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Autonomous Railway Track Crack Detection and Accident Prevention System

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ABSTRACT

Train derailment is a predominant issue that needs to be solved, the major cause of the derailment is due to cracks and bridges on the track. To overcome this problem we have proposed an autonomous system (Robot) that uses an ultrasonic sensor with a range of 30 cm primarily based on distance measurement and density sensor to detect deeper cracks, the sensor is used to detect cracks present on the railway track by sending ultrasonic waves. As soon as the crack is detected the GPS Sensor is used to find out the latitudinal and longitudinal coordinates of the area where the crack is detected. The detected crack along with the exact location is sent to a nearby railway station using a GSM module. These data are then sent to the cloud server which is then analysed and compared with the threshold and the cracks can be rectified on the exact location of the damage. The proposed self-governing system is a robot along with wheels and motors which are controlled by a motor driver. Here we are using an Arduino Uno Microcontroller. These sensors and modules are integrated with this Arduino UNO board. The board is uploaded with a program using the Arduino IDE to carry out the crack detection function. This board takes readings from the ultrasonic sensor and these readings are continuously stored in the cloud for analysis and it accordingly communicates with the other module to effectively detect cracks beneath the surface of the tracks and on the surface.

Keywords: *Ultrasonic sensor, Crack Detection, Arduino IDE, Density sensor, PS sensor*

1. INTRODUCTION

These days, Railways being one in all the largest network of transport within the country, its reliability and safety are issues of paramount importance, rail transport gathers an enormous amount of function in fulfilling the ever-growing needs of a steadily growing population and financial system. However, in terms of the sustainability that our railway networks provide is of great question and is nowhere near the standards of applause and safety parameters it exhibits are greatly questionable, though India stands to be one of the 4th largest networks in terms of size, the international standards have now not yet been reached. Even though demand for railways and its services are increasing at an ever-growing rate in India, the related safety infrastructure has no longer met with the quoted standards. The major squabble is the shortage of sustainable and cost-effective technology to bring out the issues inside the rail tracks and the meagerness of proper maintenance. If done perfectly the operation and renovation of transport infrastructure will have a deep impact on safety standards and thus improving the economic system

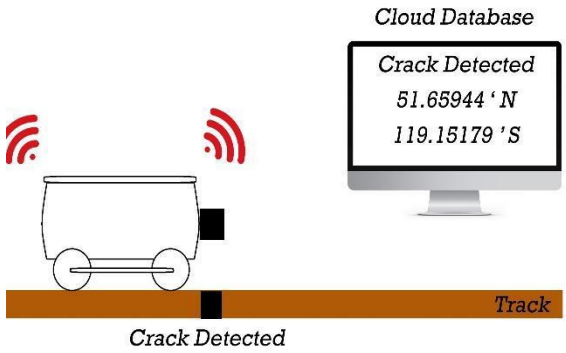

Fig. 1: Schematic of the autonomous system

Here we've proposed a prototype bot for detecting barriers and cracks in the surface and the deeper parts of the track. The robot uses ultrasonic sensors with an Arduino Microcontroller for detecting surface cracks and density sensor for detecting the cracks beneath the tracks. When surveyed the autonomous system while going in the desired direction transmits ultrasonic waves by means of the ultrasonic sensor constantly from its sensor head. On every time interval, the ultrasonic waves are reflected lower from the surface of the track and that data is passed to the Microcontroller. The Microcontroller then transmits these data to a cloud where the exact location of the anomaly is stored. Many such data are then analyzed to create a database of such irregularities in order to calculate the failure of the system or cracks which leads to disaster and collateral

damage and loss of life. The proposed system is scalable and is cost-effective in the long run, power intake is low, and with credible data management and calculations the errors can be reduced, and with this proposed machine the exact quarter of the defective rail sound can be easily located so that precious lives can be saved.

2. RELATED WORKS

The paper [1], discusses an advanced system deployed to detect the cracks present on a railway track to improve the safety of train movement. In [2], the paper talks about a system to prevent failure of tracks by using an alert system so as to improve the safety of rails. In [3], the paper discusses a system consisting of an IR sensor, Zigbee along with LCD and a Global Positioning system to detect a crack and find out the exact location.

The paper [4], introduces a system to detect railway track cracks using IR sensors and a GPS/GSM module to send a message so as to reduce train derailments and to improve the rail crossing systems so as to prevent incidents caused at railway crossings. The paper [5], implements a differential real-time GSM system which utilizes SMS service along with GPS. In [6], the paper talks about a hand-held GPS/GSM position tracker mainly used in the military, this device is used for finding lost devices, tracking of children and pets. The paper [7], uses a GSM/GPS based system to enable live tracking of vehicles which are connected to a mobile phone, the GPS gives the exact coordinates of the vehicle.

