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Design and Development of a Smart-Bot for Railway Track Detection

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Abstract — This paper proposes a mechanism for detecting railway track cracks. More specifically, this work provides a detection system that may use a microcontroller-based smart bot to find any fractures or disjoints in railway rails. Only railroads are used to convey the majority of commodities from one location to another because of their affordable transportation costs, speed, dependability, and minimal accident risk. Many individuals choose trains over automobiles for long-distance travel because trains are far more pleasant and cost significantly less. Therefore, it is imperative to guarantee the safety of the railway lines for the aforementioned reasons. As a result, a sophisticated technology-based bot is created that can find flaws or gaps in the tracks and safeguard the trains from any accident. The majority of commercial transportation in India is conducted via the railway network, which is the least expensive type of network, rather than any other mode of transportation, such as cruises, buses, and flights. Indian Rails, which presently acts as the foundation of the nation's transport network, is the largest rail passenger carrier in the world. Indian Railways is still expanding in an attempt to support the country's economic needs. The safety infrastructure facilities have not kept up with the aforementioned proliferation, despite the rapid expansion of Indian railways. Because our facilities do not meet international standards, there is often a significant loss of property and valuable human lives due to derailments. Derailments make up 60% of all rail accidents, and 90% of these derailments are due to track cracks, according to surveys and analyses about the causes of rail accidents.

Keywords— Railway's crack, microcontroller, Smart bot, crack detection, IOT, Automation.

I. INTRODUCTION

Transport is crucial for moving people and things from one location to any other location. For the economy to grow, transportation capacity and volume must be increased. The installation of an effective and affordable solution suited for railway application is shown in this study. In this research, the railway fracture will be located using an IR sensor. The procedure of surveying is then done using ultrasonic. Roadways and railroads are crucial components of modern society because they allow for long-distance travel, which is impossible without them.

The railway is the most dependable, affordable, and accessible mode of transportation out of all others. Railways are also used to carry a wide variety of items and goods [1, 2]. The majority of travelers in India choose trains over cars, buses, or any other kind of road transportation. Senior individuals would also find it very challenging to travel on these sorts of roads, which is why people give trains a higher priority than roads for transport. Therefore, it is necessary to offer the user traveling in trains the appropriate level of safety [4]. It has long been acknowledged that rail track fractures or track disjoints are the primary cause of most railway accidents [5].

One of the primary causes of train accidents that can result in fatalities is this crucial problem with the dis jointness and cutting of the railway tracks [6, 7]. Therefore, it is crucial to enhance the quality of railway tracks by conducting frequent inspections in order to prevent rail accidents. Therefore, the robot suggested in this research is based on cutting-edge technology and is capable of performing inspections and finding any flaws or fractures in railway rails [8].

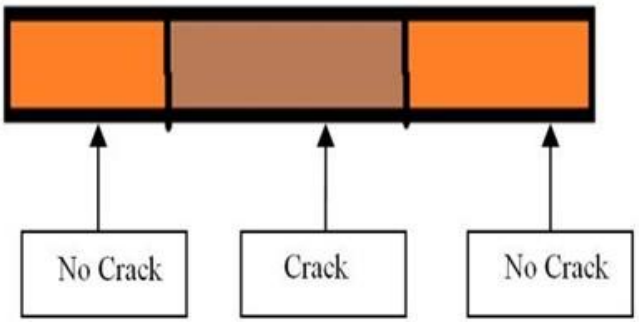

Fig.1 Crack portion in tracks

II. LITERATURE REVIEW

[1] This research paper introduces a cost-effective solution to detect railway track cracks, addressing a critical safety concern. The system employs infrared technology and robotic components such as IR LED-Photodiode assembly, ATmega32A Microcontroller, and L293DNE motor driver control. It provides in-depth technical and software details, along with an operational flowchart. The system is suitable for railway track inspection, offering an 80% accuracy rate, and it's more efficient, energy-efficient, and quicker than traditional methods, reducing derailment risks and enhancing safety. The paper also acknowledges support from the Department of Electronics and Telecommunication Engineering and external contributors.

[2] This paper addresses a critical problem in the Indian Railways network: track crack detection. Manual methods are slow and ineffective. The paper introduces an innovative solution, the Railway Crack Detection Scheme (RCODS), which uses an IR sensor system with GPS and Wi-Fi for location-based alerts and a distance-measuring sensor to monitor track deviations. It emphasizes the importance of

railway safety and robotic monitoring for cost-effective implementation. The paper details the hardware components and their functions and demonstrates the system's effectiveness in preventing track cracks, potentially saving lives and property.

