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Robot For Railway Track Monitoring with Obstacle Detection

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Abstract— *Railway safety is a major concern due to the risk of accidents caused by track cracks and obstacles on the railway line. Manual inspection of tracks is time-consuming and may not always be effective in preventing accidents. This proposed work aims to develop a low-cost, IoT-based system using the ESP32 microcontroller to detect cracks in railway tracks and identify obstacles on the track in real time. The system uses sensors such as ultrasonic sensors and IR sensors to detect track damage and any objects blocking the railway path. When a crack or obstacle is detected, the system immediately sends an alert to the control center via Wi-Fi. This helps in quick response and maintenance, improving the safety and reliability of railway operations.*

Key Words: Railway, Crack Detection, Obstacle Detection, ESP32, IoT, Ultrasonic Sensor, IR Sensor, Real-Time Alert, Safety, Monitoring

1. INTRODUCTION

Railways are one of the most widely used modes of transportation, carrying millions of passengers and tons of goods every day. With such heavy usage, ensuring the safety of railway tracks is very important. However, manually inspecting long stretches of tracks for cracks or obstacles is time-consuming, tiring, and sometimes not reliable. Even a small crack in the rail or an unnoticed object on the track can cause major accidents, leading to damage, delays, or even loss of life. To reduce human effort and improve railway safety, we propose a smart system that can automatically detect cracks and obstacles on the tracks using simple sensors and microcontroller technology.

This system is built using an ESP32 microcontroller, which is low-cost and supports wireless communication. The project uses IR sensors to detect cracks in the metal tracks and ultrasonic sensors to sense any obstacles lying ahead on the path. When a crack or object is detected, the system immediately sends a real-time alert using Wi-Fi to notify the concerned team, allowing them to take quick action. This solution can be mounted on a small trolley that moves along the railway track and continuously monitors it. The goal is to reduce accidents, save time in maintenance, and make railway operations safer and more efficient, especially in remote or hard-to-reach areas.

2. LITERATURE REVIEW

There are various automated railway monitoring systems available in the market, and as the railway sector moves toward modernization and automation, several research works and projects have been carried out in this field. Some of these works include:

This project involves a trolley-based system that travels along railway tracks to perform real-time monitoring. It uses IR sensors to detect track cracks and ultrasonic sensors to identify physical obstacles, all coordinated by an Arduino microcontroller. The system enhances inspection efficiency by automating the process and providing immediate alerts. It overcomes limitations of earlier methods that relied on manual inspection or focused only on crack detection, by also including obstacle detection, reducing human error, and improving response time to potential hazards[1].

This work proposes an IoT-based railway monitoring system that integrates crack and obstacle detection using IR and ultrasonic sensors controlled by an ESP8266 microcontroller. The methodology involves mounting the system on a DC motor-powered trolley that autonomously navigates the track, detecting faults and transmitting data via Wi-Fi to a cloud platform for real-time monitoring. The results demonstrate improved efficiency in identifying hazards on tracks with minimal human involvement. However, the system's reliance on Wi-Fi connectivity and limited sensor accuracy in certain environments are key limitations addressed in further research[2].

This paper proposes a mobile prototype for railway track crack detection using IR sensors and a microcontroller to process sensor data. The methodology involves a motorized setup that moves along the track, with alerts triggered through a buzzer and LED indicators upon crack detection. The system delivers real-time notifications while maintaining low power consumption. The results show improved responsiveness in detecting track faults, but the lack of remote communication and limited detection range are noted limitations that restrict its scalability for large-scale monitoring. [3].

This paper proposes a smart autonomous vehicle for railway monitoring that integrates GPS, GSM, IR, and ultrasonic sensors to detect track cracks and obstacles. The methodology involves using NodeMCU as the central controller, which processes sensor data while the vehicle moves along the track, sending SMS alerts with location details via GSM and GPS modules. The system enables real-time data sharing by uploading information online for monitoring by authorities. Results show enhanced safety and responsiveness; however, limitations include dependency on mobile networks for communication and possible sensor interference in complex environments[4].

