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Automated Railway Barricade Monitoring System

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Abstract: The increasing number of accidents at unmanned railway crossings has become a serious concern for public safety. Conventional manual barricade systems are often inefficient due to human error, delays, or negligence, leading to life-threatening collisions between trains and vehicles. To overcome these challenges, this project proposes an automated Railway Barricade Monitoring System using the ESP32 microcontroller, infrared (IR) sensors, LCD display, DC motor with H-Bridge driver, and signal indicators. In the proposed system, two IR sensors are strategically placed on either side of the railway track to detect the entry and exit of a train. When the first IR sensor detects an approaching train, the ESP32 activates the gate mechanism through an H-Bridge motor driver, lowering the barricade to restrict road traffic. Simultaneously, the signal indicators switch states the red light turns ON, and the green light turns OFF—alerting vehicles and pedestrians about the train's arrival. The LCD display provides real-time status messages, such as “Train Arriving,” “Gate Closing,” or “Gate Open,” ensuring visual feedback for monitoring. Once the second IR sensor confirms that the train has completely passed, the ESP32 commands the motor to raise the gate, restoring normal road traffic flow by turning the red light OFF and the green light ON. An additional feature of this system is the automatic reset capability of the ESP32 after each complete cycle, ensuring the controller always starts in a fresh, predictable state before monitoring the next train. The system can also record the number of gate cycles using non-volatile memory, which can be useful for long-term maintenance analysis.
Keywords: Internet of Things (IoT), automation, microcontroller, sensor, DC motor,servo motor, and signals

I. INTRODUCTION

Railway transportation plays a vital role in connecting cities and towns, offering an efficient and cost-effective means of travel and goods transport. However, unmanned railway crossings remain one of the most dangerous points on the railway network, often leading to severe accidents involving trains, vehicles, and pedestrians. The absence of automated safety systems at many level crossings creates significant risks due to human negligence, delayed manual barricade operation, and lack of real-time monitoring. To address these safety challenges, automation in railway crossing management has emerged as an essential solution. Modern microcontrollers, sensors, and motor control systems provide the capability to design intelligent barricade systems that operate without human intervention. Such systems enhance safety by ensuring that the gate closes automatically when a train approaches and opens only after the train has completely passed, thereby eliminating the possibility of human error. In this project, an ESP32 microcontroller serves as the central controller, interfacing with infrared (IR) sensors to detect train movement, an H-Bridge motor driver with DC motor to control the gate, and LED indicators (red and green) to guide vehicles and pedestrians. An LCD display provides real-time information about the gate and train status, improving visibility and monitoring. The system also includes an auto-reset feature, which restarts the ESP32 after each complete cycle, ensuring a clean and reliable operation for every train passage. This design is cost-effective, reliable, and scalable, making it suitable for deployment in semi-urban and rural areas where unmanned crossings are prevalent. Additionally, the system has the potential for future enhancements, such as IoT integration for remote monitoring, emergency alerts, and predictive maintenance based on cycle counts.

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By combining automation, sensing technology, and embedded control, the proposed Railway Barricade Monitoring System aims to significantly improve the safety, efficiency, and reliability of railway crossings.

II. LITERATURE SURVEY

1. Automated Level Crossing System For Trains — IJCRT (April 2025)
   What it covers: surveys detection & actuation techniques used in modern automated level crossings (IR/ultrasonic sensors, image processing, GPS/RFID onboard approaches, alarm/lighting and barrier actuation).
   Methods / focus: compares sensor-based obstacle detection approaches and integration with barrier control. Highlights practical deployment challenges (false positives, power/communication constraints).
   Takeaway: good recent survey of sensing options and tradeoffs for automatic gate closure; useful for picking detection algorithms and discussing real-world reliability concerns.
2. Assessing Safety and Infrastructure Design at Railway Level Crossings MDPI (2025)
   What it covers: microsimulation and safety analysis of level crossings (signal preemption, traffic clearance strategies) more systems/operations oriented than low-level hardware.
   Methods / focus: VISSIM microsimulation, analysis of preemption strategies to clear road traffic before train arrival; evaluates effect on vehicle queueing and safety.
   Takeaway: important for the systems-level side of automatic closure shows how gate timing and preemption strategy affect safety and traffic performance (use when arguing why precise arrival prediction matters).
3. Optimizing hybrid renewable energy based automated [railway level crossing] system ScienceDirect (2024)
   What it covers: research on powering automated crossing systems (sensors, actuators, comms) using hybrid renewable power (solar + battery + small backup) and optimization for reliability.
   Methods / focus: techno-economic and reliability modelling, optimization of sizing for remote/unmanned crossings.
   Takeaway: useful if your survey should include deployment constraints (power availability, off-grid locations) and design choices for autonomous barrier control.
4. A Review Paper on “Automatic railway gate opening and unmanned level crossing” IJAEM (Jan 2023)What it covers: survey of microcontroller/IoT/short-range sensor implementations (IR/ultrasonic/PIR, GSM, basic PLCs) used in many prototype and low-cost solutions.
   Methods / focus: summarizes architectures and component choices used in academic and student projects; highlights common limitations (lack of robust obstacle classification, manual overrides, limited comms). Takeaway: good for documenting the breadth of low-cost, prototype approaches and common shortcomings (motivate need for better sensing/ML/communication).
5. An Automated Railway Level Crossing System (IoT + ML approaches) — SemanticsScholar / ResearchGate (recent preprints and implementations, 2023–2025)
   What it covers: cluster of newer works that combine onboard train localization (GPS/RFID), IoT communications, camera-based obstacle detection and lightweight ML for object recognition at crossings. Methods / focus: practical prototypes showing end-to-end flow: train location → wireless alert to crossing → barrier actuation with obstacle verification via camera/ML → remote monitoring dashboard.
   Takeaway: the best source for current direction: moving from simple sensors to multi-sensor fusion and lightweight ML for obstacle detection and false-alarm reduction. Use these to justify ML/vision experiments in your survey.

