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Smart Railway Track and Crossing Gate Security System Based on IoT

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ABSTRACT

The railway system is one of the most widely used modes of transportation due to its low cost. To keep the railway system running smoothly, continuous track monitoring is needed. These days, the railway system is manually supervised. As a result, there is a greater risk of disasters, such as fatalities, occurring as a result of human error while monitoring. The main problem with manual system monitoring is that it takes a long time to process all of the necessary data. Since railway tracks are built over thousands of miles, it is virtually impossible to manually control the device over such a long distance. At railway crossings, a lot of accidents happen. Crossing gates are usually opened and closed after receiving direct input from the station. If there is a delay in obtaining information from the station, there is a risk of swearing incidents. The main goal of this research is to simplify and protect the railway system. The proposed system employs Force Sensitive Resistor (FSR) detectors for automatic side road crossing protection. Any type of breakage, as well as vibration, can be efficiently detected with a higher degree of precision using Light Dependent Resistor (LRR) and laser detectors. In the event of an unexpected situation, such as an accident, the GSM module will begin communicating via message with the nearest control room for assistance. Sonar sensors are often used for obstacle avoidance when something unexpectedly appears in front of the train. The Internet of Things (IoT) has been added to the system to allow it to be monitored from anywhere in the sphere. The Arduino UNO is a microcontroller that serves as the system's backbone. The framework has the potential to be extremely beneficial to our country's railway economic growth.

Key words : Crossing Gate Security, Smart Railway, Internet of things, Track.

1. INTRODUCTION

Pakistan Railways was also Called the Pakistan Western Railway from Railways provide the lowest priced and many Convenient manners of passengers for space and suburban visitors [1]. It also plays a significant part in the maturation and growth of businesses. Railways Assist in providing raw materials and other amenities to the mill sites and Finished products to the marketplace. So, safety and reliability should be highly considered in the case of a railway. As it is playing a vital role in the growth of the economy, so the importance of having a modern and improved railway system is increasing day by day. However, the present scenario of the railway is quite different. Railway mishap has become a common issue nowadays [1]. This becomes daily news losing many lives by train accidents. In today's world, transport, being among the drivers of electricity, its sustainability and safety are issues of major significance. Railways offer the least expensive and most convenient way of passengers for the local and distance visitors. Additionally, it has a vital part in the maturation and growth of businesses. Railways aid in providing raw materials and other amenities to the mill websites and finished products to the marketplace. So, safety and reliability should be highly considered in the case of a railway. As it is playing a vital role in the growth of the economy, so the importance of having a modern and improved railway system is increasing day by day. However, the present scenario of the railway is quite different. Railway mishap has become a common issue nowadays [2]. This becomes daily news losing many lives by train accidents. We come across railway accidents happening at railway crossings when we go through the newspapers. This is due to a lack of employees or carelessness in manual operations. Many accidents happened every year owing. Automatic Railway Gate Control System is an easy but very beneficial project, which the railway gate is opening and closing upon detecting the arrival or departure of the train. Railway gates have been opened or closed with a manual of a gatekeeper [3],[4]. The info concerning the arrival of the train for closure or opening of the gate is received from the station. However, some railroad crossings are unmanned, and railway accidents happen at level crossings. Railway maintenance is very tough to manage through any manual system. So, an automated system is an urgent need to stop all kinds of unwanted accidents of the railway [5],[6]. This kind of accident is occurring for the very little ignorance like small crack on the rail track or missing fishplate from the track, but the consequence of those things is very acute. During the development of this system, it mainly focuses on some essential factors, e.g., Reliability, Accuracy, Efficiency, and cost-effectiveness [7],[8]. Every year, they are losing a massive amount of lives due to the collision of two trains on the opposite and same track [9-13]. There is no such technology to break the train engine immediately to avoid the accident in our country. IoT is a relatively new field in information technology which is related to compute the accessories and devices, which can also be called digital machines and even several other objects like a Smart Train, wristwatch, glasses, Smart Home, Smart Bus, and Industry Automation, etc. Through IoT, we can manufacture our desired devices with the help of sensors, circuits, and monitoring and evaluation are made very convenient [14],[15]. The concept of the IoT is a demand-driven idea that will change the full use of information technology. There is no sufficient technology in the country to identify the crack or breakage. Besides these, in most of the cases, many accidents happen because of the miscommunication of rail level crossing and the passers-by. This system will also work to avoid this kind of mismanagement of the track and have a systematic way of maintenance. Firstly, there will be FSR sensors to sense the train on the track and based on the data of FSRs [16]. It will avoid a collision between trains. The system will send notification about a collision. Secondly, a systematic way will be there to make the road crossing automated. On the other hand, to detect the breakage of the track and obstacle the vibration sensors and LDR, Laser sensors will be used, respectively. Railway track security is the prime concern of our research. We think if we can give proper protection to the railway tracks, it will be so helpful for the transportation system of our country and this will also help a lot in the economic development of our country.

Our system is a smart, fully automated system for inspecting railway tracks. It will alleviate the troubles of manually inspecting the rail tracks' conditions. Proposed system consists of four modules that will modernize the inspection system. To prevent a collision, system can detect two trains on the same track. It would make the level crossing mechanism automated if this is included. Aside from that, it can detect large obstacles on the rail track, as well as locate breakage and missing rails.

