

## **RAILWAY TRACK CRACK DETECTION SYSTEM USING IOT**

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**ABSTRACT**-Railway transportation is one of the most widely used and cost-effective modes of transport across the globe. However, railway safety remains a critical concern due to frequent accidents caused by track defects such as cracks and fractures. This paper presents an IoT-enabled railway Track Crack Detection System designed to enhance safety through real time monitoring and automated alert mechanism.

The proposed system utilizes infrared (IR) sensors to detect surface irregularities, an ESP32-CAM module to capture visual evidence, and GPS and GSM Modules to transmit location-based alerts via Telegram. The integration of sensing, imaging and communication technologies enables continuous monitoring, reduces dependence on manual inspection and endures rapid response to potential hazards. The system is cost-effective, scalable and suitable for deployment in remote areas, making it a viable solution for modern smart railway infrastructure.

In Addition to real-time detection, the system emphasizes reliability and accuracy by combining multiple sensing and communication modules into a unified framework. The IR sensors continuously scan the railway track for discontinuities, while the embedded controller processes the sensor data and identifies abnormal conditions based on predefined thresholds. Upon detection of a crack or fault, the ESP32-CAM module is automatically triggered to capture high resolution images of the affected section, providing visual confirmation for further analysis.

Simultaneously, The GPS module determines the precise geographical coordinates of the fault location, which are then transmitted through the GSM network to a remote monitoring interface. The use of a G-MAIL based alert system ensures that railway authorities receive instant notifications, including images and location data, enabling quicker decision-making and response.

**KEYWORDS:** -

Railway Safety, Crack detection, IoT, ESP32-CAM, IR sensors, GSM, GPS, Real-Time Monitoring, Smart Transportation.

### **1.INTRODUCTION**

Railway networks serve as the backbone of transportation systems in many countries, including India. With increasing passenger demand and freight movement, ensuring the safety and reliability of railway tracks has become more critical than ever. One of the major causes of Railway accidents is track failure due to cracks, corrosion, or misalignment. These defects often go undetected until they lead to catastrophic derailments.

Traditional inspection methods rely heavily on manual labour, where workers physically inspect tracks over long distances. This approach is not only time-consuming but also prone to human error and inefficiency. Additionally, remote and rural areas often remain unmonitored due to limited resources, increasing the risk of unnoticed damage.

To address these challenges, there is a growing need for automated and intelligent monitoring systems. The advancement of Internet of Things (IoT) technologies has enabled the development of smart systems capable of real-time data acquisition, processing, and communication. The proposed system integrates multiple technologies such as IR sensing, image processing, GPS tracking, and GSM communication to create a comprehensive railway monitoring solution.

This work focuses on designing a compact, low-cost, and effective system capable of continuously monitoring railway tracks and providing instant alerts when a crack is detected. By combining

hardware and software components, the system ensures timely detection and response, significantly improving railway safety.

With the rapid expansion of railway networks and the increasing demand for faster and more efficient transportation, the need for advanced safety mechanisms has become more significant. Railway tracks are subjected to continuous mechanical stress, temperature variations, and environmental impacts, which gradually lead to wear and tear. Over time, these factors contribute to the formation of cracks and structural weakness that may not be visible to the naked eye during routine inspections. If such defects are not detected at an early stage, they can escalate into severe failures, causing derailments and large-scale accidents.

In recent years, technological advancements in the field of Internet of Things (IoT) and embedded systems have opened new possibilities for automating infrastructure monitoring. IoT-based systems enable real-time data collection, processing, and communication, allowing for continuous surveillance of Critical assets such as railway tracks. By using integrating sensors, microcontrollers, and wireless communication modules, it is possible to design intelligent systems that can detect anomalies and immediately notify concerned authorities

## 2.LITERATURE SURVEY

Railway track crack detection has been an important area of research due to its direct impact on transportation safety. Over the years, several techniques and systems have been developed to identify faults in railway tracks, ranging from traditional manual inspection methods to advanced automated solutions using sensors and artificial intelligence.

Early approaches to railway track monitoring primarily relied on manual inspection, where trained personnel physically examined tracks for visible defects. Although this method is simple and does not require complex equipment, it is highly time-consuming, labour-intensive, and prone to human error. Moreover, manual inspection cannot guarantee continuous monitoring, which increases the risk of undetected cracks, especially in remote or less frequently monitored areas.

