IOT based Railway Crossing Gate Status detection and Security Code Generation System based on ESP8266

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Abstract - In rapidly developing nations like India, the railway system plays a pivotal role in facilitating transportation for the population. However, the safety of level crossing gates within this extensive railway network is of utmost importance and requires careful consideration. Unfortunately, due to human oversight, a significant number of accidents occur daily at these junctures, prompting a pressing need for technological interventions to address this issue. This study delves into two key approaches: firstly, the automation of railway gate operations at level crossings to streamline closure processes and reduce human involvement. A practical demonstration of this concept is showcased through a scaled-down model, which effectively tackles the challenge at hand. In this model, strategically positioned sensors near the level crossing gates detect approaching trains at a predetermined distance from the railway track. Subsequently, these proximity sensors relay signal pulses to a controller situated at the level crossing site, triggering motor activation for automated gate closure and opening. Secondly, the focus shifts towards monitoring the status of the crossing gates. Instances occur where gatekeepers unintentionally overlook gate closure and fail to communicate the security code to the station master, potentially leading to accidents. To address this issue, a system is proposed to generate the security code upon detecting the status of the railway gate, utilizing microcontrollers, LCD displays, and proximity sensors.

***Key Words*:** Railway Gate, Sensors, Microcontroller, IOT

1. INTRODUCTION

The innate human inclination for travel, be it for leisure or daily commitments, is undeniable. Individuals often select transportation modes based on personal preferences and convenience factors. Railways emerge as a favored means of travel, esteemed for their time efficiency and cost-effectiveness in comparison to roadways. India proudly hosts the fourth-largest railway network worldwide, with approximately 49% of its routes electrified and 33% featuring double or multi-tracking. Consequently, the extensive presence of level crossing gates throughout the country becomes indispensable. Nonetheless, overseeing a large number of these gates presents considerable challenges, highlighting the imperative need for automation to ensure precision and accuracy in their management.

Automated level crossings are strategically incorporated into railway lines to facilitate the efficient regulation of road traffic. These crossings come in different types, such as Road Over Bridges (ROBs) or Road Under Bridges (RUBs), each catering to specific requirements. The design of level crossing gates typically incorporates locking mechanisms, such as hasp and staple types or two chains with loops, ensuring compliance with standardized lifting barrier configurations. Manned level crossings are equipped with spare chains and prominently displayed red-painted discs labeled "stop," strategically positioned near the tracks and overseen by distinct operating departments.

This prototype model prioritizes automated gate operation, aiming to minimize manual tasks and maintenance demands post-deployment. A critical aspect of this model is the generation of security codes, which plays a vital role in ensuring gate closure prior to code issuance, thereby enabling station masters to conduct status checks efficiently. The implementation of such a system holds the promise of substantially reducing accidents at level crossings and mitigating human errors. By harnessing open-source IoT platforms, cost-effective microcontrollers, and the widespread availability of the internet, the railway sector can adopt automated solutions to enhance safety standards and improve the overall passenger experience.

Fig-1. Railway Crossing Gate

In essence, the proposed system offers a proactive approach to mitigating railway accidents, leveraging technological advancements for efficient gate management and improved traveler safety.

2. LITERATURE REVIEW

According to L. N. Pattanaik, Gaurav Yadav (2015)

This paper introduces a decision support framework tailored for automated railway level crossings (LC) employing fuzzy logic control (FLC). Its aim is to bolster the reliability of decision-making processes at unmanned railway level crossings, thereby curbing overall operational time and averting accidental fatalities. The proposed decision support model emulates human-like intelligence, specifically in discerning actions during train arrivals and departures at railway level crossings. The FLC model is intricately designed to detect pertinent events and produce corresponding action signals. Such a model holds particular relevance for unmanned railway crossings where the risk of accidents is heightened, necessitating a dependable control mechanism. The model considers three key inputs: visual, acoustic, and vibration cues. Configured as a multiple input multiple output (MIMO) system, the FLC structure ensures resilient decision-making capabilities in overseeing railway level crossings.

