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Railway Track Crack Detection System

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Abstract: *An Railway Track Crack detection system is an innovative solution for ensuring the safety and security of railway systems. The system uses a combination of sensors and cameras that are installed along the railway track to monitor it for any signs of damage or obstructions. The sensors can detect crack or other type of obstructions. The camera can perform real time images processing of the track to detect the hair like crack and other obstruction. Once the system detects an issue, it can send an alert to the railway operators or maintenance personnel, allowing them to quickly address the problem before it causes any accidents or delays. Railway track crack detection system can greatly improve the safety and efficiency of railway operations.*

Keywords: Embedded system, Internet of things, Sensor, Microcontroller

I. INTRODUCTION

Railway transportation plays a crucial role in supporting the economic framework of developing nations, enabling the movement of goods and passengers over vast distances. Despite continuous advancements, railway safety remains a primary concern due to frequent accidents caused by cracks on tracks. Track failures often result from environmental stress, or poor maintenance, leading significant loss of life and property. The traditional manual method of track inspection is tedious, time-consuming, and prone to human error, making it inadequate for large railway networks.

An IoT-Based Railway Track Crack Detection and Alert System is designed to enhance railway safety by using modern technology. The system uses sensors to continuously monitor the railway tracks for cracks or structural faults. When a crack is detected, the system's processes the data, uses a GPS module to exact location, and immediately transmits an alert to railway authorities through wireless communication modules (such as GPS). This real-time approach helps prevent accidents by enabling quick repairs, reduces human error compared to manual inspections, and allows for efficient and cost-effective maintenance of extensive railway networks. The system is usually powered by batteries, often supported by solar panels for reliable operation in remote areas.

Fig 1. Manual method Keyman's daily patrol.

The above bar graph highlights the trends in train accidents, deaths/injuries, and fatalities due to rail cracks or derailments in India from 2018 to 2024. While the number of train accidents shows a relatively stable trend, there is a

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significant spike in deaths caused by rail cracks or derailments in the year 2023–24, emphasizing the urgent need for a reliable track monitoring system.

The system reads sensor values continuously, and if any anomaly is detected, it immediately halts the vehicle and sends an alert with GPS location data to the user through the Blynk IoT platform. This approach enables timely intervention and minimizes the risk of derailments. The system is cost-effective, portable, and scalable, making it suitable for widespread deployment across railway networks. Its real-time monitoring and early warning capabilities contribute significantly to safer and smarter railway infrastructure.

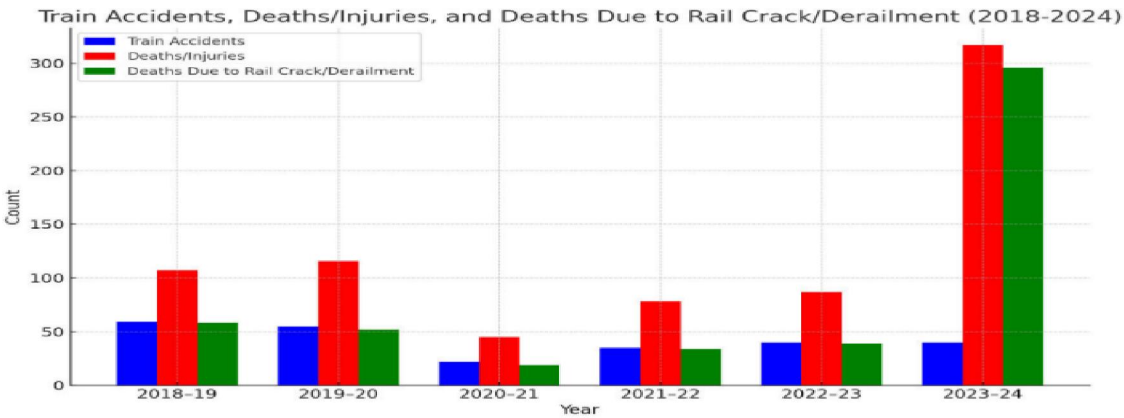

Fig 2. Trends in Rail Accidents

II. LITERATURE REVIEW

The following chapter is a literature survey of the previous research papers and researches which gives the detailed information about the previous system along with its advantages and disadvantages to make the system more advanced.

