International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

RailGuard: An IoT Enabled Multi-Modal System for Real-Time Railway Trak Defect Detection

Uday Bhatnagar, Vidhi Chauhan, Vineet Goyal, Vivek Chauhan

Department of Computer Science & Engineering, Moradabad Institute of Technology, Moradabad, India

Udaybhatnagr502@gmail.com, cvidhi070@gmail.com, vineetgoyal741@gmail.com, vivekchauhan4440@gmail.com

Abstract

In India, people rely heavily on public transport to travel from one place to another, and among all the available options, railways are the most preferred as it is affordable, convenient and widely used. However, despite being one of the most used modes of transportation, railway safety continues to face challenges due to issues such as cracks in the tracks, misalignment or obstacles on the track-problems that are not always detected through traditional manual inspections. In this paper, we propose a solution to solve these problems. We developed a project called RailGuard, an IoT-enabled railway safety system capable of providing continuous, real-time monitoring of track health. It uses ultrasonic sensors, IR sensors and gyroscope to accurately identify structural defects and abnormal inclinations of tracks. Whenever any fault is detected, the RailGuard immediately captures the GPS location and sends an alert to the Railway Control Room through the GSM module. The system can also record and broadcast a short video clip of the issue, helping officials respond quickly and effectively. RailGuard provides a low cost and efficient solution to enhance railway safety and reduce the risk of accident while reducing the burden of manual inspection.

Keywords: Crack Detection, GPS module, GSM module, ultrasonic sensor, IR sensor, Manual Inspection.

INTRODUCTION

The Railway is the biggest means of transportation in India. India is the fourth largest railway network in India. Rail transportation is of the utmost importance as a component of public transport system. Its advantages of fast, punctual, and large capacity make to become the most frequent

facilities are inadequate compared to the international standards and as a result, there have been frequent derailments that have resulted in severe loss of valuable human lives and property as well [6]. About 60% of all the rail accidents Is due to derailments, recent statistics reveal that about 90% are due to cracks on the rails. Hence these

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

of rail usage. These cracks generally go unnoticed due to improper maintenance and irregular and human involvement in track line monitoring [7].

Advance image-processing studies have demonstrated that digital analysis can identify cracks more accurately than human inspection, reinforcing the importance of automated fault detection in modern railway systems [3]. Other works have shown that IR based patrol vehicles can successfully detect obstacles and basic track faults, proving the usefulness of sensor-based railway monitoring [4]. Ultrasonic sensor research confirms that distance-based crack detection is a reliable method for identifying breaks or gaps on the track [5]. GSM based systems have further proven that instant alerts sent to control rooms significantly reduce response time and improve safety management [6].

Building on these proven concepts, RailGuard integrates ultrasonic sensing, IR detection, a gyroscope for alignment monitoring, PS-based location tracking, GSM alerts, and video capture to create a unified, real-time, IoT enabled solution for railway safety and maintenance.

PROBLEM STATEMENT

Transport is a key necessity for specialization that allows production and consumption of products to occur at different locations [6].

Railways provide the cheapest and most suburban traffic. Also, most of the transport in India is being carried out by railway network. Still, accidents are the major of the transport concern in terms of railway track crossing and unidentified crack in rail tracks in Indian railway. About 60% of accidents occur at railway track crossings and due to cracks in railway track resulting in loss of precious economy [1].

Example: - **Khanna Rail Disaster** (26 November 1998, Punjab)

The Khanna Rail Disaster occurred on 26 Nov. 1998 near Khanna in Punjab when the Frontier Mail (Golden Temple Mail) derailed due to a broken rail caused by an undetected crack.
Six of its coaches fell onto the adjacent track. Within moments, the Jammu Tawi-Sealdah Express arrived at high speed in the same section and collied with the derailed Frontier Mail Coaches, blocking the line.

Fig 1: Khanna Rail Disaster

The Accident resulted in over **200 deaths** and is remembered as India's most devastating rail collisions, the root cause of which was rail fracture, poor crack detection and inadequate track inspection.

Therefore, there is need to have new technology which will be robust, efficient and stable for both crack detection in railway track as well as object detection.

LITERATURE REVIEW

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

The Paper “**RailGuard:** An IOT Enabled Multi Modal System for real time Railway Track Defect Detection” according to authors is more reliable and less time-consuming mode of railway track defect detection, it also saves human efforts as it is transforming human work into automation.

The inappropriate upkeep of tracks which have brought about the arrangement of breaks in the tracks has been distinguished as the primary driver of wrecking [3].

