Railway Track Fault Detection and Localization using IoT

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Abstract-The Indian Rail road operates among the biggest rail systems on the globe and offers the most significant form of public transportation in India, as well as the most popular and reasonably priced long-distance transportation system in the nation. Of all the affordable and environmentally friendly forms of transportation is the railway. In anation like India, the majority of people rely on trains for transportation. Worldwide, there are a lot of reported train accidents every year because of flaws in the railway system. Finding cracks in the track is the keyissue with a railway analysis. If these problems are not addressed quickly, they might result in a lot of derailments and a substantial ruin to people and to their belongings. The conventional procedure of physically inspecting the railway track that used a railway vehicle is expensive and error-prone. In this paper, we present a concept that intends tocreate a metal proximity sensor-based technique foridentifying railway cracks. This manages to avoid therailway collisions by sensing the crack on rail tracks. This device can quickly identify cracks without the need for human involvement. It can also notify the appropriate authorities via SMS messages and providetheir position using the GPS modules. This method ofcrack detection may be used day and then night andmight pick up cracks in the wrong places. This would prevent unnecessary rail track damage to a number of trains in India.

Keywords: *Railway track, fault detection, IoT, GPS, metal proximity sensor.*

1. Introduction

Transport is crucial for moving people and things from one location to another. India has the biggest rail networks in the world, yet manual method and crack detection on these lines is a time- and labor-intensive procedure. The safe operation of railway transportation is seriously threatened by postponed inspections and problem findings. Figure 1 shows the fault on rail track.It is possible to effectively identify track fractures and prevent train damage with a Microcontroller based module [1].For this work, we employ a metal proximity device that can also alert authorities to SMS and GPS location messages and identify rail faults. After the track is clear, the planned system is setup to travel back and for thonitat irregular intervals. And via the WIFI module, it will alert the authorities if it notices any cracks in the railway track. Since current systems require manual labor, the proposed system in corporates a model that will operate independently along the track. That costs a lot and is not particularly precise. The present system is inefficient, difficult, and sometimes time-consuming [2].

Figure 1: Crack on the railway track

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2. Survey on recent trainaccidents

The number of fatalities related to train accidents is shown in Figure 2. Figure 2 shows that number of fatalities is raising annually. Consequently there is a huge demand for technology solutions for the issue of rail cracks.

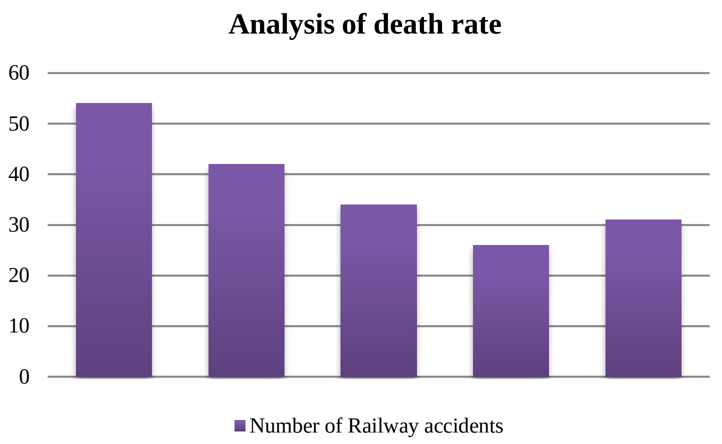

Figure 2:Year based railway accidents death rate

Table 1 provides data about the number of accidents brought on by railway accidents.

Table 1:Year based railway accidents death rate

Year	Number of train accidents	Number of deaths/Injuries	Number of deaths due to rail track
2021-2020	20	275	156
2020-2021	15	196	124
2019-2020	17	249	150
2018-2019	29	57	58
2017-2018	59	37	108

3. Literature Review

Predictive maintenance, issue detection, and eventually reducing the probability of train accidents are the major reasons for checking railway lines. Train tracks must be inspected often. The manual examination of millions of track yards is labor intensive, time exhausting and prone for mistake. Automatic track fault or crack identification and monitoring is essential since humanly operated systems are insufficient to consistently, regularly, and uniformly assess the health of tracks owing to human mistake. Subsequently, a number of automatic solutions are created for saving work and increase efficiency. In order to check rail lines, NDE methods are applied [1-4]. Computer vision, guided, and electromagnetic categories are used to group the material. IoT and acoustic-based methods are described here.

