

# Railway Track Monitoring and Alert System using IOT & ESP32-CAM

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**ABSTRACT:** The safety of the railway tracks is of the utmost importance in the modern transport system because sometimes the cracks and structural defects cannot be noticed and, therefore, result in the most serious accidents. In this paper, an IoT-based Railway Track Monitoring and Alert System with the ESP32-CAM module to inspect and detect faults in real-time is presented. The offered system is based on a mobile robotic unit that has IR sensors on it to constantly check track conditions and identify cracks. When a fault is detected, the system halts the robot, takes real-time pictures with the ESP32-CAM, and sends notifications and GPS position to authorized personnel on a Telegram platform. There is also activation of a buzzer to give instant local alerts. The ESP32 microcontroller organizes sensor data processing, motor control and communication. The system provides a cost-efficient, automated and dependable service to track continuously the condition of railway tracks, minimizing manual inspections and enhancing the railway safety.

**KEY WORDS:** Railway Track Monitoring, IoT, ESP32, ESP32-CAM, Crack Detection, IR Sensors, GPS Module, Real-Time Alerts, Embedded Systems, Robotic Inspection.

## I. INTRODUCTION

Transportation via railways is significant in the way people are connected and the economic activities. It is among the cheapest and common methods of transport. However, maintaining railway safety is still a major issue due to problems like track cracks, misalignment, and lack of continuous monitoring. Such defects may result in severe train crashes, and lives and property can be lost. Therefore, the necessity to have an effective system to monitor railway tracks and identify faults at an early stage is great. As technologies such as Internet of Things (IoT) and embedded systems emerged, new ways of improving railway safety have been implemented. The IoT-driven systems are equipped with sensors and communication units to identify cracks and transmit data in real time. Existing literature [1], [2] demonstrates that this type of system can minimize manual inspection and enhance safety. Moreover, the systems built with the help of controllers such as NodeMCU facilitate quicker data transmission and enhanced monitoring performance [4]. Another significant enhancement in this regard is automation. Other researchers have developed robots capable of self-moving along railway lines and automatic fault detection [3], [5]. Such robotic systems save the human effort and are capable of operating in harsh or hazardous conditions, thereby making the inspection process more dependable. Besides this, railway tracks are also monitored using wireless sensor networks as well as embedded systems. Such systems aid in gathering information in various places and offer real-time fault detection [7]. Embedded-based designs enhance better performance and reliability of the system [6]. Moreover, some systems use ultrasonic sensors to measure internal cracks smaller in size [8]. These systems have been enhanced by the recent technologies such as cloud computing and artificial intelligence. The cloud-based systems enable the storage and accessibility of the data remotely [9]. Images are also detected using deep learning techniques to detect defects with high accuracy [10]. Additionally, intelligent transport networks and real time

warning systems are used to assist in making expedient decisions and minimizing dangers [11], [12]. The current systems continue to experience such problems as high cost and complexity. In this work, a simple IoT-based system detecting track cracks and providing real-time alerts is described, which can be used to enhance safety and minimize the risks of accidents.

**Table 1.1: Literature survey of some of the existing work :**

Sl.No	Author	Description	Methodology	Key Findings
1.	Revathi et al. (2024)	IoT-based railway crack detection system	Sensors with IoT communication	IoT systems help in early fault detection and reduce manual work
2.	Shalini & Gopalakrishnan (2021)	Intelligent crack detection using IoT	IR sensors with wireless system	Sensor-based detection improves efficiency but depends on accuracy
3	Vijaya Sekhar Babu et al. (2023)	Babu et al. (2023) Robotic railway inspection system	Robot with sensors and camera	Robotic systems reduce human effort and improve inspection coverage
4.	Chougule et al. (2024)	NodeMCU-based monitoring system	IoT-based data transmission	Real-time monitoring is possible with low-cost controllers
5.	Nandanwar et al. (2022)	Automatic crack detection robot	Robotic system with sensors	Automation increases reliability in track inspection
6.	Rajasekaran & Nagaraj (2022)	Smart monitoring using embedded systems	Embedded controller with sensors	Embedded systems provide faster response and better control
7.	Kumar & Singh (2021)	Fault detection using WSN	Wireless sensor network approach	WSN helps in covering large railway areas efficiently
8.	Sharma et al. (2022)	Ultrasonic crack detection system	Ultrasonic sensing with IoT	Ultrasonic sensors give more accurate crack detection than IR
9.	Khan et al. (2023)	ESP32-based monitoring system	IoT with cloud integration	Cloud integration allows remote access and data storage
10.	Lee et al. (2023)	Vision-based inspection system	Deep learning techniques	AI-based systems provide high accuracy but increase complexity
11.	Mishra & Das (2022)	Smart railway safety system	IoT and AI integration	Combining IoT and AI improves overall safety performance
12.	Nguyen et al. (2023)	Real-time fault detection system	Embedded IoT devices	Real-time systems help in quick response to faults
13.	Kumar & Patel (2021)	Smart railway monitoring	IoT sensor-based system	Continuous monitoring improves maintenance planning
14.	Ramesh & Suresh (2020)	Embedded crack detection system	Embedded programming	Embedded design reduces system cost and complexity
15.	Gupta & Sharma (2020)	Railway monitoring using WSN	Distributed sensors	Distributed systems increase scalability of monitoring
16.	Verma & Singh (2021)	IoT-based safety system	IoT communication modules	IoT improves connectivity and real-time communication
17.	Singh & Kumar (2020)	Ultrasonic crack detection	Ultrasonic sensors	Accurate sensing reduces chances of missing small cracks

