A Novel SMS-Based Crack Detection System

Aman Nirala[1], **Anuja Bokhare**[2], **Ishita Agrawal**[3], **Akshat Jain**[4]

[1]*Symbiosis Institute of Computer Studies and Research, Symbiosis International (Deemed University),Atur Centre, Gokhale Cross Road, -Model Colony, Pune, India,* *amn1921010@sicsr.ac.in*

[2]*Symbiosis Institute of Computer Studies and Research, Symbiosis International (Deemed University),Atur Centre, Gokhale Cross Road, -Model Colony, Pune, India,* *anuja.bokhare@gmail.com*

[3]*Symbiosis Institute of Computer Studies and Research, Symbiosis International (Deemed University),Atur Centre, Gokhale Cross Road, -Model Colony, Pune, India,* *isa1921039@sicsr.ac.in*

[4]*Symbiosis Institute of Computer Studies and Research, Symbiosis International (Deemed University),Atur Centre, Gokhale Cross Road, -Model Colony, Pune, India, akj1921007@sicsr.ac.in*

Abstract.

The study aims to design a simpler system that automates the detection of cracks in railway tracks using an Ultrasonic or IR sensor and Arduino. In this study, use of HC-SR04, an Ultrasonic sensor module is made. The purpose of the module is to emit pulses of ultrasonic sound waves (greater than 20kHz [1]) that reflect as echo after striking the surface and are detected by the receiver. By calculating the time difference between the emission of the waves and the detection of the echo, the distance of the surface from the sensor can be calculated. In the case of an IR setup, the infrared pulses emitted from the IR blaster on striking the surface comes back as reflected electro-magnetic waves to the IR receiver. Also, the GPS and the GSM service are used to send these location coordinates to the user's mobile, desktop, or web interface. Lately, with the advancement of railways, the capabilities of the trains have been continuously increasing. Hence, an inspection of a rail track is a necessary task, which should be inspected periodically. To make it time-efficient, an automatic crack detection system is proposed which detects the abnormality on the surface of the rail track. It uses simple statistical analysis to detect the cracks on edge.

Keywords. Crack detection system, HC-SR04, Arduino, rail industry, sensor.

1. INTRODUCTION

There are many problems around us which we face in our daily life. We want to create a project that can help and benefit the people of our country, so we look into various public sector domains that are used widely that require some changes in the system. And one such domain that requires attention is transportation. Today, transportation is of great importance for its sustainability and safety due to its primary usage. There are many changes or updates that one can make in this sector for the betterment of our nation. Also, IoT is dynamic in the field of technology and its advancement. When we talk about transport, Railways occupies a leading position in India in reducing a fast-growing economy's growing needs, but there are still many problems which can be corrected to make this system more efficient. The main issue that is faced here is that there is no reliable and affordable equipment to diagnose train track issues and the lack of proper maintenance. The railway infrastructure dates back to the colonial history of India. These tracks were laid by the British back then for transporting goods from different parts of India. After the independence, this whole system that was once used to transport Indian goods to the major ports for export was converted as a medium of transportation and in very few years became the most used mode of traveling as well as transportation. After these many years, a lot of things were upgraded but the system used for the maintenance of these decades-old tracks remains the same. With the increasing number of trains and usage of the railway system, the current methods of maintenance are not very productive and take a lot of time and labour.

Thereby, authors thought of making the current proposed model that speaks of a proposed test train design for detecting obstacles and cracks in the tracks, similar to the line following the test train. This project will help improve the rail industry and many people will be benefited from this. It is the most economical and efficient solution provided to achieve good results of railways of our country to minimize the stats of accidents caused. Besides this, it also saves time and money when this project is applied in real life.

2. RELATED WORK

According to current research-based study, authors came across multiple research papers that discuss similar ideas. Most of the methods discussed in those research papers are about detecting a crack and sending an SMS to a particular mobile number. However, it is believed that there are many other ways to use and deliver this data. In this study, authors have proposed some of these ideas with their benefits. Also discussed some of the important aspects mentioned in most of these research papers, points to improve them, and a small demo project we built with the limited resources we had. In [2] the authors propose a system where they use Raspberry Pi with a camera module on a mounted platform. The camera took images of the tracks and they used computer vision and image processing to detect cracks on the tracks. The idea is quite fascinating and useful but many other ways are quite simple and less sophisticated than using computational intelligence and image processing. This requires a lot of extra resources and the maintenance of this system itself won't be very easy. As the parts used are comparatively expensive and repair is a bit difficult. This system could however be a real add-on as a surveillance module. Another excellent application is seen in [3] where the authors discuss the use of neural networks for precise classification of cracks or damage and present an implication where a motorized cart is mounted with an Arduino board, IR sensors, and GPS/GSM modules which sends a notification into a mobile device when a crack is detected. This system is quite effective and less expensive to maintain.