This paper proposes an ESP32-based crack detection system that uses IR sensors to monitor railway tracks and sends fault alerts via cloud services. The methodology involves real-time data collection through sensors, with alerts and historical data stored online for analysis. The results indicate effective crack detection with reduced reliance on manual inspections and improved data accessibility. However, limitations include dependence on stable internet connectivity and the system's inability to detect obstacles or other types of faults beyond cracks. [5].

3. METHDOLOGY

The proposed system can provide an effective solution for railway safety by continuously monitoring the condition of railway tracks and detecting both cracks and obstacles. It uses an ESP32 microcontroller as the main controller, which is connected to IR sensors for detecting cracks in the metal rails and ultrasonic sensors to identify objects or obstructions ahead on the track. The entire setup is mounted on a small, motorized trolley that moves along the track. When a crack or obstacle is detected, the system immediately sends a notification through Wi-Fi to the concerned authorities. The sensors scan at regular intervals to ensure real-time monitoring. A 12V power source is used to operate the motors and sensors. The compact design and automation make it suitable for deployment in remote or less accessible railway areas.

A. Proposed System:

In our proposed model, we are concentrating on monitoring the railway track condition through efficient detection of cracks and obstacles. We are aiming to bring the technology closer to railway departments and maintenance workers. This system eliminates the manual effort of physically inspecting railway tracks by staff.

1. Circuit Diagram:

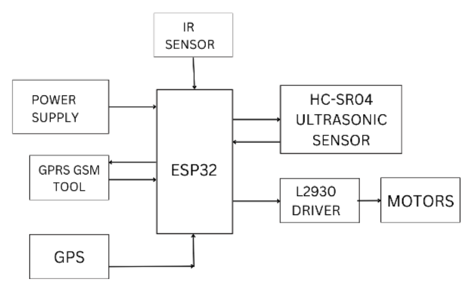

Fig.1: Circuit dia. of proposed system

1. **Working:**

To achieve the main goal of our proposed system, we have divided it into three main modules. The implemented system is very useful in areas where long tracks need to be monitored and human inspection is not efficient. The first module consists of an IR sensor, which is used to detect cracks in the railway track. When a crack is present, the IR beam gets interrupted, and the ESP32 microcontroller receives this signal. Based on this, it can trigger an alert indicating a crack has been found.

The second Stage includes an ultrasonic sensor, which is used to detect any obstacle on the railway track ahead of the trolley. If any object is detected within a specific range, the system will immediately stop the trolley and notify the

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concerned personnel through a wireless alert system. The distance is regularly monitored as the trolley moves.

In the third Stage, we use the ESP32 to connect the system to Wi-Fi and send real-time data to the web page. This helps the railway monitoring team check crack and obstacle data remotely. All readings can also be stored in the cloud for future reference and analysis. The system is fully automated, reducing the need for constant manual track inspection and improving safety.

2. **Flow Chart:**

the working flow of the proposed model. It starts with the initialization of GSM and GPS modules for communication and location tracking. Once the modules are locked, the robot begins its forward movement along the railway track. During movement, the obstacle detection sensor continuously checks for any obstruction on the path. If an obstacle is detected, the robot immediately stops, and the GPS module tracks the exact location. The GSM module then sends this location to the connected railway authority for further action.

