"IOT-BASED AUTONOMOUS RAILWAY TRACK FAULT DETECTION"

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Abstract

This research develops an Internet of Things (IoT)-based autonomous railway track fault detection scheme to enhance the existing railway cart system to address the aforementioned issues. In addition to data collection on Indian railway lines, this work contributes significantly to railway track fault identification and classification based on acoustic analysis, as well as fault localization. Based on their frequency of occurrences, six types of track faults were first targeted: wheel burnt, loose nuts and bolts, crash sleeper, creep, low joint, and point and crossing. Support vector machines, logistic regression, random forest, extra tree classifier, decision tree classifier, multilayer perceptron and ensemble with hard and soft voting were among the machine learning methods used. The results indicate that acoustic data can successfully assist in discriminating track defects and localizing these defects in real time. The results show that MLP achieved the best results, with an accuracy of 98.4 percent.

1. Introduction

The main objective is to locate the gaps in the railroad tracks and to determine if there are any hazards in the tracks to avoid and dissuade accidents. This type of model provides a cost-effective solution to the railroad crack detection problem by using a ultrasonic sensor and a IR sensor joint that responds to the exact situation of the faulty track, as well as forwarding the information to the control room via SMS, so that any incidents can be gridlocked.

Railway is one of the most significant transportation modes of our country but it is a matter of great sorrow that, railway tracks of our country are very prone. That's why, a vast number of accidents are occurred every year due to this primitive type of railway tracks and as the consequences of those accidents we lose huge number of lives every year. These types of incidents motivate us to think over the above mentioned issue and take necessary steps to protect those lives. Through our proposed system, we need to establish more modern and secure railway system. Besides this, there is no such type of technology or system in our country which can stop the collision between two trains coming from the opposite direction of each other on the same track.

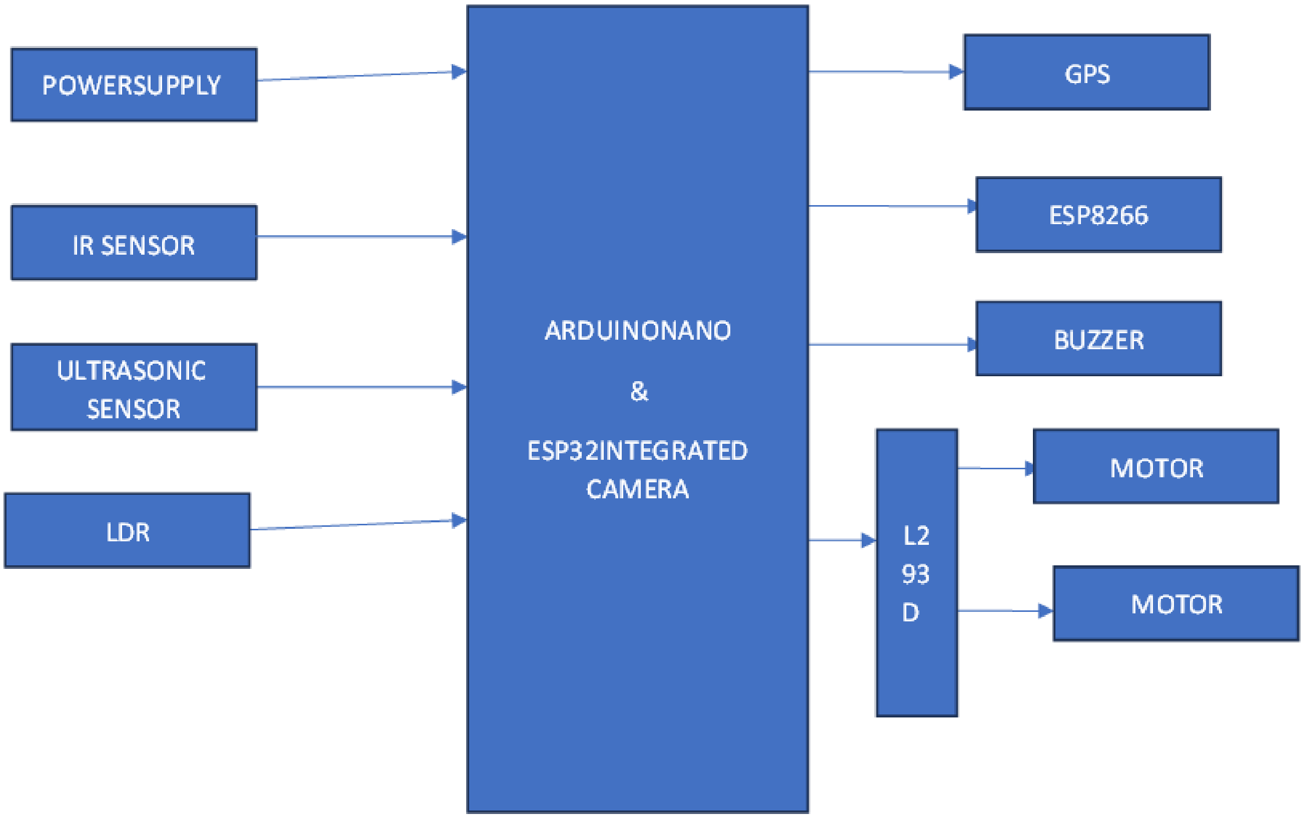
We actually think over this matter and motivated to do so. More over natural disaster can throw any object on the rail track which cannot be removed very quickly in the remote area. We thought if our system can detect those object or barrier and inform to the control room then they can take necessary steps 3 to avoid accident. Figure1 depicts the crack on track. The Rail transport is growing at a rapid pace in India. It is one of the major mode of transport but still our facilities are not that accurate, safer as compared to international standards. A survey on the internet states that about 60% of all the railway accidents is due to derailments, recent measurements shows that about 90% are due to cracks on the rails. Hence, it is not safer for Human Life. This needs to be at the utmost attention. These goes unnoticed and the properly maintenance of tracks is not done.