According to shan Jain, Shubham Malik, Soumya Agrawal (2017)

This research presents an innovative system utilizing arrays of infrared sensors to monitor the position and movement of trains. This gathered data is utilized to autonomously control the opening and closing of railway barriers via a motor system linked to a microcontroller unit. Moreover, the system incorporates a GSM module connected to the microcontroller to notify drivers of potential collisions with approaching trains, sending SMS alerts as precautionary measures. Additionally, the train's whereabouts are transmitted to a webpage through the GSM module, facilitating real-time tracking capabilities.

According to Afsana Ahmed, Kazi Rifah Noor, Ahmed Imteaj and Tanveer Rahman (2018)

This paper presents a method designed to automate the control of railway gates at level crossings. The proposed approach integrates sensors with Wemos D1 to autonomously manage rail gates by measuring distances. Utilizing the Thing Speak server enables centralized control, facilitating the management of multiple rail gates. Notably, this system is characterized by its cost-effectiveness, real-time functionality, and automatic operation, thus offering a promising solution for reducing rail accidents.

According to Damodar Reddy Edla, Diwakar Tripathi, Venkatanareshbabu Kuppili, Ramesh Dharavath (2019)

The evolution of technology geared towards offering practical, cost-effective, and effective measures to prevent accidents at unmanned railway level crossings remains a vibrant field of study. Despite the myriad of methodologies put forth in this realm, none have demonstrated sufficient efficacy to obviate the necessity for human involvement at unmanned crossings entirely. This investigation pinpoints deficiencies in current technologies aimed at tackling unmanned railway crossings, whether through the establishment of road over bridges, road under bridges, or manned alternatives. In light of these shortcomings, we introduce a financially feasible and exceptionally effective multi-tier automated system tailored to forestall accidents at railway level crossings via sensor networks.

According to Y. Arockia Jesuraj, K. Hemalatha (2020)

This paper presents a prototype design for automated gate closure employing a Piezoelectric vibration sensor. In this model, the sensor is strategically placed 70 feet prior to the level crossing to detect oncoming trains. Upon train detection, the sensor communicates a signal to the gate through an RF module. Consequently, the gate shuts within a 30-second timeframe upon signal reception. Following a lapse of 180 seconds, the gate automatically opens, guaranteeing the safe traversal of pedestrians and vehicles. This model presents an economical solution that is both simple to conceive and execute.

According to Mrs. P. Sunitha, M. Eswar Krishna, D. Deepika, D. Divya, K. Bhargav (2020)

This method employs ultrasonic sensors strategically placed at a predetermined distance threshold, tailored according to the characteristics and velocity of the train. These sensors discern the arrival and departure of trains. Once detected, the green traffic signal shifts to red, and the level crossing gates swiftly shut while audible warning signals (buzzers) activate until the train has completely traversed the crossing. Furthermore, the system continuously updates the train's status in the cloud upon each detection by the ultrasonic sensor. The deployment of this system necessitates Arduino microcontrollers, servo motors, ultrasonic sensors, and Node MCU ESP8266.

According to T. A. Selvan, A. Viswanathan, S. Madhankumar, R. Dhanush Kumar (2021)

This study delves into the implementation of an automated railway gate system designed for level crossings, with the objective of supplanting conventional gatekeeper-operated gates. In this automated configuration, a sensor is strategically positioned near the level crossing gate, set at a specific distance from the railway track. As a train approaches and progresses along the track, the sensor detects the vibrations emanating from its movement. Consequently, the sensor transmits signal pulses to a controller situated at the level crossing column setup. Upon reception of these signals, the controller triggers the motor, facilitating the automatic opening and closing of the gate. The detailed design calculations essential for the realization of this setup are meticulously elucidated and discussed.

According to Prashant Singh, Zeinab Elmi, Vamshi Krishna Meriga, Junayed Pasha, Maxim A. Dulebenets (2022)

This research conducts a thorough and comprehensive examination of various IoT technologies pertinent to railway operations, covering aspects such as management, maintenance, video surveillance, and safety, with a particular focus on level crossings. It delves into the contemporary landscape of IoT, emerging technologies within this domain, and environmentally sustainable IoT applications. Furthermore, it scrutinizes a multitude of research initiatives undertaken in the field of railway applications. Additionally, the study tackles the numerous challenges inherent in IoT applications and explores potential strategies to alleviate these challenges.