Some of the Research done by researchers is presented in this section. Mao et al. build up sensor blame location conspire for rail vehicle latent suspension frameworks, utilizing a blame inspector discovery spectator, within the sight of indeterminate track normality and vehicle clamors that are demonstrated as outer aggravations and stochastic process signals. Faghih – Roohi et al. proposed a profound convolutional neural system answer for the investigation of picture information for the location of rail surface deformities. They looked at the consequences of various system structures described by various sizes and actuation capacities. Hu et al. recognized uneven shine and glamour, the substantial rail surface deformities, as indicated by the qualities of overwhelming rail surface imperfections, considering the numerical morphology of multi-scale and double structure components. Contrasted and the customary edge identification administrators, the outcomes demonstrate that their technique possesses solid hostile to commotion execution, can identify the little deformity edge precisely under clamor [3].

Related Work

Several research has focused on improving automated railway crack detection and safety Monitoring. Early studies found that manual inspection methods often fail to detect micro-fractures, which later develop into larger cracks and cause derailment[3].To avoid reliance on human inspection, computer-vision and image-processing techniques were introduced to analyze rail surface conditions and improve crack detection using transformations and segmentation; however, these systems were computationally expensive and highly sensitive to change in track lightning[8].

Sensor-driven models later gained popularity due to their low cost and real-time reliability. IR-based inspection units were shown to detect surface cracks and obstructions with good accuracy, making them suitable for continuous track monitoring [9]. Ultrasonic-based fault identification further improved the detection of internet and subsurface cracks by measuring distance variations; however, standalone ultrasonic modules struggled in noisy and vibrational environment during field deployment [10].Wireless communication technologies began to help improve safety, with Bluetooth-based systems sending alerts to nearby receivers upon detecting a crack, but their limited coverage limited their usefulness on long railway routes [9].

To address long-distance communication challenges, GSM-enabled systems were developed to automatically send crack alerts along with GPS-based location coordinates

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

to railway control authorities. This significantly reduced emergency response times and improved the accuracy of locating defective track segment [11]. Later solutions expanded the scope beyond crack detection by integrating PIR and ultrasonic sensors to detect animals or moving objects on railway tracks, helping to prevent collision-based derailment in addition to rail fractures [12].

Learning from previous systems, the proposed **RailGuard** model adopts a multi-sensor fusion architecture that includes ultrasonic crack measurement, IR-based obstacle detection, gyroscope-assisted misalignment sensing, GPS-based emergency reporting. This integrated approach leverages the strengths of each technology and mitigates the individual drawbacks, providing a more robust, scalable and reliable smart railway monitoring solution than previous single-method implementations.

Methodology

The **RailGuard** system follows a multi-modal fault detection process that integrates Sensing, data acquisition, geolocation tracking, and communication alert mechanisms. The railway track is continuously scanned while the inspection module moves along the track. Ultrasonic sensor measure changes in the distance between the module and the rail surface; any abnormal deviation beyond a predetermined threshold is interpreted as a crack or structural deformity [5]. Additionally, IR sensors monitor the path ahead to identify obstruction on the track, ensuring dual-level safety monitoring [4]. To detect track misalignment, another common factor in derailment, the system uses a gyroscope that continuously records angular tilts values.

Any unexpected tilt triggers a fault flag and initiates emergency reporting. When a fault (crack, obstruction, or misalignment) is confirmed, the GPS module immediately captures the location's latitude and longitude and longitude and transmits it to the control room via the GSM module [6]. In addition to alert transmission, the system records a short video clip corrective action. The entire inspection cycle is automated and requires no manual involvement, reducing reliance on human personnel while enabling scalable, real-time fault monitoring over long railway sections.

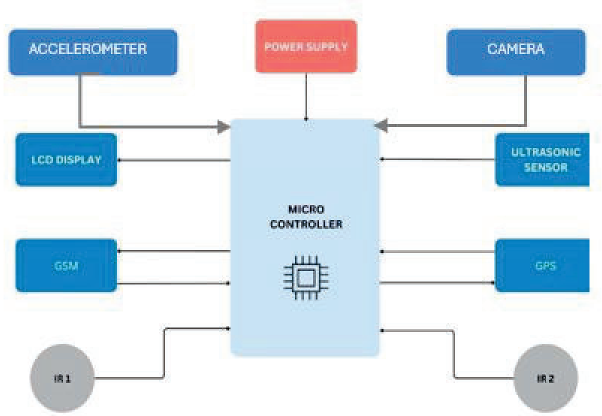
To enhance detection accuracy while in motion, the **RailGuard** robot uses a 30-RPM geared motor to maintain low traversal speeds and minimize vibration, preventing false readings-a limitation observed in fast moving crack-detection modules [8]. All sensor values are processed by the Arduino microcontroller using a multi-sensor validation approach. The ultrasonic sensor corrects for dust or light interference where IR reflection is unreal, while the accelerometer and gyroscope detect structural misalignment -a critical derailment factor often overlooked in crack-only monitoring architectures [11]. With GPS-GSM integration, accurate fault coordinates are instantly reported over long distances, eliminating the coverage limitations associated with Bluetooth-based system [5]. Sensing, validation, communication, and video logging combine to provide an end-to-end autonomous

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

monitoring workflow suitable for large-scale railway surveillance.