3.1 Electromagnetic techniques

The idea of a variations eddy current sensing system based on trains for fastener detection. The sensor works using electromagnetic induction, where a carrying coil for an alternating current creates an electromagnetic field on the railway track and coil detects the reflection field [2]. Field measurements and laboratory tests show that the suggested approach can identify a specific placing the installing structure beyond 65 nm above the train. A measurement signal's time domain characteristic was also employed to identify absence of clamps in installed structure. Train-based inductive proximity sensors were used for assessing the efficacy of a procedure for recognizing and detecting misplaced clamps. This study looked at 6 algorithms for classification, with KNN coming out on top, with accuracy and recollection of 96.70 & 94.5 percent, respectively. An example of an induction coil with an eddy current sensor used to mimic a rail crack. A multi-sensor approach based on MFL, with the main sensor and three secondary sensors located in the faulty path. Initially RMS value of sensor signal was computed. The relative levels of the sensors' signals suggested that there were more defects occur. The proper spacing provided in between these sensors. Finite element modeling and experimental results show that this method effectively reduces vibration interference and enhances efficiency.

A detection method orthogonal to the steel surface that employs a circular probe with an spark coil at both ends as well as a gradiometer that includes two asymmetrical magnetic resistance sensors. A numerical method for damage detection is proposed. To detect slight flaws in the rail surface, a ferrite is fitted to an LMF sensor to reduce the reluctance to boost the magnetic pull above the faults.

3.2 Guided wave system

A ultrasonic NDT was carried out with the DIO 572 equipment, which included included measurement data processing. The device duplicated the shape of the rails during an ultrasonic test. The personal computer and the specialized program DIO 2000 were used to assess the measurement. A diagnostic approach based on ultrasonography is suggested. Rotational laser vibrometryis used to quantify angular velocity, deformation of elastic material, and rail displacement of angle during echo receipt. Rail faults were detected applying distinct ultrasonic sound signal-based markers. A quantitative detection technique for accomplishing a visual assessment of crack is proposed. The signal was also divided into various intrinsic mode functions (IMF) using VMD. The correlation variables along with SNR metrics were used to choose the most effective IMF element [5]. Ultimately, employing ultrasonic propagation images and properties of signals are employed for generating wave momentum.

3.3 IoTbased system

A self-driving robot powered by microcontroller and sensors. GPS module tracks the precise detective position and sends SMS notification. The planned system check the location of each clip on every single joint bar and alert trains if any bolt went loose [7]. A robot technique prototype exhibited the ability to identify rail side flaws. The model used ultrasonic input from sensors combiningimage processingand deep learning techniques, to identify faults. Each robot was powered locally by the Raspberry Pi 3, a microcontroller, which sent real-time information to an ethernet server [9]. To detect abnormalities, 4 ultrasonic sensors were put overhead and on both ends of an elevated train surface. An investigation on an automated defect tracking module integrated into an automated robot that uses several sensors. The layer containing an infrared sensor, a restriction shift, and ultrasonic sensors that were all driven by an LPC 1768 ARM microprocessor. If a defect was identified, the GSM module sent the position and kind of fault to the inspection room. An ultrasonic metal detection sensor was employed in the investigation to more precisely locate fractures. Encoding systems and radio frequency broadcasters were used for crack detection, with an ongoing supply of electricity between the encoding devices indicating fault-free tracks [10]. RF signals would be produced by the transmitter for so long as the electrical supply was steady. The flow of current might be disrupted if there was a break in the track. This stops RF signal production, which prevents the locomotive's receiver from receiving a signal, causing train to stop.