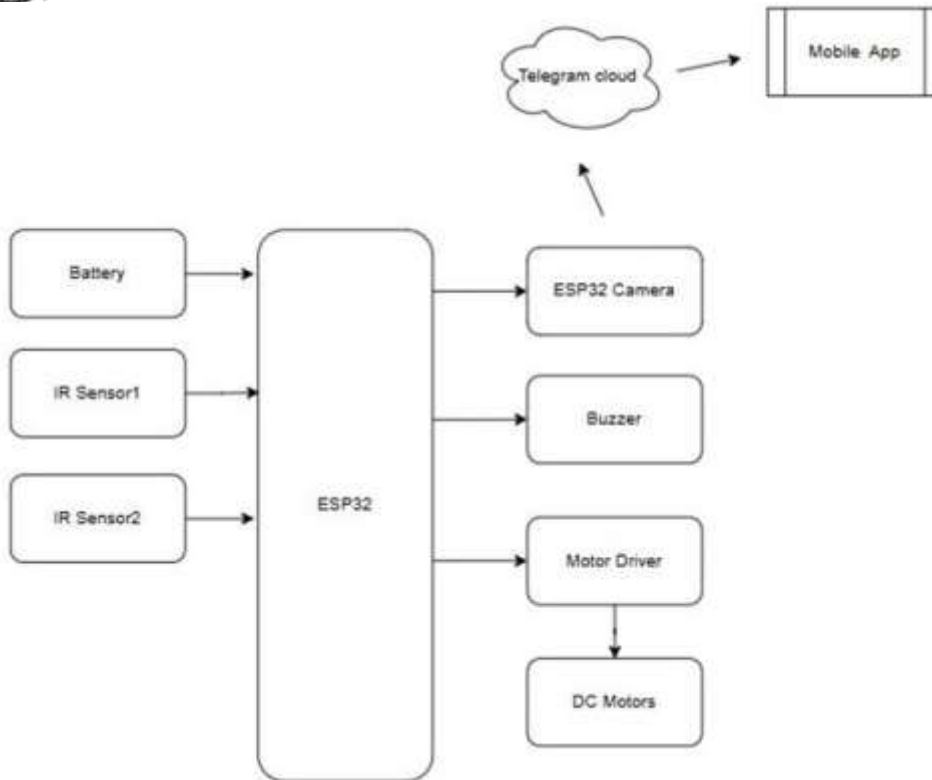
18.	Mehta & Shah (2021)	Cloud-based railway monitoring	IoT with cloud system	Cloud platforms improve data availability and storage
19.	Reddy & Rao (2022)	Robotic inspection system	Robotics with sensors	Robotics enables automatic and continuous inspection
20.	Das & Mishra (2021)	IoT fault detection system	Sensor-based IoT system	IoT systems enable faster detection and alerts
21.	Verma & Singh (2020)	GSM and GPS system	Communication modules	Location tracking helps in quick maintenance response
22.	Joshi & Kulkarni (2020)	Arduino-based safety system	Microcontroller design	Low-cost systems are suitable for basic monitoring
23.	Wang & Chen (2021)	Deep learning detection system	AI-based image processing	Deep learning improves accuracy but needs high processing power
24.	Patel & Mehta (2021)	IoT monitoring system	Real-time IoT approach	Continuous monitoring reduces risk of accidents
25.	Brown & Wilson (2022)	Smart transportation system	IoT-based framework	Integrated systems improve overall railway safety