2. LITERATURE REVIEW

Firstly, we had a survey of existing technologies of automatic track security. This survey helped us to understand which technologies are suitable for our system, which will make it more efficient and easier to use [3-12]. From all the developed or established system worked only one or two parts of the whole system [17],[18]. Here, we give a short review of the technologies which are already developed. Collision is one of the major issues of train accidents in every country. To make an anti-collision system, the author provides a method by using DLSR (Digital Single-Lens Reflex) sensor [15],[24]. This technology will identify the collision points and also send the distance of two trains to the control room. It will monitor the system to slow down the speeds of trains. The author also used. LED and LCD panel to find if two trains are on the same track or different track. Obstacle detection is another essential part of a railway security system [19],[20]. For detecting an obstacle, the system needs to sense train arrival, so the author used a vibration sensor [16]. To sense the obstacle in the path of trains obstacle sensor is used and send a signal to the microcontroller [25]. The author divided the rails into several blocks, and all blocks consisted of laser sensors and microcontrollers. The laser sensor mainly sends message to train either to stop or continue to run [21]. A vision-based method [22] is used for automatic railroad track inspection. In this system, the camera plays a vital role in capturing and collect images and videos. Author used image processing and MUSIC algorithm in this system. Image processing helped to process the frame image, and the MUSIC algorithm helped to detect a number of signals in the presence of noise.

Now, situation, in the level-crossing lineup, the railway gate is controlled generally with a way of a gatekeeper [9]. This takes place when the railway line is a cross across the road, and there's a gate that has to be controlled. The gatekeeper to work after getting advice about the train came to the nearby station [3],[6]. When the train begins to leave the channel, the specific station provides the information to supplying the signal for the gatekeeper to get prepared. Furthermore, this automated railway gate system may contribute a good deal of advantages either to the street user to the railway administration. This form of the gate may be implemented in the level crossing in which the odds of injuries are higher. The computer integration Will Probably Be utilized to Supply an addition to the Latest technology.

The main goal of this can be Railway monitor crack detection with image processing and also is a lively approach, which combines the use of GPS monitoring system and WIFI module to send alert messages along with also the geographical coordinate of place [3],[4],[6],[15]. A Raspberry Pi is used to command and organize the actions of these apparatus. This endeavor prevents train derailment by discovering a crack in the railway track utilizing IoT technologies.

In [25] authors presents that in recent years, the sensor technology is being drastically expanded and now became an emerging technology. The cost of sensors has become cheaper, which became advantageous for the use of sensors [24]. This, in turn, expanded the structure of vehicles, frameworks, and hardware components, making use of sensors. The key components are the advancement made in the present remote sensor system (WSN) that can be used for checking the railway alignment, railway tracks, wheels alignment, the track foundation, and the placement. The use of this technology reduces the effort made by humans for manual checking. This technology using sensors is necessary for the advancement of the railway systems and improvising in terms of their designs.

3. METHODOLOGY

IoT based smart railway track security system is developed by using unsophisticated components. This system makes an interface with Arduino. This solution was proposed to construct this system and components such, Arduino Uno IR Sensor Servo Motor, LDR Sensor, FSR, and others used in the proposed safety alert system can be easily integrated with Arduino & Mobile platform. We also have developed an Android-based mobile application to keep the cost low yet a scalable and efficient system. We used the open-source Arduino platform for the hardware and Android for the controller application.
The design specification is determined based on the objective of the project. The project is divided into three stages initialize with the hardware design stage, then the software design stage and the last step is testing, tuning, and troubleshooting the project design. The hardware design stages act tools to determine whether the transducer used is correct and compatible with the circuit diagram. In this stage, the sensor is 15 chosen based on experimental characteristics such as accuracy, precision, factors affecting the measurement, and the performance under forced condition. The software design stage is designed according to the operation at the flow of the project. The software part itself is divided into two categories, which are sequence programming and interface programming. Both parts must be joint together and run simultaneously in tell to produce the approve intention of the project. The testing, tuning, and troubleshooting stages are the keys to the design process. These stages are subsequent after the combination of both the hardware and software parts. Therefore, a slight error in design can be time-consuming and may result in retracing to previous stages for affirmation.

4. IMPLEMENTATION AND DISCUSSION

There will be ESP32 as a microcontroller, GPS, SIM800L GSM, and FSR sensors to build proposed system. In our system implementation, FSR is used very vastly. Firstly, we have used SR sensors to detect two trains on the same track to avoid a collision. Secondly, it is also used to make the level crossing system automated. In the implementation section, we have used GPS to detect the location of the trains and Wi-Fi to convey alert messages about the possible risk. Moreover, we have used some other components such as Sonar, sensor, buzzer, servo motor, to make our system more efficient.

