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Microcontroller – Based Automatic Railway Crossing Control and Track Obstacle Monitoring System

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Abstract: In many countries, a significant number of accidents occur at unmanned level crossings, where the lacks of human supervision and obstacles on the tracks have become serious daily concerns. Traditionally, railway gates are operated manually by gatekeepers. This paper proposes replacing manual operations with an automated railway gate system utilising Arduino, Sensors, Servo Motors, Buzzers and GSM modules to eliminate human intervention and reduce accident risk. The system detects trains and track objects using sensors positioned alongside the tracks. When a train approaches, the gate closes automatically and the system issues alerts to prevent accidents. Once the train departs, the gate reopens. Compared to manual operation, the automated gates are closed for a shorter duration. Obstacle detection is achieved in two ways: sensors at the front of the train sense objects on the track, and detected obstacles are communicated to nearby railway stations via GSM technology. The system employs infrared sensors to monitor train arrival and departure, ultrasonic sensors for obstacle detection, and Arduino to manage gate operation and messaging. The automated approach improves safety, efficiency and reliability at rail crossings.

Keywords: Arduino, GSM modem, Obstacle, Infrared sensor, Ultrasonic sensor

I. Introduction

Railway level crossings, where roadways and railway tracks intersect at the same elevation, are critical points of safety concern. These crossings may be either manned or unmanned, with the latter being more prone to accidents due to human negligence, delayed gate operations, or shortage of manpower. To reduce such risks, this work presents an automated railway gate control and obstacle detection system based on simple electronic components and microcontroller technology.

The system employs vibrant sensors mounted on the track to detect the movement of train wheels and notify a microcontroller (Arduino) of the train's approach. Once addition, an ultrasonic sensor positioned at the train's front end continuously monitors for obstructions on the tracks or the presence of an oncoming train from the opposite direction. Upon detecting an obstacle, the microcontroller triggers a GSM module that sends immediate warning messages to predefined contacts, enabling timely action.

By automating gate control and integrating real-time obstacle detection with GSM communication, the proposed system significantly reduces the chances of accidents at level crossings and minimizes the likelihood of train collisions

Rail Accidents Statistics

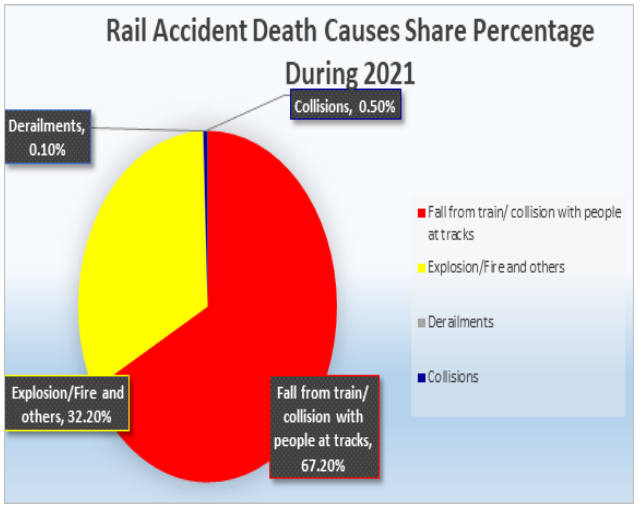

Fig. 1 Illustrates the percentage of railway accidents in India due to various reasons during 2021.

Railway accidents have numerous underlying causes, but incidents at level crossings represent the highest percentage among them. Based on recent data, collisions at level crossings and accidents involving pedestrians on tracks account for approximately 67% of all railway-related accidents. These often result from mistakes made by gate operators or the absence of personnel at unmanned crossings. The adoption of automated gate systems at these intersections can significantly decrease, or even prevent, such accidents.

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II. System Architecture

Overview of the proposed System:

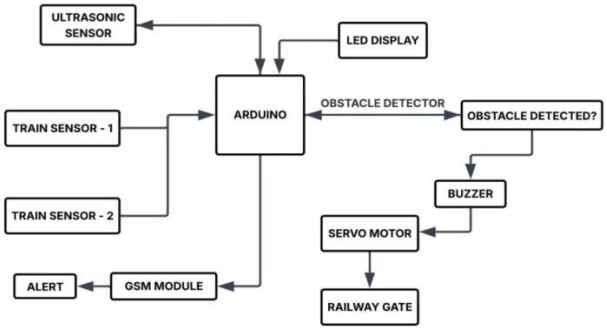


Fig 2 System Block Diagram

The Arduino UNO ATMEGA328 serves as the central processor in the automated railway crossing system. It coordinates input from infrared sensors, which are tasked with detecting when trains approach or leave the level crossing area. For track safety, an HC SR04 ultrasonic sensor is mounted to identify obstacles ahead. When an obstacle is detected, the system uses a SIM900A GSM module to notify the nearest railway station, supporting rapid incident response.

Gate operation is handled by a servo motor controlled by the Arduino, allowing automatic opening and closing of barriers in sync with train movements. Additionally, road users are kept informed through indicator signals – LED lights and buzzers – activated by the microcontroller. As soon as a train is sensed to be incoming, the system switches the traffic indicator to red and ensures the gate remains closed until the railway crossing is clear.