To improve detection accuracy, ultrasonic testing techniques were introduced. These systems use ultrasonic waves to detect internal flaws within the rails. When ultrasonic waves encounter a crack, they are reflected back and analysed to determine the presence of defects. While this method is highly effective in identifying internal cracks, it requires expensive equipment and skilled operators. Additionally, ultrasonic systems are typically mounted on specialized inspection vehicles, limiting their ability to provide real-time continuous monitoring.

In recent years, sensor-based systems have gained popularity due to their ability to provide automated and real-time detection. Several researches have proposed systems using vibration sensors, piezoelectric sensors, and infrared (IR) sensors to detect irregularities in railway tracks. IR sensor-based systems are particularly advantageous because they are cost-effective, simple to implement, and capable of detecting surface-level discontinuities. However, many of these systems lack integrated communication mechanisms, which limits their effectiveness in providing timely alerts.

With the advancement of embedded systems and wireless communication, Internet of Things (IoT)-based solutions have emerged as a promising approach for railway monitoring. IoT-enabled systems integrate sensors with microcontrollers and communication modules to enable real-time data transmission. Some studies have proposed the use of wireless sensor networks (WSNs) to monitor track conditions and send alerts to control centres. These systems improve efficiency but often face challenges related to power consumption, network reliability, and scalability.

The proposed system addresses these gaps by integrating IR sensors, an ESP32-CAM module, GPS, and GSM communication into a unified IoT-based framework. It combines real-time detection with image-based verification and instant alert transmission, making it a more practical and efficient solution compared to existing approaches.

Some researchers have also explored hybrid systems that combine multiple technologies, such as sensors and image processing to improve detection reliability. These systems aim to overcome the limitations of individual methods by providing both physical detection and visual confirmation.

However, many existing hybrid models are still in the experimental stage and are not optimized for cost-effective large-scale deployment.

Despite significant progress in this field, several challenges remain. Main existing systems are either too expensive, lack real-time alert capabilities, or are not suitable for deployment in remote areas. There is a clear need for a system that is not only accurate and reliable but also affordable, scalable, and capable of continuous monitoring.

### 3.METHODOLOGY

The proposed Railway Track Crack Detection System is designed as an integrated frame network that combines sensing, processing, and communication technologies to achieve real-time monitoring and alert generation. The methodology focuses on continuous inspection of railway tracks, early detection of cracks, and immediate transmission of information to concerned authorities. The system is structured in a modular manner to ensure flexibility, scalability, and ease of implementation.

#### 3.1 system Overview

The overall system consists of multiple hardware components working together in a synchronized manner. The key components include infrared (IR) sensors for crack detection, a microcontroller unit for data processing, an ESP32-CAM module for image capture, a GPS module for location tracking and a GSM module for communication. These components are interconnected to form a complete automated monitoring system.

The system continuously scans the railway track using IR sensors. When a crack or discontinuity is detected, the microcontroller processed the signal and triggers subsequent actions such as capturing an image, obtaining an image, obtaining location data, and sending an alert message. This sequential operation ensures accurate detection and efficient communication.

#### 3.2 System Architecture

The architecture of the proposed system is divided into major layers:

- Sensing Layer

This layer includes IR sensor that are responsible for detecting cracks or irregularities on the railway track surface. The sensors emit infrared rays and measure the reflected signals. Any variation in reflection indicates a possible crack or defect.

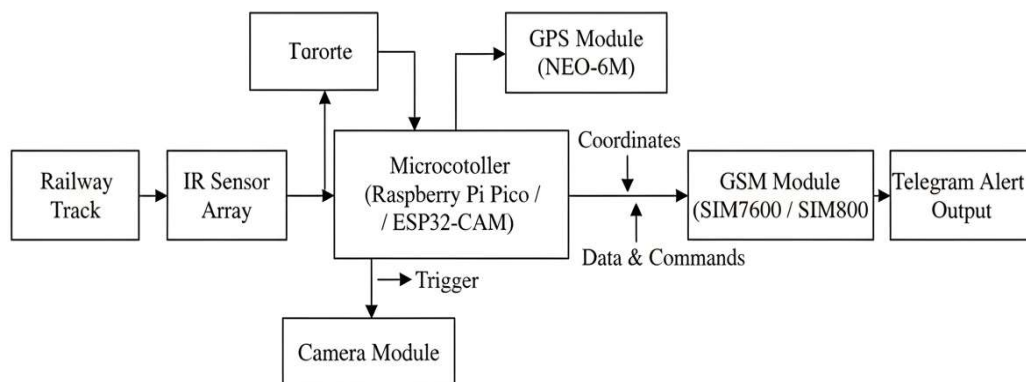
- Processing Layer

The processing layer consists of a microcontroller (Such as ESP32-cam) that receives input from the sensors. It analyses the data and determines whether the detected variation exceeds a predefined threshold. If a crack is identified, it initiates further actions.