With the technology stack discussed above, it's quite clear that almost all the solutions are collecting huge bundles of data that could be useful in training more sophisticated systems. Current study on the other hand uses simple, less sophisticated and less resource consuming statistical analysis to detect the cracks.

3. METHODOLOGY

This section focuses on the system design. The components used during the experiment design are:

Ultrasonic sensor: This is an electronic sensor that measures the distance of objects by emitting ultrasonic (high-frequency) sound waves and converting the reflected sound waves (echo) into electrical signals. These sensors are one of the best tools to measure distance as they are fast and can be 97% precise for long distance. [4]

GPS: The Global Positioning System is used to receive the position data of an individual or vehicle and display it on a digital map. It will also have an interface to the communication link. Authors [5] interfaced neo-6m GPS module with Arduino to get the location co-ordinates which could be using with Google Maps API to improve the presentation.

3.1. Interface Model

Figure 1 describe about the interface used to connect HC-SR04 with Arduino board. The ultrasonic module HC-SR04 is a 4-pin system. One is VCC which is the 5V live pin connected to the 5V pin of Arduino. The 'GND' pin is the Ground pin connected to the Ground pin of the Arduino. The next is the TIRG pin that stands for 'Trigger pin' which is an output pin. It is connected to the digital I/O pin-number 2. It provides the pulse with respect to which the sensor module emits high-frequency sound waves of 40kHz. The last pin is the 'Echo pin' which acts as the input pin. This pin is used to take distance measurement as this pin goes HIGH after a burst of waves is send and goes LOW only after it receives an echo. [6]

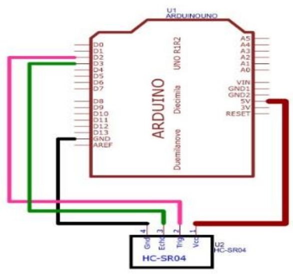

Figure 1. Arduino and HC-SR04 circuit diagram

3.2. Mathematical relation:

Velocity of sound wave in air ($\boldsymbol{v}$) ≈ 343m/s. [7] [8] [9] (one can ignore some errors on the precise measurement in the velocity as the detection of surface abnormality is purely relative and it should work till, consider the same value of v throughout the procedure.)

$$v = \frac{S}{\Delta t} \quad (1)$$

Where **S** = distance travelled by the wave and Δt = time taken.

Distance of the object from the source of wave (**S**) is:

$$S_{actual} = \frac{\Delta t \times v}{2} \Rightarrow \frac{343\,(\Delta t)}{2} m \approx 170(\Delta t)\mathrm{m} \tag{2}$$

3.3. Proposed model for crack detection system

Figure 2 describes the organization of different element of the whole system. The 'track surface' data is collected by the HC-SR04 sensor which sends the data to the Arduino. Arduino then formats the data and send to the 'crack detection interface' (a software service) running on the Raspberry Pi (or any computer) which is responsible to process the data and detect the cracks. The 'crack detection interface' saves the data collected in a separate log file that could be used for real-time visitation or reference later. The software service has to be calibrated in a control environment which will calculate the error generated by the sensor. This information will be provided to the detection block which will compare the data in real-time to detect a crack in the surface. If a crack is detected, an SMS is sent by the user with the location coordinates by the software service.

