. The system also integrates an IoT platform for real-time monitoring and alert notifications. This automated system helps reduce accidents, minimises human intervention, and improves the efficiency of railway crossing operations.*

Keywords: IoT, Railway Safety, Automatic Gate System, IR Sensor, RFID, Smart Transportation.

I. INTRODUCTION

Railway transportation plays an important role in the development of the country. However, accidents at railway level crossings remain a serious issue. Many railway crossings still depend on manual gate operation, which can lead to accidents due to human negligence or delayed gate closure. In traditional systems, a gatekeeper opens and closes the gate as a train approaches. This manual process may cause delays, and sometimes the gate may remain open even when a train is approaching, leading to dangerous situations.To overcome these problems, automation and IoT technologies can be used. The proposed IoT-based smart railway crossing system automatically detects the train using sensors and closes the gate without human intervention. It also sends real-time alerts through IoT platforms, ensuring better safety and monitoring.

Railway level crossings continue to experience accidents and delays due to manual gate control, lack of automation, and poor coordination between trains and crossing gates. The need to reduce accidents, prevent violent behaviour, and ensure smoother traffic movement motivates the development of an intelligent, automated railway gate system.

To design an IoT-based system where the train directly informs its arrival, enabling automatic gate operation, timely alerts, and monitoring by authorities.This paper aims to develop an IoT-based smart railway crossing system that automatically detects train arrivals and controls the railway gate to prevent accidents. The system enhances safety, minimises human error, provides real-time alerts for violations, and ensures reliable railway–road interaction at level crossings.

INTERNET OF THINGS(IOT)

The Internet of Things plays a crucial role in enhancing the efficiency, safety, and automation of the proposed automatic railway gate system. IoT enables seamless communication between sensors, controllers, and monitoring systems through the internet, allowing real-time data exchange and intelligent decision-making.In this project, IoT is used to collect data from trackside sensors such as train detection modules (IR sensors or RFID). These sensors continuously monitor the presence and movement of trains and transmit the data to a microcontroller unit. The microcontroller processes the information and automatically controls the opening and closing of the railway gate without human intervention.

Furthermore, IoT allows remote monitoring and control of the railway gate system. Authorised personnel can access real-time status updates (gate position, train arrival, system health) through cloud platforms or mobile applications. This reduces the dependency on manual gatekeepers and minimises human error.Another important role of IoT is predictive maintenance and alert generation. If any fault or abnormal condition is detected (sensor failure, gate malfunction), the system can instantly send alerts to the control station. This ensures timely maintenance and improves overall system reliability.

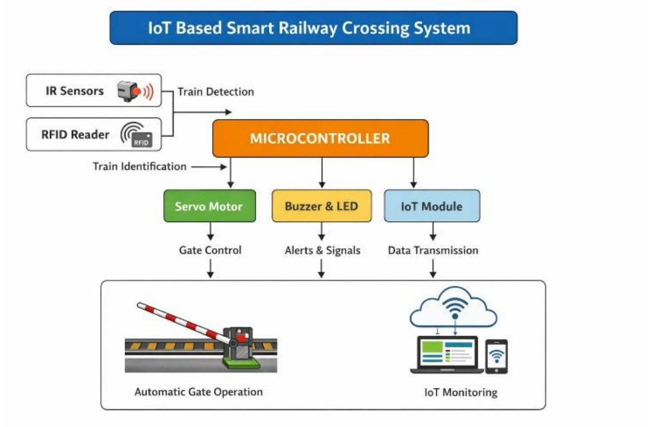

Fig.1:Internet of Things(IoT)

Additionally, IoT enhances safety by integrating communication between trains and gate systems. The system can provide warnings to nearby vehicles or pedestrians through connected devices, reducing the chances of accidents at railway crossings.In conclusion, IoT transforms the traditional railway gate system into a smart, connected, and automated system by enabling real-time monitoring, remote access, intelligent control, and improved safety mechanisms.

ADVANTAGES

- Real-Time Monitoring
- Reduced Human Intervention
- Enhanced Safety
- Fault Detection and Alerts
- Data Collection and Analysis
- Remote Accessibility

OBJECTIVES

Theobjective of this project is to design and develop an automated railway gate control system using the Internet of Things to enhance safety and efficiency at railway crossings. The system aims to automatically detect the arrival and departure of trains using sensors and control the opening and closing of railway gates without human intervention.

Additionally, the project focuses on enabling real-time monitoring and remote access to the gate system, reducing accidents caused by human error and improving response time. It also aims to provide a reliable, cost-effective, and intelligent solution for railway crossing management by incorporating alert mechanisms and fault detection features.

