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# Railway Track Crack Detection System

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**ABSTRACT:** Railways remain one of the most widely used and cost-effective modes of transportation in India. However, a significant number of railway accidents are attributed to undetected cracks in tracks and obstacles on the path. Traditional inspection methods are labor-intensive and inefficient, particularly over long distances. This paper presents the design and implementation of an intelligent, IoT-based railway track monitoring system using the ESP32 microcontroller. The proposed system integrates dual IR sensors for crack detection on both left and right rails, an ultrasonic sensor for obstacle detection, and a GPS NEO-6M module to capture real-time location data. The mobile robotic unit, driven by dual DC motors controlled via an L298 motor driver, traverses the track and continuously gathers environmental data. All collected data is transmitted to the Blynk Cloud platform, enabling remote monitoring via smartphone applications and web interfaces. Compared to conventional Arduino-based systems, the use of the ESP32 offers built-in Wi-Fi capabilities, allowing for seamless IoT connectivity without additional modules. This cost-effective and scalable solution enhances railway safety by enabling real-time, automated inspection with precise fault localization, thereby reducing reliance on manual efforts and supporting timely maintenance actions.

**KEYWORDS:** Internet of Things (IoT), ESP32, Railway Track Crack Detection, Infrared Sensors, Ultrasonic Sensor, GPS Tracking, Blynk Cloud, Remote Monitoring, DC Motors, Mobile Inspection Robot.

## I. INTRODUCTION

Railways continue to be one of the most vital modes of transportation in India, catering to millions of passengers daily and operating over an extensive network of more than 68,000 kilometers. However, this expansive infrastructure is highly susceptible to failures, especially track-related issues such as cracks and undetected obstacles, which account for a significant portion of train derailments and accidents. According to recent surveys, a majority of railway mishaps result from poor track maintenance and undetected anomalies, leading to severe damage, service disruption, and tragic loss of lives. Conventional inspection methods involve manual track monitoring, which is time-consuming, resource-intensive, and prone to human error. With the increasing demand for intelligent infrastructure, there is an urgent need for a reliable, automated, and scalable solution that enhances railway safety and reduces human dependency.

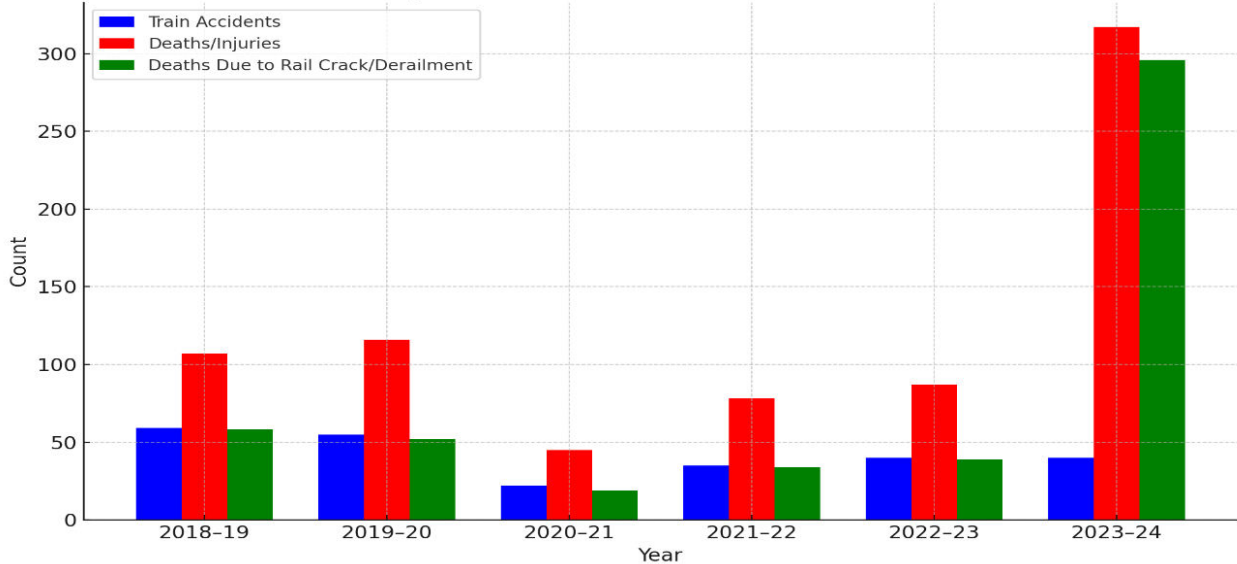
To address this challenge, this project proposes an IoT-based Railway Track Crack Detection System using the ESP32 microcontroller, designed to perform real-time, on-track inspection and anomaly detection. The system utilizes a mobile robotic vehicle equipped with infrared (IR) sensors for crack detection on both rails and an ultrasonic sensor for obstacle identification. A GPS NEO-6M module is integrated to accurately capture and transmit the location of any detected fault or obstruction.