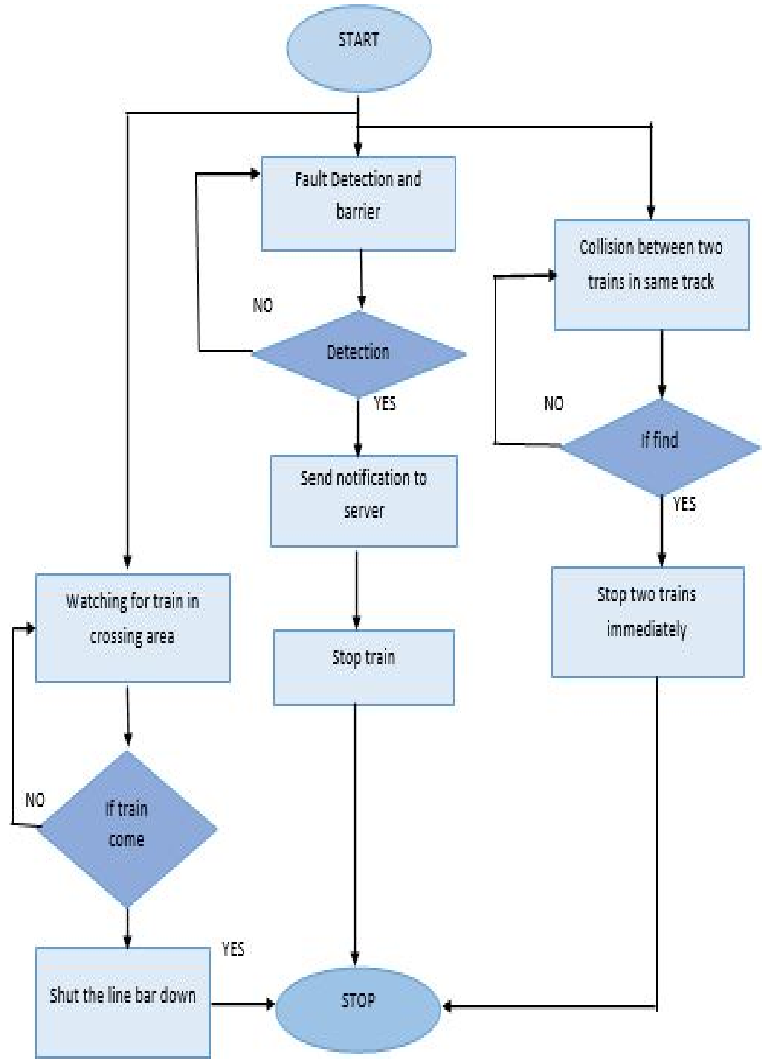
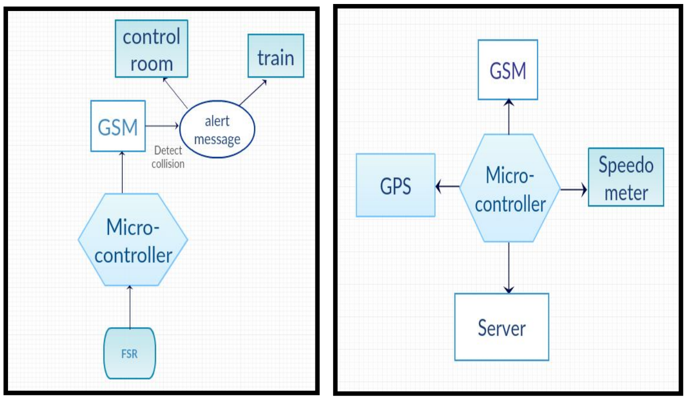


Figure 4.1. Flowchart of Whole System

4.1 System Model

4.1.1 Collision Detection

In this system, FSR sensors will set every 500m. Every FSR location and every train's unique identification number and phone number will set in the system database. Every train has GPS, which will give an exact train location [13] and save it in the database. When the train starts running, the location of it will up-to-date after 500m. Wi-Fi will send a message that is online when the system starts working. FSR sensor senses the force and identifies the train on track.



Track side **Train side**

Figure 4.2. System model of Collision detection

Collision detection is one of the core objectives of this system. FSR sensors will detect collision to stop the trains. When FSR detects a collision, the system will search all the trains within 5km from the collided area. The system will analyze which train's locations are equal to collided FSR's location from the database. After that, Wi-Fi (Internet) will notify all the trains within 5 km from collided FSR to slow down the speed. Moreover, Wi-Fi (Internet) will alert that exact two trains and control room by message. FSR will stop the particular two trains of the collided track to stop the collision, and the distance between them will be 1km.

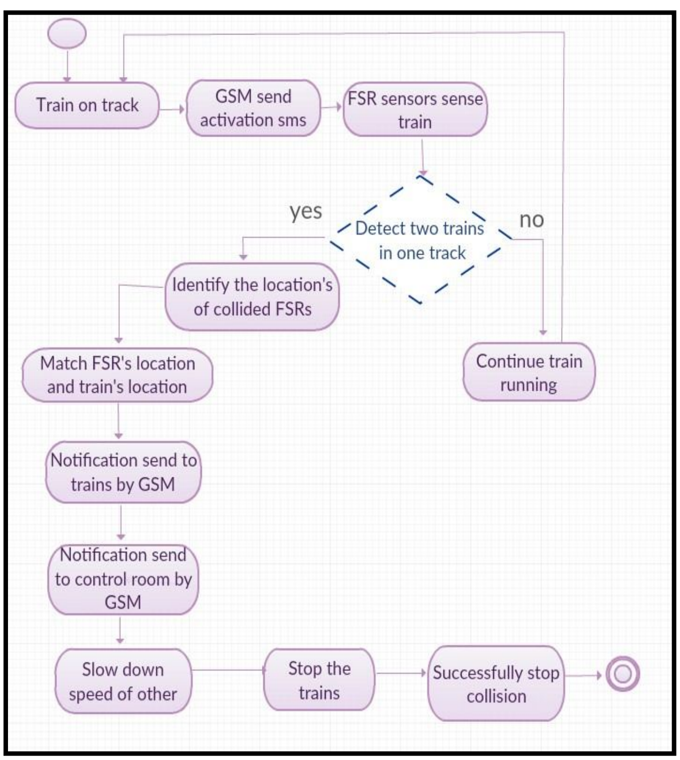
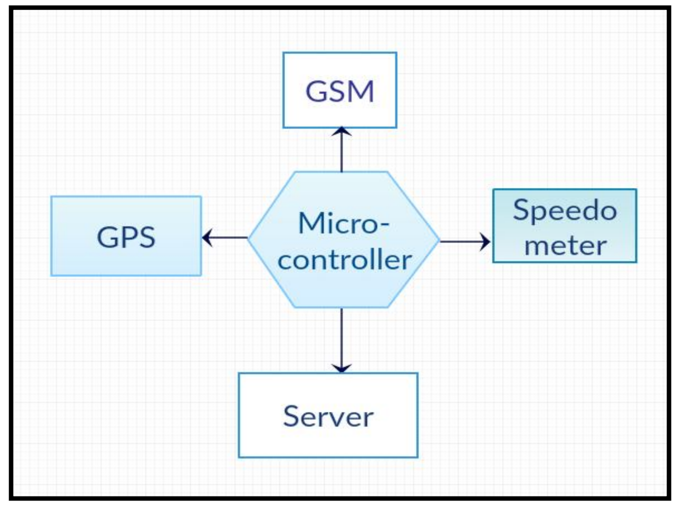