[3] The paper presents a Railway Track Crack Detection system utilizing IR sensors, GPS, and GSM technology to enhance railway safety in India. Given the significance of the Indian Railways as a primary mode of transportation, the system addresses the crucial challenge of timely crack detection on railway tracks. When a crack is detected, the system triggers a GPS receiver for precise location identification, sends SMS alerts via GSM to authorities, and provides a live video feed through a camera. This technology-driven solution aims to prevent derailments and accidents, potentially saving lives and minimizing economic losses associated with railway incidents.

[4] The paper discusses a Railway Track Crack Detection and Alert System that aims to address the significant problem of crack detection on railway tracks in India, which, if left unchecked, can lead to derailments and accidents. The system utilizes IR sensors to detect cracks and is implemented on a robotic vehicle equipped with a camera. When a crack is detected, the system sends alerts via SMS, including the location coordinates obtained from GPS and GSM modules. Additionally, a distance-measuring sensor measures the track deviation distance between the two rails. This technology-driven approach offers a cost-effective and efficient solution to enhance railway safety and reduce accidents.

[5] The paper titled "Improving Railway Safety with an Innovative Track Crack Detection System" presents a novel solution to address railway accidents caused by track issues. This system integrates Infrared (IR), Ultrasonic, and Passive Infrared (PIR) sensors, along with GPS and GSM modems to detect track cracks, monitor distances, and identify individuals on the tracks. When issues are detected, it sends their coordinates to the nearest railway station. The paper also explores alternative methods like electromagnetic acoustic transducers (EMATs) and wideband guided ultrasonic waves for crack detection. This system is more efficient and cost-effective than traditional approaches, significantly improving railway safety.

[6] The research paper, "Automated Railway Track Crack Detection System Using GSM & GPS," tackles the issue of railway track safety in India, home to one of the world's largest rail networks. It proposes a system employing sensors, Arduino microcontrollers, GSM modules, and GPS modules to detect track cracks and obstructions. This automated approach provides efficient and cost-effective solutions, outperforming manual and visual inspection methods. Results demonstrate successful track crack detection and SMS alerts with location coordinates, ultimately enhancing railway safety and maintenance accuracy.

[7] The paper "Design and Development of Device for Railway Track Crack Detection" addresses safety concerns in the Indian railway network, which suffers from outdated technology and inadequate safety measures leading to frequent accidents. The paper's primary goal is to create an automated system using GPS, GSM, IR, PIR, and ultrasonic sensors to identify track cracks, obstructions, and human presence. This system not only detects cracks but also promptly alerts the nearest railway station through GSM. The paper reviews related work and details the device's materials and methods, circuitry, mathematical modeling, and robot design. Motion analysis results confirm the device's suitability for track inspection, promising improved railway safety.

[8] The research paper titled "GSM Based Railway Track Crack Detection Using Ultrasonic and Infrared Sensor" addresses the pressing issue of railway track cracks in the Indian railway system. It proposes an innovative solution employing IOT technology and various sensors mounted on a vehicle to autonomously detect cracks and obstacles on railway tracks. When a crack is detected, the system sends real-time alerts, including GPS coordinates, via GSM communication. This system has the potential to significantly enhance safety, reduce accidents, and save lives by automating the monitoring process and mitigating the risks associated with manual inspections of India's extensive railway network.

[9] The paper tackles a significant railway safety issue: derailments caused by track cracks, providing an innovative solution. Derailments disrupt rail operations and pose safety risks. The proposed solution uses an autonomous vehicle with various sensors (GPS, IR, ultrasonic, and GSM) to continuously monitor tracks. When a crack is found, the system sends alerts, GPS coordinates, and messages to railway maintenance via GSM. This system offers cost-efficiency, low power consumption, and quick analysis, improving safety and maintenance on India's extensive railway network. The authors emphasize the potential to save lives and reduce accidents through timely detection and maintenance.

[10] The paper introduces a Railway Track Crack Detection System aimed at improving railway track safety in India, where the railway network is crucial for transportation. This system uses an Arduino microcontroller and a variety of sensors, including ultrasonic, GPS, and GSM modules, to continuously monitor tracks for cracks. When a crack is detected, it stops the vehicle, collects GPS coordinates, and sends alerts to the nearest railway station via GSM. This automated and technology-driven solution offers a cost-effective, efficient, and precise way to enhance railway track safety and reduce accidents.