## II. PROBLEM STATEMENT

The safety of railway tracks is of great concern as issues such as cracks, misalignment, and damage may lead to severe accidents. Today, the majority of railway track inspection is performed manually, which is time-consuming and requires much human labour. Humans can also fail to notice small cracks that can be hazardous in future. IoT, sensors, and robots have been utilized in the development of many systems to address this issue. Nevertheless, these systems have a few disadvantages such as being very expensive, complex in nature, and in some cases they fail to issue alerts in real-time. Certain systems also require certain conditions and are to be checked by humans regularly. The other significant problem is that the majority of the current systems are not a full solution. Other systems are good in spotting the faults only, whilst others are good in tracking the track only yet they do not integrate the two with an appropriate alert system. The key issue is, therefore, to create a simple, inexpensive, and efficient system to measure cracks in railway tracks, track them and notify about them in real-time and prevent accidents. Besides, the system must be user-friendly, have few servicing needs, and functionality across various environmental conditions to guarantee stability and enhanced safety.

## III. METHODOLOGY

The system suggested will monitor the cracks in the railway tracks and provide alerts through IoT. With this system, a tiny robotic unit will be travelling on the railway line using DC motors. The motor driver is a means of controlling the motors which are controlled by the ESP32 microcontroller. As it travels, the robot constantly keeps track of the condition of the tracks. IR sensors are used to detect cracks. These sensors work based on infrared reflection. In case the track is normal, the sensor output is constant. When the crack or gap exists, the reflection of the signal is altered and the ESP32 recognizes the alteration. The sensor output is constantly monitored by the controller to detect faults. When a crack is detected, the ESP32 stops the robot and activates a buzzer to give an alert. Simultaneously, the ESP32-CAM takes a photo of the damaged circuit. The exact location of the fault is obtained with the help of a GPS module. The photograph and the position are transmitted to the user via a Telegram message with the help of Wi-Fi. This assists in prompt action. It is a non-stop system that lowers the number of hand inspections that enhance the safety of railways.



**Fig 3.1: Block diagram of system**

The above Figure 3.1 illustrates the overall architecture of the proposed Railway Track Monitoring System, in which the ESP32 serves as the central control unit interfacing with sensors, ESP32-CAM, motor driver, and communication modules, enabling accurate fault detection, real-time image capture, and instant alert transmission to authorized users.

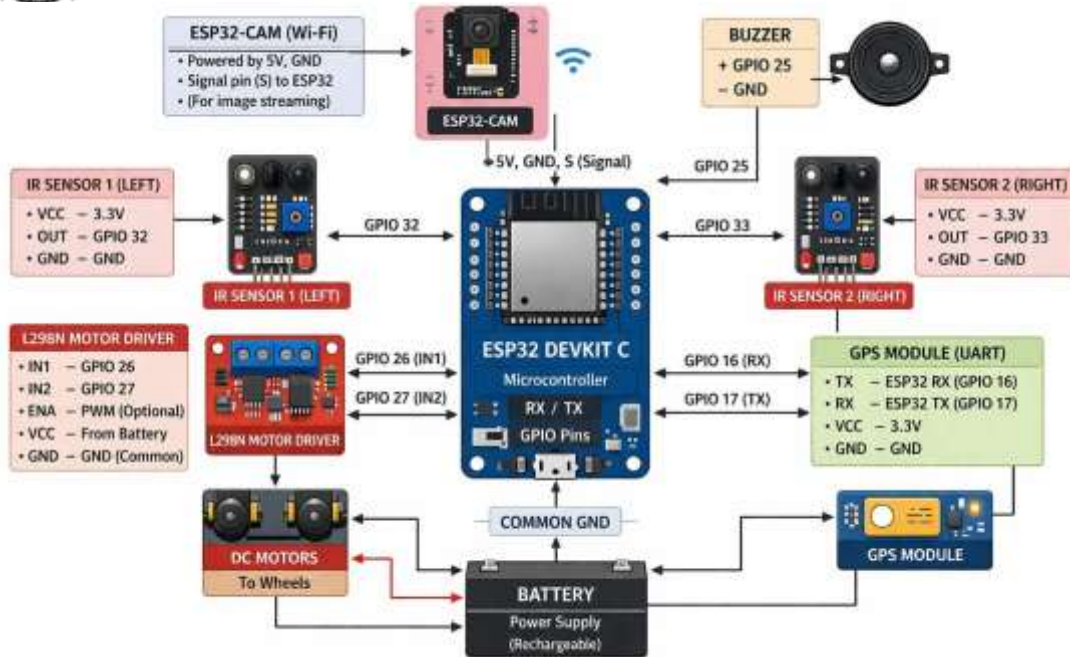
#### **IV. SYSTEM DESIGN AND IMPLEMENTATION**

