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# A Smart Device for Crack Detection and Location Identification of Railway Track

Gopiya Naik S<sup>1</sup>, Shridhar Agasimani<sup>2</sup>, Cheluvvaraju A.R<sup>2</sup>, Rajeshwari R<sup>2</sup>, Sriram H<sup>2</sup>

Professor, Department of Electrical and Electronics Engineering, PESCE, Mandya, Karnataka, India<sup>1</sup>

U.G. Students, Department of Electrical and Electronics Engineering, PESCE, Mandya, Karnataka, India<sup>2</sup>

**ABSTRACT:** Railway transportation plays a vital role in modern infrastructure, but cracks and faults in railway tracks remain a major cause of derailments and safety hazards. Conventional track inspection methods are mostly manual, time-consuming, and prone to human error, which creates a need for an automated and reliable monitoring system. In the proposed system, a mobile robotic unit continuously moves along the railway track and monitors the rail surface using IR sensors. When a crack or discontinuity is detected, the sensor output changes and the controller immediately stop the vehicle, captures the fault condition, and determines the exact location using a GPS module. The detected information is then transmitted to the concerned authorities through Wi-Fi using a Telegram-based alert mechanism for rapid response and maintenance action.

**KEYWORDS:** Railway track, IOT, location identification, Embedded monitoring system, Rapid response.

## I. INTRODUCTION

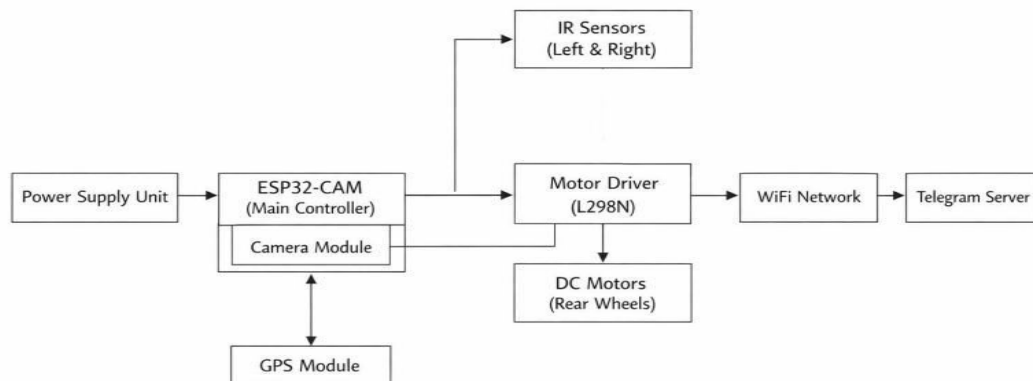
In Railway transportation is one of the most important and widely used modes of travel and freight movement, and its safety is strongly dependent on the health and reliability of railway tracks. Even a small crack, fracture, or discontinuity in the rail surface can grow over time due to repeated mechanical loading, vibration, and environmental stress, eventually causing derailment, infrastructure damage, and major loss of life and property. Because of this, railway track inspection has become a significant area of research, with increasing attention being given to automated and intelligent fault detection systems instead of purely manual inspection practices [1]. Conventional inspection methods are often slow, labor-intensive, and unable to provide continuous real-time monitoring over long railway routes, which creates a serious limitation in early crack identification and preventive maintenance [2]. To overcome these drawbacks, recent researchers have begun developing embedded systems that combine sensors, controllers, and communication modules to improve railway safety through faster and more reliable fault detection [3]. The growing use of smart electronics and low-cost communication technologies has enabled the development of railway crack detection systems capable of automatically identifying damaged sections of track and reporting them to the concerned authorities. In this direction, sensor-based embedded systems have been proposed to continuously inspect the rail path and provide an alternative to periodic manual checking [4]. Wireless communication has also become an important part of such systems, because once a fault is detected, alert information must be transmitted immediately to the maintenance team for corrective action [5]. Furthermore, IoT based architectures are now being integrated into railway safety applications, allowing remote monitoring, better connectivity, and improved coordination between the fault detection device and the supervisory unit [6]. The concept has been extended in some studies through the addition of protection-oriented mechanisms and smart guard features, showing that railway crack detection can be coupled with broader safety functions in order to reduce accident risk and improve overall operational reliability [7]. Another important development in this field is the integration of geological and intelligent communication with physical fault sensing. Modern railway crack detection systems are no longer limited to identifying the existence of a crack alone; they increasingly aim to provide the exact fault location and instant notification through GPS, GSM, Wi-Fi, or cloud-based platforms [8]. Such functionality is especially valuable in large railway networks, where locating the faulty section quickly is essential for timely maintenance and accident prevention. Practical implementation-oriented studies have shown that compact hardware systems with sensor modules, micro-controller, and mobile platforms can be deployed at low cost for real-time track monitoring [9]. More recently, IoT enabled crack detection devices have demonstrated that automated fault identification, location tracking, and digital alert communication can be combined into a single embedded framework suitable for intelligent railway safety applications [10].