According to Muhibul Haque Bhuyan, Sheikh Md. Mamunur Rahman, Md. Tofayel Tarek (2022)

This paper centralizes on the creation of a PLC and IoT-driven automatic interlocking system designed to avert train accidents or collisions, thereby ensuring the safety and security of passengers. A model was meticulously devised utilizing LOGO software in tandem with PLC, employing ladder logic programming customized through LOGO software. Communication between the PLC and computer was established by utilizing an RS485 Serial port. Detection of train presence on the track was realized through the utilization of ultrasonic and radio frequency (RF) transducers, alongside infra-red (IR) sensors functioning as both transmitters and receivers. System simulation was conducted via LOGO software. Furthermore, the integration of Internet of Things (IoT) and Visual Basic Programming software facilitated connectivity with mobile applications and the development of a Graphic User Interface (GUI), respectively.

According to Kapu Ajay, Telugu Sivasankar, Telugu Raghava, E Sharath Raj, Y Diwakar Babu, S Mohammad Aktar, S A Mansoor (2023)

The core objective of this endeavor is to automate the management and functioning of railway gates, thereby minimizing accidents and prioritizing human safety. Through the utilization of Arduino and IR sensor technology, accidents can be averted, and the reliance on manual intervention markedly diminished. The IR sensor harnesses an IR transmitter to detect the arrival of trains, transmitting the gathered data to the microcontroller through the IR receiver. Arduino, in conjunction, utilizes a DC motor to orchestrate the opening and closing of the gate. Furthermore, the integration of RFID Reader functionality serves to capture station information, subsequently furnishing it to registered users, thus enhancing operational efficiency.

3. PROBLEM IDENTIFICATION

In India the Railway Crossing stations are manually Operated by the railway gate operator. The railway gate Operator is responsible for operating the gates according to the train arrival and departure. The Train arrival and Departure information is sent to the gate operator by using the communication devices. The present system is very Error prone and which leads to many accidents at railway Level crossings. The train information is shared from one Crossing system to another when the train leaves the Crossing station. At Some time where there is not interlocking of signal with gate and the security code is manually printed on the log book that Gate man has to share. As the security code is already printed on the book hence there will be no cross detection of status of Railway Gate, therefore there will be chances of failure of status detection of Railway Gate.

4. AIM AND OBJECTIVES

The primary aim of this setup is to offer a streamlined automated system for the opening and closing of railway gates and Security Code Generation System based on IOT and ESP8266 module.

We are developing the setup that automate the Railway Crossing Gate by using sensors, motor, and microcontroller. This setup is interfaced with the Railway Gate for its status detection. The security code will be automatically generated and Displayed on the screen after detecting the status of the railway gate (i.e. opened or closed) and online updated on the Server of Security Code. This setup brings significant advantages to both road users and railway management by reducing waiting times at railway crossings. This technology is based on IOT and ESP32 Node MCU controller.

5. METHODOLOGY

The current project employs the ESP8266 microcontroller to address railway safety concerns associated with accidents occurring at railway crossings, provided it is implemented effectively. This initiative relies on the utilization of two robust proximity sensors strategically positioned at a height greater than that of an average person, precisely aligned with the railway track. The activation timing of these sensors is meticulously calibrated by calculating the duration required for a train traveling at a particular speed to traverse at least one standard-sized railway compartment. These sensors are installed at intervals of 1 kilometer on both sides of the railway gate. One sensor is designated as the "foreside sensor," positioned in the direction of the approaching train, while the other is referred to as the "afterside sensor". Upon activation of the foreside sensor, the gate motor is initiated to close the gate, securing it until the train completely passes the gate and reaches the afterside sensors. Simultaneously, a 4-digit security code is generated and transmitted to the cloud, ensuring instantaneous receipt by the station master. Subsequently, when the afterside receiver is activated, the gate motor operates in the opposite direction, opening the gate before halting. A buzzer alarm is triggered immediately upon activation of the foreside receiver, and the gate remains closed for an additional 30 seconds, providing ample time for drivers to clear the gate area and preventing any entrapment between the gates. The buzzer ceases once the train has cleared the crossing.

