ISSN 2277-2685
IJESR/April. 2026/ Vol-16/Issue-2s/68-75
Mohd Roman Ali *et. al.,* / International Journal of Engineering & Science Research

Full Length Article

IoT Based Railway Track Crack Detection System

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Accepted 25-04-2026

Abstract:
Railway Safety is a critical concern as track defects, particularly cracks, frequently cause derailments and catastrophic accidents. This project introduces IoT- based railway track detection and alerting system to address this issue. The proposed system employs Ultrasonic sensors, a microcontroller and a GPS module to identify structural anomalies in real time. Upon detecting a crack, the system halts its operation and transmits the precise GPS location to railway authorities using IoT protocols, enabling timely interventions and reducing the risk of accidents .The system operates autonomously, significantly minimizing the need for manual inspections while providing continuous monitoring over extensive railway networks. By leveraging IoT, the system ensures efficient, cost- effective operations, enhancing both the safety and reliability of railway transportation. The implementation of this solution has the potential to reduce maintenance costs, prevent derailments, and improve overall infrastructure safety. The IoT-based system significantly reduces the need for manual inspection, lowers operational costs, and enhances the overall reliability of railway infrastructure .This technology not only improves detection accuracy but also enables predictive maintenance by identifying faults at an early stage, thereby preventing derailments and major accidents. The IoT-based system significantly reduces the need for manual inspection, lowers operational and maintenance costs, and enhances the overall reliability and safety of railway infrastructure. By leveraging automation, cloud analytics, and real-time monitoring, the proposed system offers a smart, scalable and cost-effective approach to modern railway safety management.

Introduction

Railway transport plays a major role in transportation because it is economical and suitable for long-distance travel. Millions of people depend on railway systems every day. However, maintaining railway safety is a challenging task due to continuous usage and environmental factors. One of the main causes of railway accidents is the presence of cracks in railway tracks. These cracks may occur due to metal fatigue, temperature changes, or heavy loads. Even a small crack can expand over time and cause derailment of trains.

Traditionally, railway track inspection is done manually by workers. This method is time- consuming and not always reliable. Human errors may occur, and it is difficult to monitor long railway tracks continuously. With the advancement of technology, the internet of things (IOT) provides a better solution. IOT allows devices to communicate with each other and send data over the internet. By using IOT, railway tracks can be monitored continuously without human intervention. Indian railway network, the fourth largest in the world, serves as a backbone for transportation across the country, with a route length of over standards. Derailments caused by track defects, particularly cracks, are a major concern, leading to severe accidents and loss of lives. In the year 2016-17 alone, derailments accounted for the highest number fatalities in a decade, with approximately 90% caused by undetected track cracks.

2. Traditional methods of railway track inspection rely heavily on manual efforts, which are time- consuming, prone to errors, and incapable of providing real-time monitoring across large distances. To address these limitations, this project introduces as IOT-based railway track cracks detection and alerting system that enables automated and efficient detection of track anomalies. The proposed system integrates a microcontroller Ultrasonic sensor, and a GPS module to identify cracks on railway tracks and alert authorities in real time. By leveraging IOT technology, the system ensures continuous monitoring, reduces dependency on human intervention, and enhances overall railway safety. The rapid advancement of internet of things (IOT) technology has significantly transformed traditional monitoring systems into intelligent, automated, and real-time solutions. One critical application of IOT is in railway safety, particularly in the detection of cracks and faults in railway tracks, which are among the leading causes of

train accidents worldwide.

Literature Survey

Name of the paper	Authors and year	Contributions	Limitations
"Iot Based Railway Track Crack Detection System"	Dr. M. Revathi et al, 2024	Designed a real- time IOT system using Arduino, ESP82866, and Sensors. Used cloud-based data processing (firebase) for monitoring. Improved detection accuracy with integrated hardware architecture.	Requires stable internet connectivity. Power consumption issues in remote areas. Scalability challenges for large railway networks.
IOT Based Railway Track Crack Monitoring System	Ganesh Chougle et al. 2024	Implemented NodeMCU (ESP8266) with proximity sensors. Used Blynk IOT platforms for real- time monitoring. Introduced solar-powered system for sustainability.	Limited detection range. Not suitable for high-speed railway systems. Sensor-based detection may produce false positives.
Railway Track Crack Detection Robot using GPRS-GPS	Srijith Kamalasanan et al. 2018	Developed a robotic vehicle using Raspberry Pi. Used IR sensors for crack detection and GPS for location tracking. Enabled wireless communication using GPRS.	Slow inspection speed due to robotic movement. Not suitable for continuous large-scale monitoring. Requires manual deployment.
Real-Time Railway Track Crack and Obstacle Detection System using Arduino and IoT Alert	Yukta P.Gosavi et al. 2025	Combined crack detection with obstacle detection	Limited processing capability of Arduino Difficulty in detecting micro-cracks.