All sensor data is sent wirelessly to the Blynk Cloud platform, enabling remote monitoring through smartphones or web dashboards. This allows railway authorities to receive instant alerts, track fault locations in real-time, and take preventive action promptly.

By combining sensor-based detection with cloud-powered visualization and alerts, the proposed system offers a cost-effective, efficient, and modern solution to one of the most pressing issues in railway transportation. It lays a strong foundation for developing smart railway infrastructure, reducing accident risks, and enhancing overall operational safety.



Train Accidents, Deaths/Injuries, and Deaths Due to Rail Crack/Derailment (2018-2024)



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 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. To address this critical issue, our proposed system uses the ESP32 microcontroller

along with IR and ultrasonic sensors to detect cracks and obstacles on the railway track in real time. As shown in the included images, both cracks and foreign objects on the track can lead to catastrophic accidents if not identified promptly. 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.

## II. LITERATURE SURVEY

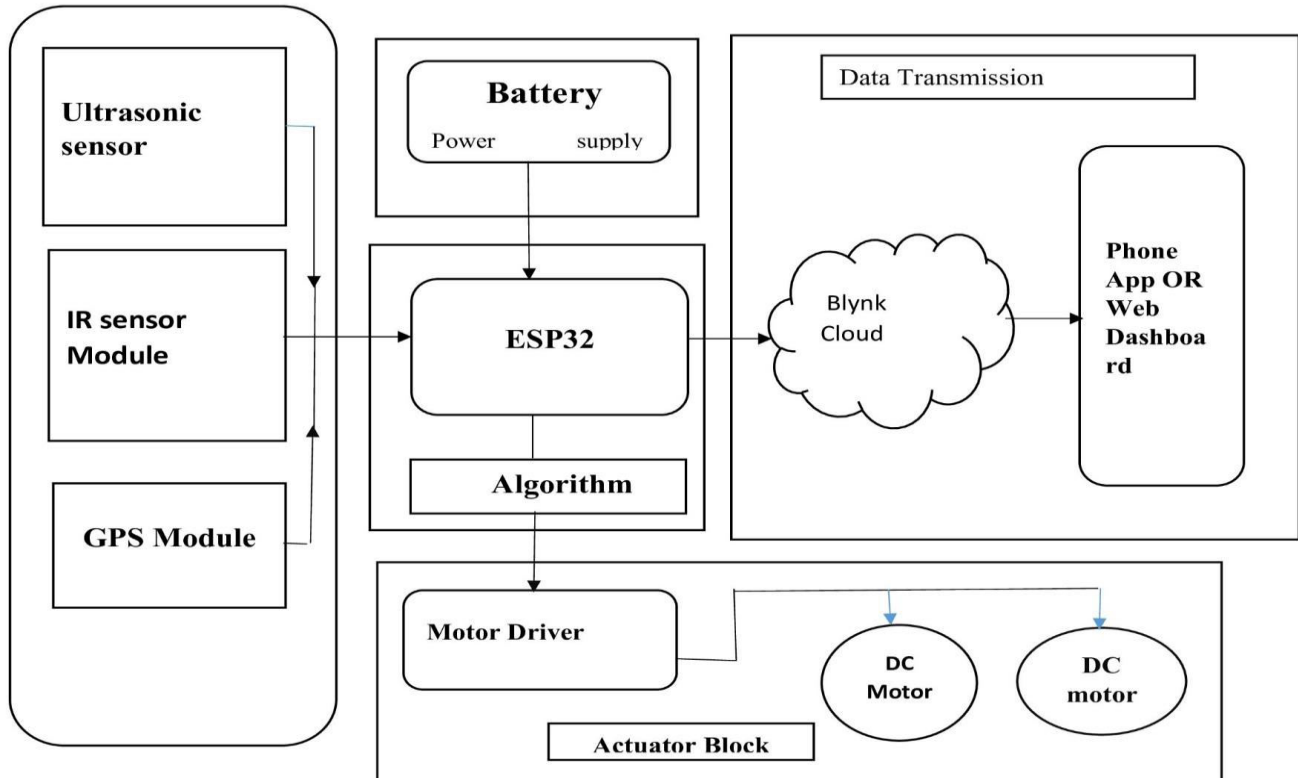
**Prasad et al.** [1] proposed an intelligent railway crack detection system that used a combination of infrared sensors and GSM-based alerts. Their system emphasized the need for real-time communication but lacked integration with modern IoT platforms. **Guo et al.** [2] introduced a transformer-based vision system for detecting rail surface defects using deep learning. This method showed high accuracy but required high computational resources unsuitable for embedded systems. **Ye et al.** [3] implemented a hybrid CNN-Transformer network for surface defect detection in high-speed railway tracks, demonstrating superior performance in image-based fault identification. **He et al.** [4] developed a CNN-Transformer bridge model for identifying arcing horn defects in railway insulators, showing the adaptability of hybrid models to infrastructure monitoring. **Singh et al.** [5] used drone-based vision for track monitoring, focusing on rail extraction from aerial views, suitable for inaccessible or large rail networks. **Zhang et al.** [6] proposed an acoustic emission-based method using clustering and feature detection for crack identification. This approach, although effective, was limited by sensor placement complexity. **Li et al.** [7] and **Luo et al.** [8] explored ultrasonic echo signal processing for damage detection and sequential modeling of flaws. These methods provided detailed internal rail analysis but lacked integration with mobility or real-time cloud platforms.