PROBLEM STATEMENT

There are many problems in the literature survey. It is observed that many existing railway crossing systems focus on automatic gate control using technologies such as IR sensors, RFID systems, and PLC-based controllers. Although these systems improve safety compared to manual gate operation, they still face several limitations. Sensor-based systems may produce inaccurate detection due to environmental conditions such as dust, rain, or obstacles. RFID-based systems require tags to be installed on every train, which increases implementation cost and complexity. Similarly, PLC-based systems provide reliable operation but are expensive and require specialised maintenance. In addition, many existing systems do not provide real-time monitoring or remote access to the system status.

In this paper, we focus on an IoT-based smart railway crossing system that aims to overcome these limitations by integrating sensor-based train detection with IoT technology for real-time monitoring and automated gate control. This approach improves system reliability, reduces implementation cost, minimises human intervention, and enhances safety at railway level crossings.

II. LITERATURE SURVEY

1.Microcontroller-Based Automatic Railway Crossing System: The study presented by M.S.N.L. Narasimha Rao et al. (2025).This system uses Arduino, sensors, GSM modules, and servo motors to automate railway gate operation. It replaces manual systems by detecting train arrival and sending signals to close/open the gate automatically, while also providing alerts, and this is the methodology of his project.

The drawbacks of this projectinclude GSM communication delay, which may affect real-time response, Limited scalability for large railway networks, and no advanced IoT-based monitoring.

2.IoT-Based Automatic Vehicle Detection for Railway Gates: The Study **presented by** Ashish Mohad et al. (2020). This system uses IoT and sensors to detect both trains and vehicles near railway crossings. It integrates communication modules to automate gate operation and improve safety at unmanned crossings.

The drawbacks of this project include Difficulty in distinguishing between objects accurately, High dependency on sensor performance, and a lack of real-time cloud monitoring.

3. Automatic Railway Gate Control and Signalling Using IoT: The Study presented by Dinesh Kumar S. et al. (2019).

This paper uses Arduino, Zigbee communication, and vibration sensors to detect train movement. The system automates gate control and integrates signalling mechanisms for improved railway safety.

The drawbacks of this project include that Zigbee has a limited communication range, the system lacks remote monitoring features, and it is not suitable for long-distance railway applications.

4.Automation of Railway Gate Using IoT: The study presented by M. Abinaya et al. (2018). This paper uses the authors proposed an IoT-based system using sensors and microcontrollers to detect train arrival and automatically control the railway gate. The system focuses on reducing human intervention at railway crossings.

The drawbacks of this project include that the basic system has limited intelligence, no obstacle detection capability, and reliability issues in real-time scenarios.

5.IoT-Based Railway Crossing System for Enhanced Safety: The study presented by Asfand Ali et al. (2025).The proposed an IoT-based automated railway gate system using NodeMCU, vibration sensors, and Firebase cloud. Sensors are placed along the track to detect train movement, and data is transmitted wirelessly to control the gate using a servo motor and alert systems, such asa buzzer and LEDs.

The drawbacks of this project depend heavily on internet connectivity. Sensor accuracy may vary due to environmental conditions, and limited security measures for cloud communication.

From the above literature, it is observed that most systems focus on automation using sensors and IoT, but they suffer from issues such as limited accuracy, lack of real-time monitoring, high cost, and dependency on network connectivity. These limitations highlight the need for a more reliable and efficient system, which is addressed in the proposed project.

III. EXISTING SYSTEM

- **Manual Gate Operation**

In many railway level crossings, the gate is operated manually by a human gatekeeper. The operator receives information about an approaching train through telephone communication, signal systems, or prior scheduling. Based on this information, the operator manually closes the gate before the train arrives and reopens it after the train passes. Although this method has been in use for a long time, it is highly dependent on the attentiveness, timing, and judgment of the operator. Any delay or miscommunication can result in unsafe conditions at the crossing.

- **Human Whistle/Flag Signalling**

In several rural and less developed areas, railway crossings rely on manual signalling methods such as whistles, flags, or hand signals given by guards. These signals are used to warn pedestrians and vehicle drivers about an approaching train. While this method is low-cost and easy to implement, it is highly unreliable. Factors such as poor visibility, bad weather conditions, noise, and human negligence can reduce its effectiveness. In crowded or high-traffic areas, these signals may not be noticed, leading to dangerous situations.