III. METHODOLOGY

The traditional railway level crossing systems in use today can be broadly categorized into manual, semi- automatic, and basic automatic systems. While they have been used for decades, they present several limitations and challenges.

3.1. Manual Gate Operation

- In most **rural and semi-urban areas**, railway crossings are still controlled manually by gatekeepers.
- The operator receives information about an approaching train via telephonic or wireless communication from nearby stations.
- Upon confirmation, the operator manually lowers the barricades and signals road traffic.
- **Limitations:**
  - High dependency on human efficiency.
  - Delays in communication may lead to accidents.
  - Risk of human negligence or fatigue.
  - Not cost-effective in terms of manpower deployment at each crossing.

3.2. Semi-Automatic Systems

- Some crossings use a combination of **sensors** and **manual intervention**.
- Train detection sensors may alert the gatekeeper, who then closes the gate manually.
- **Limitations:**
  - Still requires a human presence, which does not completely eliminate human error.
  - Maintenance of partial automation systems is often neglected.
  - Response time is not always optimized.

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3.3 Basic Automatic Gate Systems

- A few modern crossings are equipped with **basic automated barriers** triggered by train approach sensors placed near the track.
- These systems close the gate when the train nears the crossing and open it after it passes.
- **Limitations:**
  - o Expensive to implement at scale due to reliance on high-end equipment.
  - o Many systems are not integrated with **signal lights or displays**, leaving road users confused.
  - o Lack of real-time monitoring and communication with central railway systems.
  - o Failure in sensors or motors may cause serious accidents if not backed up with redundancy.

Summary of Existing System Drawbacks

- High **risk of accidents** due to human error or system malfunction.
- **No centralized monitoring**, making it difficult to track performance across multiple crossings.
- **Delayed operations** in manual and semi-automatic systems.
- **Costly and complex** maintenance in advanced automatic systems.
- Not aligned with modern **smart transportation and IoT** trends.
- **LCD Display:** Provides real-time information such as *Train Arriving*, *Gate Closing*, *Train Departed*, and *Gate Opening*.
- **Automatic Reset:** Ensures the ESP32 restarts after each cycle to prevent system hangs or logic errors.

2. Working Principle

1. **Train Detection:**
   - o When IR1 detects the arrival of a train, the system identifies an incoming train.
   - o LCD displays *Train Arriving*, LEDs switch (Red OFF, Green ON), and the motor lowers the gate.
2. **Gate Control:**
   - o The H-Bridge driver operates the DC motor to close the barricade securely before the train reaches the crossing.
   - o Red LED indicates "STOP" for vehicles and pedestrians.
3. **Train Passing:**
   - o While the train is between IR1 and IR2, the gate remains closed.
   - o LCD continuously updates the train status.
4. **Train Exit:**
   - o Once IR2 detects that the train has passed, the system triggers the gate opening sequence.
   - o Green LED indicates "GO," the motor lifts the gate, and the LCD displays *Train Departed.*
5. **System Reset:**

o After the gate is fully opened and the cycle is completed, the ESP32 resets automatically to ensure reliability for the next train detection.

3. Advantages Over Existing System

- **Fully Automated:** Removes the need for human operators.
- **Low Cost & Efficient:** Uses ESP32 and simple sensors, making it affordable for large-scale deployment.
- **Reliable & Safe:** Automatic reset prevents malfunction; gate always synchronizes with train movement.
- **Real-Time Updates:** LCD display and traffic signals provide clear communication to road users.
- **Scalable:** Can be enhanced with IoT integration (e.g., ThingSpeak, Telegram alerts, cloud monitoring).

IV.EXPERIMENTAL RESULTS & DISCUSSION

The proposed Railway Barricade Monitoring System is a fully automated, ESP32-based solution that ensures safe and efficient control of railway level crossings. The system integrates IR sensors, DC motor with H- Bridge, LCD display, and LED indicators to eliminate human dependency and minimize the chances of accidents.