## II. LITERATURE SURVEY

up- Kanse et al. [1] proposed an IoT-based railway track crack detection system using an ESP32, dual IR sensors, an ultrasonic sensor, and a GPS NEO-6M module. The robotic unit moves on the track, detects cracks on both rails, and identifies obstacles in front of the vehicle. The sensed data is transmitted to the Blynk Cloud for remote monitoring through a phone or web dashboard. The work mainly focuses on real-time monitoring, precise fault localization, and reduced dependence on manual inspection. S. J. et al. [2] presented a railway track obstacle and crack detection system aimed at improving railway safety through automation. Their method combines IR sensors, ultrasonic sensing, image processing, and machine learning to detect both cracks and obstacles in real time. The system also integrates GPS and GSM modules to send fault location and alerts to the authorities. The authors reported that the model is cost-effective, scalable, and capable of working under different environmental conditions. Shinde et al. [3] developed an automated railway track crack and fault detection system using GPS and GSM technology. The proposed system uses infrared or ultrasonic sensors, a microcontroller, a GPS module, and GSM communication to identify rail discontinuities and immediately notify authorities through SMS. Their work emphasizes exact fault-coordinate transmission for faster maintenance response. The study highlights that automation can reduce delay, manual effort, and accident risk in railway operations. Rao et al. [4] proposed an IoT-based railway track crack and object detection system to improve railway safety and security. Their system uses sensors and cameras placed along the railway track to monitor damage and obstructions continuously. The sensors detect vibration changes that may indicate cracks, while the camera captures supporting visual information from the track. This work shows how combining sensing and visual monitoring can strengthen early fault detection in railway infrastructure. Bhosale et al. [5] introduced a GSM-based railway track crack detection system using Raspberry Pi 5, dual Pi cameras, a GSM900A module, an ultrasonic sensor, and a wheel encoder. The system captures high-resolution rail images and applies machine learning to identify cracks. Once a fault is found, the location and status are sent to the concerned authority through GSM communication. The paper focuses on real-time communication, autonomous inspection, and reliable fault localization. Dharanidaran et al. [6] presented an automatic railway track crack detection system using IoT to reduce accidents caused by rail fractures. The system uses GPS along with sensor technology to determine the exact location of a crack. A NodeMCU IoT module sends the sensor data to the cloud, while an AT89S52 microcontroller supervises overall system operation. The work demonstrates how real-time crack detection and cloud-based reporting can support faster preventive maintenance. Deepa et al. [7] proposed an automated crack detection and smart guard system using Arduino Uno, ultrasonic sensors, ESP8266, ESP32 camera, IR sensors, and GPS. Their system detects obstacles within a threshold distance, activates a siren, and automatically stops the train when the obstacle remains critical. At the same time, IR sensors scan the track for fractures and send GPS-based alerts to the Blynk app. The addition of live video through the ESP32 camera improves real-time surveillance and response capability. Tojo et al. [8] designed an IoT-based automatic railway track crack detection system integrated with GSM communication for real-time monitoring. The system uses sensors placed along the track to identify cracks and abnormalities in the rail structure. Once a crack is detected, an automated GSM alert is sent to the relevant authority for timely action. The study shows that IoT and GSM integration can improve reliability, maintenance planning, and railway safety. Kumar B. P. et al. [9] developed a railway track crack detection system using Raspberry Pi for both crack and object detection. Their system uses IR sensors, PIR sensors, location tracking, and communication features to identify anomalies and notify railway operators. The paper emphasizes the need for a robust, efficient, and stable solution because rail cracks and track-crossing faults cause major railway accidents. The proposed method is described as a cost-effective and efficient track-integrity monitoring system. Shaik et al. [10] presented an IoT-enabled railway track crack detection system using a compact autonomous robotic unit for identifying surface and sub-surface rail defects. The system combines automated anomaly detection, geolocation tracking, and cloud-based analytics to improve railway safety. When a crack is detected, the device raises audible and visual alerts and sends geotagged data for remote monitoring and predictive maintenance. Experimental validation showed that the system can support timely defect detection and localization.