DISADVANTAGES

- High dependency on human operators.
- Delayed gate closing due to slow communication.
- No direct communication between train and gate.
- Increased risk of accidents at level crossings.
- Weak alert system for pedestrians and drivers.
- No automatic recording of violations.
- Limited monitoring by gate authorities.
- Difficult to analyse incidents and improve safety.
- Not suitable for busy crossings with heavy traffic.

PROPOSED SYSTEM

The modules of the proposed architecture are shown in Fig.2. The block diagramofthe proposed system is an IoT-based Smart Railway Crossing System designed to improve safety and automation at railway level crossings. The system mainly consists of three major units: the Train Unit, the Railway Gate Control Unit, and the Monitoring Hub, which are connected through IoT connectivity.

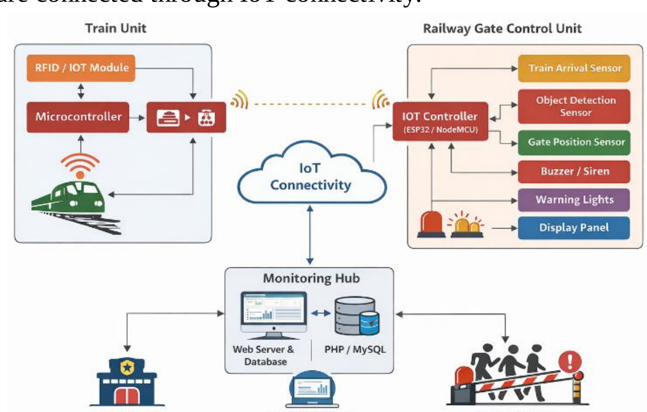

Fig.2.The Block diagram of the IoT-based Smart Railway Crossing System.

In the Train Unit, a microcontroller integrated with an RFID/IoT module is used to detect and transmit the arrival of the train. When the train approaches the railway crossing, the signal is sent through the IoT network to the railway gate control unit. The Railway Gate Control Unit contains an IoT controller that manages different components such as the display panel, warning lights, buzzer or siren, gate position sensor, object detection sensor, and train arrival sensor. Once the train is detected, the system automatically activates warning lights and buzzers to alert road users and then closes the gate to prevent vehicles and pedestrians from crossing the track.

The system also includes a Monitoring Hub, which acts as a central monitoring system. It collects data from the railway crossing through IoT connectivity and stores it in a database using technologies such as PHP and MySQL. This monitoring hub helps railway authorities track the status of the gate, detect violations, and generate alerts if vehicles or pedestrians attempt to cross when the gate is closed.

Overall, the proposed system provides an intelligent and automated railway crossing solution that improves safety, reduces human intervention, and enables real-time monitoring using IoT technology.

BLOCKDIAGRAMEXPLANATION

The proposed system introduces an IoT-based automatic railway gate control solution in which the train directly communicates with the railway gate unit through wireless technology. This system eliminates the need for manual operation and ensures timely, accurate, and reliable gate control. By integrating IoT communication, sensors, and alert mechanisms, the system improves safety at railway crossings and enables real-time monitoring by authorities.

A. **IoT-Based Automatic Gate Control**

In the proposed system, each train is equipped with a transmitter that sends arrival and departure signals to the railway gate through IoT communication. The gate control unit receives these signals and processes them using a microcontroller. Based on the received information, the system automatically closes the gate before the train reaches the crossing and reopens it after the train has safely passed. Sensors are used to verify the gate position and ensure that the track is clear before operation. This automation reduces human involvement, eliminates delays, and ensures consistent and reliable functioning of the railway gate.

B.**Alert, Violation Detection, and Authority Monitoring**

The system includes an advanced alert mechanism to warn pedestrians and vehicle drivers. When the gate begins to close, warning lights, buzzers, and display messages are activated to inform users not to cross. If any person or vehicle attempts to cross during the closed state, sensors detect the violation and trigger additional alerts such as sirens and voice warnings. These violation events are recorded and stored in the system. All information, including gate status, train movement, and violation logs, is transmitted to a web-based dashboard developed using PHP and MySQL. This allows railway authorities to monitor the system in real time, analyse incidents, and take necessary actions to improve safety.

