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Smart Railway Track Monitoring for Real-Time Crack Detection Using GSM and GPS

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Abstract- Railway track safety is a critical concern for preventing accidents and ensuring smooth train operations. This project presents a robot-based crack detection system that autonomously detects cracks and obstacles on railway tracks and communicates the information to authorities in real time using GSM and GPS technology. The system employs a microcontroller-based robotic platform equipped with crack sensors for detecting surface discontinuities, IR sensors for obstacle detection, a GPS module for precise location tracking, and a GSM module for sending instant alerts. The robot navigates along the track using motor drivers and DC motors, and detected cracks are displayed on an onboard LCD. Experimental testing demonstrates that the system can effectively identify cracks of various sizes and accurately transmit the location data, enabling prompt maintenance actions. The proposed system enhances railway safety, reduces human inspection efforts, and provides a reliable, real-time monitoring solution.

***Key Words:** Railway Track Monitoring Crack Detection, GSM And GPS Communication, Robotic Inspection System, Microcontroller-Based Automation*

I. INTRODUCTION

Railways are a vital mode of transportation in India, making safety and reliability essential. However, undetected cracks in tracks caused by temperature changes, material fatigue, corrosion, and vibrations pose a major threat, leading to accidents and derailments. Current manual inspection methods are slow, labor-intensive, and prone to human error, especially over long and remote routes. To address these limitations, the project *"Smart Railway Track Monitoring for Crack Detection Using GSM and GPS"* introduces an automated, real-time system that scans rails using sensors to identify cracks or obstacles. When a defect is detected, the system instantly sends an SMS alert with accurate GPS coordinates to the control station, enabling rapid maintenance and significantly improving railway safety. The system is designed to be cost-effective, energy-efficient, and adaptable for deployment across varied terrains within the Indian railway network. By integrating GPS for location detection and GSM for wireless communication, along with obstacle identification capability, this project contributes toward smarter, safer, and more reliable railway infrastructure, aligning with India's vision of intelligent transportation systems. Railway transportation plays a vital role in ensuring efficient passenger and freight movement, making railway safety a subject of high national priority. One of the most serious threats to railway safety is the development of cracks or structural defects in tracks, which can lead to derailments and severe accidents. Traditionally, visual inspection and manual patrolling have been the standard approaches for detecting such faults; however, these methods are time-consuming, labor-intensive, and prone to human error. To overcome these limitations, recent research has focused on automated crack detection and real-time monitoring using technologies like sensors, wireless communication, image processing, and embedded systems. The following reviews significant existing contributions in the domain of railway and surface crack detection.

Henrique Oliveira and Paulo Lobato Correia [1] proposed a 2-D feature-based automatic road crack detection approach using captured images to identify defects in pavement surfaces. Their system measured the width and length of cracks and analyzed image overlap patterns to ensure robustness in crack localization. Although the work was focused on road pavements rather than railway tracks, the study highlighted the importance of automated feature

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extraction and digital image analysis in crack assessment.Lad and Pawar [2] developed a railway crack detection system comprising GPS, GSM, IR, and PIR sensors. The integration of GPS and GSM enabled continuous monitoring and transmission of geometric parameters of track conditions to the nearest railway control station. Additionally, a PIR sensor was used to detect human or animal movement across the tracks, enabling both crack detection and obstacle identification during day and night.Rijoy Paul et al. [3] proposed a crack detection technique using Raspberry Pi, ultrasonic sensors, and image processing. When the IR sensor detected a deformation or discontinuity, the system calculated geographic coordinates through GPS and communicated the information to railway authorities via Wi-Fi or SMS. The research emphasized that automated crack detection significantly reduces dependence on manual inspection, improving accuracy and response time.Rizvi Aliza Raza et al. [4] introduced a system for detecting railway cracks using image processing techniques with continuous video capture and image segmentation. By replacing manual inspection with automated visual monitoring, the system could immediately identify crack occurrence and reduce the probability of accidents. The method also highlighted the scalability of image-based monitoring for long track stretches.Anand S. Muley et al. [5] designed a GSM-based crack detection system utilizing an operational amplifier and microcontroller to detect discontinuities in the rails. Upon detecting a crack, the system transmitted a warning message via GSM to the main control branch.