A TRVis used for rail track problem diagnostics. According to site-specific testing [11], the system is more efficient than conventional method. The authors put forth a novel system of automation built on robot the localization over an interval of 3-6 inch. To identify possible flaws, the system used machine learning and adapted it to the photographs it got from the tracks [13].

3.4 Acoustic based system

The purpose of defect detection and diagnosis, the author presented an acoustic analysis-based system. Dataset gathering was done using a system that had sensors installed. Two tests run on the full dataset using MFCC features, with more accuracy. An independent railway track defect detection system that used acoustic analysis to distinguish between three sorts of failings: normal track, wheel burned, and super elevation.For classification, MFCC characteristics were taken from the audio of defects and supplied into the decision tree (DT)models. The

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DT and RF variants perform better than the others in terms of accuracy. The accuracy of both algorithms in identifying the aforementioned flaws was 97% [12].A system for inspecting railway tracks that enhances performance by merging deep learning models with conventional acoustic technique [15]. To derive acoustic-specific characteristics of time-domain frequency spectrograms a model was suggested.

According to test findings, the suggested model successfully completed the task of assessing the rail system's status. AE technique for locating and locating fractures in train rails. The AE gathering module turned the signals that were captured through device into digital data. Using an advanced algorithmic model, the digital data was handled and classified to identify cracks in the steel rail after being de noised to remove background noise and wheel/rail contact noises. The AE indicators were used to train and evaluate the computer model. In order to identify fractures in the steel trains, an approach put into actionwith high accuracy rates. During electromagnetic tracking, intensity of the signal may vary due to the velocity impact, thus it is sensitive to disturbance from the surroundings.Electromagnetic examination, as opposed to ultrasonic inspection, may find defects that are near to the surface. The accuracy of vision-based systems using defect pictures from various camera types is good in controlled conditions [17]. In practical applications, these systems perform significantly less well because to environmental factors such temperature changes, dirty lenses, and light fluctuations. Thermographic devices are expensive and widely used. Such systems are expensive due to the sensor and equipment deployment costs. Additionally, inaccurate sensor replacement is necessary when a sensor fails, driving up the cost of the system. Additionally, specialized employees must be hired in order to maintain such systems. The theme made use of recordings of sound of railway line flaws and an audio spectrogram. AE detects cracks in railroad lines and even though each achieved good precision, the sensor that stores AE must be placed on the rails and because of the complex shape of the rail section and the expensive sensors to record AE, it is hard to recognize cracks without the precise and manually operated sensor placement on the railroad line [14].

In order to enhance the present railway cart system, this project creates an autonomous Internet of Things-based system for detecting railway track faults. The purpose of this effort is to lessen the difficulties associated with labor, bias, intervention from humans, and resource constraints.The acoustic information of six commonly occurring problems on Pakistan's operating railway rails was collected. In comparison to other studies, this one takes into account more defects, and it makes a substantial contribution to the acoustic analysis-based identification, classification, and localization of railway track faults [16].