IoT Based Smart Railway Track Crack Detection and Monitoring System	Aakanksha Pal et al.2025	Introduced smart monitoring using IoT and automation. Focused on continuous real-time surveillance	High implementation cost. Requires maintenance of multiple sensors.
An End-to –End Approach to Detect Railway Track Defects using Deep Learning	M. Haroon et al. 2024	Proposed a hybrid deep learning model using YOLOv8 and U-Net.	Requires large computational resources
Detection of Surface Defects on Railway Tracks Based on Deep learning	M. Wang et al. 2022	Applied CNN-based models for defect detection.	Needs labeled datasets. Not suitable for low- cost IoT deployment
Autonomous Fault Detection in Railway Tracks Using Deep Learning	S. Nguyen et al. 2020	Introduced automated Inspection using AI models. Improved detection speed and accuracy.	High implementation cost. Requires advanced hardware.
Automatic Railway Track Crack Detection Robot Car using IoT	Avini Nandanwar et al. 2022	Developed IoT- enabled robot for track inspection. Uses ultrasonic sensors and GPS for crack detection.	Slow inspection speed. Limited coverage area.
A Systematic Literature Review of Railway Defect Detection Techniques	A. Kumar et al 2024	Comprehensive review of detection methods Identifies trends like deep learning and automation.	Does not propose a new system Focuses mainly on analysis rather than implementation.

In 2023-2024, research shifted towards more efficient and connected systems. The work “IoT- Based Railway Track Crack Detection System” by M, Revathi introduced cloud-based monitoring using IoT platforms, enabling real-time data access and improved system scalability. Likewise “IoT-Based Railway Track Crack Monitoring System” by Ganesh Chougle (2024) focused on energy-efficient designs using solar power and NodeMCU modules.
Railway Track Crack Detection Robot using GPRS-GPS by Srijith Kamalasanan (2018) introduced robotic inspection systems using IR sensors and GPS modules. These systems focused on reducing manual inspection but were limited by slow operation and lack of continuous monitoring.
Real-Time Railway Track Crack and Obstacle Detection System using Arduino and IoT Alert (2025) the works by Yukta P. Gosawi focus on real time Iot-based railway track monitoring systems, where sensor data is processed and transmitted to cloud platforms for instant fault detection. IoT Based Smart Railway Track Crack Detection and Monitoring System (2025) Aakanksha pal focuses on significantly improving railway safety and reducing manual inspection. Data collected from sensors is transmitted to a cloud or IoT platform, allowing remote monitoring and analysis.
An End-to-End Approach to Detect Railway Track Defects using Deep Learning by M. Haroon (2024) which uses deep learning models such as YOLO and U Net for highly accurate defect detection. Similarity, Detection of Surface Defects on Railway Tracks Based on Deep Learning by M. Wang additionally using ESP32 and wireless sensor networks has enhanced communication and automation capabilities.
Autonomous Fault Detection in Railway Tracks Using Deep Learning by S. Nguyen (2020) demonstrates the growing role of AI in railway safety. The system then sends alerts to railway authorities via SMS or email for immediate action.
Automation Railway Track Crack Using Detection Robot Car using IOT (2022) by Avini Nandanwar this system uses a robot car equipped with ultrasonic

ISSN 2277-2685
IJESR/April. 2026/ Vol-16/Issue-2s/68-75
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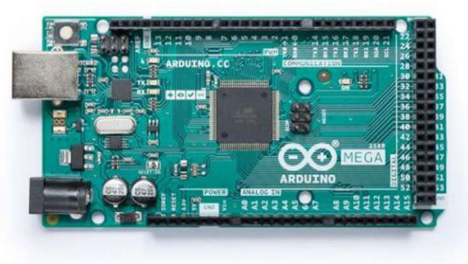
sensors to identify cracks and damages on the track surface. A GPS module is used to determine the exact location of the fault, while a NodeMCU (ESP8266) module enables wireless data transmission to a control station.

A Systematic Literature Review of Railway Detect Detection Techniques (2024) by A. Kumar , it analyzes different methods used for crack detection such as ultrasonic sensing, infrared sensing, and computer vision techniques. The paper mainly focuses on comparing existing approaches and identifying research gaps for future development.