The study also compared different crack-sensing mechanisms and established GSM as an efficient medium for communication in railway applications. The reviewed works collectively demonstrate significant progress in automated crack detection using sensors, GSM, GPS, and image processing. However, most existing solutions are limited to either image-based detection or simple sensor-based crack identification, with fewer systems combining crack detection, obstacle monitoring, and precise GPS-enabled location feedback in a single low-cost platform. This presents an opportunity for developing a more robust, scalable, real-time railway monitoring system that enhances safety and maintenance efficiency. The objective is to develop an automated, low-cost railway monitoring system that detects cracks and obstacles in real time using sensors, reports precise GPS coordinates, sends instant GSM alerts to authorities, minimizes manual inspection, enhances safety, prevents derailments, and supports smart infrastructure advancement for Indian Railways

2.1. Methodology

The methodology adopted in this project focuses on designing and implementing an automated railway track monitoring system capable of detecting cracks and obstacles in real time and communicating fault information to authorities. The system operates on a compact robotic platform designed to move along the railway track and continuously scan its surface. The core of the system is an Arduino Uno microcontroller, which interfaces with all sensing and communication modules. Line tracker sensors guide the robot along the rail path, ensuring precise alignment. Crack detection is carried out using IR sensors that continuously monitor the continuity of the track surface; a fall in reflection indicates a crack or dislocation. In the event of such detection, the motor relay is stopped, and a buzzer is triggered to provide an immediate audible alert. Simultaneously, the GPS module retrieves the exact latitude and longitude of the fault location. Once the coordinates are obtained, the GSM module automatically transmits an SMS alert to a predefined railway authority number, including a clickable Google Maps link for easy navigation to the affected site. In addition to crack sensing, an ultrasonic sensor is used for obstacle detection. If an object is detected within a predefined distance, the robot halts and enters warning mode, preventing collision and enabling early awareness of obstructions. Real-time system status, sensor readings, and fault notifications are displayed on the LCD for user visibility during prototype testing. The entire unit is powered through a regulated battery supply and driven by 30 RPM gear motors mounted on a mobile chassis. During normal operation, the system continuously cycles through sensor readings and control commands, moving forward as long as no threats are detected. When a crack or obstacle is encountered, the system transitions to alert mode, stops movement, triggers alarms, and communicates the GPS location to authorities. This integrated methodology ensures continuous, autonomous, and reliable monitoring of railway

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tracks, minimizing manual inspection requirements and enhancing safety by enabling rapid detection and response to track failures. The block diagram of smart railway track monitoring and crack detection using GSM and GPS is shown in figure1

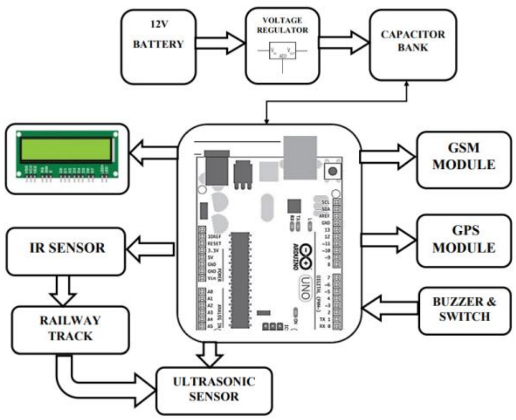

Figure 1. Block diagram of smart railway track monitoring and crack detection using GSM and GPS

2.2. Hardware & Software Description

The Smart Railway Track Monitoring System is implemented using a combination of electronic components and embedded software. The main hardware elements include the Arduino Uno microcontroller, IR sensors for crack detection, an ultrasonic sensor for obstacle monitoring, a GPS module for geographical location acquisition, and a GSM module for wireless communication. A relay driver circuit controls the movement of 30 RPM gear motors mounted on the robotic chassis. Additional components such as an LCD display, buzzer, voltage regulator, battery, wiring harness, and chassis frame form the supporting hardware architecture. From the software perspective, the Arduino IDE is used to write and upload embedded C programs to the microcontroller. The code handles sensor reading, motor control, GPS extraction, GSM message formatting, alert triggering, and LCD display updates. Conditional logic and decision routines ensure that the robot switches between normal operation and alert mode based on the presence or absence of cracks or obstacles. The integration of hardware and software enables seamless real-time monitoring and communication. The Arduino uno, ATmega328- a 28 pin microcontroller arduino board and Arduino Architecture are used in the present study are shown in figure2