4. Proposed Methodology

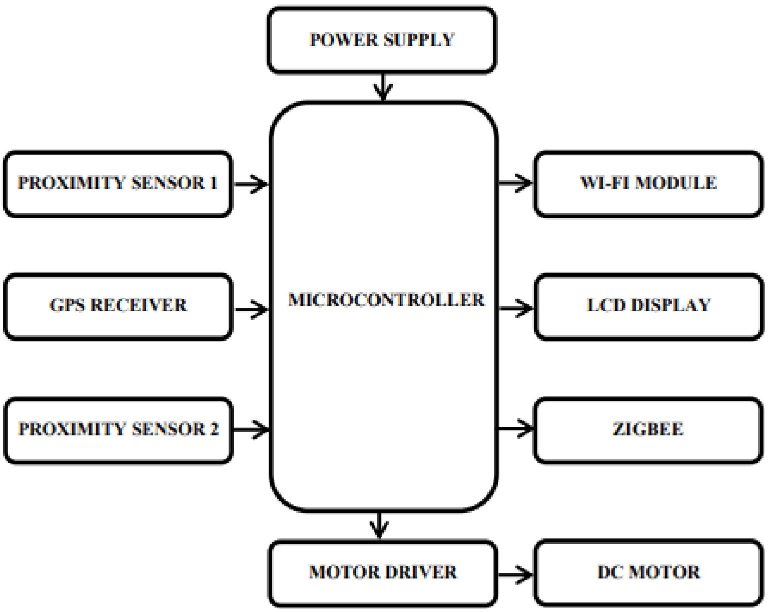

Figure3:Blockdiagram of proposed system

Figure 3 depicts the proposed diagram of rail track defect recognition utilizing metal proximity sensor which displays 3 pairs of Proximity sensor units mounted into the front of the vehicle with the controller to check for flaws in rail track.

The vehicle advances on the track after being turned on. The track's condition is examined using proximity sensors. Starter engine and LDR sensor are existing in beginning phases over normal situations. Motor is started moving forward when the microcontroller receives electricity and serial communication is used for message transfer to the microcontroller.

The GPS manipulates location of train to obtain the coordinates of the latitude,the longitude utilizing satellites, once a crack is identified by the proximity sensor immediately the train stop. The position coordinates acquired by GPS is translated to a SMS that is performed by Arduino. The SMS message is sent through IOT via theWi-FiUnit.

Ifthesystemdetectsadefectonthetrack,thesensor reflectance will be at zero, and the vehicle willstopimmediately.Whenthisvalueishigh,itisassumed there's not a crack with in track. But, if thesensor detects a crack, the sensor's output towards themicrocontroller will now be 0, and the vehicle will bestopped once more. That is, when a Proximity sensordetects a crack, the vehicle immediately stops and GPS recipient transfers location for the train toget coordinates of current location from satellite, as illustrated in Figure3.

5. Background Components

5.1 Arduino UNO

Figure 4: Arduino UNO

Various types of microprocessors and controllers are used in the Arduino board's designs. A variety of boards for expansion as well as additional circuit are interfaced with the digital and analog input/output (I/O) pins. The devices have serial terminals which are often utilized for downloading applications through personal devices, especially USB-compatible versions for some cases.

5.2 GSM

GSM, is extensively used cell phone technology. By looking for local cell phone towers, mobile devices connect to a cell telephone provider's GSM network. A universally accepted standard for modern cellular communication is the worldwide standard for mobile communication.

5.3 GPS

The only fully operational GNSS is a GPS. The GPS system employs a constellation of 24 to 32 Intermediate Earth Orbit satellites can emit accurate microwave signals, allowing GPS receivers to identify their location and speed. The GPS satellite network is controlled by the 50th Space Wing of the United States Air Force.

Figure 5: GPS module

5.4 Proximity Sensor

A device called a metal proximity sensor utilizes EM waves to identify metal pieces despite touching them.It's detection range vary based on the kind of materials it detects.Proximity sensors employ eddy currents generated on a conductive layer by an external magnet to detect magnetic leakage. By changing the resistivity, accomplished by producing a fluctuating magnetic field on the detector spiral, eddy currents generated on a metal surface are discovered.

5.5 Wi-Fi module (Node MCU)

A freely available Internet of Things (IoT) platform is Node MCU. It has ESP12 hardware and runs ESP8266 Wi-Fi SoC firmware.

5.6 Internet of Things (IOT)

The spread of Internet networking into tangible items and ordinary objects is known as the Internet of things (IoT). Due to its integrated technology and online access, these gadgets may communicate among themselves through online networks as well as might be regularly tracked and managed.

5.7 Zigbee

In order to facilitate inexpensive, economical Machine to Machine and Internet of Things, the Zigbee transmission protocol emerged. A free protocol for efficient applications is known as Zigbee. Compared to Wi-Fi, the Zigbee consumes a lot less energy.