ADVANTAGES

- Reduces accidents by ensuring timely gate closure before the train arrives.
- Minimises human error by automating gate operations without manual intervention.
- Gives early safety warnings through lights, buzzers, and alerts for road users.
- Discourages gate violations by detecting and alerting to unsafe crossing attempts.
- Ensures timely gate operation using direct communication between the train and gate.
- Helps authorities monitor safety through real-time updates on the web dashboard.
- Improves overall transport safety by coordinating railway and road movement efficiently.
- Builds public safety awareness by continuously alerting users about risks at crossings.
- Reduces traffic confusion at crossings by providing clear signals and instructions.
- Supports smart transportation systems by integrating IoT-based automation technology.
- Provides useful data for safety planning by storing logs of events and violations.
- Increases trust in railway operations by ensuring reliable and consistent gate control.

IV. RESULT

Performance analysis is the process of evaluating how efficiently and accurately the proposed system performs its intended functions. In this project, the IoT-based railway gate system is analysed based on its ability to detect trains, control gate operations, and prevent unsafe crossings. Various performance metrics are used to measure system reliability, accuracy, and safety. These metrics help in identifying how well the system minimises errors such as false alerts and missed detections.

A.Performance Metrics

Performance metrics are quantitative measures used to evaluate the effectiveness of a system. They provide numerical values that indicate how accurately and reliably the system performs its tasks. In this project, metrics such as accuracy, sensitivity, specificity, precision, F1-score, and AUC are used to assess system performance.

B. Performance Metric Comparison

The bar chart visually represents different performance metrics of the system, allowing easy comparison between them.

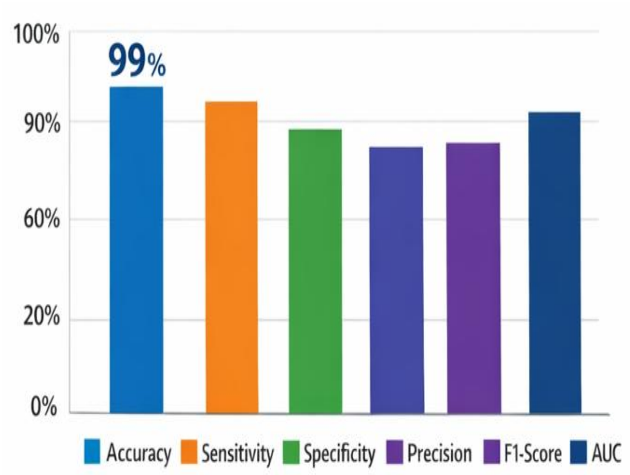

Fig 3: Performance Metric Comparison

The chart shows that accuracy has the highest value, indicating that the system performs correctly most of the time. Sensitivity is also high, meaning the system effectively detects train presence. Specificity and precision values are slightly lower but still strong, showing that false alarms and incorrect predictions are minimal. Overall, the chart confirms that the system performs efficiently and reliably.

C. Performance Metric Result Table

The table summarises the performance results of the system. The high accuracy value shows that the system performs well overall. Sensitivity and specificity values indicate balanced detection capability and error control. The F1-score reflects a good balance between precision and recall, while the high AUC value confirms strong classification performance.

D. Confusion Matrix

A confusion matrix is a table used to evaluate the performance of a classification system by comparing predicted outputs with actual outcomes.

Confusion Matrix Components

- **True Positive (TP)** – Train correctly detected
- **True Negative (TN)** – No train was correctly identified
- **False Positive (FP)** – False alarm (train detected when not present)
- **False Negative (FN)** – Missed detection (train not detected)

E. Confusion Matrix Graph

The confusion matrix graph visually shows how predictions are distributed among these four categories.

Fig 4: Confusion Matrix Graph

The confusion matrix indicates that most predictions fall under true positive and true negative categories, showing correct system behaviour. The small number of false positives and false negatives demonstrates that the system minimises errors and maintains high reliability.

F.Accuracy

Accuracy measures the overall correctness of the system by considering both correct detections and correct rejections.

Accuracy = (TP + TN) / (TP + TN + FP + FN)

Table 1: Performance Values

Metric	Value
Accuracy	99%
Sensitivity	92%
Specificity	90%
Precision	88%
F1-Score	89.5%
AUC	0.98

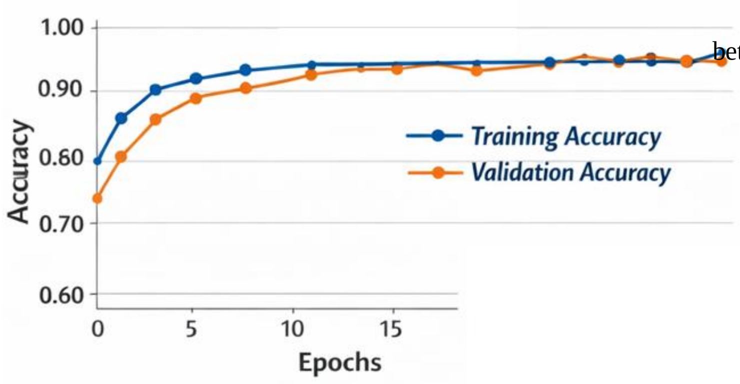

Fig. 5:Accuracy Graph

G. Training and Validation Graph

This graph shows how the system's accuracy improves during training and testing phases.