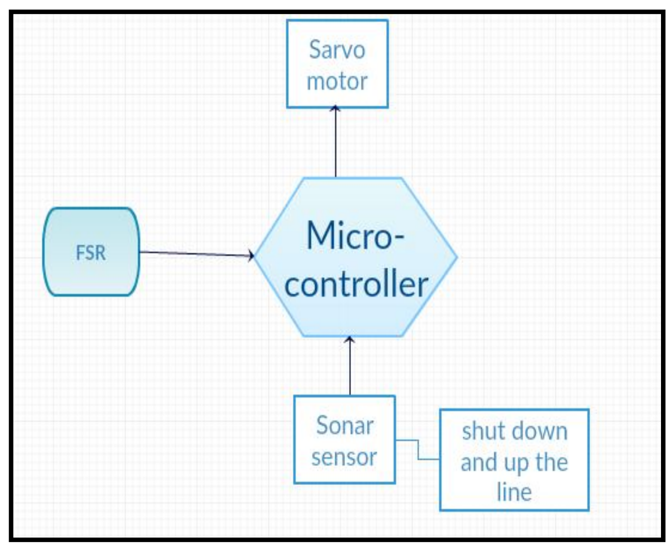
Figure 4.3. Collision Detection Activity diagram

4.1.2 Automated Road Crossing

In this system, the FSR sensor will sense the train, and the microcontroller will shut the line bar down automatically. After the train crosses the track, the line bar will be up for the vehicles. We will use the Wi-Fi (Internet) here to make the system more efficient as no internet connection will be needed. This system will reduce the pressure of handling the line bar manually. When the FSR sensor senses the train, the buzzer will be rung. After that, the liner bar will automatically get down, and no vehicle can pass through the track. On the other hand, when the train will go away, then the line bar will be up for the other vehicles to pass through the rail track.



Train side



Track side

Figure 4.4. System model of automated rail crossing

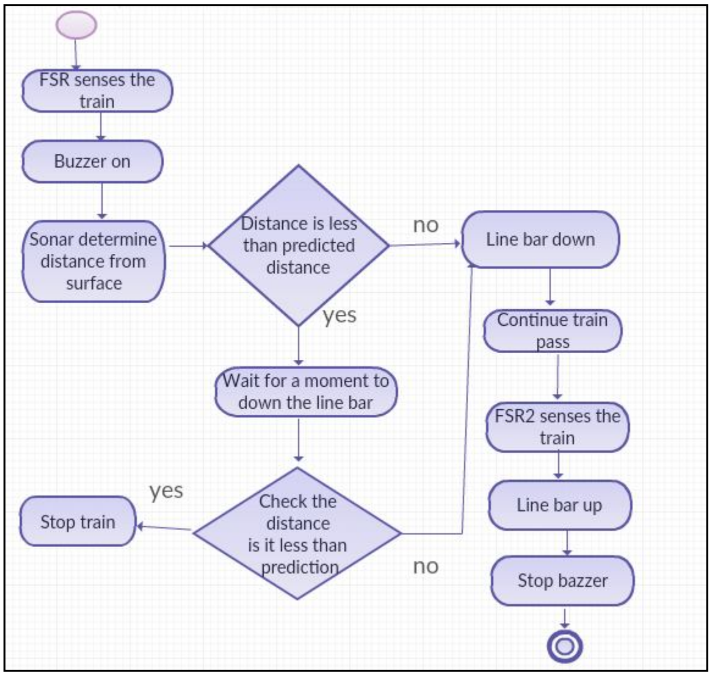
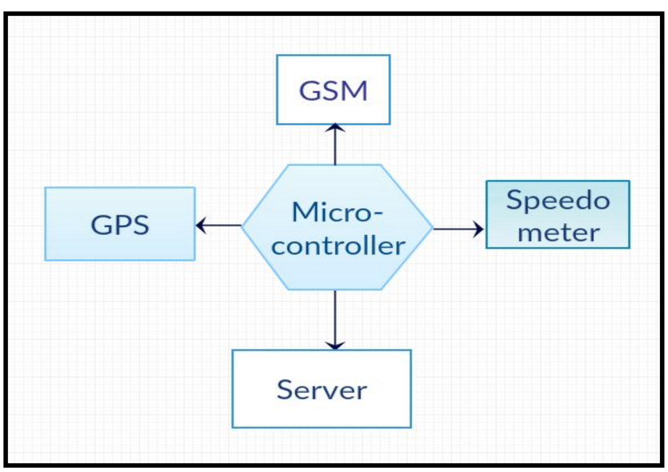


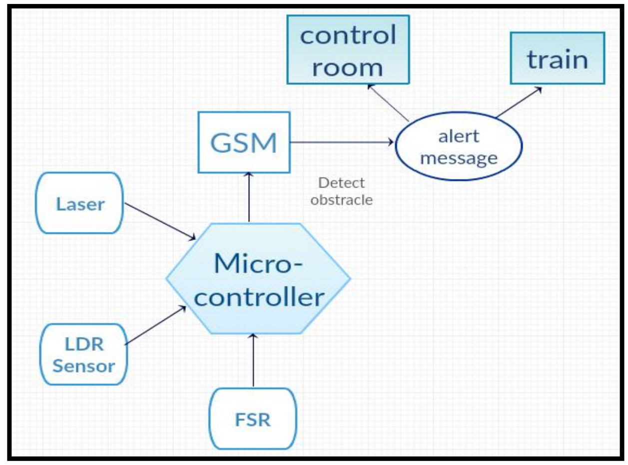
Figure 4.5. Automated rail crossing Activity diagram

4.1.3 Breakage Detection

Breakage and crack, as well as missing rail on the railway track, is a common reason for a train accident. The proposed system can detect any crack and missing rail on the railway track and alert the control room with the location where breakage is detected. Piezo vibration sensors will be used to identify faults on the railway track, and the Wi-Fi & GSM will be used to convey the message with the help of a microcontroller. There will have some predefined data sets of probable graphs based on the input of piezo vibration sensors and the mass and velocity of the train. The value of different train speeds and different mass versus vibration sensors in the database will be stored.