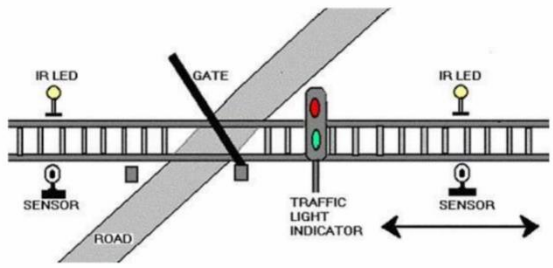

Fig-2. Technology used in Railway Gate

6. COMPONENTS

1. ESP8266: Espressif Systems has developed a versatile system-on-a-chip (SoC) microchip tailored for Internet of Things (IoT) applications, known as the ESP8266. Its widespread adoption is attributed to its cost-effectiveness, compact form factor, and seamless integration capabilities within diverse embedded devices across the IoT landscape. Operating on 2.4 GHz Wi-Fi networks compliant with IEEE 802.11 standards, the ESP8266 module acts as a bridge for microcontrollers, offering the option to either enhance external host MCUs with Wi-Fi functionalities through ESP-AT firmware or operate independently as a standalone MCU utilizing an RTOS-based SDK. Powering the ESP8266EX microcontroller is a Tensilica L106 32-bit RISC processor, renowned for its energy efficiency and clock speeds of up to 160 MHz. Notable software advancements for the ESP8266 encompass Punyforth, a Forth-inspired programming language tailored specifically for the platform; Sming, a robust asynchronous C/C++ framework praised for its performance and extensive networking capabilities; and uLisp, a variant of the Lisp programming language optimized for processors with limited RAM resources.

Table-1. ESP8266 Specification

1	ESP82666	DESCRIPTON
2	Core	1
3	Architecture	32 bits
4	Clock	Xtensa LX106 80-160 MHz
5	Wi-Fi	IEEE802.11 b/g/n support for WPA and WPA2
6	Bluetooth	No
7	RAM	160 KB - 64 KB Instruction – 96 KB Data
8	Flash	Extern QSPI – 512 KB A 4 MB
9	GPIO	16
10	DAC	0
11	ADC	1
12	Interfaces	SPI – 12C – UART – 12S

2. Proximity sensor: A proximity sensor refers to a tool designed to detect objects in close proximity without necessitating physical contact. Typically, it operates by emitting either an electromagnetic field or a radiation beam, such as infrared, and then observes changes in the field or the returning signal. The object under scrutiny is often referred to as the sensor's target. These sensors are esteemed for their reliability and longevity as they don't rely on mechanical parts and avoid direct physical interaction with the objects they detect.

3. IR Sensor: An infrared sensor, also known as an IR sensor, is an optoelectronic device sensitive to radiation within the infrared wavelength range, typically spanning from 780 nanometers to 50 micrometers. These sensors find extensive application in various fields, notably in motion detection systems utilized in building management for activating lights or in security setups to identify intruders. Active infrared sensors function by both emitting and detecting infrared radiation. Consisting of two key components, namely a light-emitting diode (LED) and a receiver, active IR sensors operate by emitting infrared light from the LED, which upon interacting with nearby objects, reflects back and is subsequently captured by the receiver for analysis.

4. Servo Motor: A servo motor operates as an electromechanical apparatus generating torque and speed contingent upon the current and voltage it receives. Integral to a closed-loop system, the servo motor responds to commands for torque and speed from a servo controller, which utilizes feedback from a designated device to ensure precision. Its primary role is to translate the control signal from the controller into rotational angular displacement or angular velocity at the motor's output shaft. Servo motors are commonly employed to actuate the movement of joints.

5. Buzzer: A buzzer or beeper serves as an auditory signaling apparatus, available in mechanical, electromechanical, or piezoelectric variants, abbreviated as piezo. This signaling device, whether electromechanical, piezoelectric, or purely mechanical, primarily transforms audio signals into audible sound. Typically powered by direct current (DC) voltage, it finds widespread application in various devices such as timers, alarm systems, printers, computers, and other equipment requiring audible alerts.

6. LED: A light-emitting diode (LED) stands as a semiconductor component capable of emitting light upon the passage of an electric current. Its operation involves the recombination of electrons with holes within the semiconductor material, resulting in the emission of light.