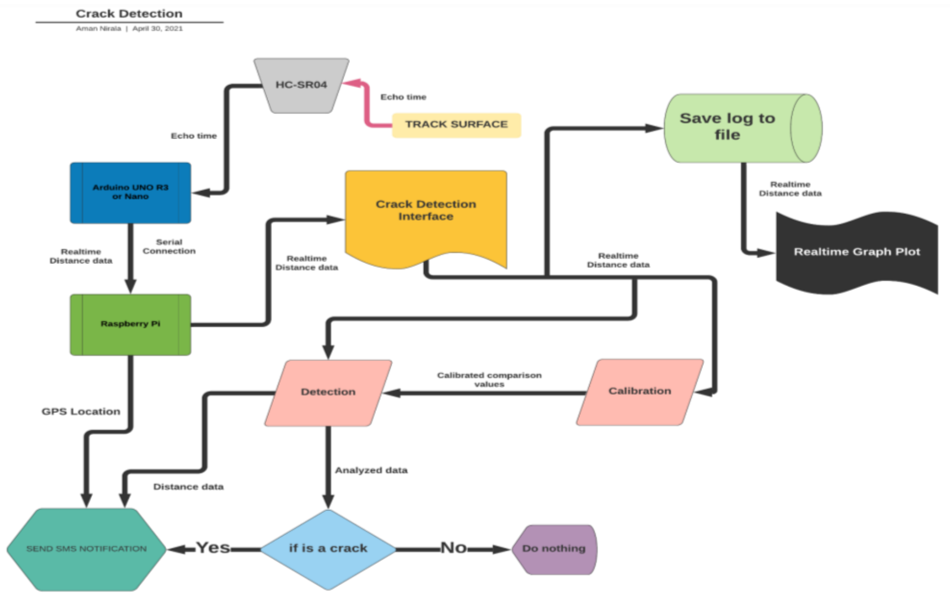

Figure1. Block diagram of crack detection system

3.4. Arduino module

Figure 3 (a) represents the HC-SR04 module on the Arduino board. Figure 3 (b) represents the connections of the HC-SR04 with the Arduino board.

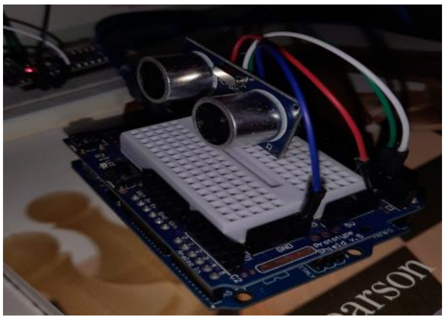

Figure 3(a) Front view Arduino UNO with Prototyping shield and HC-SR04)

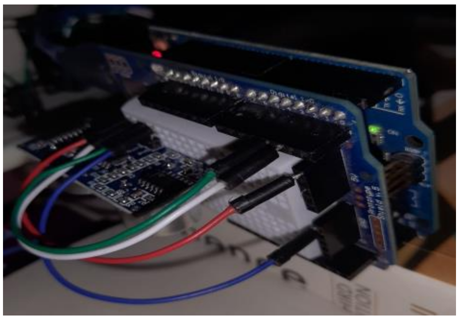

Figure 3(b) Arduino UNO with Prototyping shield and HC-SR04) Pin connection

4. RESULT ANALYSIS

The client application (built in Python) can be deployed in a platform independent way. The service is responsible for processing the data collected by the sensor. The application requires three parameters, 'depth sensitivity', 'max distance allowed' and 'calibration time'. 'Depth sensitivity' tells the program the tolerance level of a structural abnormality. If the deviation is larger than the threshold, it is marked as a potential candidate. 'Max distance allowed' is the maximum possible value of reading, this eliminates some noisy reading that might be caused due to environmental factors or defect in the instrument. 'Calibration time' parameter is the value that tells the program how long it should collect the data in a controlled environment to calculate the mean absolute error generated by the instrument $\left(\boldsymbol{MAE = \frac{1}{n}\sum_{i=1}^{n}\left|d_i - \bar{d}\right|}\right)$ [10] which can be used to evaluate errors in the real reading value. The mean of the data collected by the sensor is considered the normal surface level ('surface normal'). The threshold for detecting a crack is the sum of the depth sensitivity/tolerance and the surface normal. When a crack is detected on the track, an SMS is sent to the preferred number/portal by using a remote SMS client (will be using GSM modules in the future) and GPS service. The message contains a Google Maps link with the latitude and longitude of the place where the crack is detected. Figure 4 shows a diagrammatic representation of the applied system which different elements calculated during the calibration period. Figure 5(a) represents the raw surface data collected during the calibration period in a controlled environment. Figure 5(b) represents different features calculated from the data. Table 1 represents different information collected during a calibration period which will be used by the detection system to classify a data point as a significant crack.

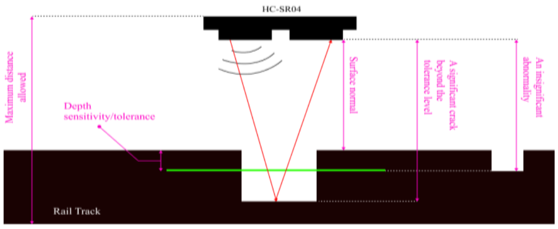

Figure. 4 Applied system

TABLE I. CALIBRATION INFORMATION

Measures	Values
Surface normal	74.82452512
Surface minimum	73.71
Surface maximum	75.77
Max error	0.945474876
Min error	-1.11452512
Mean absolute error	0.279969167

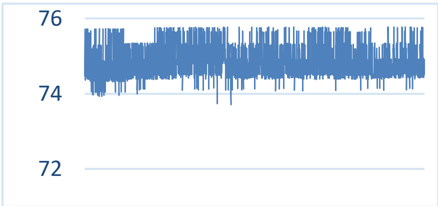

Figure 5(a) Calibration result

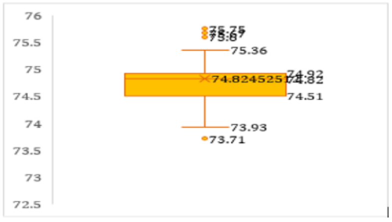

Figure 5(b) Box plot of features

Figure 6 (a) represents the reading from the sensor with a significant crack. Figure 6 (b) represents the SMS notification sent to the user mobile with the information of the crack and the location coordinates.