- Communication layer

This layer includes the ESP32 CAM, GPS module and GSM module. He ESP32-CAM Captures images of the detected crack, the GPS module provides location coordinates, and the GSM module transmits this information to a remote user via a GMAIL notification system

### BLOCKDIAGRAM



- IR Sensors

These sensors are placed near the railway track to continuously monitor the surface. They detect cracks by analysing the reflection of infrared rays. A sudden variation in reflection indicates a discontinuity or crack.

- Microcontroller Unit

The microcontroller acts as the brain of the system. It receives input from IR sensors, processes the data, and decides whether a crack is present based on predefined threshold values

- ESP32-CAM

Once a crack is detected, the microcontroller activates the ESP32-CAM module. This module captures an image of the damaged track area, providing visual confirmation.

- GPS Module

The GPS module determines the exact geographical coordinates (latitude and longitude) of the detected crack location. This helps in identifying the precise position for maintenance.

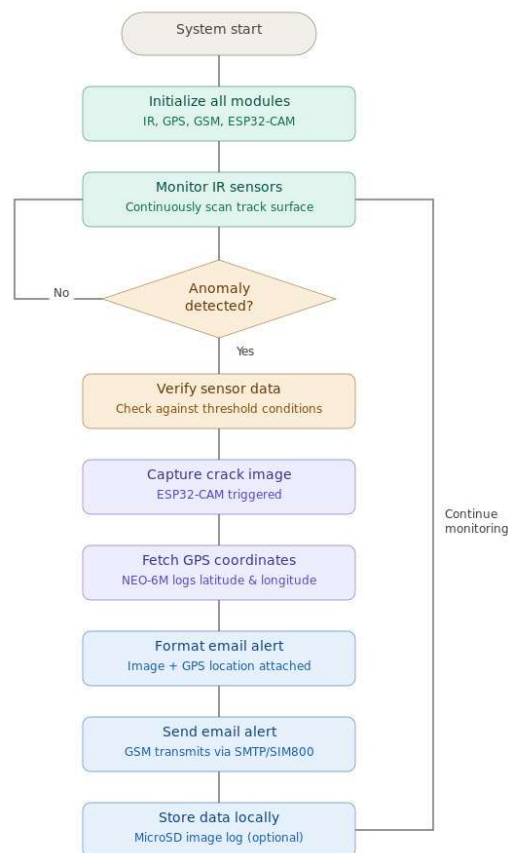
- GSM Module

The GSM module is responsible for communication. It sends the alert message along with location details and captured image to the user.

- GMAIL alert system

The final output is delivered through GMAIL, where authorities receive instant notifications, ensuring quick action.

### FLOWCHART



#### 1.START

The system begins its operation when power is supplied. All modules are prepared for execution.

#### 2.SYSTEM INITIALIZATION

The microcontroller initializes all connected hardware components, including:

- IR sensors for crack detection
- ESP32-CAM for image capture
- GPS module for location tracking
- GSM module for communication

Proper initialization ensures accurate data collection and reliable communication.

### 3.SENSOR DATA ACQUISITION

The IR sensors continuously monitor the railway track surface. These sensors emit infrared radiation and analyse the reflected signals to identify surface discontinuities.

### 4.CRACK DETECTION DECISION

The system evaluates the sensor readings against a predefined threshold:

- If the readings indicate normal conditions -No crack detected
- If abnormal readings are found-crack detected

This decision-making step is critical for triggering further actions.

### 5.IMAGE CAPTURE

When a crack is detected, the ESP32-CAM module is activated to capture a real-time image of the affected track section. This provides visual confirmation of the defect.

### 6.LOCATION ACQUISITION

The GPS module retrieves the exact geographical coordinates (latitude and longitude) of the detected crack. This helps in pinpointing the fault location accurately.