In [8], implements a system to track a vehicle using GPS module and a GSM module to send the location of the vehicle, a mobile app is used to view the Google maps tracking of the vehicle. In [9], the paper uses an Ultrasonic sensor to get accurate measurements of distance for various diverse applications. The paper [10], introduces a DSP based system to accurately get the distance values from ultrasonic sensors. In [11], the paper implements a sensor on the train engine itself so as soon as a crack is detected the train engine stops and the trains have sensors to detect trains coming from the opposite side so as to avoid collision between trains.

The paper [12], uses a system consisting of a mobile robot to detect cracks in a concrete tunnel for safety purposes. In [13], the paper discusses a system to detect cracks on a railway track and to notify about it via SMS. The SMS will be sent using a GSM module along with the location, using the GPS fitted on it. The paper [14], uses a system consisting of IR sensor, Ultrasonic sensor and a PIR sensor to detect cracks on railway tracks at the same time also detect a human and notify about it using a GSM module.

3. METHODOLOGY

The train derailments due to outer and inner cracks in the railway tracks are the main motive of this project. This system is nothing but an autonomous robot equipped with sensors like ultrasonic and density modules which detect the cracks present in the railway track and then sends a message with the exact latitudinal and longitudinal coordinates using the GSM and GPS modules respectively. The first and foremost function of the autonomous system is to detect any kind of crack on the railway tracks while moving over it. There are two types of cracks present on a track. One is the outer surface cracks which might sometimes be visible to a naked eye and the other is the inner crack present underneath a track which further develops to bigger cracks. The outer surface crack is detected using an Ultrasonic sensor, which measures the distance between objects, so based on the distance calculation and threshold set, the outer surface crack can be determined.

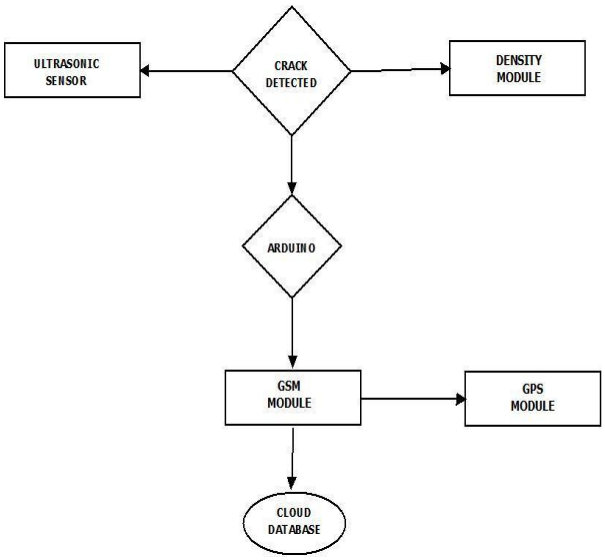

Fig. 2: Flow chart of the autonomous system

IR sensors can also be used to determine the crack instead of the Ultrasonic sensor, but the problem with IR sensors is that it does not work under sunlight. The inner surface cracks are measured by using a density module, which measures the density of the railway track. If the density of the railway track is found to be lesser than the normal threshold density of the track, then it means that inner cracks are present inside. These sensors send their respective signals to the Microcontroller. Secondly, the Arduino Microcontroller processes the signals received either from the Ultrasonic sensor or Density module and accordingly triggers the GSM and GPS modules to send the message along with the accurate latitudinal and longitudinal coordinates of the exact location where the respective crack on the railway track was detected. This information is then sent to a cloud database, where the data can be viewed or inspected for future references. This autonomous robot can save lots of time and increase the accuracy of detecting cracks in the railway tracks thereby improving rail safety. The entire system flow is shown in Fig 2. The system is capable of detecting any kind of crack present and then sends the exact location of crack detected to the database.

3.1 Hardware Required

- **Arduino Uno R3:** The Microcontroller used here is the Arduino Uno R3 (Fig. 3.). It is the main processing unit of this system. All the input and output sensors, actuators are connected to this Microcontroller board. The high I/O capability of Arduino Uno is the very reason why it is used for this autonomous robot. The controller receives the input signals from various sensors, processes them and correspondingly actuates an output.