Survey Existing System

The principal goal of the track crack detection and fitness tracking in base station among indicators any track are broken, reduce the track, and any fault manner sign is transmitted to sign engineer, due to the fact strength can be passing to track This method used best for base station. The railways infrastructure like wagons, rail tracks, bridges. gadget having tracking gadget that use wi-fi sensor. For enlargement and upgrading of railway this gadget is useful. They supply constant tracking for motionless structure. Author targeted on sensor era producing situation tracking facts to permit sensible situation and additionally the work to recognize current tracking the use of clever sensor.

This robotic consists of ultrasonic sensors, GPS, GSM modules, and Arduino Mega primarily based totally crack detection meeting that is value powerful and strong to facilitate higher protection requirements in railways. As quickly because the robotic exceeded via a crack that could reason the derailment of a educate, the ultrasonic sensors feel that and generate a signal. Then this sign is fed into the Arduino Mega. At that point, with the help of GSM and GPS modules, an alert SMS include the geographic coordinate of that broken track is dispatched to the close by railway authority who can effortlessly take vital steps to clear up the hassle earlier than any mos important coincidence occurs. This will shop numerous trains from an undesirable discontinuity from the rail track. The proposed gadget may be networked with more than one robots and vital laptop gadget can manage these types of robots, in order that whole track may be scanned for detecting any crack earlier than on every occasions educate passes via track.

Author	Published Year	Publication Paper Name	Methodology	Findings
Pranav Lad, Manshi Pawar	2024	Evolution of Railway track crack	Ultrasonic based crack detection, robot with	Traditional Railway system and Modern

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		detection system	sensor, GPS & GSM module.	Railway system are for more different in technology, management and Services.
R Dharanidaran, S Jagan, B Anandhakeerthi, S Kaveyen, U Gowtham	2024	Automatic Railway Track Crack Detection System using IOT	IR sensor on moving vehicles, GPS for location, GSM for data transmission.	Real-time crack detection & cloud alerts improve prevention maintenance & safety.
P Bhargav, V Lokesh Reddy, Trina Xavier, E Tejaswi	2023	IOT Based Fault Detection in Railway Track System	IOT module ensure continuous tracking and reporting on track health, enabling timely intervention for maintenance.	Detect cracks & obstacles with 80% accuracy, sends GPS based alerts for maintenance.
Dr. M. Revathi* , G. Harikaa , Dr. M. Divyab , G. Raga Sindhujac , S. Swethad , L. Mounikae , P. Bhavyaf , Shaik Sehanaz Aktarg	2024	IoT Based Railway Track Crack Monitoring System	It uses IR and GPS module to detect the crack and inform through web app.	Its is Simple IOT system, detected big crack on the track and inform Station manager to the Faluts.
Omkar Kanse, Sayali Raut, Himanshu Gaikwad, Prof.K.C.Wanzare, Prof M.P.Potdar	2025	Railway Track Crack Detection System	ESP based system uses cloude to send and process the data.	Its Is capable of detecting the larger size crack in tracks.

Working

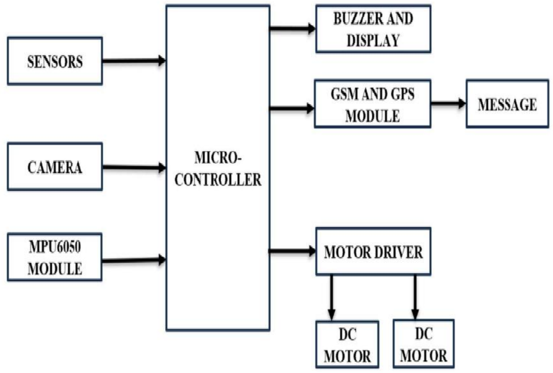
The main objective of the project is to develop a system capable of detecting cracks along railway tracks using sensor and camera module. Transmitting the detected crack coordinates to the help of GPS module. The block diagram depicted in Fig-2 illustrates the key components and their interconnections within the system.

