Automated Railway Crossing System: A Secure and Resilient Approach

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October 31, 2023

Abstract

In today's world, the railway has emerged as a shining example of an environmentally friendly and well-linked mode of transportation, particularly in significant metropolises worldwide. Its popularity stems from its widespread use and its inherent comfort to commuters. A key aspect that bolsters this appeal is the railway network's well-earned reputation for being the safest and most efficient transportation system. However, railway crossings remain perilous, challenging traffic control and safety. To address this concern, we propose an innovative and automated railway crossing system that promises to revolutionize how we approach railway safety. Our automated railway crossing system encompasses multiple essential features to ensure unparalleled safety and efficiency.

First and foremost, the heart of this system lies in its automatic control of the railway crossing gates. By removing the need for manual operation, the potential for human errors is significantly reduced, providing commuters with an added layer of assurance during their journeys. In addition, our system boasts an advanced warning mechanism designed to alert approaching traffic well before the gate closure. This crucial feature enhances the safety of vehicular traffic and pedestrians by giving them ample time to prepare for the crossing. A clear and user-friendly LCD display serves as the medium for this alert system, making it intuitive and visually accessible to all users. Understanding the value of commuters' time, we have also integrated a real-time counter into the system. This counter keeps track of the estimated waiting time, empowering commuters to know when they can expect the gates to open again. With this feature, we strive to minimize inconvenience and optimize the efficiency of railway crossings. In our relentless pursuit of safety, we have taken it further by incorporating innovative anti-collision and line-breaking technology. By actively detecting potential collisions and disruptions, our system acts as a vigilant guardian, thwarting accidents and safeguarding lives.
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Abstract—In today’s world, the railway has emerged as a shining example of an environmentally friendly and well-linked mode of transportation, particularly in significant metropolitan areas worldwide. Its popularity stems from its widespread use and its inherent comfort to commuters. A key aspect that bolsters this appeal is the railway network’s well-earned reputation for being the safest and most efficient transportation system. However, railway crossings remain perilous, challenging traffic control and safety. To address this concern, we propose an innovative and automated railway crossing system that promises to revolutionize how we approach railway safety. Our automated railway crossing system encompasses multiple essential features to ensure unparalleled safety and efficiency. First and foremost, the heart of this system lies in its automatic control of the railway crossing gates. By removing the need for manual operation, the potential for human errors is significantly reduced, providing commuters with an added layer of assurance during their journeys. In addition, our system boasts an advanced warning mechanism designed to alert approaching traffic well before the gate closure. This crucial feature enhances the safety of vehicular traffic and pedestrians by giving them ample time to prepare for the crossing. A clear and user-friendly LCD display serves as the medium for this alert system, making it intuitive and visually accessible to all users. Understanding the value of commuters’ time, we have also integrated a real-time counter into the system. This counter keeps track of the estimated waiting time, empowering commuters to know when they can expect the gates to open again. With this feature, we strive to minimize inconvenience and optimize the efficiency of railway crossings. In our relentless pursuit of safety, we have taken it further by incorporating innovative anti-collision and line-breaking technology. By actively detecting potential collisions and disruptions, our system acts as a vigilant guardian, thwarting accidents and safeguarding lives.

Index Terms—IR sensor, LED, Servo Motor, GPS tracking, Direction detection, safety wire

I. INTRODUCTION

Road accident at railway gate is prevalent and a leading cause of death and injury worldwide. So Rail transportation is meeting critical questions in our daily life. On the other side, it has to face the basic requirements of people to be superior in transporting without difficulty and safely. At the same time, it must also offer a legitimate option to other transport nodes alongside a backdrop of increasing fuel costs and enhancing the meaning validity of transportation around the surroundings. In the present system, the gates are turned on physically, which could conduct to human boob. There are two primary categories of level crossings on the Bangladesh Railway: guarded and unguarded. Nowadays, swing-type gates, movable barriers, or chains are utilized while a train passes a protected level crossing. Railway watchmen often maintain and operate the gate or portable fence. The watchmen ensure that every train crosses the level crossing once they have closed the level gates. These gates can be opened and closed automatically or manually. Contrarily, no such mechanism is employed at unattended level crossings, which increases the risk of accidents involving passing cars and running trains. There are currently 3,111 level crossings along the nation’s 3,093-kilometer-long railway network. According to the most recent Bangladesh Railway (BR) statistics, 1,225 crossings, or around 40%, are illegal [1].