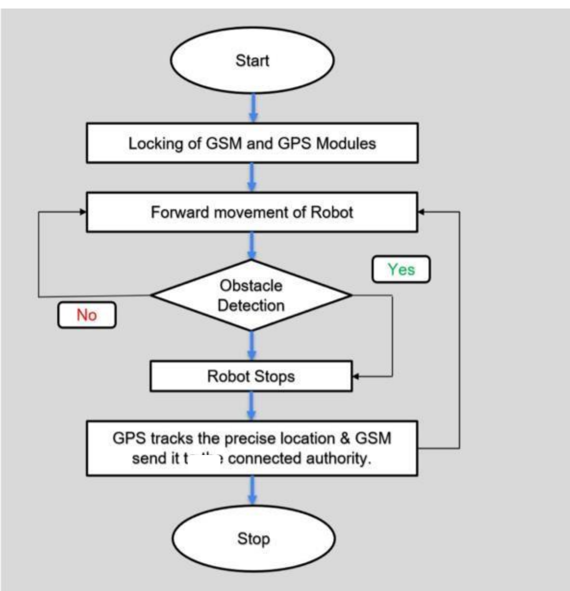

Fig.2: Flowchart

3. TOOLS AND TECHNOLOGY USED

In this system we have used IR sensors which help in detecting cracks on the railway track by identifying interruptions in the infrared beam. If a crack is found, the sensor sends a signal to the ESP32 microcontroller. For obstacle detection, we have used an ultrasonic sensor that continuously measures the distance in front of the trolley.

Another important component is the GPS module which provides accurate location data, and the GSM module is used to send alerts to the railway authority. The system uses Wi-Fi and Blynk app for live monitoring.

4. RESULTS AND ANALYSIS

Based on the IR sensor and ultrasonic sensor data, the proposed system effectively detects track cracks and obstacles. Compared to previous systems which only focused on single detection, our model provides added features like obstacle avoidance, location tracking using GPS, and automatic alert through GSM. After successful prototype testing, the system gave accurate detection results on test tracks. Graphs show the readings of obstacle detection and crack detection with response time. Another output shows the alert received on web page with precise location details.

Fig.3: Output(robot)

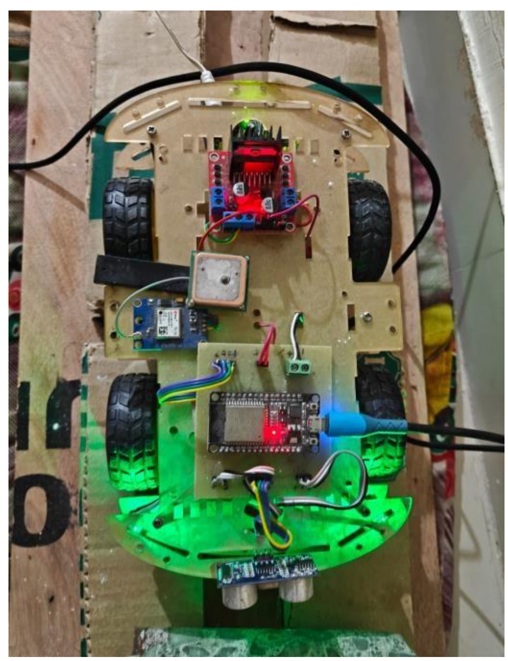

Fig.3: Robot with homemade track

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Fig.4: Output(obstacle detection)

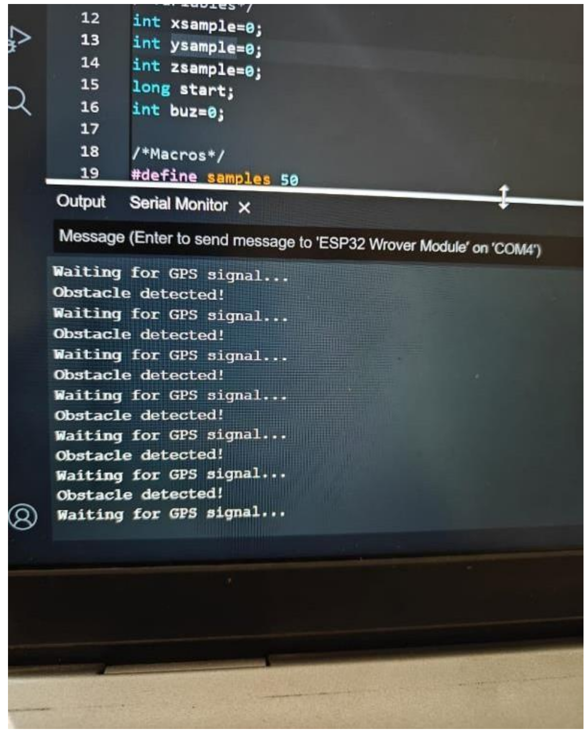

Fig.5: Output(obstacle detected)