### 7.ALERT TRANSMISSION

The GSM module sends an alert message via GMAIL. The alert typically includes:

- Crack detection notification
- captured image
- GPS location coordinates

This ensures immediate notification to railway authorities

### 8.DATA STORAGE

The system may store detected data locally or in a cloud database for future analysis and maintenance planning

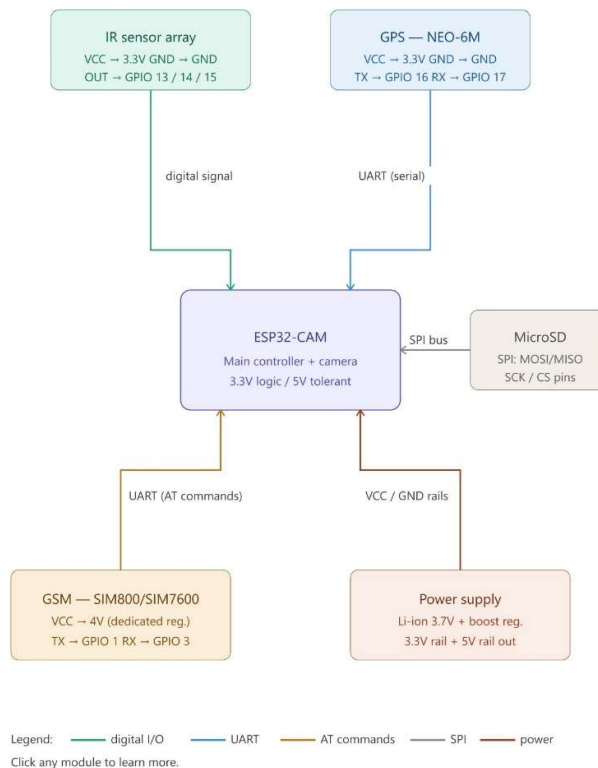
### 9.CONTINUOUS MONITORING LOOP

After completing the alert process, the system returns to monitoring mode. This loop continues indefinitely, enabling real-time surveillance of railway tracks.

### 10.END

Although the system is designed for continuous operation, the process formally ends when the system is powered off.

## CIRCUIT DIAGRAM



The proposed Railway Track Crack Detection System is built around microcontroller-based architecture that integrates sensing, imaging, and communication modules to ensure real-time monitoring of track conditions. The circuit is powered by a regulated 5v supply, which provides the necessary operating voltage to all components. Infrared (IR) sensors are positioned along the railway track and connected to the digital input pins of the microcontroller. These sensors continuously emit infrared radiation and detect the reflected signals from the track surface. Any disruption in the reflection pattern, accused by cracks or gaps, is interpreted as an anomaly and is processed by the microcontroller.

Upon detecting a crack, the microcontroller activates the ESP32-CAM module through serial communication. The ESP32-CAM captures an image of the affected region, providing visual confirmation of the defect. Simultaneously, the GPS module, interfaced via UART communication, retrieves the precise geographical coordinates of the detected fault location. The system then utilizes a GSM module to transmit an alert message to the concerned authorities. This alert includes the captured image and the GPS coordinates ensuring quick identification and response.

All modules share a common ground to maintain signal stability and proper circuit operation. The microcontroller serves as the central control unit, coordinating data acquisition, processing, and communication between the IR sensors, camera module, GPS, and GSM units. THE overall circuit design ensures efficient real-time detection, minimal power consumption, and reliable data transmission, making it suitable for deployment in both urban and remote railway environments.

## RESULTS

The proposed railway Track crack Detection System was successfully designed, implemented, and tested under controlled experimental conditions to evaluate its performance, reliability, and accuracy. The system integrates IR sensors, an ESP32-CAM module, GPS, and GSM communication to detect cracks in railway tracks and provide real time alerts. The results obtained from the prototype

demonstrate the effectiveness of the system in identifying track faults and transmitting timely notifications.

#### **A. Crack Detection Performance**

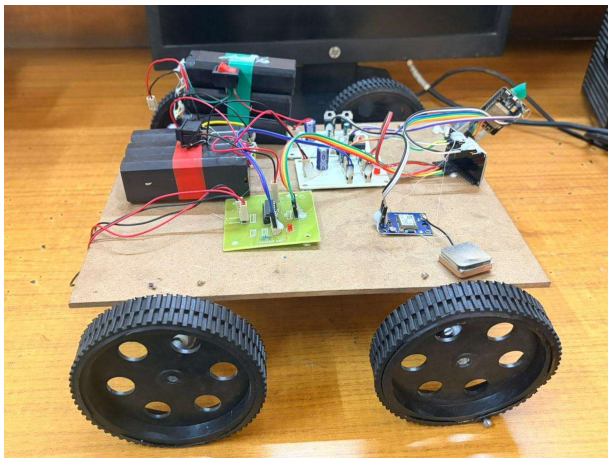
The IR sensors were tested on different track conditions, including normal tracks, minor gaps, and visible cracks. It was observed that the sensors could reliably detect discontinuities in the track surface by identifying variations in reflected infrared signals. The detection accuracy was found to be high for surface-level cracks and gaps. The system responded almost instantly when a crack was introduced, triggering the subsequent processes without noticeable delay.