The block diagram of RailGuard shows how all components send signals to the Arduino.

Block Diagram



Hardware component

Arduino Uno:

Acts as the central controller, processing input from sensor and controlling output modules such as GPS, GSM, and LCD. It works as a brain of our system as it controls every component, it takes input from different components and accordingly make decisions.

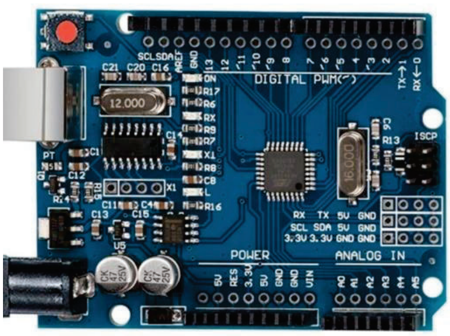


Fig 2: Arduino Uno

IR Sensor:

Detects surface-level cracks and obstructions by analyzing reflected infrared signals during track scanning. It is the main Component for detecting the cracks on the railway track. It has two leds, one is for transmitting the rays and another one is for receiving the rays.

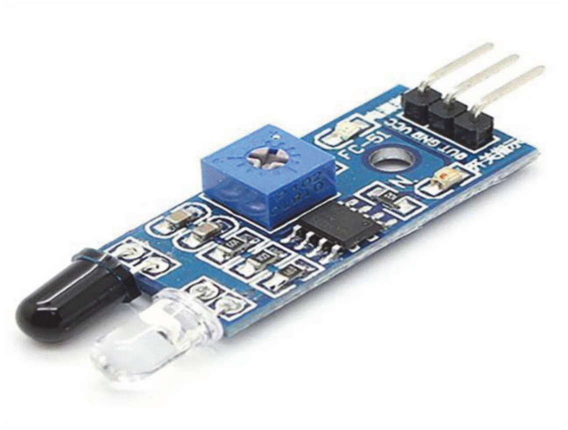


Fig 3: IR Sensor

Ultrasonic sensor:

Measure the distance from the surface to identify internal cracks or micro-level gaps that cannot reflect IR light.

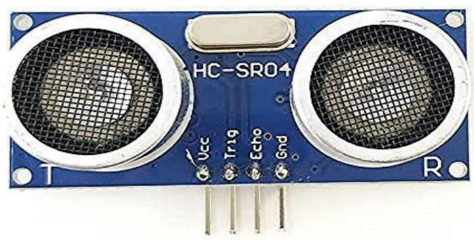


Fig 4: Ultrasonic Sensor

Accelerometer /Gyroscope:

Tracks vibration patterns and tilt changes to detect misalignment and geometric instability of the railway track.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

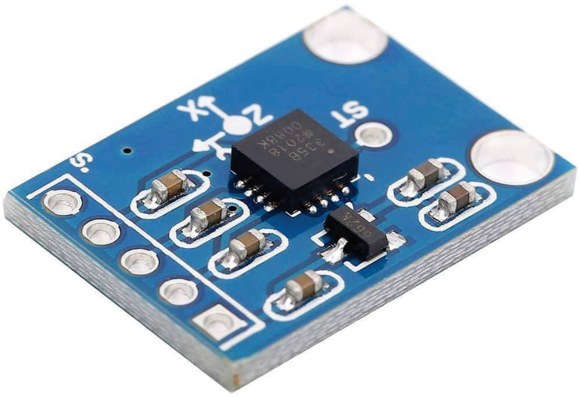


Fig 5: Accelerometer

LCD Display:

Displays the system status and the location of defective cracks to help provide immediate feedback to on-site inspectors.

Fig 6: LCD Display

GPS Module:

Generates the exact latitude and longitude of any detected defect, allowing for quick location tracking during maintenance.