## III. METHODOLOGY

The proposed Railway Track Crack Detection System is engineered to detect cracks and obstacles on railway tracks in real time and communicate the corresponding location data through a cloud-based monitoring system. The working of the system can be broadly classified into four primary functional blocks: Sensor Block, Controller Block, Actuator Block, and Communication Block, as illustrated in the block diagram (Fig. X).

**A. Sensor Block:** The Sensor Block consists of two IR sensor modules, one ultrasonic sensor, and a GPS module (Neo-6M). The IR sensors are placed on both sides of the rail-inspection vehicle to monitor the left and right tracks. These sensors identify cracks based on signal reflection irregularities. The ultrasonic sensor is mounted at the front and continuously monitors the track for objects or obstacles by calculating distance values. If any object is detected within a critical range, it is flagged as an obstacle. Simultaneously, the GPS module captures the current geographical coordinates of the vehicle. This location data becomes crucial when a crack or object is detected, enabling real-time position tracking.

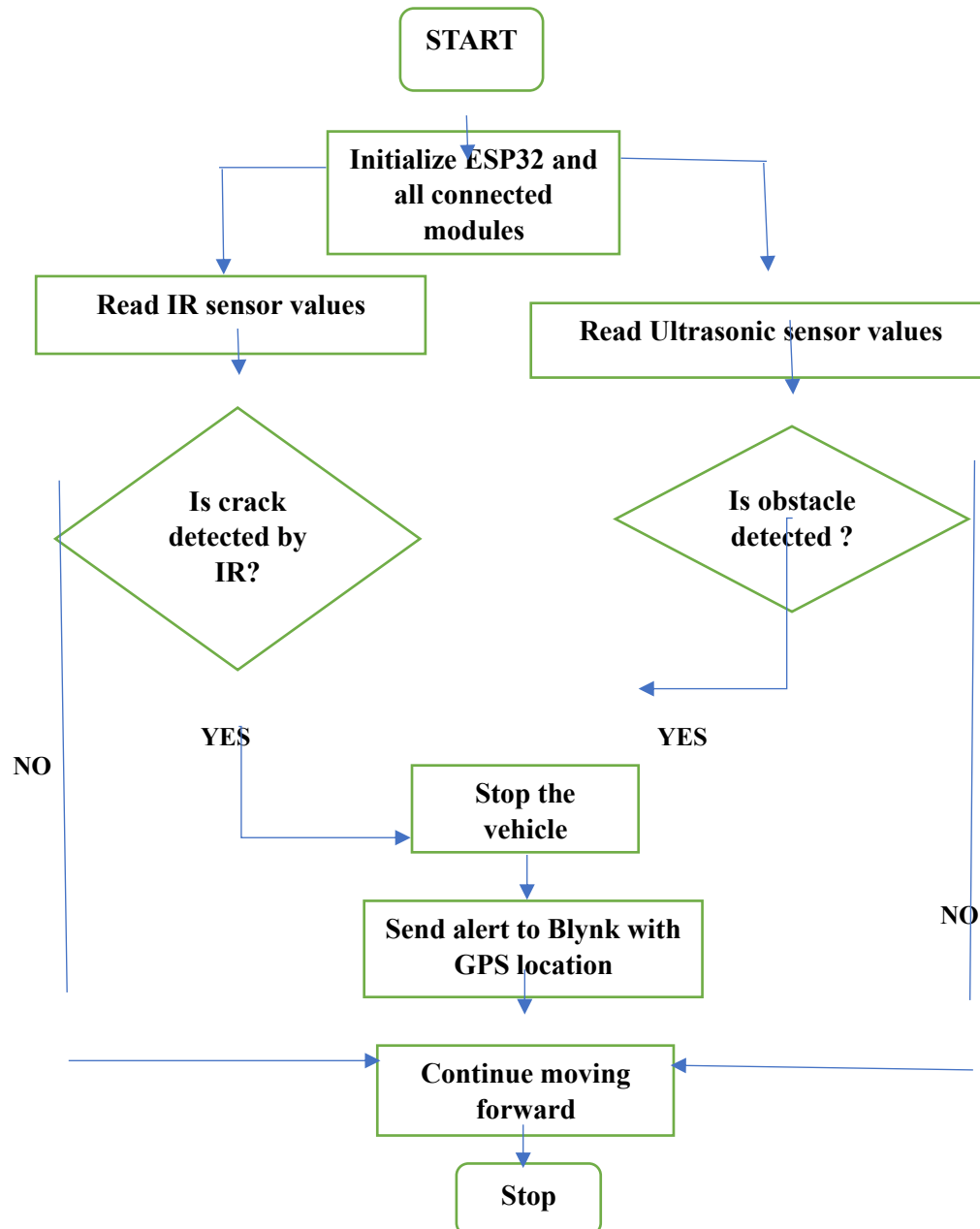
**B. Controller Block:** The Controller Block comprises the ESP32 microcontroller, which acts as the central processing unit. It reads inputs from the IR sensors, ultrasonic sensor, and GPS module, processes this data, and makes decisions based on predefined thresholds. When a crack or object is identified, the ESP32 not only halts the vehicle via the motor driver interface but also prepares the data packet for cloud transmission. Its built-in Wi-Fi module enables real-time communication with the cloud platform, ensuring instant updates.