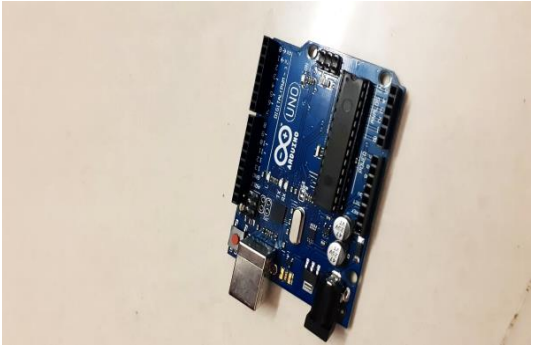

Fig. 3: Arduino Uno R3.

- **GSM Module:** The module used here is a GSM SIM 900 A. It is the Global System for Mobile Communication, which is used to send an alert SMS or SOS over a 2G network. In our system, it is used to send an alert message when a crack is detected by the sensors. The message also contains the latitudinal and longitudinal coordinates of the location.
- **GPS Sensor:** The sensor used here is the GPS NEO 8M which is used to give the exact latitude and longitude of a location. When a crack is detected by the autonomous robot system, the Arduino UNO triggers the GPS module to send the exact latitudinal and longitudinal coordinates of that location.
- **Mobile Phone:** Used to receive the message from the GSM module along with the exact coordinates of the location.
- **Wiring System:** The various sensor connections are made using copper wires or strips with proper encasing so as to prevent any kind of snap or breakage in connection.
- **Li-Po Battery:** The Lithium Polymer battery is used to power the entire autonomous system to give it a long run time, so that the charging time reduces.
- **Motor Driver:** To run the prototype robot the motor driver used here was the L298N motor driver. It has the feature of speed control which is not available with other types of motor drivers.
- **Ultrasonic Sensor:** It is one of the most vital sensors in this autonomous system. This sensor is used to detect the outer surface cracks present on the tracks. The module used here is the HC SR04 Ultrasonic sensor as shown in Fig. 4.. It is based on the SONAR concept. The sound waves are sent by a transmitter and then received by the receiver based on the time at which the sensor receives back the sound, the distance of the object is calculated. The sensor has a range of approximately 30 cm. Ultrasonic sensor is preferred over an Infrared sensor because it is not affected by sunlight and it also gives accurate distance readings. The ultrasonic sensor is placed on the front, facing downwards of the moving robot. The sensor continuously measures the distance values from the track, if the distance is found to be greater than the set threshold, the system analyzes that there is a crack present on the outer surface of the track and it immediately sends the signal to the Arduino Uno, which in turn triggers the GSM module to send the alert message along with the location using the GPS module.

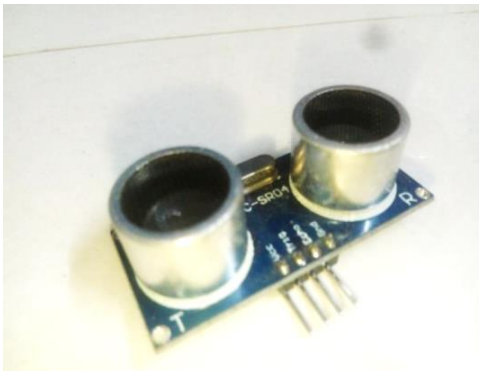

Fig. 4: HC SR04 - Ultrasonic Sensor

- **Density Module:** The density module is used to measure the density of a certain object. This sensor is very essential as the ultrasonic sensor is only capable of detecting the outer surface cracks present on a track. But the inner cracks must also be detected as they grow further and become bigger cracks. This is where the density module comes to play as it is capable of detecting all kinds of inner cracks or holes present inside a railway track. The density module is fitted on the front side of the autonomous robot and is positioned in such a way that it is always in contact with the railway track. As the robot moves, the density module keeps measuring the density of the track. If the density of the track is found to be less than the threshold density, then the Microcontroller notifies the back-end server. The notification is sent via an SMS, which is triggered by the GSM module. Along with the SMS, location is also sent using the GPS module.

3.2. Software Required

- **Arduino IDE:** Arduino IDE as shown in Fig. 5., is the software where the program for the Arduino Microcontroller is written. It is easy to use software with lots of inbuilt libraries and functions required to integrate and run various sensors.
- **Cloud Server:** The data from the system will be sent to a cloud database, where it can be stored, retrieved and monitored anytime.