Upon detecting the train's departure, the controller changes the traffic light to green and activates the servo motor to open the gate for vehicles.

The fully automated mechanism minimizes manual intervention and helps reduce risks at railway crossings by integrating sensor-based monitoring and wireless communication.

Function Modules:

The architecture of the system is divided into following primary modules:

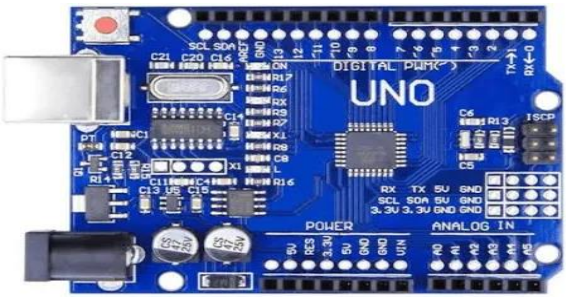
a. Train Detection Module

Components: Two pairs of IR transmitter-receiver sensors

***Functionality*:** Vibration Sensor detects train wheels on the track and sends signal to Arduino/Microcontroller

b. Microcontroller Unit

***Model used*:** Arduino UNO (ATMEGA328)



***Functionality*:** Receives input from sensors, processes data, and performs decision-making, and controls the gate motor and communication modules.

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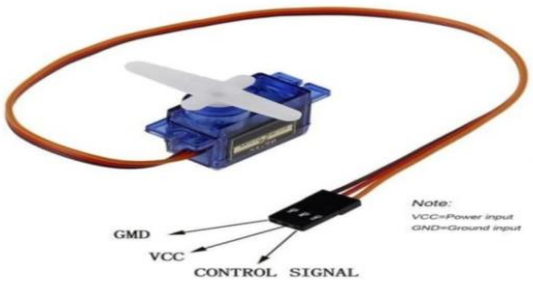
***Power Supply*:** 12V regulated DC supply with buck converter for 5V logic level**.**

c. Gate Control Mechanism

***Components*: Servo Motor, Buzzer**



Control Logic: Operated via relays controlled by microcontroller and automatically lowers gates when train approaches and raises them after the train passes.

A buzzer is an audio signal device, which may be mechanical, electromechanical or piezoelectric type. It contains a built-in oscillator, and only need to provide a steady DC voltage to produce a sound.

d. Traffic Signal Integration

Components: Red and Green LED's

***Function*:** When gate is closed, red signal flash for road traffic. When the gate is open, green signals allow vehicle to proceed.

e. GSM Module

Model used: GSM Modem SIM900A

Control Logic: When an obstacle is detected, the system uses a SIM900A GSM module to communicate over cellular networks for voice calls, sending messages to the nearest railway station, supporting rapid incident response.

f. Ultra Sonic Sensor

Model used: HC SR04

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Control Logic: The ultrasonic detector module consists of a transmitter, a receiver and a control circuit. It is used to measure the distance of the obstacle in front of it. It interfaces with a microcontroller using two primary pins: a trigger pin (output) and an echo pin (input). The sensor operates at DC voltage of 5V with a current consumption of approximately 15mA. It functions at a frequency of 40 kHz, with a detection range between 2 centimetres (minimum) and 4 meters (maximum). An ultrasonic wave is sent from transmitter of the module, and then the wave is reflected back and received at the receiver.

III. Flowchart

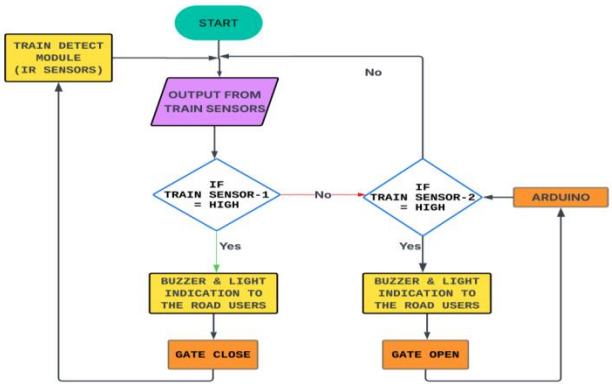

Fig 3 Flow chart for automatic railway gate control

At the beginning, the train module which consists of two (IR) transmitter-receiver sensors to detect both the arrival and departure of the trains. When a train approaches, the train sensor-1 is triggered, sending a **'HIGH'** signal. This activates the Buzzer and Light indicators to alert road users, and the gate is **'CLOSED'** by the servo motor. Once the train departs the crossing, then the train sensor-1 deactivates, and the train sensor-2 is triggered, and its output goes **'HIGH'.** This signal turns '**OFF'** the Buzzer and Light indicators, and the gate is **'OPENED'** by the servo motor, allowing normal traffic flow.