2. Literature Survey

- Rizvi, P. Khan, and D. Ahmad (2017) proposed a method for crack detection in railway tracks using image processing techniques [1]. Their system captures track images and analyzes them to identify surface-level defects. While effective under controlled conditions, the approach is limited by its dependence on lighting, environmental factors, and camera resolution, making it less suitable for autonomous outdoor applications.
- S. Srivastava, R. Chaurasia, S. Abbas, P. Sharma, and N. Singh (2017) developed a mobile vehicle for railway track crack detection [2]. The vehicle uses sensors to detect physical defects along the track. However, the design lacks real-time data transmission and IoT integration, which are crucial for modern monitoring systems that require immediate response and cloud-based analysis.
- K. Bhargavi and M. Janardhana Raju (2014) introduced a cost-effective crack detection system using an LED-LDR assembly [3]. This method is simple and economical for identifying cracks based on light interruption but falls short in accuracy, long-distance monitoring, and is not practical for autonomous or large-scale deployment.
- Siva Ram Krishna et al. (2017) designed a system using IR sensors and Bluetooth technology to detect railway track faults [4]. The IR sensors help detect discontinuities, while Bluetooth facilitates communication with nearby devices. However, the short range of Bluetooth and absence of GPS support limit its application in remote fault reporting and real-time alerts.
- P. Navaraj (2014) proposed the use of ultrasonic and PIR sensors for crack detection in railway tracks [5]. The ultrasonic sensor detects gaps or misalignments, and the PIR sensor senses movement. While the design enhances fault detection capability, it does not support remote data logging or IoT-based connectivity, which are essential for smart railway infrastructure.
- Narendhar Singh and D. Naresh (2017) emphasized both crack detection and data analysis in their work [6]. Their approach recognizes the importance of analyzing historical data to understand fault patterns and trends. This aligns closely with the goals of IoT systems that aim for predictive maintenance using cloud platforms and big data.