Train side



Track side

Figure 4.6. System model of breakage detection

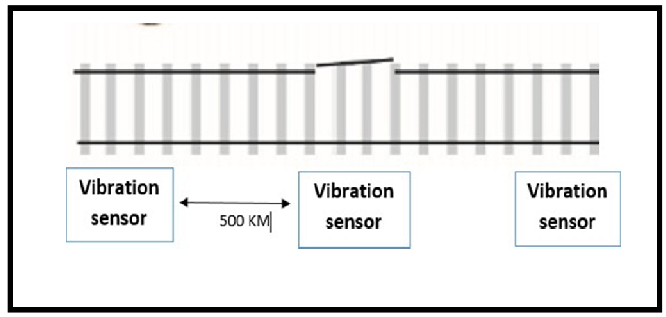


Figure 4.7. Breakage detection

The sensor will be placed after every 500m in the track. In usual case if a train runs in V mph and the wait is M kg then based on the input of sensor microcontroller will generate a graph considering train's velocity and mass after that the ESP32 microcontroller will match this graph with each probable graphs in database, if it matches or is close enough with likely Graph then there is no problem in the track. But if it does not match, that means there is a breakage or something wrong in the track.

$$P_{value} \propto \frac{1}{MV} \qquad (3.1.3)$$

Where,

P value= Piezo vibration sensor analogue value M= Mass of the train

V = Velocity of train

The vibration sensor value is inverse proportional to the mass * velocity of the train. The graphs follow this equation.

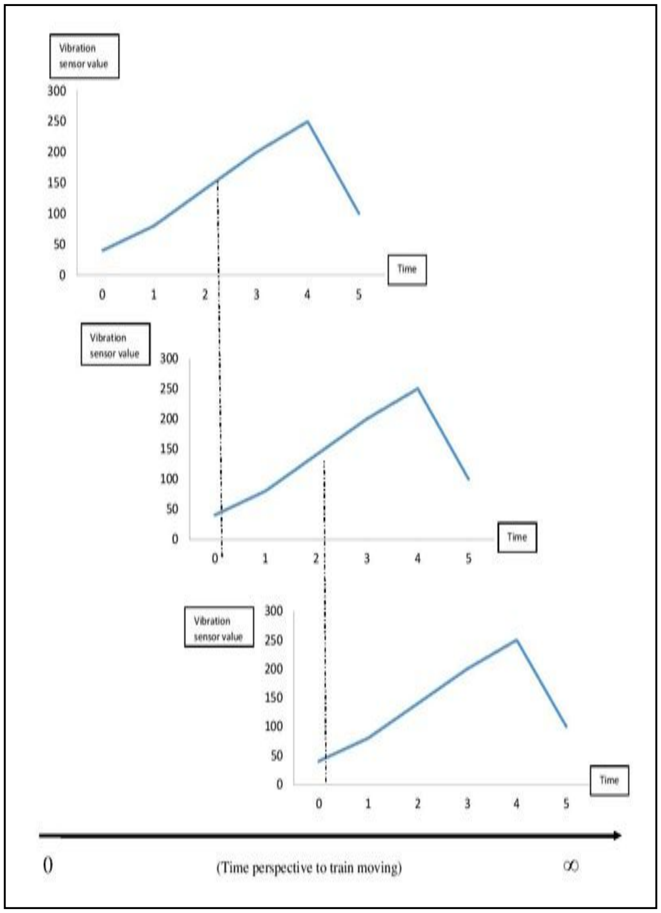


Figure 4.8. Graph of Vibration Sensors

In Figure 4.9, there are three active vibration sensors graph shown. The straight line below the graph is time perspective to train to move. It is assumed that each train starts from 0 and runs up to infinity, which means until the road has finished, the train will move on. Though the sensors can sense the appearance of the train almost from 1km away, but still for better security, each sensor will be placed after 500m. Considering Fig 3.8 the 1st sensor will start getting input for creating the graph when the train will be 500m away from the sensor it won't be 0 because it starts sensing when the train is 1km far away from the sensor. Then as much as the train came closer to a sensor, the frequency will be getting higher, and the analog value of the sensor will be getting larger. When the train is precisely on the sensor, the value of the sensor will be highest after then the value will start decreasing. Each sensor will work in the same manner. If a train cross over that three sensors system will generate three graphs like Figure 9, here each graph will be checked to be matched with the probe. If it does not match or not even close enough with the likely graph, then the system will send a notification to the nearest control room and notify the train to stop before reaching the next sensor.