### III. METHODOLOGY

#### A. Block diagram



**Fig.1. Proposed system architecture of a smart device for crack detection and location identification of railway track**

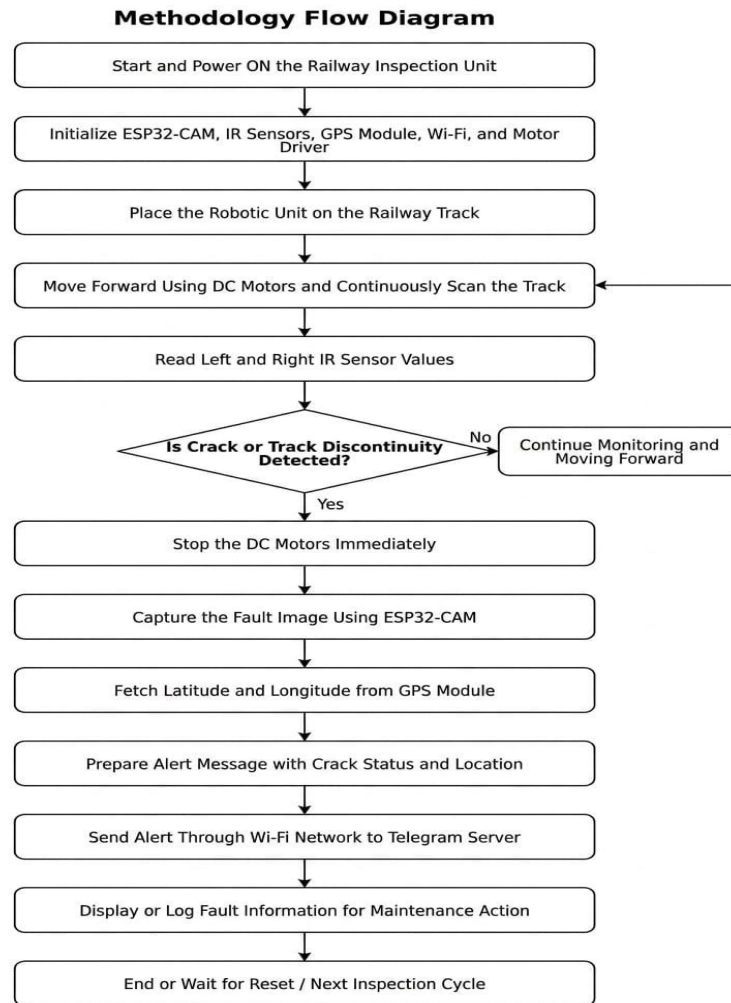
The proposed a smart device for crack detection and location identification of railway track is organized as an embedded mobile monitoring unit that continuously inspects the railway track for possible cracks and discontinuities. As shown in Fig. 1, the complete system consists of a Power Supply Unit, ESP32-CAM main controller, left and right IR sensors, GPS module, L298N motor driver, DC motors, Wi-Fi network, and Telegram server. The power supply unit provides the required operating voltage to the controller and other hardware modules. The ESP32-CAM acts as the central control unit of the system and processes the input signals received from the sensing and positioning modules. The left and right IR sensors, shown in Fig. 1, are placed to monitor both sides of the railway track continuously. These sensors detect cracks or discontinuities based on changes in reflected infrared signals from the rail surface. The sensed output is given to the ESP32-CAM, which analyzes the abnormal condition and determines whether the track is in a normal or faulty state. The use of two IR sensors improves detection coverage and increases the reliability of crack identification. The GPS module, also connected to the ESP32-CAM in Fig. 1, is used to identify the exact geographical location of the detected crack. Once a fault is identified, the controller acquires the latitude and longitude values from the GPS module so that the damaged track position can be reported accurately. This location information is essential for enabling quick maintenance action and reducing the response time of railway authorities. For movement control, the ESP32-CAM sends control signals to the L298N motor driver, which in turn drives the DC motors mounted on the rear wheels of the robotic inspection unit, as illustrated in Fig. 1. Under normal conditions, the motors keep the unit moving along the track. When a crack is detected, the controller stops the motor operation immediately to prevent further motion and to initiate fault reporting. The communication section of the system is achieved through the Wi-Fi network and Telegram server, as depicted in Fig. 1. After crack detection and location acquisition, the ESP32-CAM transmits the fault status and GPS coordinates through the Wi-Fi network to the Telegram server, allowing a real-time alert to be sent to the concerned authority. Therefore, the overall architecture shown in Fig. 1 integrates sensing, processing, location tracking, mobility control, and wireless alert generation into a single low-cost and efficient railway safety monitoring system.