Over half of the 1,886 legal level crossings also need a dedicated gatekeeper. Presently, between Jurine and Abdullahpur in Dhaka city, there are 42 railroad level crossings and 6 railroad stations. According to Bangladesh Railway (2008), 29 level crossings are approved, 13 are not, 20 are connected to important highways, and 22 are connected to minor roads [2]. Figure 1 demonstrates number of accident data from 2007 to 2017. 175 persons perished in railroad incidents between 2014 and 2020, according to information made by Bangladesh Railway (BR). Out of them, 145 of them altogether, or 83%
of all train accident fatalities happened at level crossings [3].

In summary, in this research work, we make the following contributions:

- In this system, we introduced how to prevent collisions between trains. Besides that, this system can detect a rail coming and automatically close the crossing gate. While the train is coming, it warns to close and open the gate so the traffic can quickly and safely pass the gate before the train arrives.
- Besides that, we proposed a manual override control system to handle any emergency situation. In this paper, we also worked with line-breaking issues.
- In this article, we consider this system’s essential hardware components and software components, block diagrams and control flow of this system, hardware and software implementation, and performance analysis on a real-time scenario for this system.

II. BACKGROUND STUDY AND MOTIVATION

In this section, we represented some challenges in railway automation. This motivated us to provide a solution to address all the identified challenges. Moreover, we included all the recent technologies and existing research works that encourage us to move forward.

A. Why do we need an automated rail-crossing system?

Automated rail crossing systems have several advantages over traditional physical rail crossing systems, which is why they are becoming increasingly popular. Here are some of the key reasons why we need automated rail crossing systems:

- Increased safety: Automated rail crossing systems are designed to operate automatically, significantly reducing the risk of human error and making them safer.
- Automated systems are equipped with sensors that can detect the approach of vehicles and pedestrians and automatically close the gates when necessary, which minimizes the risk of accidents.
- Greater efficiency: Automated rail crossing systems can operate more efficiently than physical systems because they do not require manual intervention. They can detect approaching trains and close the gates promptly, reducing the time drivers and pedestrians have to wait.
- Improved traffic flow: Automated rail crossing systems can help to improve traffic flow by reducing delays and minimizing congestion. They can detect approaching trains and close the gates quickly, which allows traffic to continue moving smoothly.
- Reduced maintenance costs: Automated rail crossing systems typically require less maintenance than physical systems because they have fewer moving parts. This can result in lower maintenance costs over time.
- Improved accessibility: Automated rail crossing systems can be designed to be more accessible for people with disabilities by providing audio or visual signals to indicate when it is safe to cross.

B. Challenges that Physical rail crossing face:

Without automation, physical train crossing systems face several difficulties that may lower safety and efficiency. Some of the most severe challenges are as follows:

**Human error**: Physical rail crossing systems rely on human operators to open and close the gates, which can lead to mistakes and accidents. Human error is a common challenge in physical rail crossing systems where a human operator may make mistakes due to distraction, fatigue, or lack of training, leading to accidents or delays. For instance, the operator may need to remember to close the gates after a train has passed, or they may open the gates too early, causing a collision with an approaching train. Similarly, if the operator is distracted, they may not notice an approaching train, leading to an accident.

**Limited visibility**: Physical rail crossing systems can be obstructed by Greenery, Structures, or other objects, limiting visibility and making it difficult for drivers and pedestrians to see approaching trains.

**Inadequate warning systems**: Inadequate warning systems are another challenge that physical rail crossing systems can face. Warning systems are essential for alerting drivers and pedestrians of the presence of an approaching train and the need to stop or wait for it to pass. When these warning systems are inadequate or not in place, it can make it difficult for people to be aware of the potential danger, leading to accidents.

For example, physical rail crossing systems may have warning signs that are difficult to see or lights that are not bright enough to be noticed in daylight or in adverse weather conditions. In some cases, there may be no warning systems at all, leaving drivers and pedestrians unaware of the presence of a train until it is too late.