The connection diagram and flowchart together explain the overall design and working of the proposed system.

##### **A. HARDWARE INTERFACING :**

The connection diagram shows how all the components are connected with the ESP32 microcontroller. The ESP32 acts as the main controller of the system. IR sensors are connected to detect cracks in the railway track, and they send signals to the ESP32. The motor driver is used to control the DC motors, which help the robot move along the track.

The ESP32-CAM is used to capture images and send them through Wi-Fi. A GPS module is connected to provide the exact location of the fault. A buzzer is also connected to give an alert when a crack is detected. All components are powered using a battery, and a common ground is maintained.



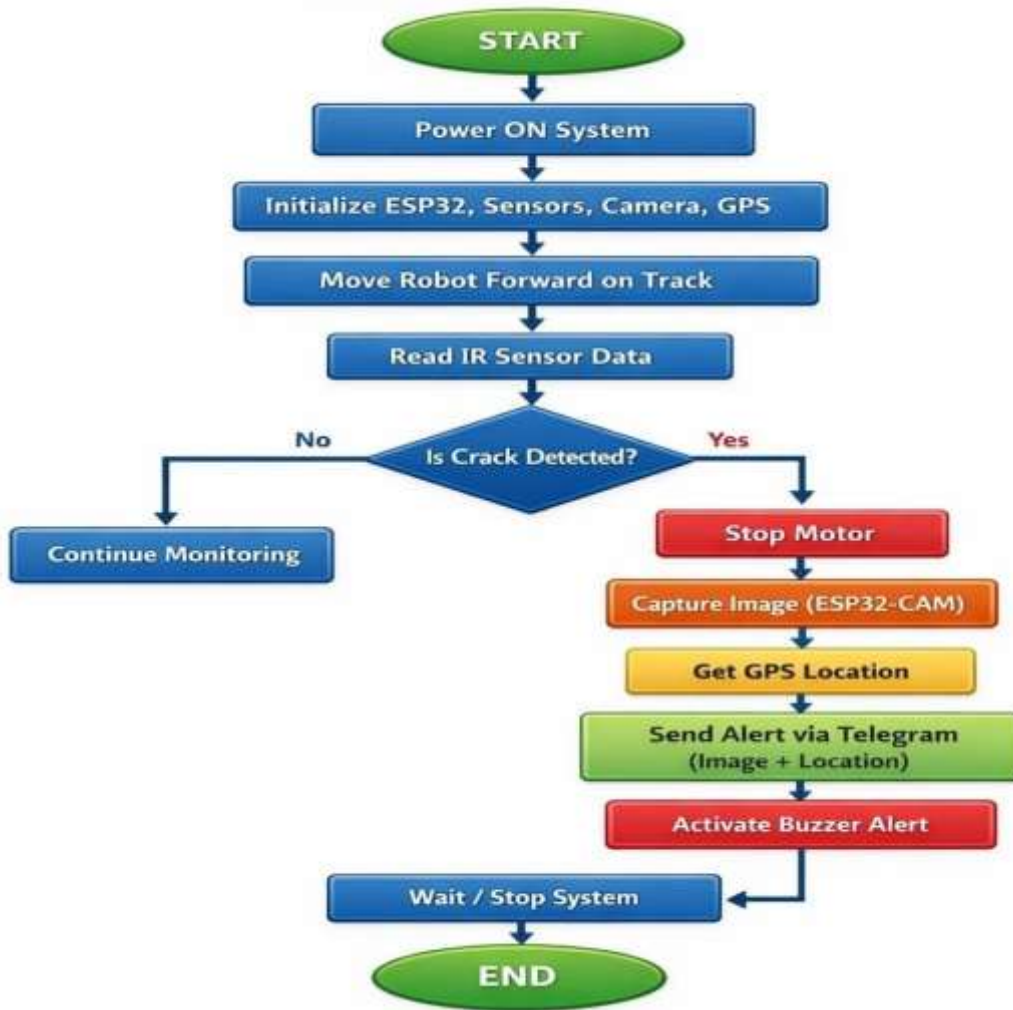
**Fig 4.1: Schematic diagram**

The above Figure 4.1 shows the complete hardware interfacing of the proposed system, where the ESP32 acts as the central controller connecting all components. The IR sensors are used to detect cracks on the railway track and send signals to the ESP32. The ESP32-CAM captures images of the detected fault, while the GPS module provides the exact location. The motor driver controls the movement of DC motors, and the buzzer gives an alert during fault detection. All components are powered by a battery with a common ground connection. This setup enables smooth coordination between sensing, processing, and alert transmission for effective railway track monitoring.

## B. SYSTEM FLOWCHART :

The flowchart explains the working of the system step by step. First, the system is powered ON and all components are initialized. Then the robot starts moving on the track and continuously reads data from IR sensors.

If no crack is detected, the system continues monitoring. If a crack is detected, the motor stops immediately. Then the ESP32-CAM captures an image, and the GPS module provides the location. After that, an alert is sent through Telegram with image and location details. Finally, a buzzer is activated, and the system stops.