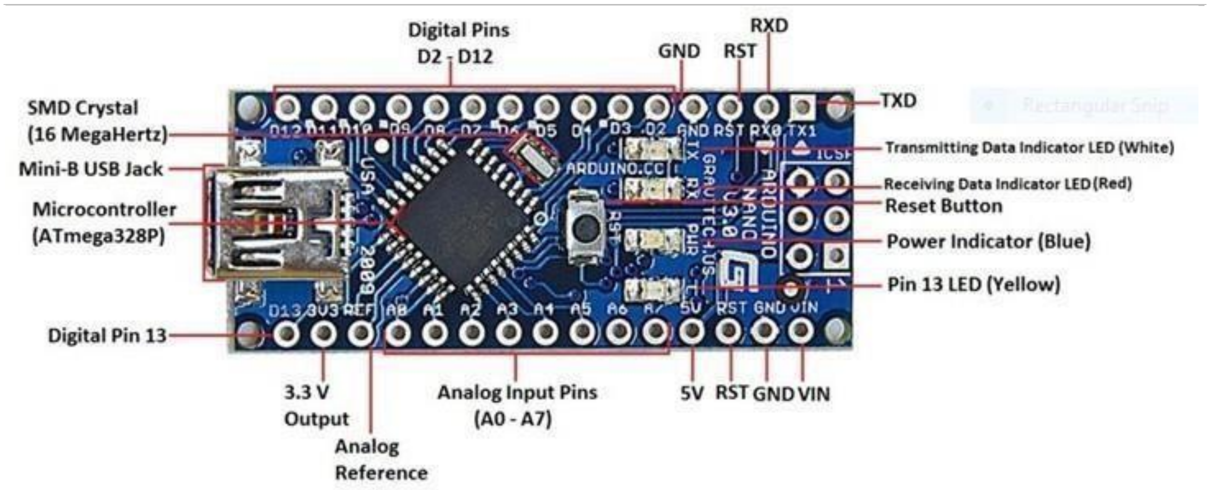
Supporting the relevance of this work, a report from *The Times of India* (2017) revealed that out of 586 train accidents in five years, 53% were caused by derailments due to track faults [7]. This alarming statistic highlights the urgent need for automated and intelligent fault detection systems.

3. Block Diagram



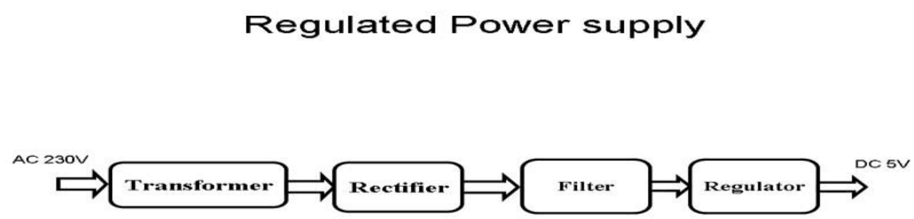
The Arduino Nano, as the name suggests is a compact, complete and bread-board friendly microcontroller board. The Nano board weighs around 7 grams with dimensions of
4.5 cms to 1.8 cms (L to B). This article discusses about the technical specs most importantly the pinout and functions of each and every pin in the Arduino Nano board.

Arduino Nano has similar functionalities as Arduino Duemilanove but with a different package. The Nano is inbuilt with the ATmega328P microcontroller, same as the Arduino UNO. The main difference between them is that the UNO board is presented in PDIP (Plastic Dual-In-line Package) form with 30 pins and Nano is available in TQFP (plastic quad flat pack) with 32 pins. The extra 2 pins of Arduino Nano serve for the ADC functionalities, while UNO has 6 ADC ports but Nano has 8 ADC ports. The Nano board doesn't have a DC power jack as other Arduino boards, but instead has a mini-USB port. This port is used for both programming and serial monitoring. The fascinating feature in Nano is that it will choose the strongest power source with its potential difference, and the power source selecting jumper is invalid.