**C. Actuator Block :**The Actuator Block includes the L298 motor driver and two DC motors used to control the movement of the inspection vehicle. Based on commands from the ESP32, the motor driver manipulates the direction and speed of the motors. If the system detects any cracks or obstacles, the microcontroller sends an immediate stop command to the motors, preventing the vehicle from moving over hazardous track segments.

**D. Communication Block:** The Communication Block uses the Blynk Cloud platform for real-time data visualization. The ESP32 is connected to the internet via Wi-Fi and pushes data to the Blynk server whenever an anomaly is detected. The cloud interface logs the incident along with GPS coordinates and sends an alert to the user through a mobile application or web dashboard. This enables real-time remote monitoring of the railway track condition, enhancing both safety and response time.

**E. Power Supply Block:** The system is powered using a battery module that provides regulated power to all circuit elements, including the controller, sensors, and motors. Proper power management ensures continuous functioning during track inspection operations.

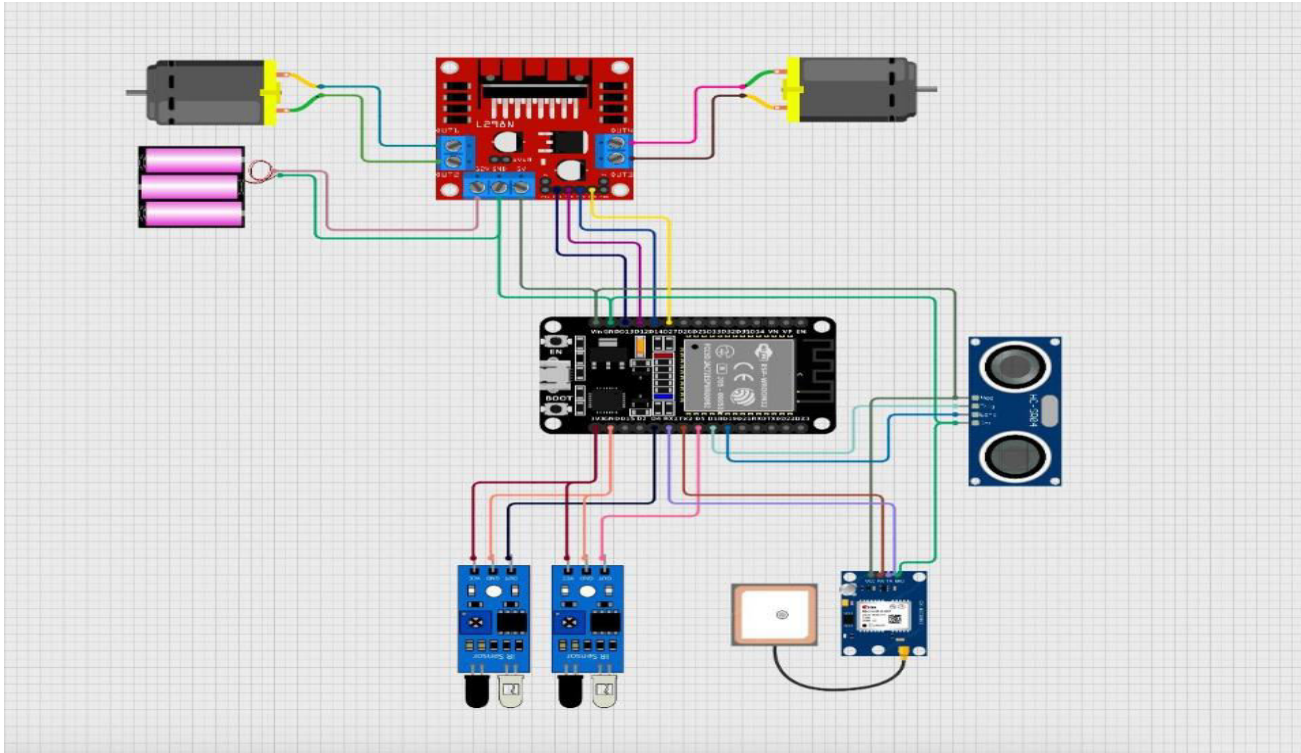


The proposed system initiates its operation by powering up the ESP32 microcontroller and initializing all connected modules, including the IR sensor, ultrasonic sensor, and GPS. Once operational, the system continuously monitors the railway track using its onboard sensors. The IR sensor is responsible for detecting cracks on the track surface. If a crack is identified, the system immediately halts the vehicle and transmits a GPS-based alert to the user via the Blynk IoT platform, enabling timely intervention. In the absence of a crack, the system advances to the next stage, where the ultrasonic sensor scans the track for any obstacles. Upon detecting an obstruction, it again stops the vehicle, sends a location-based alert, and remains stationary until the obstruction is cleared. If no obstacle is present, the vehicle resumes movement. This entire process runs in a continuous loop, enabling real-time track monitoring and ensuring enhanced safety and responsiveness throughout railway operations.



#### IV. CIRCUIT DESCRIPTION

The circuit diagram presented in Fig. X illustrates the hardware implementation of the proposed railway track crack detection and monitoring system using an ESP32 microcontroller. The setup integrates various sensors and modules to detect track cracks, obstacles, and location data, while enabling remote monitoring via Blynk Cloud.