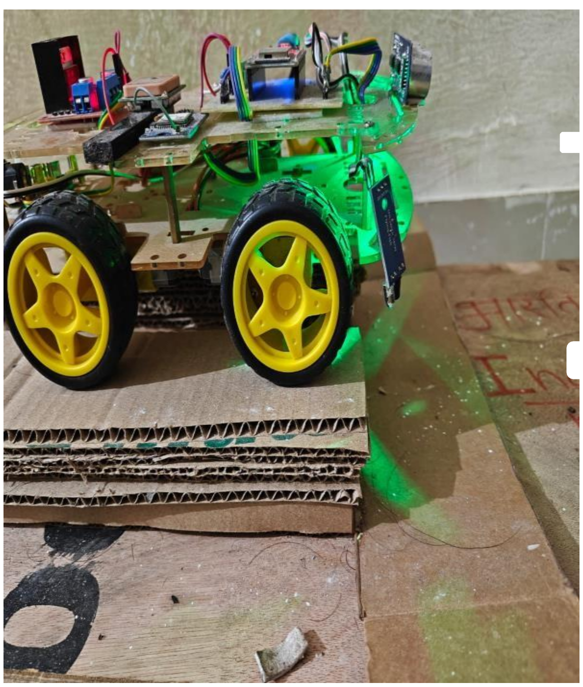

Fig.6: Output(crack detection)

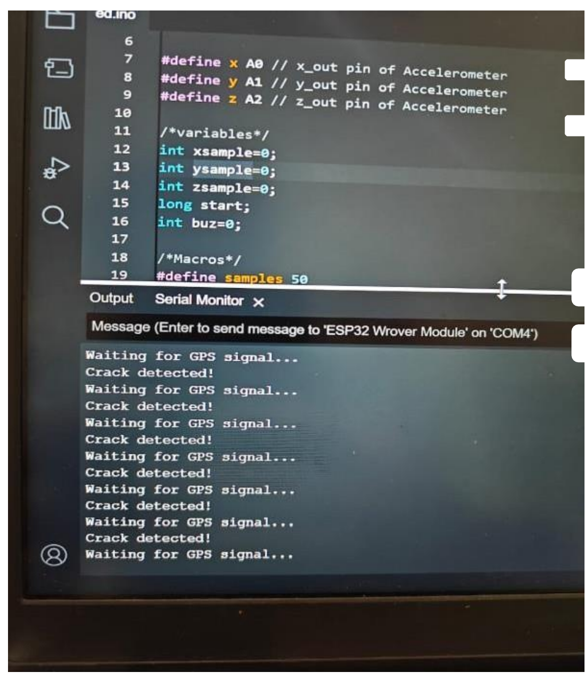

Fig.7: Output(crack Detected)

5. Future Scope

In the future, this system can be upgraded by adding camera modules with image processing to visually confirm track cracks or obstacles. Integration of AI algorithms can help in predicting the severity of cracks and suggest maintenance actions automatically. Solar panels can be added to make the system more power-efficient and suitable for long- distance remote railway track monitoring.

Additionally, the robot can be enhanced to detect broken rails or loose joints using vibration sensors and metal detectors. The data collected over time can be analyzed to identify commonly affected areas and improve maintenance scheduling. Real-time alerts can also be expanded to mobile apps or centralized dashboards for faster action by railway authorities.

6. CONCLUSION

This paper presented the development of a smart railway crack and obstacle detection system using ESP32, IR, and ultrasonic sensors. The aim was to reduce the manual inspection workload and improve the reliability of railway maintenance by detecting defects in real-time. The system successfully identifies cracks and obstacles on the track, and provides instant alerts through a web-based platform. This helps ensure timely intervention and prevents possible accidents, making the railway system safer and more efficient.

The system is designed to be low-cost, portable, and adaptable for different terrains and track conditions. It has shown promising results during testing and can be scaled for long-distance railway lines. By integrating automated detection with remote monitoring, this project supports the modernization of traditional railway maintenance methods. With future improvements like AI-based crack analysis or solar- powered mobility, the system could become an essential part of smart railway infrastructure.

7. REFERENCES

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