Arduino nano Board

Flowchart



PROPOSED SYSTEM

A framework capable of detecting, responding, and acting/reacting whenever it is exposed to a change or stimulus from a situation in which it is kept without the need for human intervention. The framework presented in this manuscript is designed for a real case situation. The microphone, and GPS sensor are all directly connected to the RPi, running under a Linuxbased operating system Raspbian. The RPI is a credit card sized, low-cost computer [55]. The microphone, and GPS are mounted on top of the RPi. The microphone records the acoustic signal caused by the friction of wheel and railway track. An acoustic stereo signal, with a sampling frequency of 44100Hz and GPS locations are recorded and sent every 5 seconds to a Cloud via WIFI network (IEEE 802.11n) using parallel computing via multiprocessing library that enables parallel and distributed computing in python [56] to save disk space. Due to the memory constraint, the RPi memory is organized in Round Robin fashion, where the acoustic signal of wheel track interaction, time stamp and its location are stored in local memory for short period of time and then overwritten by the latest data (acoustic signal, timestamp, and GPS location), once the previous signals are pushed to the cloud. In the case of an absence of internet or interruption in the internet connectivity, the acoustic signals are stored locally and all files are subsequently pushed with a time stamp and GPS location to the cloud when the internet is available.

4.Hardware Overview:

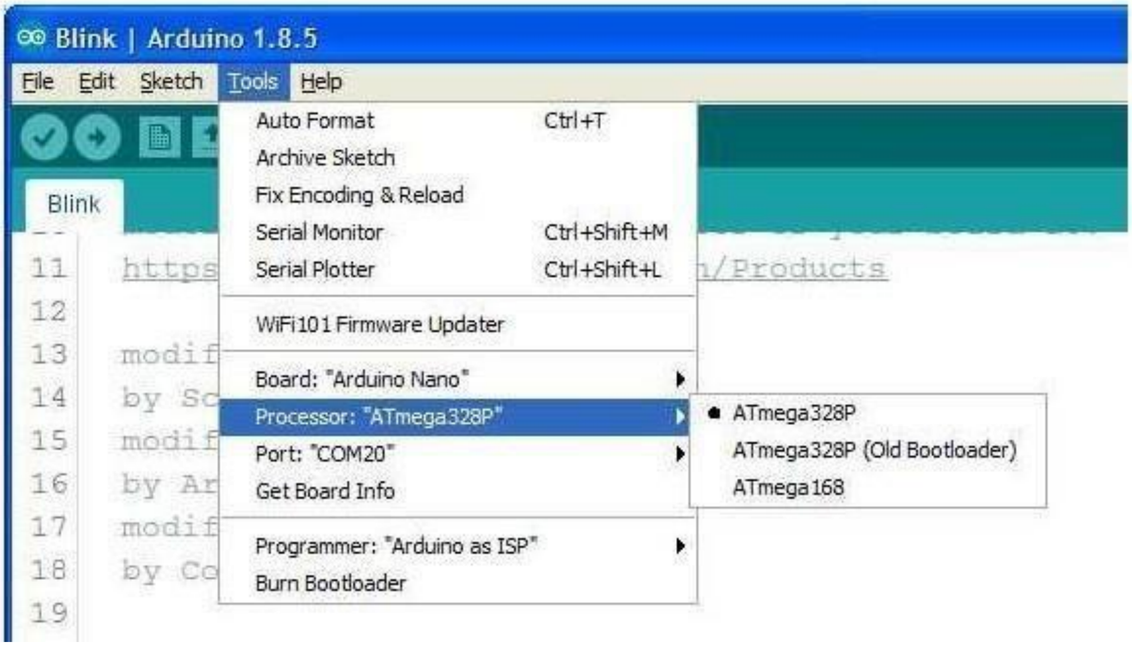
- 1x Arduino UNO board
- 1x PN2222 Transistor
- 1x Small 6V DC Motor
- 1x 1N4001 diode 1x 270 fi Resistor

5.Software Overview:

The Arduino Nano is programmed using the Arduino Software (IDE), our Integrated Development Environment common to all our boards

Select your board type and port

Select **Tools** > **Board** > **Arduino AVR Boards** > **Arduino Nano**.