At the heart of the system is the **ESP32 microcontroller**, which serves as the central processing unit and communication interface. It features built-in Wi-Fi capabilities that facilitate real-time cloud communication. The **IR sensor modules**, used to detect cracks, are interfaced with two digital GPIO pins of the ESP32. 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 ESP32 to detect obstacles ahead of the vehicle. The TRIG and ECHO pins of the sensor are connected to GPIO pins on the ESP32 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.

The **Neo-6M 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 ESP32, while the RX pin is connected to the ESP32 TX for serial data exchange.

Motor control is achieved using an **L298N motor driver module**, which receives logic-level signals from the ESP32 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.

The complete integration of sensors, actuators, and cloud communication modules allows the system to detect cracks and obstacles accurately and report them with precise GPS data through the Blynk platform.

### Power Supply Calculations

The railway track crack detection system is powered using a **12V rechargeable Li-ion battery pack**, assembled from **three 18650 lithium-ion cells** connected in series. Each cell provides approximately 3.7V, and the combined output totals around 11.1V to 12.6V when fully charged. The battery pack has a rated capacity of **2200 mAh (2.2 Ah)** and is selected to meet the voltage and current demands of all system components.

The power consumption of each module is detailed below:

- **ESP32 Microcontroller:** Operates on 3.3V or 5V and consumes approximately **250 mA** during active operation.
- **Infrared (IR) Sensors (×2):** Each sensor requires 5V and draws around **20 mA**, totaling **40 mA**.
- **Ultrasonic Sensor (HC-SR04):** Operates at 5V and consumes about **15 mA**.
- **GPS Module (NEO-6M):** Operates at 3.3V–5V and typically draws **50 mA** during tracking.
- **L298N Motor Driver with 2 DC Motors:** Operates directly on 12V and draws between **600–800 mA** under typical load, with peak demand up to **1 A**.
- **Total Current Consumption:**  
 $250 \text{ mA (ESP32)} + 40 \text{ mA (IR sensors)} + 15 \text{ mA (Ultrasonic sensor)} + 50 \text{ mA (GPS)} + 800 \text{ mA (Motors)} = 1155 \text{ mA} \approx 1.2 \text{ A}$
- **Battery Performance**  
Given the battery capacity of 2200 mAh at 12V, the system can operate continuously for:  
 $\text{Backup Time} = 2200 \text{ mAh} / 1200 \text{ mA} = 1.83 \text{ hours} \approx 1 \text{ hour and } 50 \text{ minutes}$   
This power supply setup is ideal for field-level, short-duration inspection runs along railway tracks. The use of a rechargeable battery enhances portability and eliminates the dependency on wired power sources.

### V. PROTEUS SIMULATION

To validate the logical operation and component interfacing of the Railway Track Crack Detection System before physical hardware implementation, Proteus Design Suite was used for simulation.