Sensor: The IR sensor serves as the primary crack detection component. It is positioned strategically along the railway track to continuously monitor its surface for any cracks or abnormalities. When a crack is detected, the IR sensor triggers the system to initiate further actions. Ultrasonic sensor are used to continuously monitor obstacles on railway track such as fallen tree, cows, Humans etc.

Motor Driver and Motor: The motor driver and motor are likely utilized as part of a mechanism to facilitate movement along the railway track. This movement could be for the purpose of deploying the sensor along the track or for any other operational requirements of the system.

GPS Module: The GPS module integrated into the system provides accurate geographical coordinates of the location where the crack is detected. These coordinates are essential for precisely identifying the location of the crack along the railway track.

Camera Module: The Camera module are integrated into the system to detect the minor crack in railway track that are not detect by the sensor. We perform image processing to detect the crack in track.



Buzzer and Display: This component are used to indicate that crack is detected in the track and inform the surrounding people.

MPU6050 Module: The MPU6050 module detects track shifts by measuring changes in tilt and vibration using its 3-axis accelerometer and gyroscope. When a railway track moves or shifts, these changes trigger alerts, ensuring early detection of structural issues for enhanced safety.

ESP32Microcontroller: The ESP32 microcontroller serves as the central brain controlling all components in the railway track crack detection system. With its dual-core 240 MHz processor, 34 GPIO pins, and rich peripherals like I2C, SPI, UART, and PWM, it seamlessly interfaces with MPU6050, sensors, camera, GSM module, motor driver, GPS, buzzer and display. The ESP32 reads sensor data, processes logic for crack detection and track shifts, captures GPS coordinates and image processing triggers alerts, and manages motor operations—all in real-time. Its built-in enables wireless monitoring, making it efficient, powerful, and ideal for this IoT-based safety project.

III. METHODOLOGY

This flowchart explains the working of Railway Track Crack Detection System with the following steps:

1. Start: The process begins.
2. Activate all sensors: All the system's sensors are turned on for detection.
3. Move the vehicle forward: The vehicle carrying the sensors moves along the railway track.
4. Check if a crack is detected: The sensors and camera keep checking for cracks on the track.
   - If no crack is detected: The vehicle continues moving forward and keeps checking.
   - If a crack is detected: The flow continues to the next steps.
5. Stop the vehicle: The vehicle stops moving.
6. Get GPS location: The system gets the exact location (coordinates) where the crack is found.
7. Get the Black & White Camera picture: Camera send the a photo of the cracked area.
8. Send location and picture: The location and crack photo are sent to a predefined phone number or contact—likely railway authorities.
9. Reset: The system resets itself.
10. Decision:
    - It either returns to "Start" to repeat the process.
    - Or it completely stops if required.

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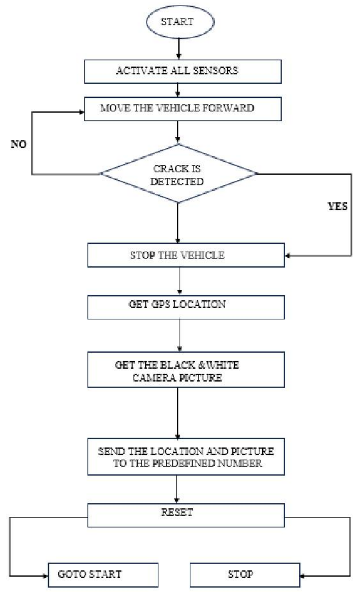

IV. MODEL IMPLEMENTATION

The primary aim of this model is to efficiently detect faults on railway tracks, particularly cracks, through regular inspections. The system employs a vehicle propelled by a motor and motor driver assembly. Detection of cracks is achieved using infrared sensors and camera module, while the precise location of the faults is determined via a GPS module. By integrating these technologies, the model ensures comprehensive coverage of the railway network, facilitating early identification and timely maintainance of track defects. This proactive approach enhances railway safety and operational reliability and reduce the risks associated with track failures. Furthermore, the automated nature of the system reduces reliance on manual inspections, improving efficiency and reducing labor costs. Overall, the model represents a significant advancement in railway track maintenance, offering a reliable and scalable solution for ensuring the integrity and safety of rail infrastructure.

