iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 9 **Issue:** VIII **Month of publication:** August 2021

**DOI:** https://doi.org/10.22214/ijraset.2021.37681

# Crack Detection by Ultrasonic System on Locomotive-Track

Vijay Mayekar[1], Roshan Aalshi[2], Harshdeep Singh[3]
[1, 2, 3]*Department of Physics, Ramnarain Ruia Autonomous College, Mumbai-400019*

***Abstract: It has been found that major cause of the Railways accidents is due to the derailment attributed to the cracks developed on the rails. Crack development and its prolongation happens due to regular movement of locomotives, absence of timely detection. The maintenance lapse poses serious questions on the security of Railways transport operation. Manual detection of cracks on locomotive-tracks by maintenance team is arduous task, time consuming, irregular due to environmental factors and tight scheduling of trains, which may lead to maintenance work errors.***

***This project aims at addressing the issue of crack detection by ultrasonic crack detection system, which would work in real time, with the control action taken to avoid major accident. Ultrasonic crack detection system is mounted on the locomotive itself, include precision ultrasonic sensor, LCD display, GPS module and its power supply. System will detect crack, subsequently it will generate Visual warning-signal for the authorities and generate location coordinates of the Crack. This will help for authority to generate caution signal for locomotives running on the same track for slow movement and emergency maintenance action could be undertaken.***

***Keywords: locomotive-track, crack, ultrasonic Sensor, GPS Module, Arduino microcontroller.***

## I. INTRODUCTION

Transport is a key factor in development of nation that facilitates consumption of products at different locations which are connected by transport system. Economic prosperity directly relates to the capacity of transport system distributed rationally for maximization of efficiency. Thus roadways, waterways and railways had a great impact on the productivity and thereby economics of the nation.

Our nation has fourth largest Railway networks in the world, cover 67,956 km in distance, all over India.

Total locomotives are 12,729(2019-20) The Indian Railway network is divided into 18 zones and operates more than 19,000 trains per day, including 13,169 passenger trains and 8,479 freight trains. Train accidents due to derailment in 2019-20, were 40 out of total 54 train accidents in that year. [1]

Railways has maintained Safety reliability standards to the maximum, but few areas of maintenance still need attention with respect to global standards. Railways always found very difficult to maintain strict adherence to the stringent safety standards in the maintenance. Maintenance over the years, accumulate large mass of data which has to be systematically analyzed to uncover information related to safety which help in decision making about upgradation of the technical equipment. [2]

In this paper, the designing of the efficient crack detection system using ultrasonic waves coupled with microcontroller has been discussed. It is possible to use ultrasonic waves to find flaw as well as the crack on the rail track. Flaw is the internal defect in rail track, whereas the crack is the defect visible on outer surface of the track, flaw may result in crack. To find the flaw in rail track, we need high frequency ultrasonic waves in MHz which can penetrate in the track material.

There are different techniques used for the maintenance and safety in railways system, to mention wireless sensor network, vision-based system, IR based detection with Zigbee communication, microwave antenna [3],[4],[5]

## II. COMPONENTS

### *A. Power Source*

The Arduino microcontroller and ultrasonic sensors requires power of 5V DC, which is derived from 3X3.7-volt Li-ion rechargeable batteries with buck-boost regulator to ensure standalone system. GPS module works with 3.3V DC drawn from Arduino board.

### *B. Liquid Crystal Display*

16×2 LCD has 16 columns and 2 rows of matrix dots, total 32 characters, each character made up of 5×8-pixel dots. LCD Module has Interface IC HD44780 mounted, accept Commands and Data from the Microcontroller which are then processed to display onto LCD Screen. [6]

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com*

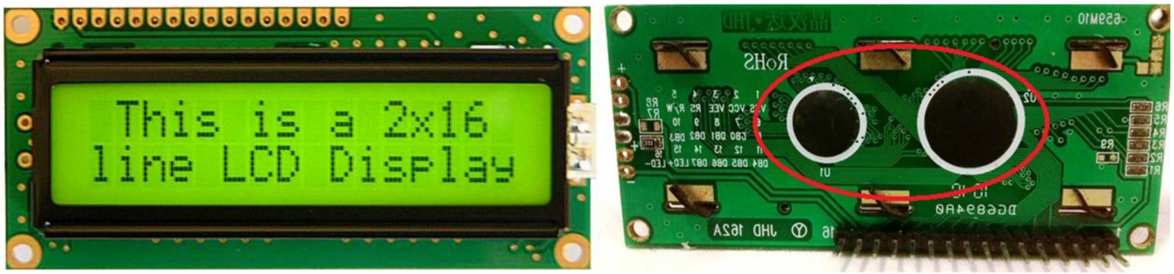



Fig. 1: LCD Module 16X2 matrix., backside of LCD Module-shows Interface IC visible as black circle