**Poor maintenance**: Physical rail crossing systems require regular maintenance to ensure they are in good working order and to address any issues before they become a safety hazard. Neglecting maintenance can lead to malfunctions such as faulty gates, broken lights or warning systems, and deteriorating road surfaces, all of which can contribute to accidents. For example, a malfunctioning gate that fails to close correctly can allow vehicles to enter the crossing area...
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**Weather conditions:** Adverse weather conditions, such as heavy rain, fog, or snow, can make it difficult for drivers and pedestrians to see approaching trains and increase the risk of accidents.

**Increased waiting time:** Physical rail crossing systems that rely on a manual operation by human operators can result in increased waiting times for drivers and pedestrians, which can be a challenge. When an approaching train triggers the crossing system, the operator must manually lower the gates before the train passes. After the train has passed, the operator must raise the gates manually before traffic can resume. Depending on the frequency of trains and the number of vehicles and pedestrians waiting to cross, this can result in significant waiting times and delays.

**Train speed:** Trains traveling at high speeds can raise safety concerns. One of them is related to the ability of drivers and pedestrians to accurately judge the distance and speed of the approaching train. At high rates, trains cover a significant space quickly, making it challenging for people to estimate how far away the train is and how fast it’s moving. This can be especially problematic at railway crossings or when pedestrians walk near railway tracks. Additionally, high-speed trains can generate strong winds and create a lot of noise, posing safety risks for people near the tracks. Therefore, following proper safety procedures and regulations when driving or walking near railways is essential, especially when high-speed trains are present.

The above-specified challenges motivated us to work on this research work. To reduce the risk of human error, physical rail crossing systems require careful management and training of operators to ensure that they follow proper procedures and remain vigilant at all times. However, our automated rail crossing systems able to solve this problem by eliminating the need for human operators’ projects altogether and instead relying on sensors and computerized controls to detect and respond to approaching trains. Additionally, automated rail crossing systems typically have advanced warning systems that can be triggered automatically when a train is coming, which can further improve safety and reduce the risk of accidents caused by inadequate warning systems. Regular maintenance and inspections of physical rail crossing systems are necessary to ensure they remain in good working order. Maintenance should include periodic checks of gates, warning systems, lights, and road surfaces and repairs or replacements as necessary. By promptly addressing maintenance issues, the risk of accidents caused by malfunctions can be significantly reduced, but it costs a lot of money. Whereas automated rail crossing systems typically have fewer moving parts and require less maintenance, which can reduce the risk of accidents caused by poor maintenance. Physical rail crossing systems may require additional measures to manage traffic flow and reduce waiting times. However, an automated rail crossing system can solve this challenge by eliminating the need for manual operation and reducing waiting times.

Automated systems can detect approaching trains and lower and raise the gates automatically, minimizing delays and improving traffic flow. An automated rail crossing system can also help to address this challenge by providing advanced warning systems that can detect and respond to fast-moving trains more quickly and accurately than human operators. Automated systems can trigger warning systems earlier, giving drivers and pedestrians more time to react and reducing the risk of accidents caused by high-speed trains.

**III. Literature Review**

This section provides a concise synopsis of recent research conducted in this specific domain. Anand et al. [4] proposed a gate that is able to sense the incoming train using sensors and regulate gate operational and traffic signals. Their proposed approach detected an obstacle along the path of a train while the gate is closed.

Shetty et al. [5] used a camera installed near the level crossing that detects any object between the tracks while the train is crossing. If the sensor detects any pedestrian or vehicle, their proposed algorithm automatically will open the gates to let the stuck object cross.

Ghosh et al. [6] proposed a smart railway crossing system in Bangladesh using two infrared sensors controlled by an Arduino Uno. The system operates on sustainable renewable energy, aligning with the national green energy policy. The system optimizes results for the Levelized Cost of Energy (LCOE) and payback periods, contributing to sustainable development and combating climate change challenges in Bangladesh.

Omkar et al. [7] proposed a single-shot object detection algorithm for detecting people, any kind of moving objects, or animals on the crossing line using a camera planted on the bank of the line. The camera captured the image which is fed through the algorithm that later is classified if there are any obstacles such as a truck or animal stuck in between the gates of the crossing line. If any object is detected, then the algorithm informed the closest two station about the situation of the crossing path and instruct the train to slow down.