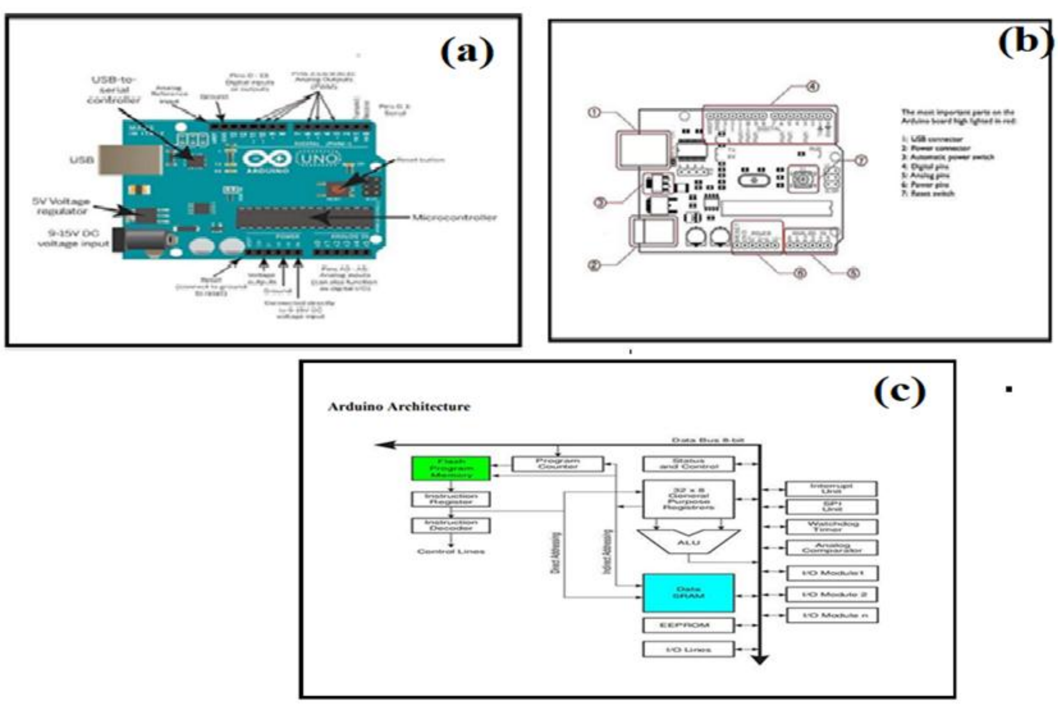

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Figure2. (a) Arduino uno, (b)Tmega 328- a 28 pin microcontroller arduino board and (c) Arduino Architecture

III. RESULTS AND DISCUSSION

Prototype testing was conducted under simulated railway conditions using track models with cracks, gaps, and obstacles of varying sizes. The IR sensors successfully detected cracks with high accuracy, showing immediate response to discontinuities on the track surface. The ultrasonic sensor consistently identified obstacles within a 10 cm range, preventing forward motion and avoiding collision. Upon detection of a crack or obstacle, the motor relay halted operation instantly and triggered the buzzer alert. The GPS module achieved precise coordinate extraction, while the GSM module delivered SMS notifications to the predefined number within 3–5 seconds, including a valid Google Maps link for exact location inspection. The LCD screen provided continuous system status updates throughout operation. Testing confirmed that the system operates reliably in both indoor and outdoor environments and maintains stable functionality even under varying light and vibration conditions. Overall, the prototype demonstrated the ability to significantly reduce inspection time and improve safety by enabling real-time reporting.