**Fig 4.2: Workflow diagram**

The above Figure 4.2 shows the system flowchart of the proposed railway track monitoring system. The process starts by powering on the system and initializing the ESP32, sensors, camera, and GPS module. The robot then moves forward along the track while continuously reading data from the IR sensors. If no crack is detected, the system continues monitoring. When a crack is detected, the robot stops immediately, captures an image using the ESP32-CAM, and retrieves the GPS location. The system then sends an alert through Telegram along with the image and location details, and activates the buzzer for immediate notification before stopping the operation.

## V. RESULTS AND DISCUSSION

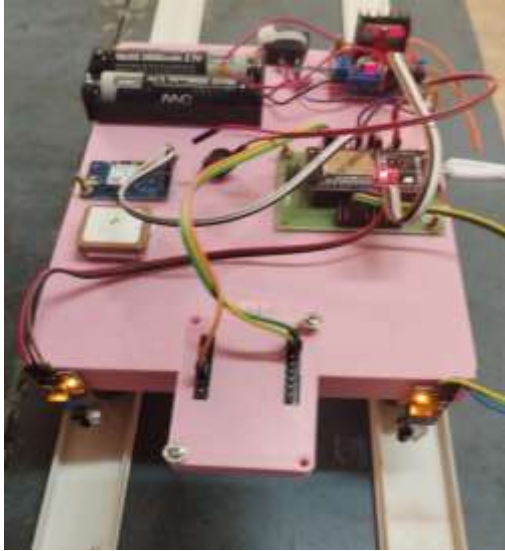
The proposed system detects railway track cracks in real time using IR sensors. When a fault is detected, the robot stops immediately and a buzzer gives a local alert. At the same time, the ESP32-CAM captures an image, and the GPS module provides the location details. This information is sent through Telegram to the user. Overall, the system enables quick detection, instant alerts, and faster response, improving railway safety.

Thus, the system performs the following actions:

Crack Detection → Robot Stop → Buzzer Alert → Image Capture → Location & Alert Message, this ensures quick detection, immediate alert, and rapid response, thereby improving railway safety.

### CASE-1: Normal Track Condition

Robot moving along the railway track during testing (No Crack Detected)



**Fig 5.1: Robot Movement on Track**

In this case, the robot was tested under normal track conditions. It moved smoothly using DC motors while IR sensors continuously monitored the track. Since no crack was detected, the robot continued without interruption. No buzzer or alert was activated, and no message was sent. This shows that the system works properly in normal conditions and remains in monitoring mode without false alerts.