*C. Arduino Microcontroller*

Arduino Uno is a ATmega328P microcontroller based board. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Arduino Uno can be programmed with the Arduino Software IDE. The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. The ATmega328 has 32 KB (with 0.5 KB occupied by the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM. The Arduino Uno can communicate with a computer, another Arduino board, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX) [7]

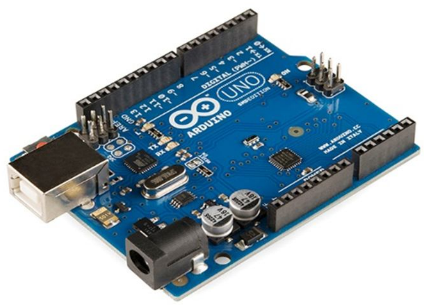


Fig 2: Arduino Microcontroller

*D. GPS Module*

The **NEO-6MV2** is a **GPS** (Global Positioning System) module used for navigation. The module simply checks its location on earth and provides output data which is longitude and latitude of its position. It is from a family of stand-alone GPS receivers featuring the high performance. The compact architecture, power and memory options make **NEO-6 modules** ideal for **battery operated mobile devices** with very strict cost and space constraints. Its Innovative design gives **NEO-6MV2** excellent navigation performance even in the most challenging environments. This module is one of popular GPS modules on the market and is also cheap to buy. The location data provided by it is accurate enough to satisfy most applications.

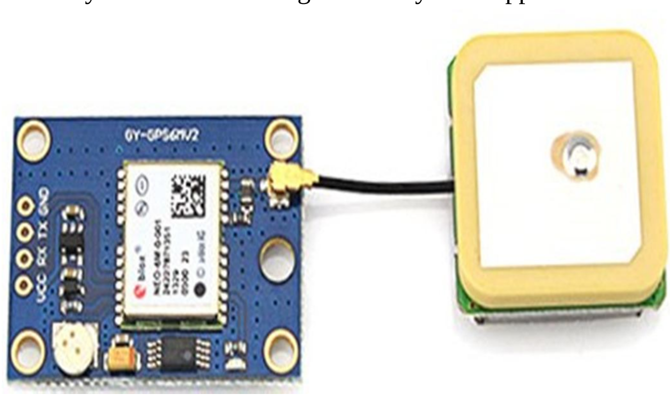


Fig. 3: GPS Module

### *E. High Precision Ultrasonic Sensor*

An ultrasonic sensor is basically a transducer which converts electrical energy into sound energy in the form of acoustic waves transmitted in the space and can work other way round too. In this study, ultrasonic sensor used is HC-SR04, have transmitter and receiver both tuned to similar bandwidth, emits ultrasonic sound waves (40 KHZ) in the cone beam directed towards target (railway track in this case) and collect back reflected beam.


Fig. 4: Ultrasonic sensor angular wave arrangement

## III. PROPOSED SYSTEM

Currently the method used for crack detection on tracks in Railways, is visual inspection by maintenance team using trollies, and SPURT vehicles (Self Propelled Ultrasonic Rail Testing Device). Standard operating procedure incorporates collection of data, processing data with relevant software, analyzing the processed data, and operating SPURT vehicle. The current method requires long time duration, skilled labor, and due to its long process, the detection of flaw requires maximum time. [9]

In this study, the system has been designed around Arduino Uno microcontroller, ultrasonics sensor, GPS module and LCD display. The flow chart of operations is in figure 5. The number near arrow line indicates flow process of working of detection. [10]

In the system, ultrasonic sensor is interfaced with Arduino Uno, powered by external power source. GPS module and ultra-sonic sensors are provided power from the rechargeable Li-ion battery with buck-boost regulator to supply required voltage. Ultra-sonic sensor is activated first by Arduino to collect crack information and then GPS module is activated to collect location coordinates. The GPS receiver will provide the target area's latitude and longitude parameter values to the Arduino microcontroller, then presented in visual way to maintenance department and authority. 16x2 LCD display interfaced with the microcontroller to display the longitude and latitude values of the crack detected by the system and warning message "Fault detected" "Latitude and Longitude parameter values"