3.1. Working Methodology

The working methodology of the Smart Railway Track Monitoring System follows a sequential and automated process to detect cracks and obstacles and transmit the fault information to railway authorities. The system begins operation when the robotic unit is placed on the railway track and powered on. The line-following arrangement ensures that the robot moves precisely along the rail path without deviation. During movement, the IR sensors continuously scan the surface of the track; if a uniform reflection is received, the system interprets the track as safe and allows the robot to continue forward.

If a discontinuity in reflection is detected, it indicates a crack or physical deformity on the track. The Arduino microcontroller immediately halts the relay driving the gear motors to stop movement and activates the buzzer for an on-site audible warning. The system then extracts the geographical coordinates of the detected fault using the GPS module. Once the GPS position is acquired, the GSM module composes and sends an SMS alert to a predefined railway authority number, containing the crack detection message along with a clickable Google Maps link for precise navigation to the location.

In parallel, the ultrasonic sensor continuously monitors the track ahead for obstacles. When an obstruction is detected within a set distance threshold, the microcontroller initiates a similar safety protocol—stopping the robot, triggering the buzzer, and displaying a warning message such as "Obstacle Detected" on the LCD screen. In normal operation, when no cracks or obstacles are found, the robot moves forward smoothly while the LCD displays real-time system status and sensor values. Through the integration of sensing, decision-making, communication, and mobility, the system achieves uninterrupted monitoring of railway tracks. Its automated workflow reduces human involvement, shortens fault response time, and significantly enhances safety by preventing rail accidents caused by undetected track failures. The Block diagram of Robot-Based GSM & GPS Crack Detection System is shown in figure 3 and workflow and subsystem function is listed in the Table 1

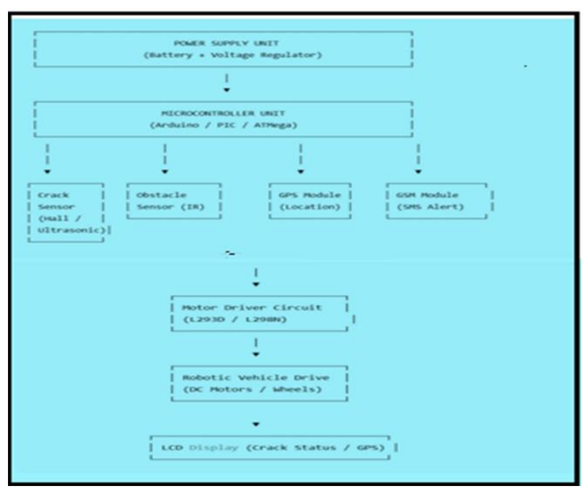

Figure3. Block Diagram of Robot-Based GSM & GPS Crack Detection System

Table1: Working Flow of the Block Diagram

Subsystem	Function
Crack Sensor	Detects rail crack / surface discontinuity
Obstacle Sensor	Detects blockage on track
Microcontroller	Central processing & decision making
GPS Module	Gets latitude & longitude of crack location
GSM Module	Sends SMS alert with location to control room
Motor Driver & Vehicle Drive	Controls movement of robot along railway track
LCD Display	Shows crack detection & GPS coordinates

IV. CONCLUSION

The Smart Railway Track Monitoring System provides an effective and automated solution to detect cracks and obstacles on railway tracks in real time. By integrating sensor-based detection with GPS-supported geolocation and GSM communication, the system eliminates the limitations of traditional manual inspection and significantly enhances track safety. The prototype effectively demonstrated rapid fault detection, precise reporting, and reliable performance, highlighting its potential for practical field implementation. This system contributes toward reducing accidents, improving maintenance efficiency, and supporting modernization in railway infrastructure. The system can be further enhanced by implementing high-resolution cameras and machine learning algorithms for advanced image-based crack classification. Solar-powered charging can increase operational duration and support long-distance deployment. Integration with cloud-based IoT platforms would enable centralized monitoring across large railway networks. Additional features such as automatic braking control, dual-track scanning, and weather-resistant chassis design can make the solution robust for real-time field deployment on active railway lines.

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