#### B. Flow Chart of Proposed Methodology

The methodology of the proposed railway track crack detection and location identification system is illustrated in Fig. 2 and represents the complete operational sequence followed by the robotic inspection unit during railway track monitoring. Initially, the system is powered ON, after which all major hardware modules, including the ESP32-CAM main controller, left and right IR sensors, GPS module, Wi-Fi communication unit, and L298N motor driver, are initialized to ensure proper coordination among sensing, control, positioning, and communication functions. Once the initialization process is completed, the robotic unit is placed on the railway track and begins

moving forward with the help of DC motors. During this movement, the left and right IR sensors continuously scan the rail surface and monitor the track condition for any crack or discontinuity.

As shown in Fig. 2, the sensed IR values are repeatedly processed by the controller to determine whether the rail condition is normal or faulty.



**Fig.2 Complete operational sequence followed by the robotic inspection unit during railway track monitoring**

If the track is in good condition and no abnormality is detected, the system follows the “No” decision branch shown in Fig. 2, under which the robotic unit continues moving forward while maintaining continuous track monitoring. This repeated sensing-and-motion loop enables uninterrupted inspection of the railway line over the travel path of the inspection unit. On the other hand, if a crack or discontinuity is detected by the IR sensors, the system follows the “Yes” decision branch in Fig. 2, and the controller immediately stops the DC motors to avoid further movement and to confirm the fault condition. After the vehicle is stopped, the ESP32-CAM captures the image of the detected faulty rail section so that the damaged area can be visually observed and verified. Following this, the GPS module is activated to obtain the exact latitude and longitude coordinates of the detected crack location. Once the crack status and geographical coordinates are obtained, the controller prepares an alert message containing the fault information and corresponding location details. This alert message is then transmitted through the Wi-Fi network to the Telegram server, enabling real-time notification to the concerned railway maintenance authority for quick response and corrective action. Finally, the detected crack information is displayed or stored for

maintenance analysis, and the system either reaches the end condition or waits for reset and the next inspection cycle. Therefore, Fig. 2 clearly explains the complete methodology of initialization, railway track scanning, crack detection, motion control, fault image capture, GPS based location identification, and wireless alert transmission in the proposed smart railway safety system.

#### IV. EXPERIMENTAL RESULTS

The developed prototype shown in fig. 3 the experimental setup was successfully assembled and tested for railway track crack detection and location identification. The hardware integration of the ESP32-CAM, IR sensing unit, motor driver, robotic chassis, and power supply was found to operate properly during the initial prototype validation.

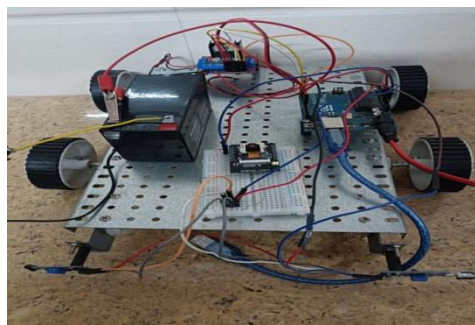


Fig. 3: Experimental prototype of a smart device for crack detection and location identification of railway track.