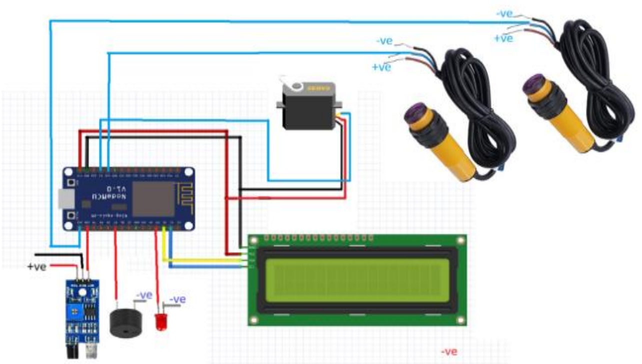

Fig-3. Circuit Setup

7. WORKING

In our project, the IoT-based security code generation system utilizes ESP8266 for programming, initiating its operations upon internet connectivity. When a train approaches, the proximity sensor detects its presence, triggering the automatic operation of the railway gates. The automation of railway gate activation through proximity sensors entails the utilization of sensors to identify approaching trains at railway crossings.

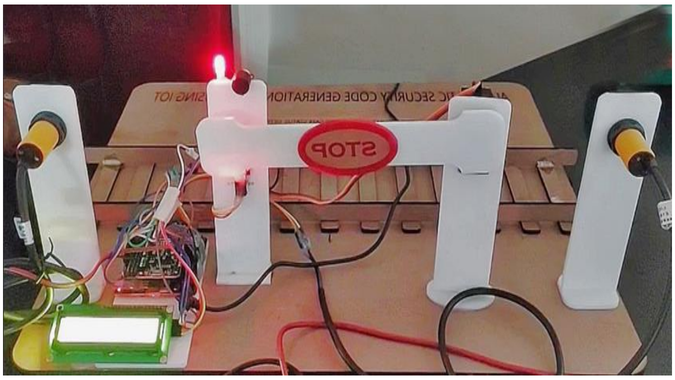

Fig-4. Actual Setup

Here's a basic working principle:

1. Sensor Placement: Proximity sensors are strategically placed near the railway tracks, typically at a certain distance from the railway crossing.

2. Detection of Train: The proximity sensor continuously monitors the area near the tracks. When a train approaches the sensor's detection range, it senses the metal mass of the train, causing a change in its output.

3. Signal Generation: Once the proximity sensor detects the train, it generates an electrical signal indicating the presence of the train. 4. Signal Processing: The signal from the proximity sensor is processed by a control unit. This unit may be a microcontroller or a dedicated control circuit.

5. Gate Actuation: Upon receiving the signal from the proximity sensor, the control unit activates the mechanism responsible for lowering the railway gates, blocking the passage of vehicles and pedestrians.

6. Gate Operation Duration: The gates remain lowered for a predetermined duration to allow the train to pass safely.

7. Gate Opening: After the train has cleared the crossing area, the control unit triggers the gate mechanism to raise the gates, allowing traffic to resume.

8. Safety Features: The system may incorporate safety features such as fail-safes to ensure that the gates lower and raise reliably, emergency stop mechanisms, and alarms to warn pedestrians and motorists of approaching trains.

Fig-5. Security Code

Overall, the system ensures the safe passage of trains at railway crossings by automatically controlling the operation of railway gates based on the detection of approaching trains by proximity sensors.

8. ADVANTAGES

Here's the advantages of this system based on IOT

1. Automatic gate closing system can reduce time of operation and also increase safety of persons.

2. Auto security code generation and sending it to the cloud-based storage system can make operation faster and reliable.

3. Reduce time of operation.

4. Security and safety increases.

5. The stored data can be further used for data analysis.

6. Working on 2.4GHz

9. DISADVANTAGES

Here's the disadvantage of this system

1. This type of advance system needs internet connection if there is no internet then the automatic system stops working.

10. CONCLUSION

Utilizing ESP8266, our IoT-based system for detecting railway crossing gate status and generating security codes presents an exceptionally efficient solution, streamlining gate operations and code generation simultaneously. This innovation promises substantial benefits for road users and railway authorities, notably by minimizing waiting times at crossings. Furthermore, our system ensures heightened reliability, performance, and cost-effectiveness compared to existing conventional systems.

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