Pavel et al. [8] proposed a novel system architecture based on object detection and classification which is "Artificial Intelligence-Based Surveillance System for Railway Crossing Traffic”. Several cameras are used in this design to capture the surrounding image of the crossing line and are classified as any of these categories such as vehicle or pedestrian presence, vehicle trajectory tracking, railway barriers or warnings, and light signaling systems. Furthermore, in detecting any of the aforementioned categories, the system will automatically notify emergency services through a central server. From the field-based result, they have achieved 89% recall using YOLO tiny model which significantly shows the system’s capability to evaluate the incident of objects stuck in the crossing line.

**IV. Hardware and Tools**

The hardware and related tools used in our system are described in the following:
A. IR Sensors

In our proposed system, we used IR sensors to detect the presence of trains. IR sensors emit radiation and sense an object based on the radiation it receives. Additionally, IR sensors can accurately measure the heat that an object radiates, making them useful for sensing motion [9]. By using IR sensors in our system, we can reliably detect the presence of trains and trigger the necessary actions accordingly. Figure 2 shows the active IR sensor’s emitting and receiving radiation.

B. Servo Motor

A Servo Motor [3] is a specialized actuator that controls position, velocity, and acceleration precisely. Our proposed system has incorporated a servo motor to automatically open and close a gate. By using the servo motor, we can precisely control the position of the gate, ensuring that it opens and closes smoothly and without any errors. This improves the overall functionality and efficiency of the gate system, providing a reliable and convenient solution for users.

C. Arduino Uno

The Arduino Uno [4] is a compact, single-board microcontroller that is capable of controlling a wide range of systems as the central processing unit. With its built-in input and output pins, the Uno can interface with a variety of sensors, actuators, and other peripheral devices to create a complete system. In our proposed approach, the Arduino Uno is the central control unit, performing as a mini-computer to control the entire system. By utilizing Uno’s versatile capabilities, we can create a highly functional and customizable system that can meet a wide range of requirements.

D. LCD Display

LCD [5] stands for liquid crystal display, a technology commonly used for presentations in smaller computers and notebooks. In our proposed system, we have integrated an LCD as our primary display, which can show warning messages in case of potential collisions between two trains or line-breaking situations. By utilizing the precise and compact display of the LCD, we can provide users with vital information in real-time, allowing them to take appropriate action to avoid accidents or other critical events.

E. Buzzer and LED

In our proposed system, we have incorporated a buzzer and LED [6] as part of our warning system. The buzzer, or a beeper, is an audio signaling device that can produce a loud warning sound to alert users of potential dangers. On the other hand, the LED is a light-emitting diode that serves as a traffic light signaling device to provide users with a visual warning signal. Together, the buzzer and LED form an effective warning system that can provide users with audio
and visual alerts in case of potential hazards. By integrating these devices into our central system, we can create a reliable and efficient warning system that can help prevent accidents and improve safety.

V. PROPOSED METHOD

The primary function of our project is to close the road when the train is passing through by the road and also detect the broken line. The extra future of our project is to make a considerable alarm and warning by red light if two trains are on the same line and opposite direction. This study used Arduino Uno as a motherboard, open-source software, and Arduino IDE for compiling the code. Here two sensors (TCRT-5000) are used for detecting the train, a buzzer for alarming, one red and one green led for the traffic signal, an LCD display to show the message, and a servo motor to open and close the gate. Now we are going to describe how it works. Here we have used a power distributed circuit for distributing power for each device. We have set up the sensor (TCRT-5000) in two specific points. TCRT-5000 sensors are IR-based sensors. It has two parts. One emits IR light, and one IR photo transistor. When IR light is reflected, the current will flow through the transistor; otherwise, there will be no current flow. We used a white surface before the train to detect the train. When the train crosses the first sensor, the alarm will start, and the message will show that: “STOP! Train is crossing the road” red led will turn on, and the servo motor will close the gate. When the train crosses the second sensor, the alarm will stop, the green led will turn on, the message will show “GO!, Road is clear”, and the gate will open. If the train detects two sensors, the alarm will start, the red signal will be shown, and the LCD will print, “Two trains are same line. Please stop both trains”. We have used a hidden wire to detect broken lines, which work as the circuit breaker. If the circuit breaks, the line is broken, the alarm will start, and the LCD will print, “Stop!!! The line is Broken”. We can also use vibration sensors and speed-sensing wires to sense the train. Figure 7 shows the block diagram of our proposed system.