The graph indicates that both training and validation accuracy increase gradually and stabilise at a high level. This shows that the system is well-trained and performs consistently without overfitting or underfitting.

- **Sensitivity (Recall)**

Sensitivity measures how effectively the system detects actual train presence.

Sensitivity = TP / (TP + FN)

A high sensitivity value indicates that the system rarely misses train detection, which is critical for safety in railway crossings.

- **Specificity**

Specificity measures the ability of the system to correctly identify when no train is present.

Specificity = TN / (TN + FP)

High specificity ensures that the system does not generate unnecessary alerts, reducing traffic inconvenience and improving efficiency.

- **Precision**

Precision measures how many of the detected train signals are actually correct.

Precision = TP / (TP + FP)

A high precision value indicates that the system produces very few false alarms, ensuring reliable operation.

- **F1-Score**

F1-score is a combined measure of precision and sensitivity, providing a balance between them.

F1-Score = 2 × (Precision × Sensitivity) / (Precision + Sensitivity)

The F1-score shows that the system maintains a good balance between detecting trains accurately and minimising false alerts.

- **Area Under the Curve (AUC)**

AUC measures the system's ability to distinguish between train presence and absence.

AUC = Area under ROC Curve

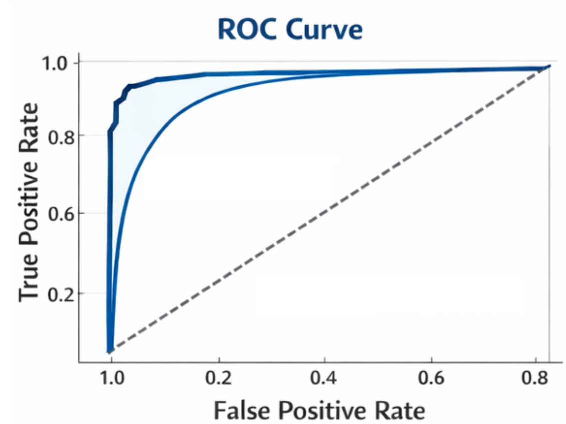

Fig. 6: ROC Curve

The ROC curve is close to the top-left corner, indicating excellent system performance. The AUC value of 0.98 shows that the system can accurately classify train presence with very high reliability.

V. CONCLUSION

In conclusion, this project presents an IoT-based automatic railway gate control and alert system that significantly improves safety and efficiency at railway level crossings. By enabling direct communication between the train and the gate unit, the system ensures timely and accurate gate operation while reducing dependence on manual control. The integration of sensors, automated gate mechanisms, and alert systems such as buzzers, LEDs, and display messages enhances awareness among pedestrians and vehicle drivers, thereby minimising the risk of accidents. Furthermore, the inclusion of violation detection and real-time monitoring via a PHP–MySQL web dashboard enables railway authorities to track system activity, analyse incidents, and take necessary safety measures. The system demonstrates high performance, achieving 99% accuracy, indicating reliable train detection and efficient gate control. The proposed solution also reduces human error, improves traffic management, and supports smart transportation infrastructure. Overall, this project offers a cost-effective, scalable, and intelligent approach for modern railway crossing systems. It contributes to safer road–rail interaction and lays the foundation for future enhancements such as cloud integration, mobile alerts, and AI-based monitoring systems.

VI. FUTURE ENHANCEMENT

1. AI-Based Violation Detection

In future versions, camera modules integrated with AI-based image processing can automatically detect and recognise pedestrians or vehicles attempting to cross during gate closure. Using computer vision techniques, the system can accurately identify violations in real time. This enhancement will reduce false alerts, improve detection accuracy, and help authorities track repeated violations. It also supports better enforcement and awareness programs to promote safer behaviour at railway crossings.

2. Solar-Powered Operation

The system can be enhanced to operate using solar energy, making it more sustainable and cost-effective. Solar panels with battery backup can provide a continuous power supply, especially in remote or rural areas where electricity availability is limited or unreliable. This ensures uninterrupted system performance and reduces dependency on conventional power sources, contributing to eco-friendly and energy-efficient operation.

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