However, the sensitivity of the IR sensors depends on proper alignment and environmental conditions. In cases of excessive dust or strong ambient light, minor fluctuations in sensor readings were observed. These issues can be minimized through calibration and shielding techniques.

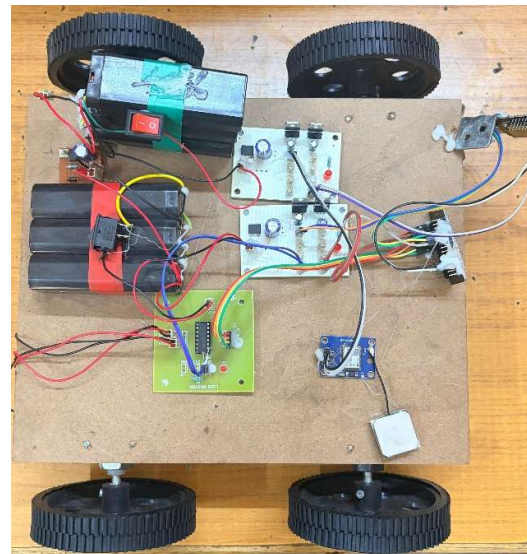
#### **B. Image Capture and verification**

The ESP32-CAM module successfully captured images of the detected crack locations. The images provided clear visual evidence, which is essential for verification by maintenance authorities. The camera response time was observed to be within a few seconds after crack detection, ensuring that no critical information is missed.

The quality of the captured images depends on lighting conditions. Under adequate lighting, the images were sharp and detailed, whereas low-light conditions slightly reduced clarity. This limitation can be addressed by integrating additional lighting components such as LEDs.



**Fig: Hardware prototype**



#### **C. GPS Location Accuracy**

The GPS module accurately recorded the geographical coordinates of the detected crack locations. During testing, the module provided location accuracy within a few meters, which is sufficient for railway maintenance purposes. The coordinates were successfully embedded in the alert message, enabling easy identification of the fault location.

It was observed that the GPS module required a few seconds to establish a connection with satellites, especially during initial startup. Once locked, the location updates were stable and consistent.

#### **D. Alert Transmission via GSM**

The GSM module effectively transmitted alert messages to the designated GMAIL interface. Each alert included:

- Notification of crack detection

- GPS coordinates
- Captured image

The transmission time was dependent on network availability but generally occurred within a few seconds. The use of telegram ensured that alerts were easily accessible and could be monitored remotely.

In areas with weak network coverage, slight delays in message delivery were observed. Despite this, the system maintained reliability and eventually delivered the alerts once the network was restored.

#### **E. System Response Time**

The overall system response time, from crack detection to alert transmission, was measured and found to be efficient. The sequence of operations—sensor detection, image capture, GPS acquisition, and message transmission—was completed within a short duration, making the system suitable for real-time applications.

#### **F. Power consumption and efficiency**

The system was powered using a battery supply and demonstrated low power consumption due to the use of efficient components such as the ESP32 microcontroller.

This makes the system suitable for long-term deployment in remote locations. Power optimization techniques, such as sleep modes, can further enhance efficiency.

#### **G. Comparative Analysis**

Compared to traditional manual inspection methods, the proposed system offers several advantages:

- Continuous monitoring without human intervention
- Faster detection and response time
- Reduced operational costs
- Improved safety and reliability

While advanced systems like ultrasonic testing provide higher precision, they are significantly more expensive and complex. The proposed system strikes a balance between cost and performance, making it practical for widespread deployment.

#### **H. Limitations**

Despite its advantages, the system has certain limitations:

- Sensitivity to environmental conditions
- Dependence on network connectivity for alert transmission
- Limited ability to detect very small or internal cracks

These limitations can be addressed in future work by integrating advanced sensors and machine learning techniques.

### **OVERALL DISCUSSION**

The experimental results confirm that the proposed system is capable of detecting railway track cracks in real time and providing immediate alerts with location and visual evidence. The integration of IoT technologies enhances system efficiency and reduces the need for manual inspection. The system demonstrates strong potential for improving railway safety and can serve as a foundation for future smart railway monitoring solutions.