The robotic platform was able to move along the test path, and the sensing arrangement was capable of distinguishing between normal track condition and discontinuity condition. When a crack-like gap was introduced in the test rail section, the system detected the abnormality and stopped the motion of the robotic unit. This confirms that the proposed sensing and control mechanism can perform basic real-time crack detection. The experimental observations also show that the prototype is suitable for low-cost embedded implementation. The use of a compact robotic base helped in integrating the sensing and control modules into a single mobile platform. The dual-side sensor arrangement at the front side of the chassis improves monitoring coverage, while the controller-based stopping action reduces the possibility of missing a detected crack. In addition, the integrated communication and location-identification concept makes the system more useful for practical railway maintenance applications, since the detected fault can be associated with its corresponding location and transmitted to the concerned authority. From the testing point of view, the proposed system demonstrates good feasibility in controlled conditions; however, its performance can further be discussed using quantitative plots such as detection accuracy, response time, alert transmission time, distance covered before stopping, and power consumption. These graphs help to present the effectiveness of the prototype. Since graphs require numerical data, you can include 3 to 5 result tables and plot them in Excel. Below are suitable tables for graph preparation

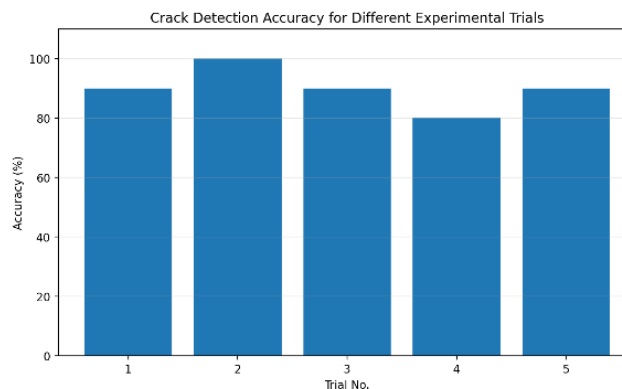


Fig.4. Crack detection accuracy for different experimental trials

Fig. 4 shows the crack detection accuracy for different experimental trials carried out using the proposed railway track crack detection and location identification system. The graph represents the percentage accuracy achieved by the system in five separate trials conducted under controlled test conditions. As observed in Fig. 4, the system achieved accuracy values of 90%, 100%, 90%, 80%, and 90% for Trials 1 to 5, respectively. The highest crack detection accuracy was obtained in Trial 2, where the system successfully detected all crack conditions without any missed or false detection. In the remaining trials, the accuracy stayed within the range of 80% to 90%, which indicates that the proposed IR sensor-based detection mechanism provides consistently good performance in identifying cracks or discontinuities on the railway track. The comparatively lower accuracy observed in Trial 4, as shown in Fig. 4, may be due to slight variations in sensor positioning, crack size, surface reflection, or environmental disturbances during the experiment. Overall, Fig. 4 confirms that the proposed system is capable of performing railway crack detection with good reliability and acceptable accuracy, making it suitable for prototype-level real-time monitoring applications.

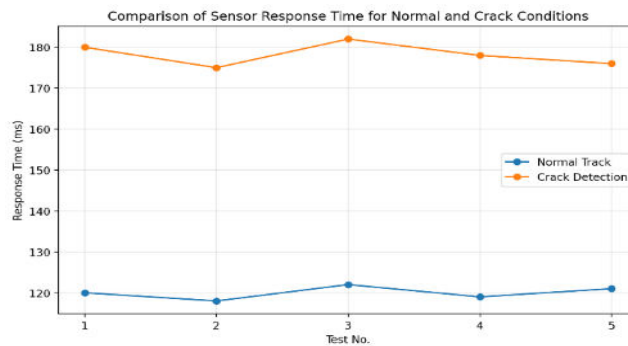


Fig. 5. Comparison of sensor response time for normal and crack conditions.