As a result, using Zigbee instead of Wi-Fi will result in much longer device battery life. Zigbee makes it feasible to make use of smaller, longer-lasting batteries, which saves energy, money, and the environment.

6. Working of proposed system

Arduino Development Board serves as the system's main structural element. The vehicle is supplied by a 12V transformer power supply, which also includes capacitors for filters and voltage regulators. Motor driver and an Android application based on Bluetooth are used to move the vehicle forward and backward.

Two motors are driven by motor drivers. Infrared sensors positioned on the vehicle's front end will inspect the track as it moves along the railway track line.The car stops, retrieves its GPS location, sends alert SMS to predefined numbers, and also produces a high-pitched alert sound when a crack ordeformation is found in the track. The train driver canseetheAlert informationonanLCD2x16monitor.

To alert individuals about rail breaks, a smartphone app has been developed. Once defect sensing technique detects a rail break, a corresponding position told with an alert notice. A GPS unit shall be used to help create this window alert solution. A defect in the tracks is identified by a gadget and an Arduino-based controller in the structure, while the space among two trains is determined. We employed multiple sensors to locate the defects. The proposed diagram demonstrates a sound sensor-based solution for identifying fractures. It's employed to figure out distance between two tracks.

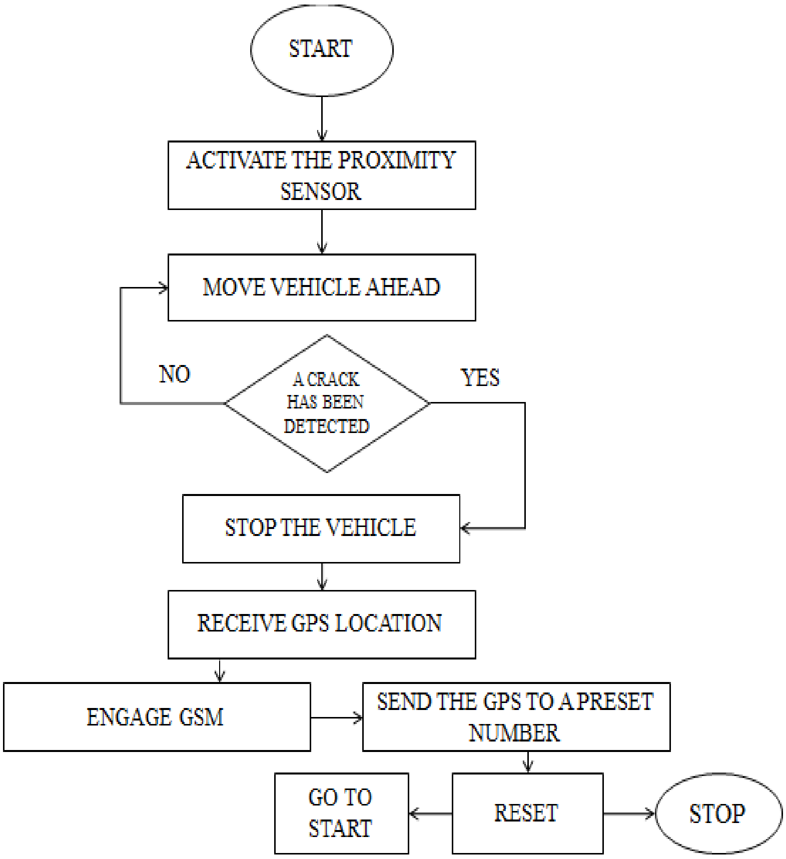

Figure 6:Flowchart of proposed system

Initially, the tracks are constantly monitored using a detector which identifies rail breaks. That tracking is done using the use of a thermal sensor to identify small variations which might be hard to notice using ordinary detectors.Once a fracture is detected by thermal sensor, an alert is delivered to the Arduinocontroller.