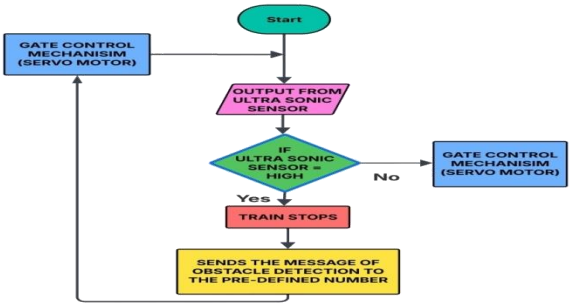

Fig 4 Flowchart for obstacle detection system

In the system, an ultrasonic sensor is mounted at the front of the train to detect any obstacles on the track. If an obstacle is detected, the sensor's output becomes 'HIGH', prompting the train to stop. Simultaneously, a notification about the obstacle is sent to predefined number with the help of the GSM module at the nearby railway station, and the gate automatically closes via the servo motor for safety.

IV. Model of Proposed System

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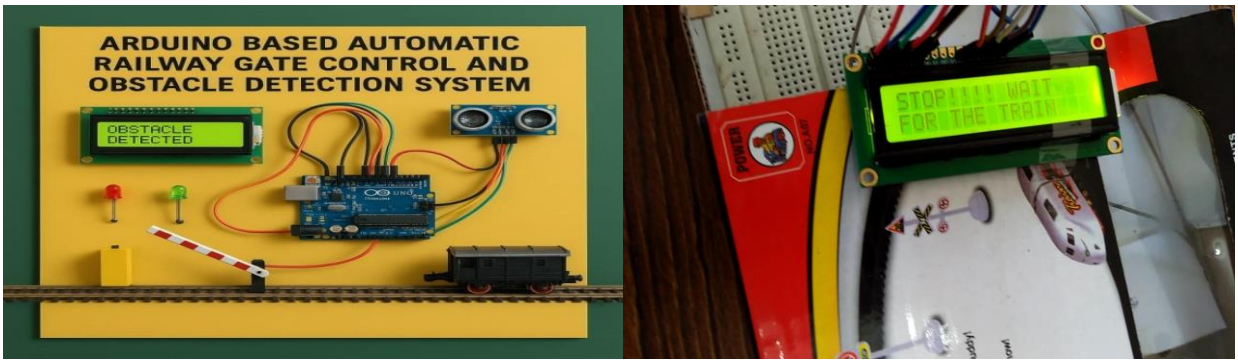
V. Experimental Results

The proposed system was tested as a working model prototype. It features an 90 cm diameter railway track, a toy train with an ultra-sonic sensor for obstacle detection and two infrared sensors, a servo motor for gate operation, four LED's acting as traffic signals, a GSM modem for message communication, and a buzzer to alert road users.

For gate operation, IR sensors are positioned 35 cm on each side of the crossing. When the toy train triggers the first sensor, the system activates a RED LED to warn the traffic and closes the gate by using the servo motor. The gate reopens and the LED turns off once the train's departure is sensed by the second IR sensor.

Obstacle detection is handled by an ultrasonic sensor mounted at the front of the train. If an obstacle is found on the track, the system sends a signal to the control room and notifies the nearby railway station via GSM technology. The train's movement is managed based on the sensor's feedback, ensuring safety and prompt action. The prototype system was constructed and tested using several key components: an 90 cm diameter railway track, a toy train, two infrared sensors, one ultrasonic sensor, a servo motor for gate operation, four LEDs as traffic signals, a GSM modem for alerts, and a buzzer for notifications.



VI. Conclusion

The automatic railway gate control system is centered on the idea of reducing human involvement for closing and opening the railway gate, which allows and prevents accidents near the level crossing. The railway gate is a cause of many deaths and accidents. Hence, automating the gate can bring about a ring of surety in controlling the gates. Humans may make errors or mistakes, so automating this process will reduce the chances of gate failures and reduce the errors made by gatekeepers. The accidents are avoided at places where there is no person to manage the railway crossing gates. Here we use the servo motor to open and close the gates automatically when it rotates clockwise or counter clockwise to operate the gate automatically.

In the obstacle detection part, the ultrasonic sensor sensed the obstacle, and the train stops as soon as the obstacle detection message is conveyed to the nearby railway station, as well as to the train operator. So through this system, any obstacle on track can be detected and an accident can be avoided, and also the message has been conveyed to the concerned.

Future Scope

The accidents due to railway level crossings and the obstacles can be avoided in real time by implementing this system, and the whole process is completely automatic. In the future, features like wireless system, camera module for real-time video surveillance, solar-powered version for energy efficiency, AI-based image recognition to detect human/animal on tracks, etc., can be implemented in the real-time operation.

In the future operations, the vibration sensors can be used in place of IR sensors for the detection of the arrival and departure of trains. Comparatively, the vibration sensor serves better than IR sensors in real-time. And also, the GPS can be implemented and interfaced with the circuitry. The GPS ensures that the correct location of the obstacle can be sent to the nearby railway station through a GSM modem. This helps to get the exact location of the obstacle so that the work for the clearance of the obstacle can be done faster.

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