[11] The paper presents a Railway Track Crack Detection System addressing railway safety in India by automating the detection of track cracks. It uses sensors, GPS, GSM, and an Arduino to identify cracks and send location data to the nearest railway station, improving safety and maintenance efficiency, and ultimately reducing accidents. This system has the potential to transform railway safety and maintenance in India.

[12] The paper presents a Railway Track Crack Detection Robot designed to address the significant issue of track

discontinuity in the Indian railway system. This system utilizes IOT technology, including Node MCU, ultrasonic sensors, and GPS, for automated and precise track inspection. It detects cracks and immediately alerts the control room via a mobile app, preventing potential accidents. This approach reduces labor costs, enhances accuracy, saves time, and improves railway safety through IOT applications. Moreover, the robot's sustainability can be enhanced with self-recharging via solar panels for long-term cost-effectiveness. In essence, this innovation has the potential to revolutionize railway track maintenance in India, leading to safer and more reliable rail transport.

[13] This review paper discusses the development of a Railway Track Crack Detection Robot that utilizes IOT technology to address safety concerns in India's extensive railway network. With millions of daily passengers relying on this system, there is a pressing need for an automated and efficient solution to detect track cracks and prevent accidents. The system combines Ultrasonic Sensors for accurate crack detection, GPS for real-time tracking, and the Node MCU ESP8266 module for data transmission, offering a promising way to improve track maintenance accuracy and efficiency. In summary, the paper highlights the potential of IOT-driven innovations to enhance railway safety and reliability in the country.

[14] The paper introduces an innovative Autonomous Railway Track Crack Detection and Accident Prevention System to address train derailment risks from track defects. It uses a self-guided robot with ultrasonic and density sensors to find surface and deeper cracks. When a crack is found, it determines the location using GPS and alerts a nearby railway station via GSM. Data is then sent to a cloud server for analysis. This system is cost-effective, and scalable, and improves rail safety, potentially saving lives and enhancing railway reliability in India and other regions.

III. Proposed Methodology

The project's primary goal is to develop ultrasonic sensors for railway fracture detection. Figure 3 depicts the project block diagram, which includes an Arduino microcontroller, an ultrasonic sensor, a motor driver, a motor, and a GPS module. When a crack is found, the nearest station will get the pertinent geographic coordinates. [4] A GPS module is responsible for recording and transmitting these coordinates. For applications that need connection rather than greater data rates, the GPS network used by mobile phones offers a low-cost, long-distance wireless communication channel. [6] One kind of LED that generates infrared rays is known as an IR transmitter or infrared transmitter. By measuring the distance from the track, the ultrasonic sensor is utilized to find the rail track crack to the sensor. The best approach for finding fractures in a railway track is the ultrasonic technique. To inform about the rail fractures, an Android app will be created. [10] The crack-detecting system will alert the appropriate loco pilot through a

A. *Process of the rail track system*

The project algorithm is shown in Figure 2, which contains the following process:

a) In the beginning, a sensor is employed to continually monitor the tracks in order to find track cracks.

b) For this monitoring, an ultrasonic sensor is used to detect even the smallest changes, which can be difficult to detect with conventional sensors.

c) When a crack is discovered using an ultrasonic sensor, an alarm that a crack has been discovered in the Arduino microcontroller is sent.

d) The task provided to the Arduino microcontroller will be carried out appropriately.

e) In order to prevent future occurrences and near-misses that might result in the loss of human life and/or serious injuries, the Railway Authority must take note of the alert as soon as it is sent to them and take significant action.