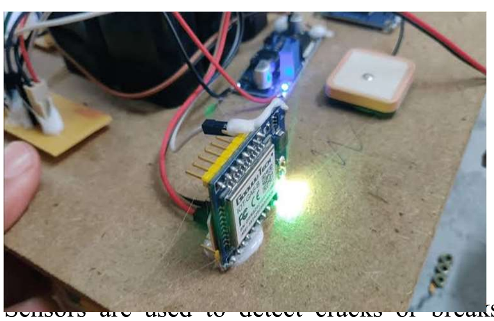
Hardware Specifications:

Microcontroller (Arduino)



Arduino is the main control unit of the system. It receives signals from sensors, processes the data, and controls other components. It is easy to program and widely used in IOT projects. The board also has a USB interface for both power supply and programming, and is supported by a large community, providing extensive resources for development.

Crack Detection Sensor



Sensors are used to detect cracks or breaks in the railway track. When the track is continuous, the circuit is complete, if a crack occurs, the circuit breaks, and the sensor sends a signal. In this project the sensor is used to detect any objects or irregularities that could interfere with the robot's movement along with the tracks.

IR Sensors

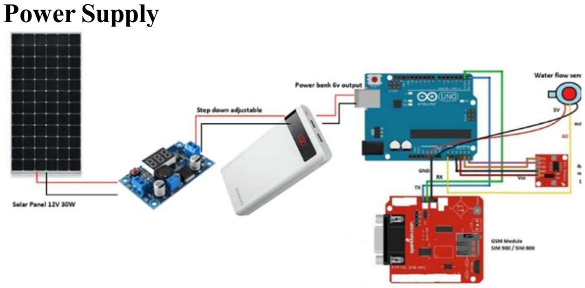
In an IOT-based railway track crack detection system, the IR sensor is used to identify surface-level defects in real time. It is connected to a microcontroller like Arduino Uno or ESP32, which processes the signal and sends alerts through IOT networks.

The sensor is low-cost, simple to use, and fast, but it is limited to detecting only visible cracks and may be affected by environmental conditions such as dust, rai**n, or sunlight.**

GPS Module

The GPS module plays a vital role in providing location data for the detected cracks. When a crack is identified by the sensors, a microcontroller triggers the GPS module to obtain the precise latitude and longitude coordinates. This location information is crucial for railway authorities to carry out immediate repairs or maintenance at the specific site of the detection. The GPS module ensures that the system can operate effectively in real-time and at large scale across extensively railway networks.

Power Supply

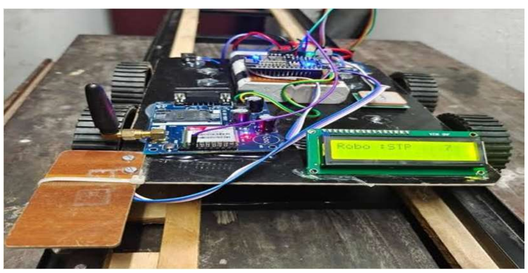


A Stable power supply is required to operate all components. It provides necessary voltage to the microcontroller and sensors. The 12V battery serves as the primary power source .The battery is ideal for providing necessary power to the components, ensuring smooth operation on the railway tracks.

Buzzer

The buzzer provides an immediate sound alert when a crack is detected. This helps nearby workers to take quick action.

LCD Display



The LCD is used to display system status such as "No Crack" or "Crack Detected". It helps in monitoring the system locally.

Ultrasonic sensors

An ultrasonic sensor is a device that uses high-frequency sound waves to detect objects and measure distances. It consists of a transmitter, which sends ultrasonic waves, and a receiver, which listens for the reflected waves (echo). When these waves hit a surface like a railway track, they bounce back to the sensor. If there is a crack, gap, or irregularity, the time taken for the echo to return changes, helping the system identify the defect.

GSM Module

A GSM (Global System for Mobile Communication) module is used for wireless communication through mobile networks. It allows a device to send and receive data using a SIM card, similar to a mobile phone. Common modules like SIM800L GSM Module or SIM900 GSM Module are widely used in IOT projects for communication
purposes.

I. Necessity of the System

The need for an automated railway crack detection system is very important for improving safety and efficiency. First, it helps in preventing accidents. Early detection of cracks can avoid serious damage and save lives.
Second, it reduces manual inspection work. Workers no longer need to inspect tracks continuously, which save time and effort.
Third, the system provides real-time monitoring. Any fault is detected immediately, and alerts are sent without delay.
Fourth, it improves maintenance efficiently. Authorities can take action quickly and repair the track before the problem becomes serious.
Finally, the system is cost-effective in the long run because it reduces accident-related losses and maintenance costs.

System Overview
The proposed system consists of sensors, a microcontroller, and a communication module. Sensors are placed on the railway track to detect cracks. These sensors continuously monitor the condition of the track. When a crack is detected, the sensor sends a signal to the microcontroller. The microcontroller processes the signal and checks whether the fault is valid. If a crack is confirmed, the system activates an alert mechanism.
The communication module, such as ESP2866, sends the alert message to a control station through the

internet. The system can also display information on an LCD screen. This setup ensures continuous monitoring and quick response.