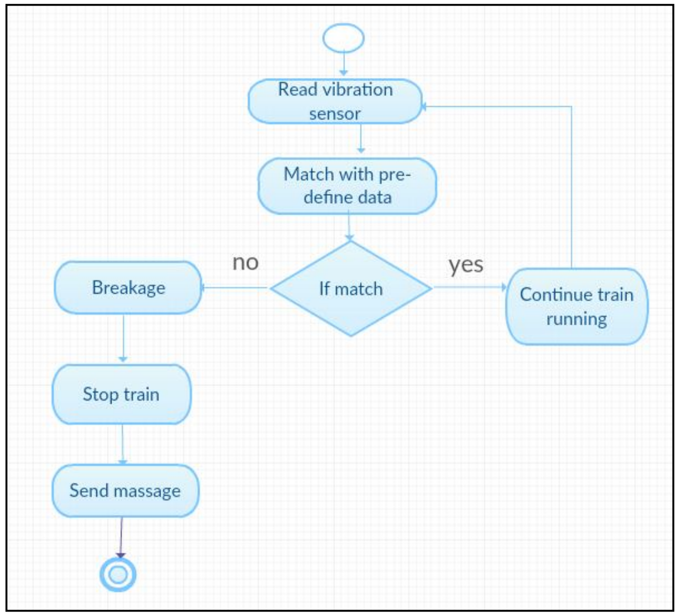


Figure 4.9. Breakage detection activity diagram

4.1.4 OBSTACLE DETECTION

A theoretical system model consists of LDR and Laser utilizing the data of the piezo vibration sensor to detect any sudden obstacle on the track. After every 500m along with the vibration sensor, an LDR and a laser will be set up. We are assuming that all will be set up in a box like the Figure-27. In each box on the right side, there will be a laser, and on the left side, there will be an LDR. When a train starts running on the track, then in the usual case, there will be found a graph like Figure-26. But if any heavy obstacle keeps falling on the track, then the graph which will be generated by the system that time, it will not match with the probable graph or won't even close enough to the likely graph.

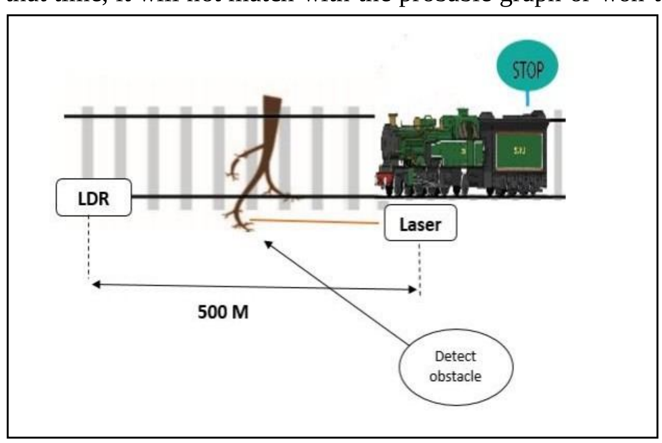
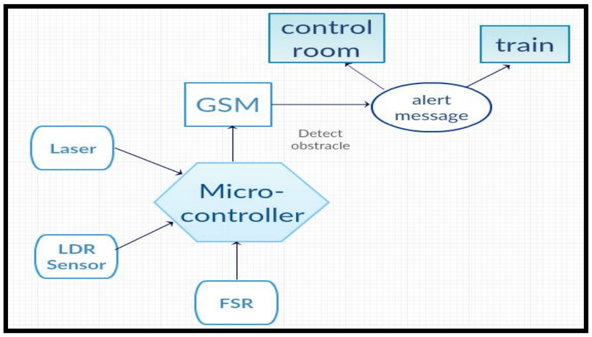
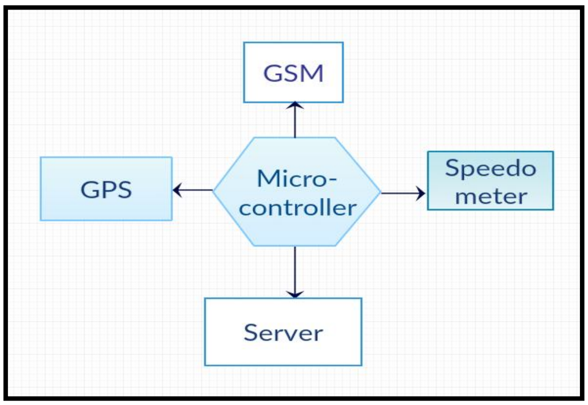


Figure 4.10. Obstacle detection



Track side



Train side

Figure 4.11. System model of obstacle detection

Then the light rays of the left laser will fall on the right LDR. If then LDR cannot get the laser which is supposed to get that means, there is something heavy obstacle on the track, and then the system will notify the nearest control room and the train which is on track to stop the train.

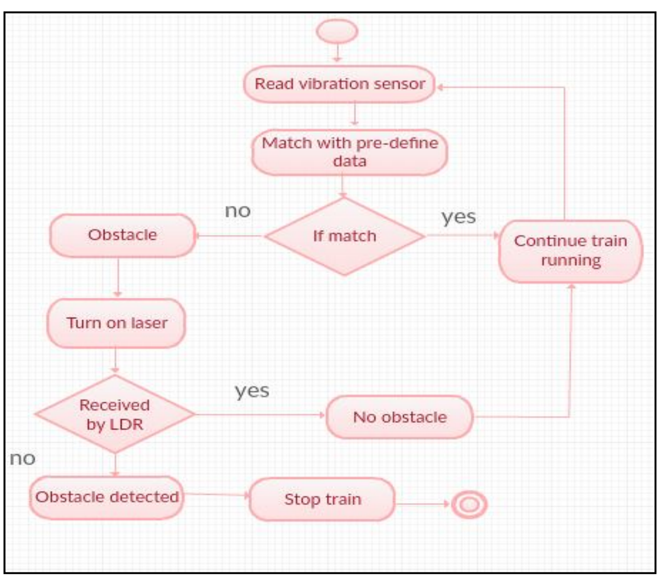


Figure 4.12. Obstacle detection activity diagram

4.2 HARDWARE IMPLEMENTATION

4.2.1 COLLISION DETECTION

Firstly, GSM will send an activation message to the system. Depend on FSR data, and collision will be detected. Every FSR will check the track and update the data continuously. When an FSR gets high data or force from a train, immediately it will check 1km distance FSR's data. For instance, FSR_i receives high data and it will observe the data of $FSR_{(i-2)}$ or $FSR_{(i+2)}$. Whenever, both FSR_i and $FSR_{(i-2)}$ or $FSR_{(i+2)}$ receive high data, FSRi will notice collision.