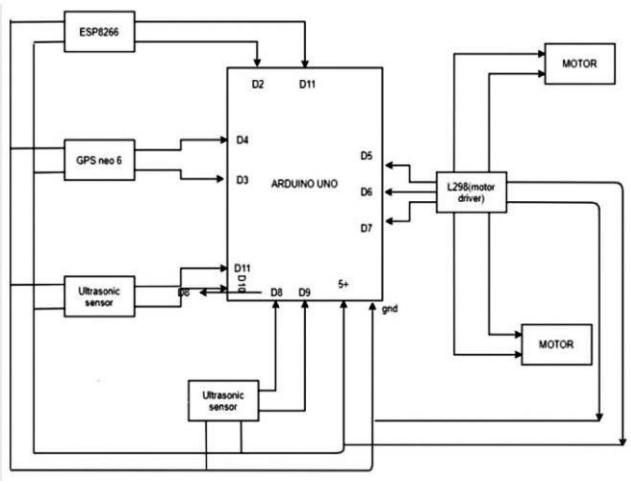

Fig.2. System Architecture

Figure 2 displays the project's block diagram, which includes the motor, motor driver, GPS module, Arduino microcontroller, and ultrasonic sensor. Initially, the system is moved along the track by the motor, which is managed by the Arduino. When the motor senses a crack and shuts off, the system comes to a stop. Cracks are discovered by means of the ultrasonic sensor. GPS modules are used to locate the system precisely when a crack is detected, and the location data is then transmitted to the control room. The controller uses this location data to tell the motor driver to start the motor, resuming the system's movement along the path, after a successful message delivery to the control room.

IV. Working

Figure 2 illustrates the project block diagram, consisting of components such as a microcontroller (Arduino), an ultrasonic sensor (HC-SR05), a motor driver (L298N), a 12V DC motor, a GPS module, and a GSM module (Sim900a, 12V:2A). Initially, the vehicle moves along the track using the motor, which is powered by the motor driver and controlled by the Arduino. When a crack is detected, the motor stops and the vehicle halts on the track. The crack detection relies on the ultrasonic sensor and the Doppler effect principle.

Following crack detection, precise location data is transmitted to the control room via a GPS module. This location information is collected by the controller.

Through the controller's interaction with the GSM module, location data is sent to the control room using AT commands. Once the message is successfully delivered to the control room, the controller sends a signal to the motor driver, starting the motor, and subsequently, the vehicle is operated until the operator decides to turn it off.

A. Ultrasonic Sensor

The ultrasonic module in question is highly precise in measuring distances, offering non-contact measurements ranging from 0cm to 1500mm with an impressive accuracy of up to 3mm. Its performance is exceptional, and it possesses a feature known as non-blind operation, meaning that it provides accurate measurements beyond 1cm, but the results may not be as reliable within the 0-1cm range during testing. This ultrasonic sensor functions similarly to how bats determine distances using sonar, providing dependable non-contact distance detection with stable and accurate readings in a user-friendly package. It includes both ultrasonic transmitter and receiver modules.

B. Motor Driver L298N

Motor drivers provide an interface between the control circuits and the motors. The motor needs a lot of current, even though the controller circuit runs on very little of it. The present indicators. Consequently, the role of a motor driver is to convert a control signal with low current into a more powerful signal that can run a motor. Managers motors using up to 2 A per channel and 5–35 V. Individual brake, direction, and speed adjustments for each vehicle. Screw terminals make it simple to attach motors and power has a strong heat sink to guarantee maximum carrying out. For the most part, connecting to robot controllers is straightforward.

C. SIM900A GSM MODULE

In this research paper, we present a novel approach to train track crack detection utilizing a C.SIM900A GSM module for real-time data communication. Our system combines advanced sensors and microcontroller technology to continuously monitor the condition of train tracks. We have developed a sophisticated crack detection algorithm capable of identifying track irregularities, including cracks, deformations, and shifts. When a potential issue is detected, the system triggers the GSM module to transmit an alert to a central monitoring station via the cellular network. This enables prompt maintenance and ensures the safety and reliability of railway infrastructure. Our research not only addresses the critical issue of track safety but also demonstrates the feasibility of leveraging GSM technology for efficient and remote track monitoring, thereby contributing to the enhancement of railway safety and maintenance practices.

D. LCD Display

The most popular versions of these presentations are for seven fragments and multi-section light radiating diodes. This kind of electronic showcase module is utilized in numerous circuits and devices, including TVs, PCs, cell phones, add-on machines, and so forth. The primary advantages of utilizing this module are minimal it is essentially programmable, has motions, and quite remarkably presents no barriers when displaying custom characters.

E. GPS Module

In the context of railway infrastructure maintenance and safety, GPS (Global Positioning System) modules play a pivotal role in real-time train tracking and location monitoring, aiding in efficient scheduling, speed control, and asset management. However, it is important to note that while GPS technology is indispensable for enhancing overall railway operations, it is not directly employed for train track crack detection, which relies on specialized non-destructive testing methods, including ultrasonic and eddy current testing, visual inspection, and track geometry measurement, to ensure the integrity of railway tracks.