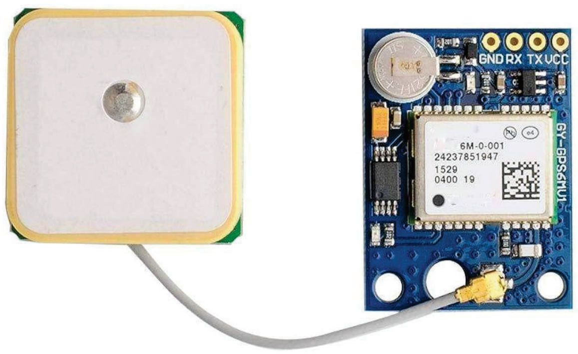


Fig 7: GPS Module

GSM Module:

GSM stands for Global System for Mobile Communication. It Immediately sends an alert and GPS coordinate to the railway control room upon detecting a crack or misalignment.

Fig 8: GSM Module

30-RPM DC Motor

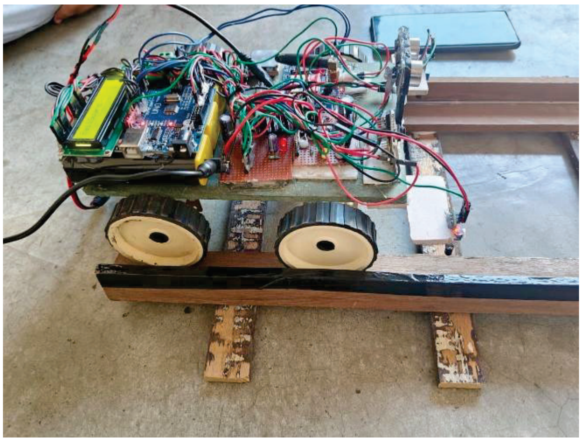
Gives the inspection robot controlled low speed movement for stable scanning and reduced sensor noise.

Fig 9: DC Motor

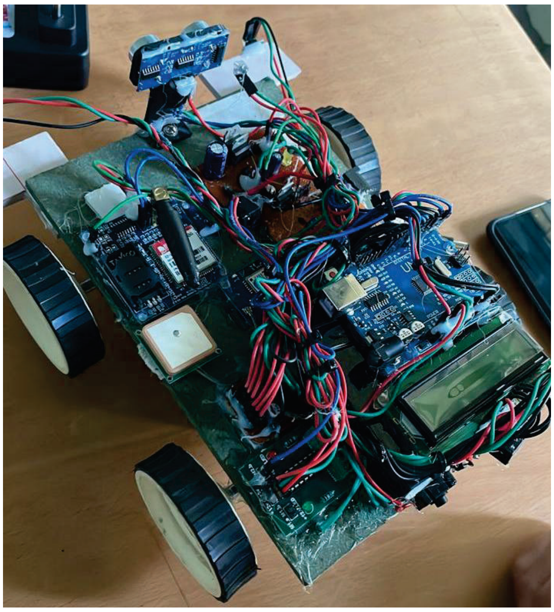
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

RESULTS AND DISCUSSION

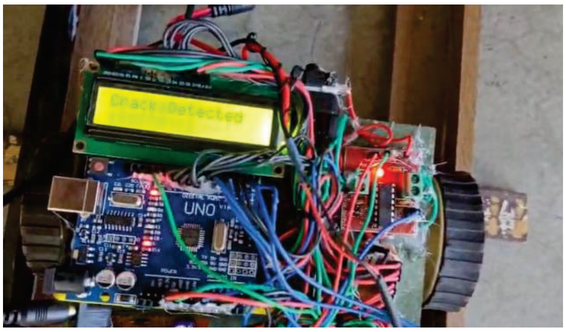
Using ultrasonic, infrared, and accelerometer sensors, the RailGuard system successfully identified cracks, obstructions, and track misalignment, demonstrating precise real-time railroad track monitoring. Instant location-based notifications were successfully transmitted via the GPS and GSM modules, and the camera offered visual evidence of flaws. Overall, the results suggest that RailGuard delivers faster, more reliable, and continuous problem detection compared to manual inspection, enhancing railway safety and minimizing human effort.



(a) RailGuard on the Track

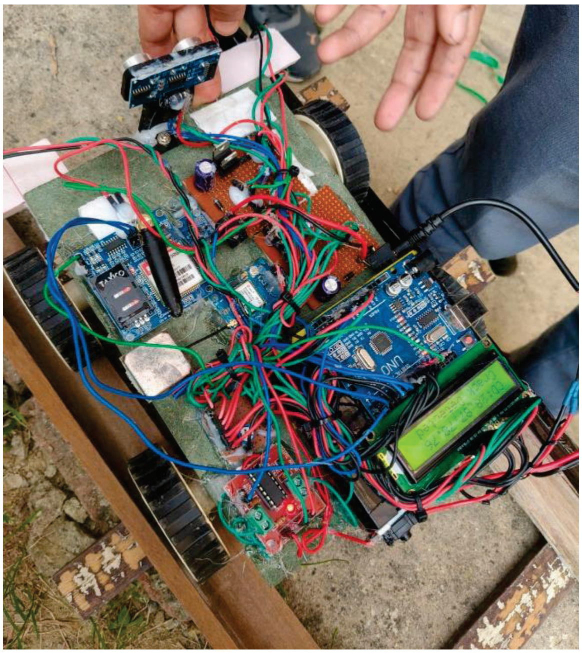


(b) Top View of the RailGuard Hardware Layout



(c) Crack detected on Railway Track

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)