The system continuously scans railway tracks using sensors. When a crack or fault is detected the sensor generates a signal and microcontroller processes the signal and confirms the defect. GPS module captures the exact location and data is transmitted to the cloud via IOT communication, and alert is sent to railway authorities (SMS/App/Email).

The IOT-Based railway track crack detection system provides an efficient, automated, and real- time solution for railway safety. By integrating sensors, GPS, and IOT communication, it significantly reduces accidents and improves maintenance efficiency.

Applications

1.This system can be used in different areas:

2.Railway track monitoring systems Industrial safety applications Infrastructure monitoring systems

3.It is especially useful in areas where manual inspection is difficult.

Future Scope

The system can be further improved using advanced technologies. GPS can be added to identify the exact location of the crack. This will help in faster repair. Artificial Intelligence (AI) can be used to predict possible faults before they occur. Cloud storage can be used to store data and analyze track conditions overtime. More advanced sensors can be used to improve accuracy and reliability. Thus system can also be integrated with automatic train control systems to stop trains in case of emergency

Conclusion

Railway safety is important, and track cracks are one of the major causes of accidents. The IOT- based railway track crack detection system provides an effective solution to this problem.

This system detects cracks automatically and sends alerts in real time. It reduces human effort and improved safety. This system is simple, reliable, and cost-effective. With further improvements, this system can be implemented on a large scale and contribute to safer railway transportation.

Thus project successfully demonstrates how IOT technology, when combined with sensors, GPS, and wireless communication, can detect cracks and faults in railway tracks effectively and in real time. By continuously monitoring the track condition and providing instant alerts with exact location details, the system helps railway authorities take immediate action and prevent serious accidents such as derailments. It also reduces manual inspection efforts, save time, and lowers maintenance costs through early detection of problems.

II. Results and Discussion

1.System Performance Evaluation

The proposed IOT- based railway track crack detection system was successfully designed, implanted and tested under both controlled and real-time conditions. The system integrates sensors such as IR sensors. Ultrasonic sensors, GPS, and GSM modules with a microcontroller to detect cracks and transmit information to a remote monitoring station. The overall system performance was found to be reliable, with quick response time and efficient communication between hardware and software components. During testing, the system was able to continuously monitor track conditions without interruption, demonstrating its suitability for real-time applications.

2.Crack Detection Accuracy

The crack detection mechanism was evaluated using IR and ultrasonic sensors placed along a prototype railway track. The sensors successfully identified discontinuous and cracks in the track by detecting changes in reflected signals. The system showed high accuracy in detecting both small and large cracks. In most test cases, cracks were detected instantly as the sensing unit passed over the affected region. Minor errors occurred in cases of extremely small surface irregularities; however, these can be minimized through proper calibration and sensor optimization. Overall, the results confirm that the system provides reliable crack detection.

3. Sensor Response and Analysis

The IR sensor effectively detected breaks in the continuously of the track by monitoring reflected infrared signals. Similarity, the ultrasonic sensor measured the distance between track surfaces and identified anomalies based on variations in echo time. The combined use of these sensors improved detection reliability and reduced false positives. The sensors responded quickly to changes, ensuring real-time detection. The experimental analysis indicates that sensor fusion enhances system performance compared to using a single sensor.

4. GPS-Based Location Tracking

The integrating of the GPS module enabled accurate identification of the location where a crack was detected. During testing, the GPS provided precise latitude and longitude coordinates., which were transmitted along with the alert message. This feature is highly beneficial for maintenance teams, as it allows them to quickly locate and repair damaged tracks. The

GPS module demonstrated stable performance in open environments, although slight variations were observed in areas with signal obstruction.

5. GSM Communication Results

The GSM module was used to send alert messages to authorized personnel when a crack was detected. The system successfully transmitted SMS notifications containing the location details and status of the track. The communication delay was minimal, ensuring timely alerts. The reliability of the GSM network played a crucial role in maintaining consistent communication. The results confirm that the system provides effective remote notification capabilities.

6. Buzzer and Alert System Performance

The buzzer was activated immediately upon detection of a crack, providing an on-site alert mechanism. This feature ensures that even local operators can be informed without relying solely on remote communication . The alert system works efficiently during all test scenarios, indicating its usefulness as an additional safety feature.

7.System Reliability and Efficiency

The system demonstrated high reliability during continuous operation. It was capable of functioning for extended durations without significant errors. The power consumption was relatively low, making it suitable for deployment in remote areas. The compact design and wireless communication capabilities reduce installation complexity and maintenance requirements. These factors contribute to the overall efficiency and practicality of the system.

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