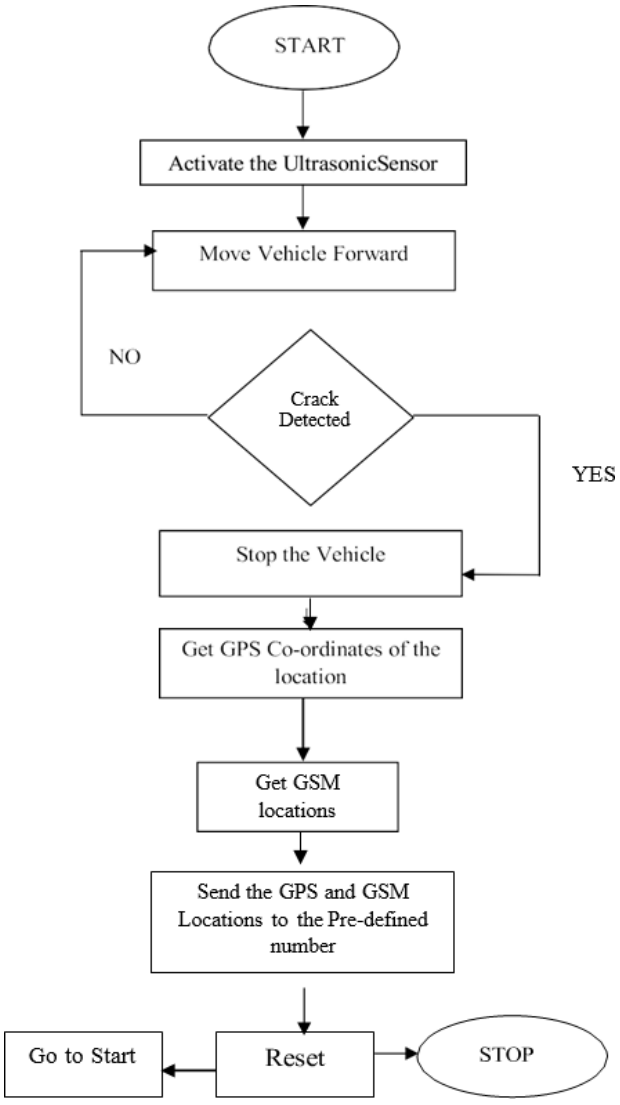

Fig 3: Program Algorithm

An explanation of the program algorithm seen in Figure 3 is provided below:

a) The motor first turns on.

b) The ultrasonic sensor is going to start working.

c) The motor will allow the car to move forward.

d) The ultrasonic sensor will keep scanning the tracks.

e) As soon as the crack is discovered.

f) The vehicle will stop.

g) The GPS will then acquire the coordinates of the location.

h) Additionally, a message will be delivered by the GSM to the scheduled.

V. LIMITATIONS

- Accuracy: Train track crack detection systems can be affected by a number of factors, including the type of sensor used, the environmental conditions, the speed of the train, and the size and location of the crack.
- Cost: Train track crack detection systems can be expensive to install and maintain.
- Complexity: Train track crack detection systems can be complex to operate and maintain, requiring trained personnel.
- False positives and negatives: Train track crack detection systems can sometimes produce false positives or false negatives, which can lead to delays and disruptions to train services.
- Limitations of specific technologies: Different train track crack detection technologies have their own specific limitations, such as ultrasonic sensors only detecting subsurface cracks and visual sensors only detecting surface cracks.
- Researchers are working to address these limitations and develop even more effective train track crack detection systems.

VI. RESULT AND CONCLUSION

The investigation revealed that the existing systems cost money and require a lot of time. The proposed method not only fixes these problems but also improves the accuracy of rail fracture detection. It is the most cost-effective method offered to improve the performance of our nation's railroads and lower accident statistics. Potentially preventing the loss of economic output and the priceless lives of the passengers. Additionally, it saves time and money when cracks are found. The current systems are costly and time-consuming, according to the study. The proposed system not only resolves these problems but also improves rail crack detection and precision. That's the most economical choice available to complete favorable results of the country's railroads in order to lower the number of reported accidents. That via conceivable to stop the precious lives of passengers from being lost and budgeted. It also conserves funds and time for ascertainment of the fracture.

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