#### **CASE-2: IR Sensor Detecting Crack**

Close-up view of IR sensors aligned with the track for crack detection

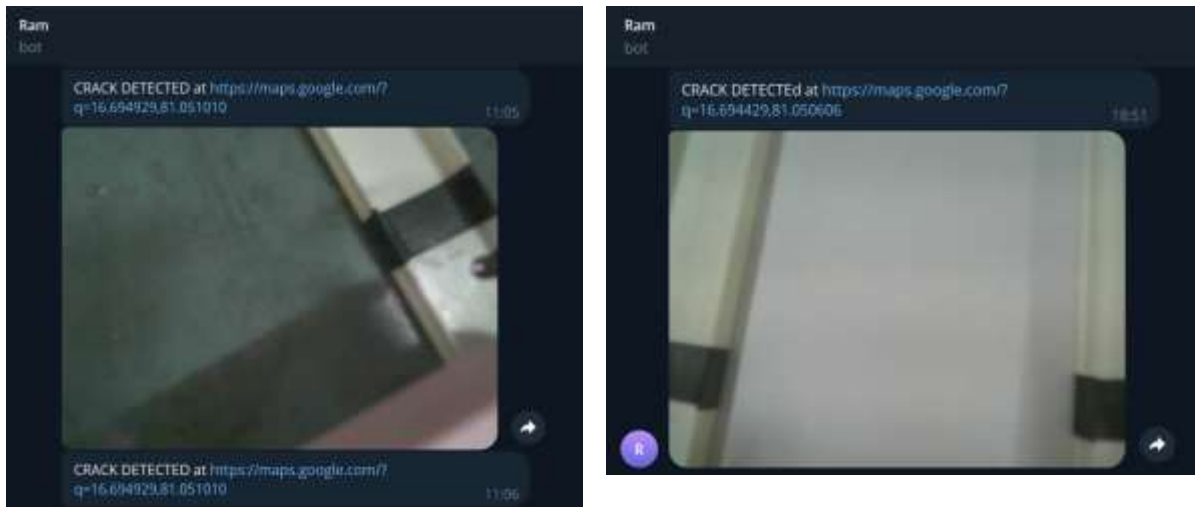


**Fig 5.2: IR Sensor Placement**

This case explains how IR sensors detect cracks on the railway track. The sensors are placed close to the track surface to monitor changes using infrared signals. When the track is normal, the output remains stable. If a crack is present, the signal changes and is detected by the ESP32. This shows that proper sensor alignment is important for accurate and reliable crack detection.

### CASE-3: Telegram Alert Message Generation After Crack Detection

Telegram message showing image and GPS location.



**Fig 5.3: Screenshot of Telegram message showing image and GPS location**

This case evaluates the communication capability of the system. When a crack is detected, an alert message is sent through Telegram using IoT. The message includes the captured image and GPS location details. This shows that the communication system works effectively and provides real-time alerts, helping authorities to respond quickly and improve safety.

### CASE-4: Captured Image of Crack

Sample image captured by ESP32-CAM showing the track defect.



**Fig 5.4: ESP32-CAM Captured Image of Crack**

This case shows the performance of the ESP32-CAM in capturing images of detected cracks. When a fault is identified, the camera captures a clear image of the track. This provides visual confirmation of the defect and helps in analyzing the issue. It also improves system reliability and reduces chances of false detection.

### CASE-5: Real –Time Fault Location Tracking Using GPS Module

Serial monitor or map view displaying latitude and longitude



**Fig 5.5: GPS Location Output**

This case evaluates the GPS module for providing the location of the detected crack. The system successfully retrieves latitude and longitude coordinates and sends them along with the alert message. This helps in identifying the exact fault location quickly. The results show that the GPS module works accurately and improves the system by enabling faster maintenance and response.

### CASE-6: Camera-Based Environmental Monitoring



**Fig 5.6: Image Captured by ESP32-CAM for Surrounding Monitoring**

In this case, the system was tested to detect obstacles near the track. When an object was detected by the IR sensors, the ESP32 stopped the robot and activated the camera. The ESP32-CAM captured an image of the surrounding area and sent it to the user through Telegram. This shows that the system can monitor nearby conditions and provide real-time visual information.



## VI. CONCLUSION

The proposed system to monitor and alert railway track based on IoT and ESP32-CAM is an effective solution to enhancing the level of railway safety by automating and monitoring the conditions in real time. The system can also identify cracks with an IR sensor, take pictures of the damaged track, and send notifications with the location information via the IoT communication. This helps to save on manual inspection and human error is minimal. The experimental outcomes demonstrate that the system is capable of identifying the faults and halting the robot quickly as well as producing local and remote warnings. The integration of ESP32-CAM and GPS helps in providing visual confirmation and exact fault location, which supports quick maintenance actions. Overall, the system is simple, cost-effective, and reliable. It may be enhanced with more sophisticated sensors, enhanced imaging and smart methods. The project can make the railways operations safer and more efficient.

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