Figure

Upload and Run your first Sketch

To upload the sketch to the Arduino Nano, click the **Upload** button in the upper left to load and run the sketch on your board:

6. Methodology for IoT-Based Autonomous Railway Track Fault Detection

The methodology for implementing the IoT-based railway track fault detection system is structured in the following stages:

The methodology for the IoT-based autonomous railway track fault detection system begins with identifying the critical need for timely detection of faults in railway tracks to prevent accidents and ensure passenger safety. The objective is to develop an autonomous, real-time monitoring system that can detect cracks, misalignments, or gaps in the track using a combination of sensors and IoT technologies.

The hardware design includes selecting a suitable microcontroller, such as an ESP32 or Arduino, for sensor integration and IoT communication. Sensors like vibration or piezoelectric sensors are used to detect discontinuities in the track, while ultrasonic or IR sensors can help identify physical gaps or obstructions. A GPS module is incorporated to track the exact location of detected faults, and communication modules such as Wi-Fi or GSM are used for transmitting alerts and data to a centralized system or cloud server. If the system is mobile (e.g., a robotic unit), motor drivers and wheels are added for autonomous movement along the railway track.

After hardware selection, sensor calibration is performed to define threshold values that distinguish normal track conditions from faulty ones. The sensors are integrated with the microcontroller, and a fault detection algorithm is implemented. This algorithm continuously monitors sensor readings and, upon detecting anomalies such as excessive vibrations or signal disruptions, identifies them as faults.

Once a fault is detected, the system immediately triggers local alerts via a buzzer and simultaneously sends real-time data, including GPS coordinates and fault type, to the central monitoring system or mobile application. This enables authorities to take prompt corrective actions. The entire system is tested on scaled or real tracks with artificial faults to validate its reliability and accuracy. Based on test results, sensor sensitivity and detection logic are fine-tuned.

Finally, the system is deployed for continuous monitoring, offering a cost-effective, autonomous solution to railway safety. Future enhancements may include machine learning-based predictive fault detection, solarpowered operation for remote areas, and networked deployment across multiple zones for broader coverage and reliability

7.Future Scope

The IoT-based autonomous railway track fault detection system holds significant potential for future development and expansion. One of the key areas of improvement is the integration of machine learning algorithms to enable predictive maintenance, allowing the system to learn from past data and anticipate faults before they occur. Additionally, using more advanced sensors and edge computing can enhance accuracy and reduce false positives. The system can be scaled to cover large railway networks by deploying multiple sensor nodes connected through mesh networking or LoRa communication for long-range, lowpower data transmission. Solar-powered units can be introduced to ensure energy independence, especially in remote or rural areas where access to conventional power sources is limited. Furthermore, integrating the system with centralized railway control centers and real-time dashboards can streamline maintenance operations and improve response time. Over time, such systems can be integrated with automated railway management frameworks, contributing to the development of smarter and safer railway infrastructure on a national scale.

8. RESULT

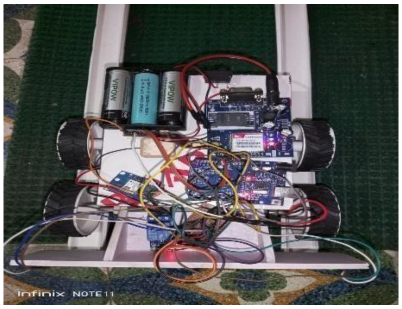


Fig.9. a. Crack Detected Fig.9

Hardware Module

Fig.9.b.SMS Received in the Mobile Phone Fig.9.

c. Location of the Instance

Here the proposed module is made up of hardware which was previously explained in the description of the system design hardware which is shown in fig .9. The fig.9.a. shows the Crack Detected in the Display Screen of the Arduino. The fig.9.b. shows that the SMS obtained on the mobile phone with the latitudinal and longitudinal position at the point where a crack is detected and gives link of the location. The fig.9.c. shows that the location of the instance.

9.CONCLUSION

As per the study the existing systems are time consuming as well as uneconomical. The proposed system is not only overcome these problems but also improve accuracy and crack detection in rails. It is the most economical solution provided in order to achieve good results of railways of our country in order to minimize the stats of accidents caused. There by possible to save precious lives of passengers and loss of economy. It also saves the time and money for identification of crack.

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