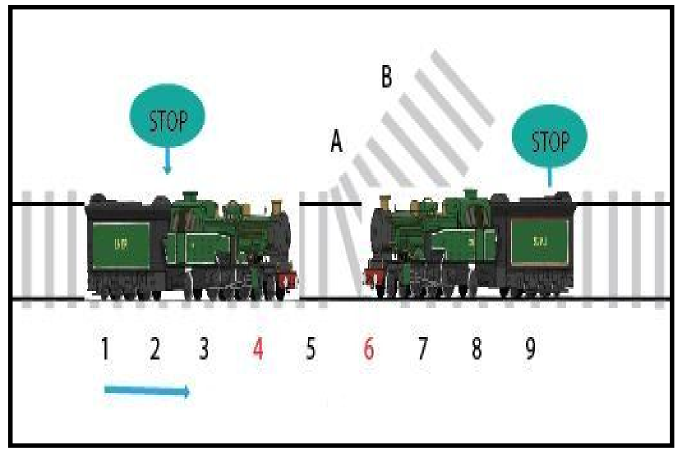


Figure 4.13: Stop collision of two trains.

FSR sensors will send data to ESP32 and internet Cloud. ESP32 will give a signal to App Mobile. Furthermore, the internet Cloud will send notification urgently to the control room and appropriate two trains. FSR will stop the running trains to control the detected collision. However, one of the FSR's data is high means there is no collision in the track. As a result, the train will run on the track properly. FSR sensors will update their data. Along with this, a train's location will be updated in the internet Cloud database.

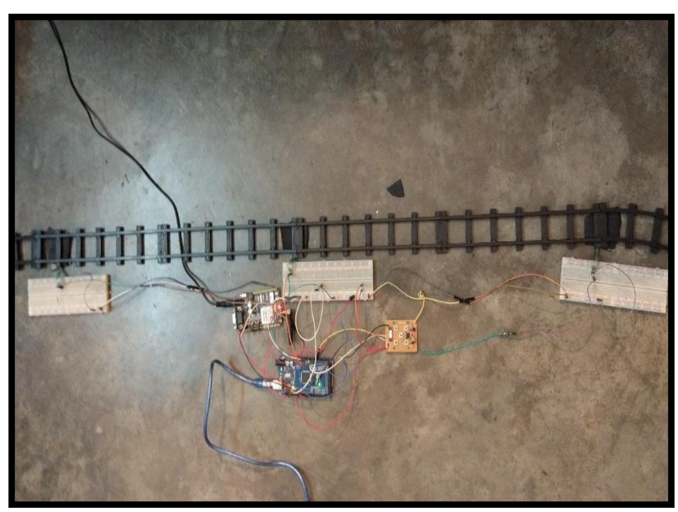


Figure 4.14: Implementation of Collision Detection

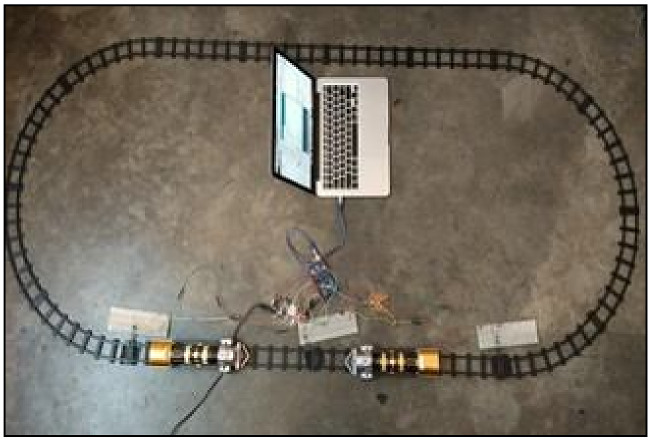


Figure 4.15: Testing of Collision Detection

4.2.2 AUTOMATED ROAD CROSSING

Firstly, there are two FSR sensors, servo motors, and sonar sensors. When FSRi senses the train, it will send data to E. ESP32 & internet Cloud will send a signal to servo motors of both sides to shut the line bar. Here, a servo motor will rotate from 0° to 90° to give safety indication. The buzzer will ring to alert people of a specific area.

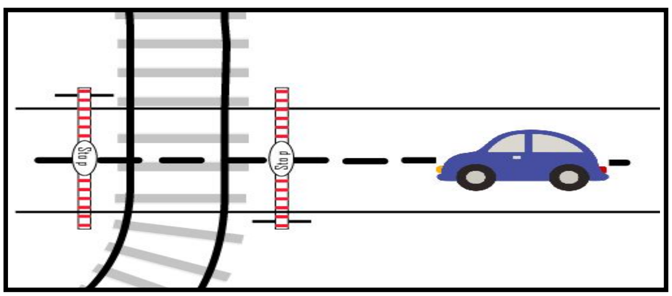


Figure 4.16: Automated Rail Crossing

After that, when the train passes, the rail crossing area $FSR_{(i+1)}$ will sense the train and send data to ESP32 & internet cloud data. ESP32 will check data and notify servo motors to take action. Servo motor will rotate from 90° to 0° and turn the line bar vertically.