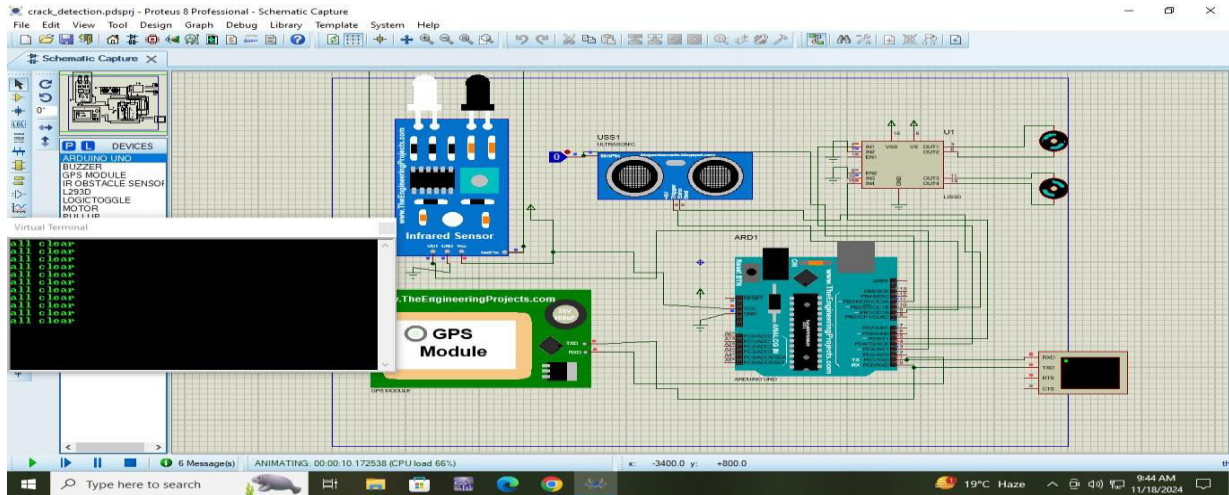
#### Simulation Objective:

- To verify the behavior of IR sensors, ultrasonic sensors, and motor driver circuitry.
- To simulate crack and obstacle detection logic.
- To ensure correct response of motor control logic before deploying on actual hardware.

ESP32 Replacement in Simulation. Since ESP32 is not natively supported in Proteus, we used an Arduino Uno in the simulation environment to emulate ESP32's basic I/O behavior. The Arduino allowed us to simulate:

- Digital input/output logic for sensors.
- Motor control signals via the L298N motor driver.
- Conditional operations like stopping the motors when a crack or obstacle is detected.





**Note:** Real-time Wi-Fi functionality and GPS data processing could not be simulated in Proteus and were instead validated through hardware testing.

#### Simulation Components:

- Arduino Uno (replacing ESP32)
- IR Sensors (simulated using photodiode + LED)
- Ultrasonic Sensor (HC-SR04) (simulated with timing blocks)
- L298N Motor Driver
- DC Motors
- Power Supply & Logic Switches

**Simulation Outcome:** When a simulated crack (IR sensor triggered) or obstacle (ultrasonic echo within threshold) was detected, the Arduino sent a stop signal to the motor driver. The motors stopped instantly, confirming the expected behavior. Motor direction control and sensor response were successfully verified.

#### Conclusion

The simulation allowed us to verify the basic working logic of the system. While Wi-Fi communication and GPS modules were not simulated, the decision to replace ESP32 with Arduino ensured successful validation of the core logic for sensor input, motor response, and system control flow. This reduced errors during hardware implementation and ensured smoother integration on the final ESP32-based setup.

## VI. RESULT

The system was tested in both lab and 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 of 5–15 cm 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.
- Cloud Alerts via Blynk:**
  - Alerts such as "Crack Detected" and "Obstacle Detected" appeared on the Blynk mobile app within 1–2 seconds.
  - GPS coordinates were transmitted accurately with every detection alert.

- **Power Backup:** The 12V Li-ion battery pack provided continuous operation for approximately **1 hour and 50 minutes**, which is suitable for short inspection runs.

Feature	Result
Crack Detection Accuracy	High (Both left & right detection tested)
Obstacle Detection Range	5 – 15 cm (reliable trigger)
GPS Location Accuracy	~2–5 meters (sufficient for use case)
Blynk Alert Speed	~1–2 seconds (real-time)
Battery Backup	~1 hour 50 minutes