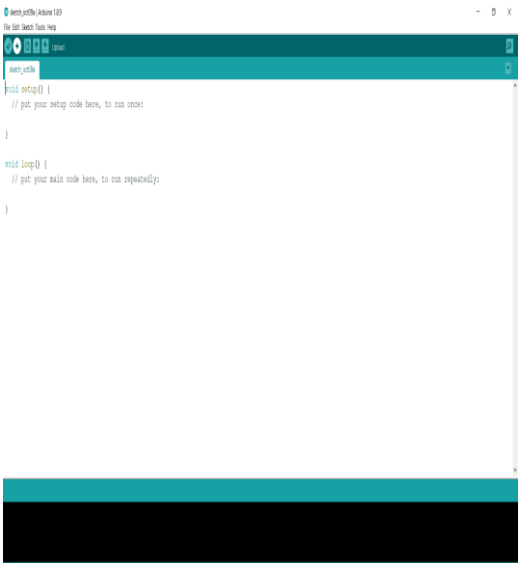

Fig. 5: Arduino IDE software.

4. RESULTS AND DISCUSSIONS

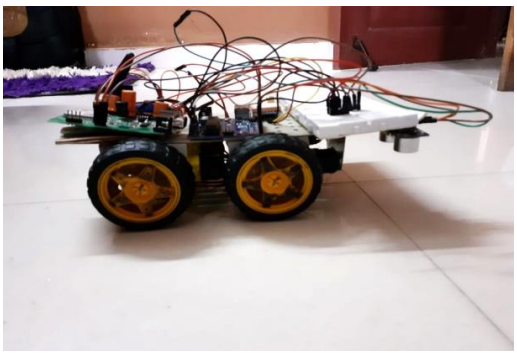

Fig. 6: Autonomous Robot.

The above Fig. 6. is the prototype design of the Automatic Crack detection robot. The prototype is fitted with an Ultrasonic sensor, a distance measurement sensor which detects the outer surface cracks present on a railway track. The density module sensor detects the inner cracks present inside a track by calculating the density difference. The Microcontroller Arduino Uno is the brain of the system which receives the readings from the ultrasonic sensor and density module. The motors of the robot are run by an L298N Motor Driver, which has the ability of speed control.

The GSM and GPS are fitted on the robot to send an SMS to the back-end along with the accurate latitudinal and longitudinal coordinates of the location, where the crack was detected. All of this data is stored in the cloud server, enabling easy access anytime. Fig shows the message received by the back-end via the GSM module, along with the location of where the crack was detected.

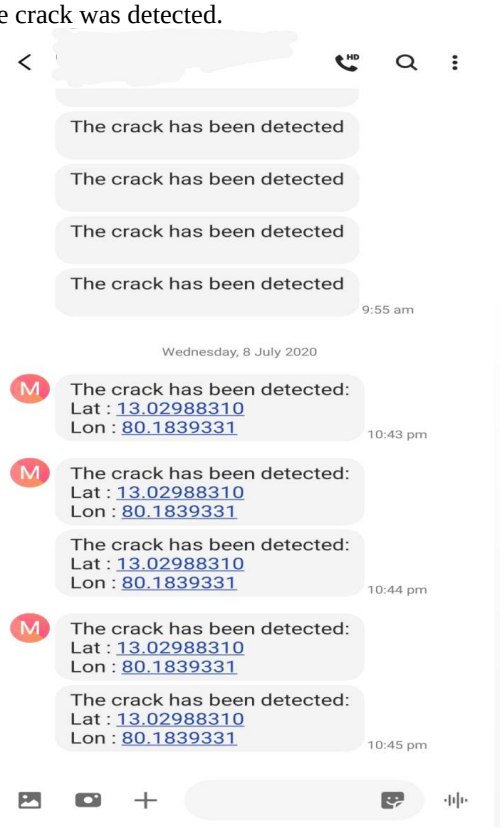

Fig. 7: SMS received when a crack was detected.

5. CONCLUSION

The purpose of this Automatic Crack detection system is to provide a low cost, at the same time an accurate automated system to detect all kinds of the crack present in the railway track. Our automated robot was able to detect the outer cracks present on the track using an ultrasonic sensor, then it gets the exact location through the GPS module and is sent to a mobile phone as an SMS via a GSM module. The data received is stored in a cloud database. This automated system can detect cracks developed on the outside as well as inside thereby avoiding derailment of trains which results in a huge number of fatalities every year.

The uniqueness of our system is that it detects the outer surface crack as well as the inner surface cracks, making it a very accurate system to detect, monitor and maintain railway tracks. Implementation of this system in our Indian Railways will prove to be revolutionary and increase the safety of train movements.

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