Microcontroller

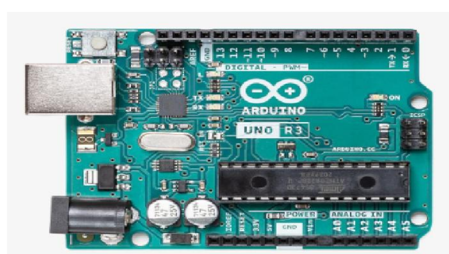

Fig 3. Arduino Uno

The Arduino Uno is a low-cost, beginner-friendly microcontroller board widely used in education, prototyping, and embedded projects. It features an ATmega328P 8-bit AVR processor running up to 20 MHz, with 2 KB SRAM, 32 KB flash memory, and 1 KB EEPROM for reliable program storage. The Arduino Uno supports various peripheral interfaces such as GPIO, ADC, I2C, SPI, UART, and PWM, shown in Fig 5.1.1, enabling control over a broad range of sensors and actuators. Its simple USB programming, vast shield ecosystem, and open-source design make it ideal for hobbyists, students, and quick prototyping of interactive devices. The Arduino Uno’s flexible architecture and rich

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feature set have made it especially popular for DIY smart devices, automation systems, and real-time remote monitoring applications.

Ultrasonic Sensor

The HC-SR04 Ultrasonic Sensor is a popular and affordable distance-measuring module widely used in robotics and automation projects. It operates on the sonar principle, emitting ultrasonic waves at 40 kHz from a transmitter and receiving the reflected waves with a receiver to calculate the distance of an object. It can measure distances ranging from 2 cm to 400 cm with an accuracy of about 3 mm. The sensor requires a 5V DC supply and includes four pins: VCC, Trig, Echo, and GND. The Trig pin sends a short 10 µs pulse to generate the sound wave, and the Echo pin outputs a signal proportional to the distance. Compact, efficient, and easy to interface with microcontrollers like Arduino or ESP32, the HC-SR04 is ideal for obstacle avoidance, level measurement, and automation systems.

Fig 4. Ultrasonic Sensor

IR Sensor

An Infrared (IR) Sensor is an electronic device that detects infrared radiation from objects in its surroundings. It consists of an IR emitter (LED) and an IR receiver (photodiode or phototransistor). The emitter radiates infrared light, which reflects off an object and is detected by the receiver. Based on the reflected signal, the sensor determines the object's presence or distance. IR sensors are classified into Active IR (which emit and detect reflected IR light) and Passive IR sensors (which detect infrared radiation emitted naturally by warm objects). These sensors operate on principles of thermal radiation and optical reflection, allowing non-contact detection. Due to their reliability and low power consumption, IR sensors are widely used in obstacle detection, temperature measurement, motion sensing, remote controls, and automation systems.

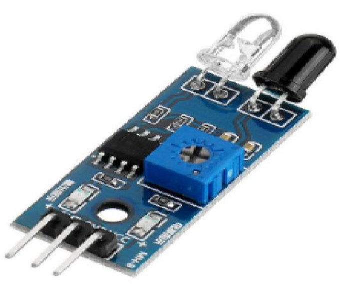

Fig 5. IR Sensor

GPS Module

The GPS NEO-6M Module is a high-performance satellite navigation module developed by u-blox, widely used for location tracking and navigation applications. It operates with up to 50 channels and can track 22 satellites simultaneously, offering a position accuracy of about 2.5 meters. The module supports multiple satellite systems, including GPS and operates on a 3.3V–5V supply. With a sensitivity of −161 dBm, it can function effectively even

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under weak signal conditions. It includes a built-in 25 × 25 mm ceramic antenna, EEPROM for configuration storage, and a backup battery for preserving data. The NEO-6M communicates via a UART interface at a default baud rate of 9600 bps, making it simple to interface with microcontrollers ESP32. Commonly used in robots, drones, vehicles, and smart tracking systems, it ensures precise real-time positioning and reliable navigation performance.