1. System Overview

- ESP32 Microcontroller: Acts as the brain of the system, processing input signals from IR sensors and controlling gate movement, signals, and display.
- IR Sensors: Installed at both entry and exit points of the railway track near the crossing to detect train movement.
- DC Motor with H-Bridge: Controls the raising and lowering of the barricade gates based on sensor inputs.
- LED Traffic Signals (Red & Green): Guide road users — Red when the gate is closed, Green when it is safe to cross.
- LCD Display: Provides real-time information such as Train Arriving, Gate Closing, Train Departed, and Gate Opening.
- Automatic Reset: Ensures the ESP32 restarts after each cycle to prevent system hangs or logic errors.

2. Working Principle

Train Detection:

- o When IR1 detects the arrival of a train, the system identifies an incoming train.
- o LCD displays *Train Arriving*, LEDs switch (Red OFF, Green ON), and the motor lowers the gate.

Gate Control:

- o The H-Bridge driver operates the DC motor to close the barricade securely before the train reaches the crossing.
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- While the train is between IR1 and IR2, the gate remains closed.
- LCD continuously updates the train status.

Train Exit:

- Once IR2 detects that the train has passed, the system triggers the gate opening sequence.
- Green LED indicates "GO," the motor lifts the gate, and the LCD displays *Train Departed*.

System Reset:

- After the gate is fully opened and the cycle is completed, the ESP32 resets automatically to ensure reliability for the next train detection.

V. WORKING

The Railway Barricade Monitoring System works on the principle of automatic train detection and gate control using an ESP32 microcontroller. The system continuously monitors the railway track using IR sensors and operates the barricade gates, traffic lights, and LCD display accordingly.

Step-by-Step Operation

1. **Idle State (Gate Open):**
   - When no train is detected, the **barricade remains open**.
   - The **Green LED is ON**, signaling vehicles and pedestrians that it is safe to cross.
   - LCD displays "Railway Barricade Monitoring – Gate Open."
2. **Train Detection at Entry (IR1 Triggered):**
   - When a train passes **IR Sensor 1 (IR1)**, the ESP32 detects the **arrival of the train**.
   - LCD updates to "Train Arriving – Gate Closing."
   - The **Red LED is turned ON**, while Green is switched OFF.
   - The **DC Motor (via H-Bridge)** rotates to **close the barricade gate**.
3. **Gate Closed State:**
   - The barricade is fully lowered before the train reaches the crossing.
   - Vehicles and pedestrians are **stopped by the red signal**.
   - The LCD displays "Train Passing – Please Wait."
4. **Train Detection at Exit (IR2 Triggered):**
   - As the train leaves the crossing, it passes **IR Sensor 2 (IR2)**.
   - The system detects that the train has safely departed.
   - LCD updates to "Train Departed – Gate Opening."
5. **Gate Opening:**
   - The **DC Motor (via H-Bridge)** rotates in the opposite direction to lift the barricade gate.
   - The **Red LED switches OFF**, and the **Green LED turns ON**.
   - Vehicles and pedestrians are now allowed to cross.
6. **Cycle Completion & Auto Reset:**
   - After the gate is fully opened, the ESP32 **automatically resets**.
   - This ensures the system is ready for the next train arrival without manual intervention.

Pin Number	Pin Name	Description
1	Enable 1,2	This pin enables the input pin Input 1(2) and Input 2(7)
2	Input 1	Directly controls the Output 1 pin. Controlled by digital circuits
3	Output 1	Connected to one end of Motor 1
4	Ground	Ground pins are connected to ground of circuit (0V)
5	Ground	Ground pins are connected to ground of circuit (0V)
6	Output 2	Connected to another end of Motor 1
7	Input 2	Directly controls the Output 2 pin. Controlled by digital circuits
8	Vcc2 (Vs)	Connected to Voltage pin for running motors (4.5V to 36V)
9	Enable 3,4	This pin enables the input pin Input 3(10) and Input 4(15)
10	Input 3	Directly controls the Output 3 pin. Controlled by digital circuits
11	Output 3	Connected to one end of Motor 2
12	Ground	Ground pins are connected to ground of circuit (0V)
13	Ground	Ground pins are connected to ground of circuit (0V)
14	Output 4	Connected to another end of Motor 2
15	Input 4	Directly controls the Output 4 pin. Controlled by digital circuits
16	Vcc2 (Vss)	Connected to +5V to enable IC function

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VI. CONCLUSION

The proposed Railway Barricade Monitoring System using ESP32 successfully addresses the safety and operational challenges faced at railway level crossings. By integrating IR sensors, DC motor with H-Bridge, LCD display, and traffic signal indicators, the system ensures automatic detection of trains, timely gate operation, and clear communication to road users. Unlike traditional manual and semi-automatic systems that depend heavily on human intervention, this project offers a fully automated, low-cost, and reliable solution that minimizes human error and reduces accidents at unmanned and rural railway crossings. The inclusion of an automatic reset mechanism further enhances system reliability by ensuring smooth functioning after each cycle. The system's scalability allows it to be extended with IoT features such as cloud-based monitoring, real-time alerts through Telegram or Thing Speak, and integration into smart city infrastructures. This makes it a future- ready solution for modern railway safety management. In conclusion, the project demonstrates that automation in railway barricade monitoring is not only feasible but also essential for improving safety, reducing costs, and building smarter transportation systems. With further enhancements, it can become a vital component of intelligent railway infrastructure worldwide.

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