Fig. 5 shows the comparison of sensor response time for normal and crack conditions in the proposed railway track crack detection and location identification system. The graph compares the time taken by the sensing unit to respond when the railway track is in a normal state and when a crack or discontinuity is present. As observed in Fig. 5, the response time under normal track conditions remains nearly constant in the range of 118ms to 122ms, indicating stable and consistent sensing performance when no fault is present. In contrast, the crack detection response time is slightly higher, varying from 175ms to 182ms. This increase in response time occurs because, during crack detection, the controller requires additional processing to confirm the abnormal sensor reading and initiate the necessary control action. The difference between the two curves in Fig. 5 clearly indicates that the system reacts quickly in both cases, while giving slightly more time for reliable fault confirmation in the presence of a crack. Even with this increase, the response time remains sufficiently low for real-time railway monitoring applications. Therefore, Fig. 5 confirms that the proposed sensing mechanism provides fast and effective response under both normal and faulty track conditions, which is essential for timely crack identification and safe robotic operation.

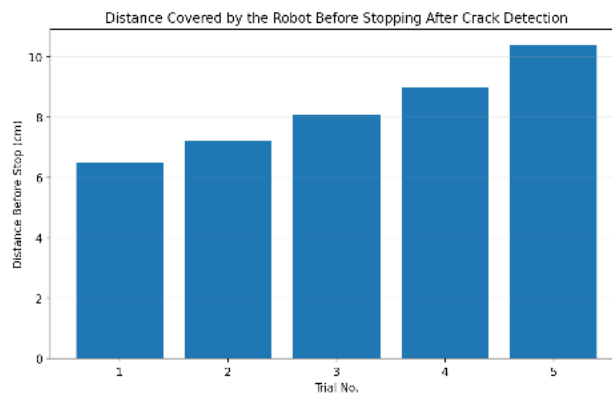


Fig. 6. Distance covered by the robot before stopping after crack detection.

Fig. 6 shows the distance covered by the robot before stopping after crack detection at different operating speeds of the proposed railway track crack detection and location identification system. The graph illustrates how far the robotic inspection unit continues to move after a crack is detected and before it comes to a complete stop. As observed in Fig. 6, the stopping distance increases gradually with an increase in the speed of the robot. At a lower speed of 10cm/s, the robot stops after approximately 6.5cm, whereas at a higher speed of 18cm/s, the stopping distance increases to about 10.4cm. This behavior occurs because the robot requires a small but finite time to process the crack detection signal, activate the stopping command, and bring the DC motors to rest. The trend shown in Fig. 6 indicates that lower operating speed provides better stopping control and reduces the chance of overshooting the crack location. Therefore, Fig. 6 confirms that the proposed robotic unit responds effectively to crack detection, while also showing that the stopping distance is directly influenced by the inspection speed of the system.

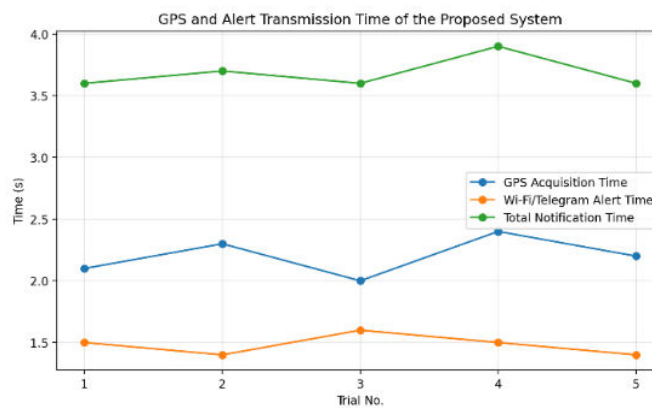


Fig. 7. GPS and alert transmission time of the proposed system.