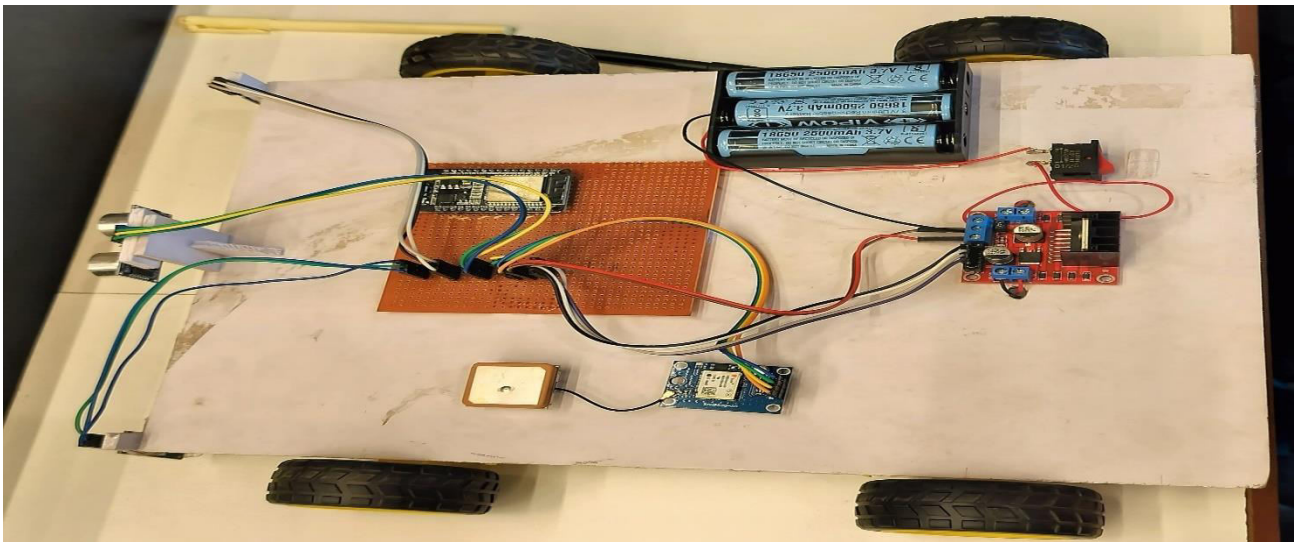


Fig. Hardware implementation Top View

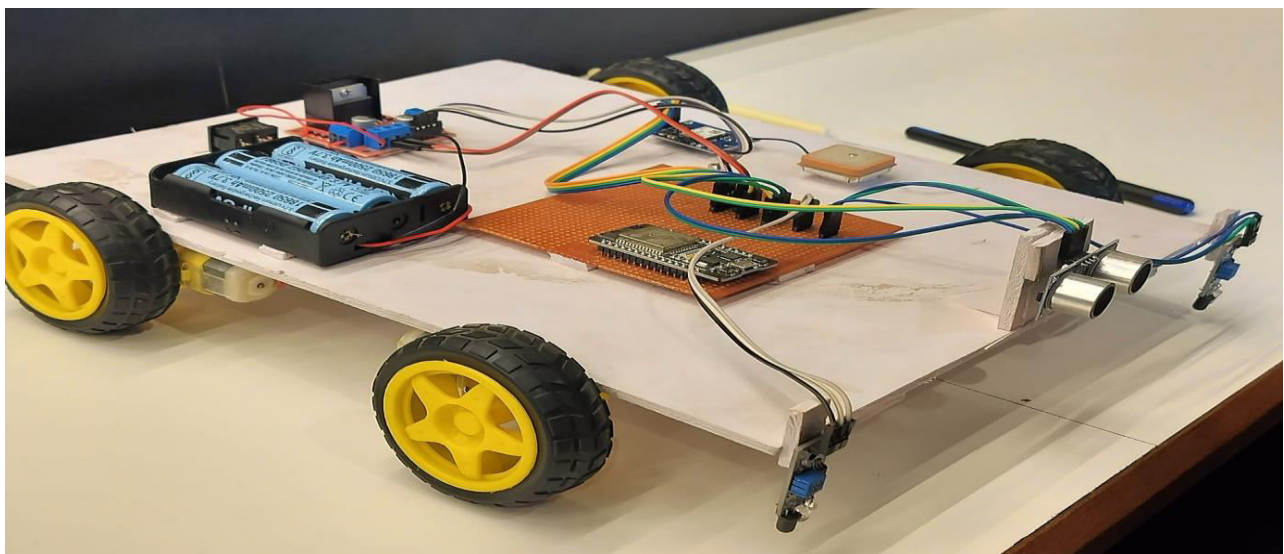


Fig. Hardware implementation Side View

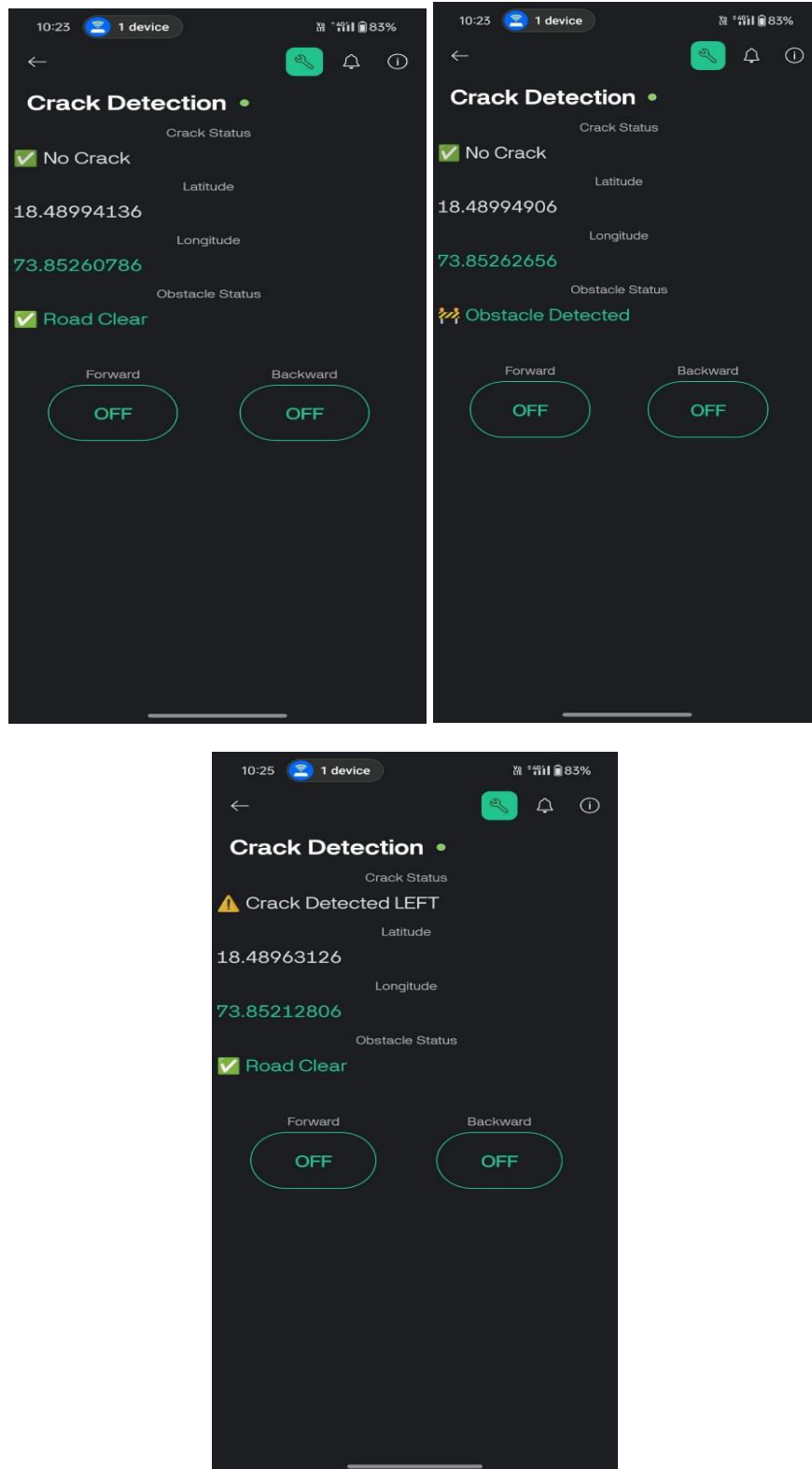


Fig. Working results on Blynk platform



## VII. APPLICATIONS

The IoT-enabled Railway Track Crack Detection System offers several practical and impactful applications aimed at improving railway safety, operational efficiency, and maintenance automation:

### 1. Automatic Crack Detection and Response

The system employs infrared (IR) sensors on both rails to detect cracks in real-time. Upon detecting a crack, the onboard controller processes the input and immediately sends an alert through the cloud platform. The mobile inspection vehicle can also be programmed to stop or reverse to avoid further damage or inaccurate readings.

### 2. Obstacle Detection on Track

An ultrasonic sensor is integrated at the front of the mobile vehicle to identify obstacles lying ahead on the railway track. This helps detect fallen objects, debris, or animals, especially in remote areas where manual inspection is rare.

### 3. Real-Time Location Tracking

A GPS NEO-6M module captures the precise location (latitude and longitude) of detected cracks or obstacles. This data is transmitted to the Blynk Cloud, allowing authorities to respond quickly with location-specific interventions.

### 4. Cloud-Based Monitoring and Alert System

With Blynk IoT integration, railway authorities can monitor track status in real-time using smartphones or web dashboards. Alerts are pushed instantly when an anomaly is detected, minimizing response time and enhancing safety.

### 5. Reduction in Manual Inspection

The automated nature of the system drastically reduces dependency on manual inspection teams. This not only saves time and labor but also minimizes human error in detecting cracks and other hazards.

### 6. Preventive Maintenance and Data Logging

Continuous data collection and wireless transmission allow for predictive analysis. Maintenance teams can use this historical data to identify recurring issues in specific track regions and perform preventive maintenance before accidents occur.

### 7. Scalability for Larger Networks

The modular design using ESP32 makes the system cost-effective and scalable. It can be deployed across various segments of the railway network, especially in rural or difficult-to-reach areas.

## VIII. CONCLUSION

Based on the analysis, traditional railway track monitoring methods are not only time-consuming but also economically inefficient. The proposed system effectively addresses these limitations by offering a cost-efficient and accurate solution for real-time crack and obstacle detection on railway tracks. By integrating sensors with ESP32 and IoT-based alert systems, this approach significantly enhances safety measures, thereby reducing the risk of derailments and associated fatalities. The system also minimizes the time and resources required for manual inspections, ultimately contributing to improved operational efficiency in railway maintenance and reducing the socio-economic impact of railway accidents.

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