Fig 6. GPS Module

GSM Module

The REES52 Mini SIM800L GSM GPRS Module is a compact communication module that allows microcontroller projects to connect to mobile networks. Using a standard micro SIM card, it supports GSM (voice calls and SMS) and GPRS (basic internet data) on quad-band frequencies (850/900/1800/1900 MHz), making it suitable for use worldwide. The module can send and receive SMS, make phone calls, and connect to the internet for data transfer. With TTL serial interface, it is simple to connect to microcontrollers like Arduino or ESP32. Operating at 3.4V–4.4V, the SIM800L is energy efficient and ideal for battery-powered and IoT applications such as remote monitoring, security, and alert systems. Its small size makes it perfect for compact projects needing reliable mobile connectivity.

Fig 7. GSM Module

MPU 6050

The MPU-6050 Module is a compact 6-axis motion tracking sensor that combines a 3-axis accelerometer and a 3-axis gyroscope on a single chip. It measures acceleration, orientation, and angular velocity along the X, Y, and Z axes, making it ideal for motion sensing applications. The module communicates with microcontrollers via the I2C interface and includes an onboard Digital Motion Processor (DMP) that processes complex motion detection algorithms, reducing the computational load on the main controller. It can operate at 3V–5V, features a 16-bit analog-to-digital converter, and offers

programmable sensitivity ranges (±2g to ±16g for acceleration and ±250°/s to ±2000°/s for rotation). Due to its accuracy, compactness, and low power consumption, the MPU-6050 is widely used in drones, robotics, IoT systems, self-balancing vehicles, and gesture-controlled devices.

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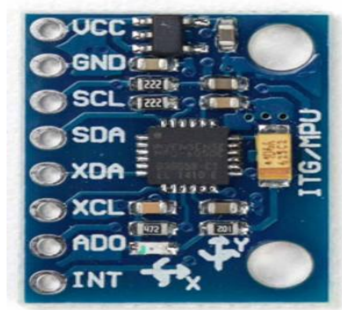

Fig 8. MPU 6050

Motor and Motor Driver

A motor driver serves as an interface between the microcontroller and the motor, as most controllers cannot supply the needed current or voltage directly. Common drivers like L293D or L298N use H-bridge circuits to control both the direction and speed of the motor by regulating voltage polarity. This allows ESP32 microcontrollers to efficiently manage motor operations in automation, and motion-control systems.

A motor is an electromechanical device that converts electrical energy into mechanical motion, enabling movement in machines and systems. The most common type used in embedded projects is the DC motor, which operates on direct current and provides controlled rotational motion. DC motors can be classified as series, shunt, compound, or brushless (BLDC), depending on how their magnetic field is generated. They are used in applications such as robotics, conveyors, fans, and automated vehicles due to their reliability and ease of control.

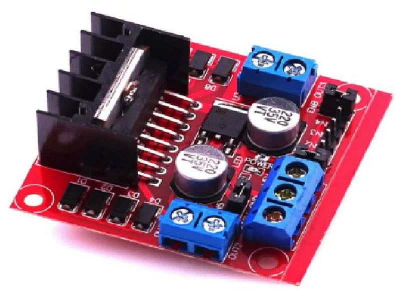

Fig 9. Moter Driver

Camera Module

Fig 10. Camera Module

The ESP32-CAM OV2640 Camera is an compact development board combining wireless communication and image capture. It features an ESP32 microcontroller with integrated WiFi and Bluetooth, making it ideal for IoT and wireless projects. The module is equipped with an OV2640 2MP camera that supports JPEG image output, well-suited for real-

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time video streaming and remote monitoring. It includes 520KB SRAM plus 4MB PSRAM, a microSD card slot for extra storage, and a built-in LED flash. The board operates at 5V, is energy efficient, and supports multiple sleep modes for low-power applications.

V. CIRCUIT CONNECTION

The circuit diagram presented in Fig 11 illustrates the hardware implementation of the proposed railway track crack detection and monitoring system using an Arduino microcontroller. The setup integrates various sensors and modules to detect track cracks, obstacles, and location data, while enabling remote monitoring.