(d) Overall Prototype of the RailGuard System

CONCLUSION

The RailGuard system provides an effective and low-cost solution to enhance railway safety through real-time, automated fault detection. By integrating ultrasonic sensors, IR sensors, an accelerometer, GPS, GSM communication, and video recording into a unified IoT-based architecture, the proposed model successfully overcomes the limitations of traditional manual inspections, which often fail to detect micro cracks, misalignments, and track obstructions in a timely manner. The multi-sensor fusion approach significantly improves detection accuracy, reduces reliance on human personnel, and minimizes false reading caused by environmental noise and vibration. Additionally, instant alert transmission with accurate geographical location ensures quick response of railway authorities, thereby reducing the chances of train derailments and major accidents due to delayed detection.

Overall, RailGuard demonstrates that an integrated monitoring system can significantly improve preventative maintenance processes across the railway network. Its robust, scalable, and autonomous design makes it suitable for long-range railway surveillance and is a practical step towards modernizing the railway security infrastructure in India. Future enhancements could include AI-based pattern recognition, improved video analysis, and solar-powered operation to further increase efficiency and usability.

REFERENCES

[1] Karthick, N., Nagarajan, R., Suresh, S., & Prabhu, R. (2017). Implementation of railway track crack detection and protection. International Journal Of Engineering And Computer Science (IJECS), 6(5), 21476-21481.

[2] Paul, R., Varghese, N., & Menon, U. (2018). Railway track crack detection. International Journal for Advance Research and Development, 3(3), 123-126.

[3] Rizvi, A. R., Khan, P. R., & Ahmad, S. (2017). Crack detection in railway track using image processing. International Journal of Advance Research, Ideas and Innovations in Technology, 3(4), 489-496.

[4] Srivastava, S., Chaurasia, R., Abbas, S., Sharma, P., & Singh, N. (2017). Railway Track Crack Detection Vehicle. International Advanced Research Journal in Science, Engineering and Technology, 4(2), 145-148.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

[5] Kumar, A., Vanishree, K., Shweta, K., Nandini, C., & Shweta, G. (2020). Railway track crack detection. International Journal of Engineering Research And Technology, 8(15).

[6] Muley, A. S., Patil, S. B., & Shelar, A. H. (2017). Railway track crack detection based on GSM technique. International research journal of engineering and technology (IRJET), 4(1), 1252-1254.

[7] Kumar, S. S. J., Titus, T. J., Ganesh, V., & Devi, V. S. (2016). Automotive crack detection for railway track using ultrasonic sensorz. International Journal of Engineering Technology and Computer Research (IJETCR), 4(6), 34-37.

[8] Patil, N., Shahare, D., Hanwate, S., Bagde, P., Kamble, K., & Titre, M. (2021, February). Designing of improved monitoring system for crack detection on railway tracks. In 2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV) (pp. 1514-1517). IEEE.

[9] Krishna, B. R., Seshendra, D., Raja, G., Sudharshan, T., & Srikanth, K. (2017). Railway track fault detection system by using ir sensors and bluetooth technology. Asian Journal of Applied Science and Technology (AJAST), 1(6), 82-84.

[10] Vohra, M., & Gabhane, S. K. (2018, August). Efficient monitoring system for railways for crack detection. In 2018 2nd international conference on I-SMAC (IoT in social, mobile, analytics and cloud)(I-SMAC) I-SMAC (IoT in social, mobile, analytics and cloud)(I-SMAC), 2018 2nd international conference on (pp. 676-681). IEEE.

[11] Salvi, S., & Shetty, S. (2019, December). AI based solar powered railway track crack detection and notification system with chatbot support. In 2019 Third International conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC) (pp. 565-571). IEEE.

[12] Sushant, S., Anand, S., James, T., Aravind, V., & Narayanan, G. (2017, September). Localization of an unmanned aerial vehicle for crack detection in railway tracks. In 2017 international conference on advances in computing, communications and informatics (ICACCI) (pp. 1360-1365). IEEE.