VI. FLOW DIAGRAM OF THE SYSTEM

Here is a flow chart of our proposed system that shows how the system interacts with its components, responds
VII. ADVANTAGES AND FEATURES

The key features and the advantages of our proposed system over existing systems are given below:

- Automatic gate control
- Anti-collision support
- Line-breaking detection support
- Low cost
- Fully automatic no need for human expertise
- The visual and audio output makes it more user friendly
- Time-saving system

VIII. IMPLEMENTATION AND SIMULATION

As part of our study, we have conducted simulations to demonstrate the implementation of our rail crossing system. Our simulations encompass a variety of scenarios that could occur at a rail crossing, and we have demonstrated how our system would respond to each situation. Our system includes a gate that can control traffic, a display screen that shows warning messages, and an audio alert system with LED lights that can provide red and green signals to direct traffic. By simulating these different scenarios, we can show the effectiveness of our approach in preventing accidents and ensuring the safety of drivers and pedestrians at rail crossings. Overall, our simulations demonstrate the robustness and reliability of our system and highlight its ability to provide real-time warnings and signals to prevent accidents and improve safety at rail crossings. Figure 9 shows the simulation of our proposed whole system. The first function of our proposed system is automated gate control. When a train approaches the rail crossing, the system utilizes IR sensors to detect the train’s presence. Once the train is detected, the display screen shows a warning message indicating a train is approaching. At the same time, the microcontroller receives the signal from the sensors and sends a command to the servo motor to close the gate.

When the train is sensed by the sensor display shows the warning massage. After the train passes the rail crossing, the gate opens to allow traffic to resume. This action is also detected by another IR sensor that tracks the train as it moves away from the crossing. Once the train has passed, the sensor sends a signal to the microcontroller, which then commands the servo motor to open the gate. By using IR sensors to detect the presence of trains, we can automate the gate control process and ensure that traffic is stopped when trains are passing through. This helps to prevent accidents and improve safety at rail crossings. Additionally, by providing a clear message on the display screen to obey traffic rules, we can promote safe driving practices and help prevent accidents and
injuries at the crossing

Now the system’s second function is a collision of two train detection. Audio alerts and display warnings are displayed when two trains are detected on the same track in the face-to-face direction. Two IR sensors track the train’s path and position in this function. This function is activated if two trains are found in the same line in a face-to-face direction. By detecting potential collisions and providing clear warnings to train operators and drivers, we can significantly reduce the risk of accidents and improve safety at rail crossings. This function is crucial for ensuring the safety of passengers and preventing potentially catastrophic collisions between trains.

Our proposed system’s third and final function is to detect broken railway lines and alert the appropriate authorities to repair them. This function is accomplished using safety wires placed along the railway tracks. If the safety wires detect a broken line, the microcontroller receives a signal and triggers the display to show a warning message. At the same time, the audio alert system is activated and rings continuously until the line is repaired. By detecting broken lines and providing timely warnings, our system helps prevent accidents and ensure the safety of train passengers and crew safety. This function is a cost-effective way to improve safety and avoid accidents, as it utilizes simple safety wires and requires minimal maintenance.

IX. CONCLUSION AND FUTURE SCOPE

The collision avoidance system is sporadic in most of the city. In our system, we developed and implemented a system containing three main key features that can save money and time and provide security for safe rail gate passing. With the proper implementation in our real-life scenario, it can make a huge difference in our daily traffic system, and it can save many soles. In our approach, we implemented three different functions that are necessary for any rail crossing and railway system. Those are Anti-collision, automated gate controlling, and broken line detection. Besides that, we can develop a rule-based expert system (AI) that can handle all functions of the system and traffic control when a collision or line breaking has occurred that is not present in our system. We can also provide speed-based and vibration-based alert systems. Besides, the train’s vibration can produce energy in the same way as foot energy. We implemented our system with IR sensors, which can also be done with Speed wire and vibration sensors.

REFERENCES