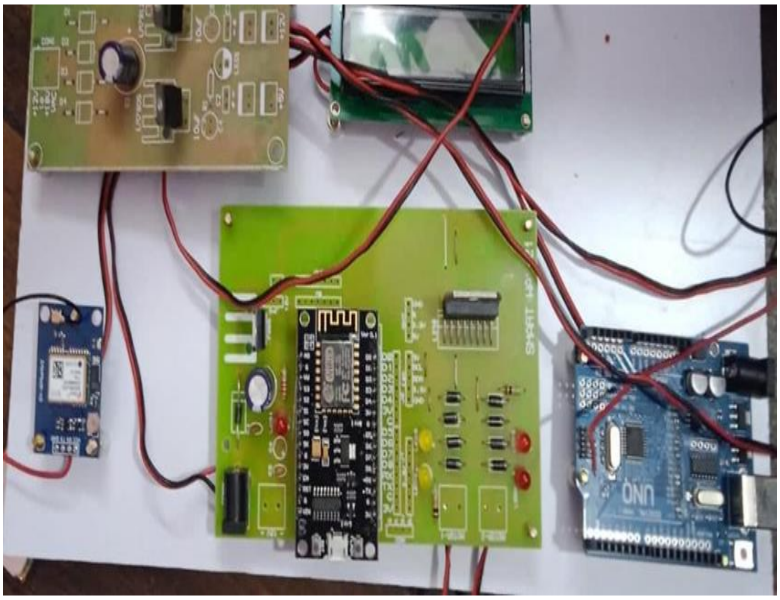

Figure 7: Proposed work's component arrangement on board

Figure 7 shows the component arrangement on board. The technique primarily comprises utilizing a GPS device to locate, communicate, and alarm. The alarm must be examined as immediately as the information is delivered to the Transportation Officials. They must take significant steps to avoid future mishaps and misses.

Ifacrackoccursinthetrack,theplace'snorthernandsoutherncoordinatescommunicatetotheadjacent control office, and aproximity sensor is to be used tomeasurethecrack. Thereareclosest twomethodsfordetecting cracks.This is a component with an imaging device which produces a fracture map to assist with tracking of conditions.

7. Applications of proposed system

The list of applications for which a railway track crack detecting system has been used follows.

7.1 Automatic Crack Testing

The process of finding a fracture in a structure using any processing method is known as rail crack detection. There are two techniques to identify cracks. The recommended approach sequentially makes use of radiometric, geometric, and contextual data. The battery provides electricity to the vehicle. The railway track crack is found using the optical sensor.

7.2 Wireless Access

Wireless Application Protocol (WAP) is a networking standard utilized for transmitting data across numerous mobile networks. WAP enables quicker connectivity between dynamic wireless items with the Internet while also improving cellular standards compatibility. WAP is a technology norm for obtaining data via a portable connection. A WAP browser is a web browser that utilizes the protocols for mobile devices like mobile phones. Despite being a novel technology, WAP makes use of Internet-related ideas.

7.3 Applications for detecting damage torailway track

In order to monitor and identify track damage, a neural network-based technique is utilized. Train crashes happen frequently by track damages. The results of the experiments demonstrate the excellent precision and suitability of this neural network-based measuring system for online track damage detection and monitoring applications. The following techniques are used to find railway flaws: The method with the most use is ultrasound. Eddy current examinations are excellent for detecting surface and close-to-surface defects. For thorough hand checks, employ magnetic particle inspection. The gap on the rail line is identified by an ultrasonic sensor by avoiding getting the soundof railway such that if the sound is heard, no fracture is found on the track.

8. Conclusion

The present approaches, based on the research, both time as well as money expensive. The proposed approach additionally addresses these problems nevertheless it significantly improves rail breakage identification precision. It involves the most economical option available for improving the efficiency of the nation's transportation including lowering accident rates. It may be possible to avoid a waste of resources and precious lives of people. Furthermore, it eliminates expenditure and time on identifying cracks.

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