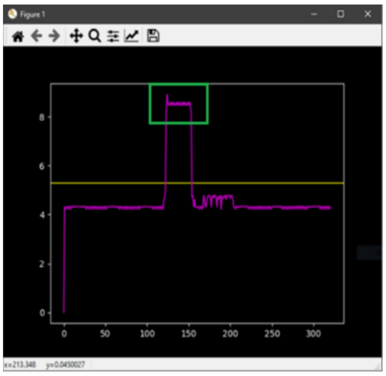

Figure 6 (a) Crack detected

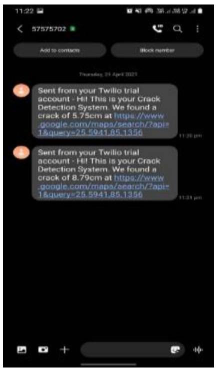

Figure 6 (b) SMS is sent on test number

4.1 Advantages of Proposed System

- Easy and automatic data collection that can be used for analysis and management.
- Low resource consumption.
- Easy to maintain and low-cost hardware.
- Less sophisticated mechanism.
- Versatile and easily scalable.
- Ability to send alerts/warnings to particular train drivers if a potential crack is detected.

4.2 Limitations of Proposed System [11]

- This method can't detect very fine fractures because to detect an abnormality the feature should be larger than the wavelength of the sound waves so that it can reflect the sound waves. This can be handled by using other technologies like LIDAR.
- Long distance of the sensor from the tracks can make the echo weak and lead to noisy readings.

The angles of reflection of the echo are governed by the Snell's law ($\frac{\sin\theta_i}{\sin\theta_r} = \frac{V_i}{V_r}$). **[1]** For the sensor to receive the echo, the emitter has to be nearly perpendicular to the surface or else the echo won't be captured by the receiver. This makes the alignment an important variable in achieving error free result. Table II shows the comparison of the existing crack detection system with the proposed system.

TABLE II. COMPARISION WITH STATE-OF-THE-ART CDS SYSTEM

Sr.No	Mean Absolute error of existing system	Mean Absolute error of proposed system	References
1	56.407	0.279969167	[12]
2	0.97		[13]
3	11.04		[14]
4	10.6		[15]

5. CONCLUSION

In this paper, a method to distinguish cracks in rail route tracks has been introduced utilizing ultrasonic waves and simple statistical analysis. The strategy replaces manual assessment of the track area, via programmed review and use of sophisticated hardware and computational intelligence. This will assist with cracks promptly and lessen the possibility of any mishappening. There will be less need for physical power, i.e., to manually detect every crack. This system can pinpoint the exact locations and send an immediate message in an economically accurate manner. The simple design of the proposed system makes the efficiency directly proportional to the capabilities of the sensors used. With the current system the mean absolute percentage error generated by the sensor is less than 0.4% making it very efficient for surface and sub-surface crack detection. In the following time, if applied at a larger scale, it will be time-saving and provide railways with a better safety system and effective testing infrastructure.

6. FUTURE WORK

Currently, authors are using the SMS-based system to deliver text messages regarding the cracks detected on the track. Moving further a smart device, web portal, and a cloud system will be added to make the applied method and algorithm more efficient and user friendly.

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Biographies

Aman Kumar Nirala. is a computer science student at Symbiosis Institute of Computer Studies and Research. His key interest area of research is Quantum computing, IOT and Embedded systems.

Dr. Anuja Bokhare is working as Assistant Professor in the department of Computer Science at Symbiosis Institute of Computer Studies and Research,. She has completed PhD from Symbiosis International (Deemed University) in faculty of Computer Studies. Her research interest includes software engineering, applications of Artificial Intelligence, machine Learning and soft computing. She had published 22 research papers in international journal and conferences along with one book in her account.

Ishita Agrawal is a Computer Science student. Her key interests' area of research are UI/UX designs and data analysis.

Akshat Jain is a computer science student at Symbiosis Institute of Computer Studies and Research. Technology has always fascinated him and his key interest areas are Blockchain,IOT and cyber security.