At the heart of the system is the Arduino Uno microcontroller, which serves as the central processing unit and communication interface. It features connectivity via module that facilitates real-time communication. The IR sensor modules, used to detect cracks, are interfaced with two digital GPIO pins of the Arduino Uno. These sensors are positioned on either side of the inspection vehicle and generate a high or low output depending on track surface reflection. Any significant deviation indicates a crack on the rail surface.

An HC-SR04 ultrasonic sensor is connected to the Arduino to detect obstacles ahead of the vehicle. The TRIG and ECHO pins of the sensor are connected to GPIO pins on the Arduino to measure the time delay of the reflected signal, which is used to compute the distance to nearby objects. If an object is detected within a pre-defined distance, it is flagged as an obstacle.

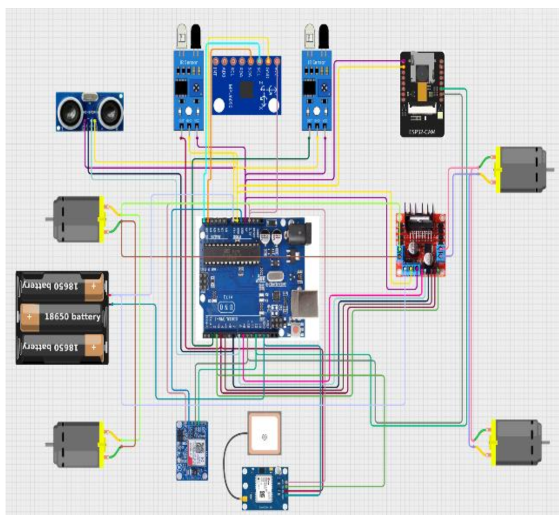

Fig 11. Connections

The GPS module is connected via UART communication to provide real-time geolocation data. It transmits longitude and latitude coordinates whenever an obstacle or crack is detected, enabling location-based alerting. The TX pin of the GPS is connected to the RX pin of the Arduino while the RX pin is connected to the Arduino TX for serial data exchange.

Motor control is achieved using an L298N motor driver module, which receives logic-level signals from the Arduino to control the two DC motors. These motors power the movement of the vehicle across the tracks. The motor driver is powered using a rechargeable battery pack, which is also used to power the ESP32 and connected peripherals. The motor driver's IN1, IN2, IN3, and IN4 pins are connected to four GPIO pins of the ESP32 for bi-directional control of the motors.

The power supply unit consists of a battery pack capable of providing sufficient voltage and current to drive the motors and electronics. A switch is included for manually powering the circuit on or off.

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VI. RESULT AND DISCUSSION

The system was tested in outdoor conditions. The following observations were made:

Crack Detection: Both IR sensors successfully detected left and right track cracks. The system consistently triggered a stop and alert signal when a crack was detected.

Obstacle Detection: The ultrasonic sensor reliably identified obstacles within a range and stopped the vehicle immediately to avoid collision.

GPS Tracking: The GPS module provided real-time latitude and longitude of the location where a crack or obstacle was detected.

Alerts Message via GSM:

o Alerts such as "Crack Detected" and "Obstacle Detected" appeared on the mobile Message within 10 seconds.

o GPS coordinates were transmitted accurately with every detection alert

Power Backup: The 12V Li-ion battery pack provided continuous operation for approximately 50 minutes, which is suitable for short inspection runs.

Fig 12. System and Outputs

VII. CONCLUSION

The Railway Track Crack Detection System is a smart automated solution that makes railway travel much safer. This project uses modern electronic parts like sensors, GPS NEO-6M for exact location, MPU6050 to check track shifts and tilts, ESP32-CAM camera for taking photos of cracks, GSM SIM800L module to send instant alerts, motors for moving the detection vehicle, and the powerful ESP32 microcontroller to control everything.

When the vehicle moves on railway tracks, sensors find cracks or problems. The system stops, gets the GPS position, click the picture, and sends to railway officers' phones right away. A buzzer and display also give local alerts. No neewd for people to check tracks manually every day. This project shows how simple electronics and smart coding can solve real railway safety problems in India. In future, we can add solar power, better AI for crack checking, and internet connection for full control from anywhere. This system will help make trains safer for everyone.

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