Fig. 7 shows the GPS and alert transmission time of the proposed system and represents the time required for location acquisition and notification delivery after crack detection. The graph compares three parameters, namely GPS acquisition time, Wi-Fi/Telegram alert transmission time, and total notification time, for different experimental trials. As observed in Fig. 7, the GPS acquisition time varies between 2.0s and 2.4s, which indicates that the system is able to obtain the geographical coordinates of the detected crack within a short duration. The Wi-Fi/Telegram alert transmission time remains almost stable in the range of 1.4s to 1.6s, showing that the communication module provides consistent performance during message delivery. As a result, the total notification time shown in Fig. 7 lies approximately between 3.6s and 3.9s for all trials. This demonstrates that the proposed system can send crack-related alerts to the concerned authority in less than four seconds after fault detection. Therefore, Fig. 7 confirms that the integration of GPS and wireless alert communication in the proposed system is effective for real-time railway fault reporting and rapid maintenance response.

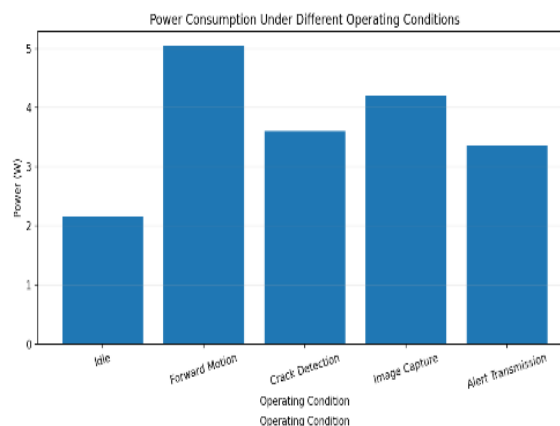


Fig. 8. Power consumption under different operating conditions.

Fig. 8 shows the power consumption under different operating conditions of the proposed railway track crack detection and location identification system. The graph presents the variation in power usage when the system operates in different modes such as idle condition, forward motion, crack detection, image capture, and alert transmission. As observed in Fig. 8, the lowest power consumption occurs during the idle condition, where the system consumes approximately 2.16W, since only the essential control circuitry remains active. The highest power consumption is recorded during forward motion, reaching about 5.04W, because the DC motors require more electrical power to drive the robotic inspection unit along the railway track. During crack detection, image capture, and alert transmission, the power consumption lies between 3.36W and 4.20W, which indicates moderate energy usage for sensing, processing, and communication tasks. The graph in Fig. 8 clearly shows that motor operation contributes the maximum share of power consumption in the system, while sensing and communication functions require comparatively lower power. Therefore, Fig. 8 confirms that the proposed system has manageable power requirements and can be effectively operated using a battery source for real-time embedded railway monitoring applications.

Overall, the results presented in Fig. 4 to Fig. 8 demonstrate that the proposed system provides good crack detection accuracy, acceptable response time, effective robotic stopping performance, timely alert communication, and manageable power consumption. Therefore, the developed prototype proves the feasibility of implementing a low-cost, real-time railway track crack detection and location identification system for smart railway safety applications.

## V. CONCLUSION

In this work, a smart device for crack detection and location identification of railway track was proposed and developed to improve railway safety through automated monitoring and real-time fault reporting. The system was designed by integrating IR sensors, ESP32-CAM, GPS module, motor driver, DC motors, Wi-Fi communication, and Telegram alerting into a compact robotic inspection platform. The developed prototype continuously scans the railway track, detects cracks or discontinuities, stops the robotic unit upon fault detection, captures the faulty section, determines the exact geographical location, and transmits the alert information to the concerned authority. Thus, the proposed system successfully combines sensing, motion control, location tracking, and wireless communication within a single low-cost embedded platform. The experimental results show that the proposed system is capable of detecting railway track cracks with good accuracy under controlled test conditions. The obtained results related to crack detection accuracy, sensor response time, stopping distance, alert notification time, and power consumption demonstrate the feasibility of implementing the system for real-time railway monitoring applications. The use of a compact hardware architecture and simple sensing mechanism makes the system economical and easy to implement for prototype-level railway safety solutions. Although the present system is mainly validated under laboratory conditions, it establishes a strong foundation for future intelligent railway inspection systems. With further improvements in sensing robustness, communication range, and mechanical design, the proposed system can be extended toward practical field deployment for safer and more efficient railway track monitoring. Therefore, the developed model provides a promising solution for reducing railway accidents caused by track cracks and contributes to the advancement of smart railway infrastructure monitoring.

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