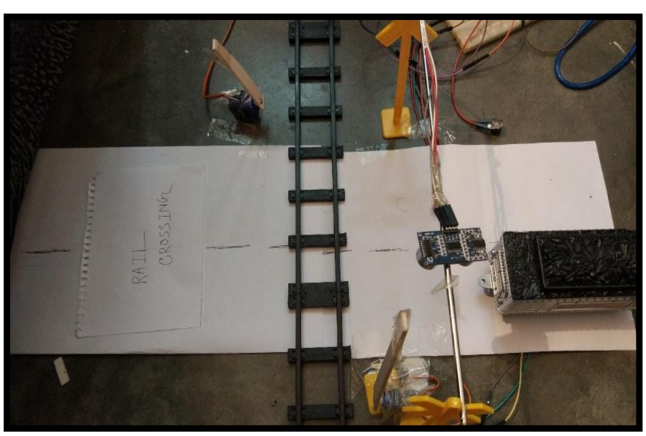


Figure 4.17: Implementation of Automated Rail Crossing

There are HC-SR-04 sonar sensors to measure the length from the surface. There is a fixed measurement of the length save in ESP32 *However*, the situation comes like that a bus/car is on the track of rail line crossing. The system will compare the current distance with a fixed distance.

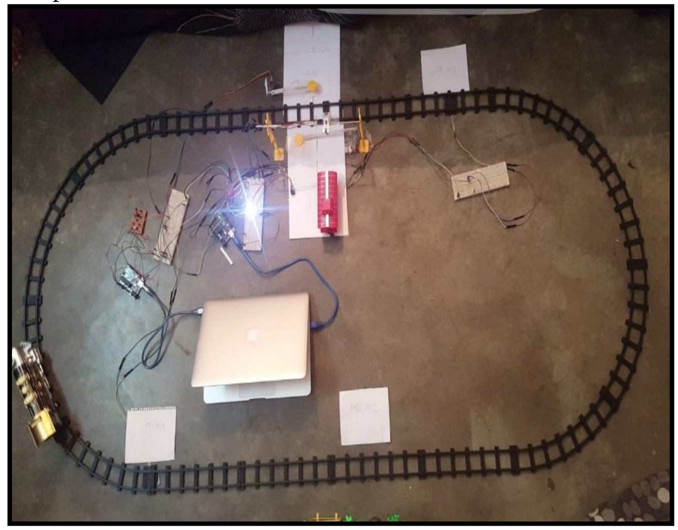


Figure 4.18: Testing of Automated Rail Crossing

The system detects the distance is less than the fixed measurement. In that case, the line bar will rotate less than 90° and allow crossing the area. The system will notify the train of the track to control the speed.

4.3 CONNECTION SET-UP

4.3.1 COLLISION DETECTION

The design of our system is accessible and efficient. FSR sensor and train controllers are configured with ESP32. FSR sensor has two pins; one pin is connected with 3.3Volt or high voltage. Another pin is connected with the input pin of the ESP32 Arduino board. FSR needs to set with the track to get the appropriate force of a train. GSM SIM800L shield is configured with ESP32 and Internet cloud databases so that it can easily send messages to the control room and trains It works almost like a typical mobile phone. For activation, we have inserted a sim card. Our GSM SIM800L comes with GPS enabled, so it will store all the data to a database. The ground pin is connected with the ground, TX and RX pins of GSM are connected with ESP32 Arduino output pins. Each train will associate with individual GPS to send its current location to the system. The ESP32 Arduino and GSM shield need a power supply that can be given by using adapters.

4.3.2 AUTOMATED ROAD CROSSING

In our connection set up, we have used ESP32. The first FSR is connected to the analog pin in the ESP32. The second FSR is connected to the analog pin in the ESP32. In this feature, we have used two servo motors. The first one is connected to the 08 no. Digital pin in the ESP32 and the second servo motor is connected to the 09 no-digital pin in the ESP32. The echo of the sonar sensor is connected to the 04 no. Digital pin in the ESP32 and the Trigger is connected to the 07 digital pins in the ESP32. To get the values of FSRs properly, we have used two resistors of 1K each in parallel connection with the two FSRs.

5. RESULT

5.1 RESULT ANALYSIS

The resistive force register (FSR) senses the input and send it to the microcontroller (Arduino). The microcontroller sends commands successfully by using a predefined algorithm. The GSM module receives the command and notifies the required location. The value from FSR was a very low range, and the weight adjustment was required to get the expected value. The resister was crucial to get the prefect outcome. IR sensor was used to stop the train in our demonstration, and the distance from the train to IR plays a vital role here. ESP32 Microcontroller was sending command very efficiently and can be able to stop the train immediately to avoid a collision. The servo motor was used to control the line-bar in the crossing. It was getting the expected input from the FSR and performed accordingly.

Figure 5.1: View of Application

The sonar sensor was working well and giving the distance correctly so that the servo stopped to fall if there were any objects below it. It was also effectively fell down the line bar as soon as the object removed. Distance from sonar to floor: 6.67cm. The output from a piezo vibration sensor was fluctuating, and it was giving a small value against very high vibration. The overall demonstration gives expected outcomes through the vibration of the train was insufficient so that it cannot detect from a desired distance by the vibration sensor. On the other hand, the FSR, Servo Motor, HC-SR04Sonar, was very much compatible with ESP32 microcontroller, and the GSM module 800L, which is used there to send a message, was quite responsive. In a demonstration, GPS could not be able to distinguish the different locations of trains as it was a minimal setup. Therefore, it was ignored to use GPS and work with IR to stop the train and sent massage through the internet only to the control room, which was working well.

6. CONCLUSION

A Before summing up, we can say accidents occurring in the railway transportation system cost a huge number of lives. So, an advanced and dependable system is needed to avert these types of accidents and also find out the possibilities of their occurrence. The proposed model is a simple prototype that will work as an independent inspector for the railway network. This system is highly reliable and cost-effective in any traffic area, sub urban area, and the routes. Furthermore, this is small in size and low power consumption, which is, in fact, a simple solution to all the problems of a railway mishap in one system. This system will work all the modules at a time to reduce accidents.

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