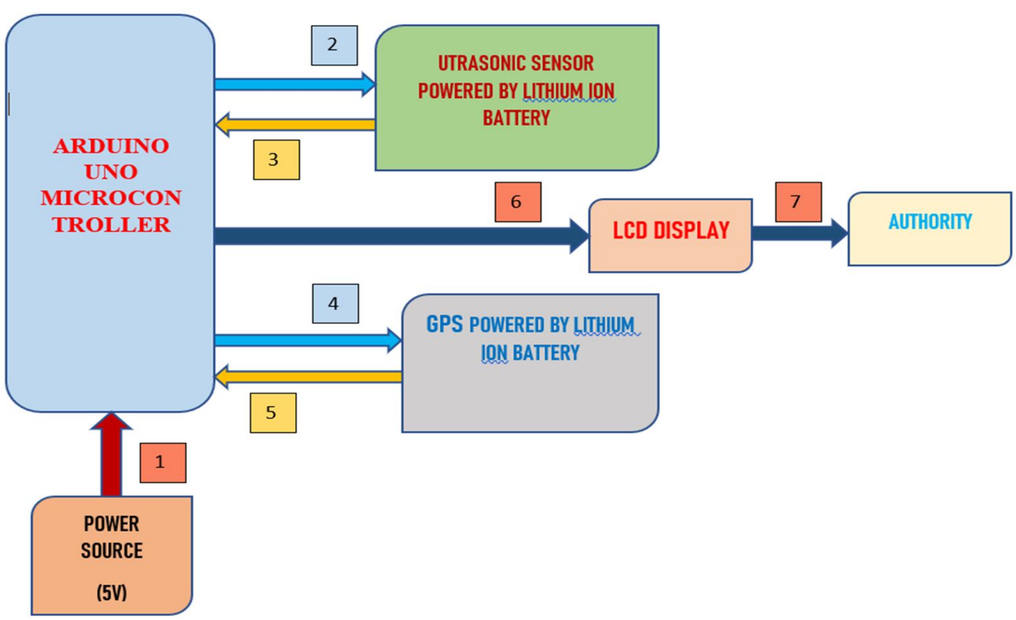



Fig. 5 - System block diagram with crack-detection process flow.

*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com*

## IV. METHODOLOGY

Detection system is mounted on the moving locomotive, and ultrasonic waves are sent in the form of pulses, directed on the track before moving locomotive. In this study, small range (3 cm-55 cm) ultrasonic sensor (HCSR 04) has been used. Two HCSR 04 sensors are used for overlapping of the beams in order to get pinpointing of the fault as program checks for detection by both beams. Higher grade ultrasonic sensors can enhance this range. Using long distance, powerful intense beam of ultrasonic waves can make detection possible at 25 meters ahead of the moving locomotive. System throws conical beam of ultrasonic waves and recollects reflected beam (echo signal) from the part of the track. If there is no echo signal, it means continuity of the track is broken which identifies crack has been developed on the track.

To begin measuring the distance, the microcontroller sends a trigger signal (duty cycle 10μs for HC-SR04) to the ultrasonic sensor. After receiving trigger, the ultrasonic sensor (HCSR04) emits eight acoustic wave bursts and initiates a time counter after eighth burst with Echo pin goes HIGH. When sensor receives same burst of signal waves reflected from the object, its Echo pin goes low. After receiving reflected (echo) signal from the target, the timer stops, see figure 6 The output of the Echo pin (ultrasonic sensor) is a high pulse with the same duration as the time difference between transmitted ultrasonic bursts and the received echo signal.

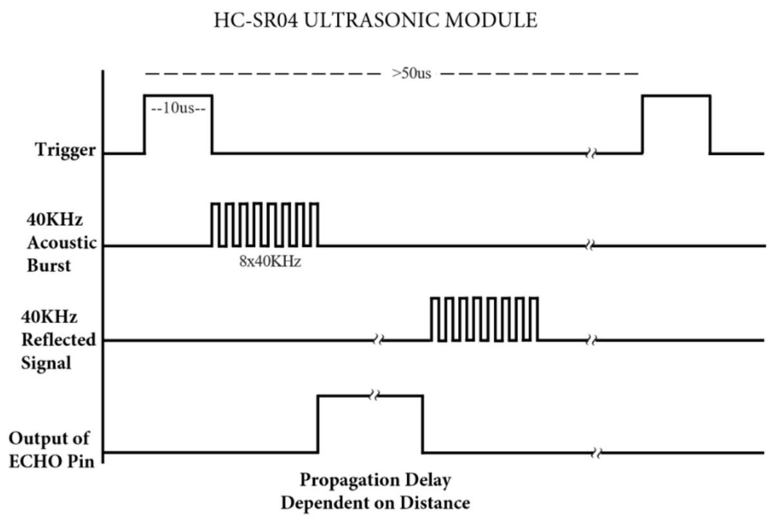



Fig. 6 – Ultrasonic signal clock diagram.

In case, if those pulses are not reflected, then the Echo signal will timeout after 38 milliseconds and return low. Thus, a 38-millisecond pulse on Echo-pin indicates no obstruction within the range of the sensor. Echo signal is coupled to the Arduino Uno (microcontroller) board to activate the GPS receiver. The GPS receiver will pinpoint the exact location coordinates of its position. This location then transferred to the control authorities as a visual on display.

In this two very closely mounted Ultrasonic sensors are used for sensing purpose, to avoid false detection. Sensing by two sensors of the same target increases validity and authenticity of the detection, and it helps in pinpointing the position of the fault as depicted by the overlapping of the two conical sonic beams emitted by sensor pair [11]

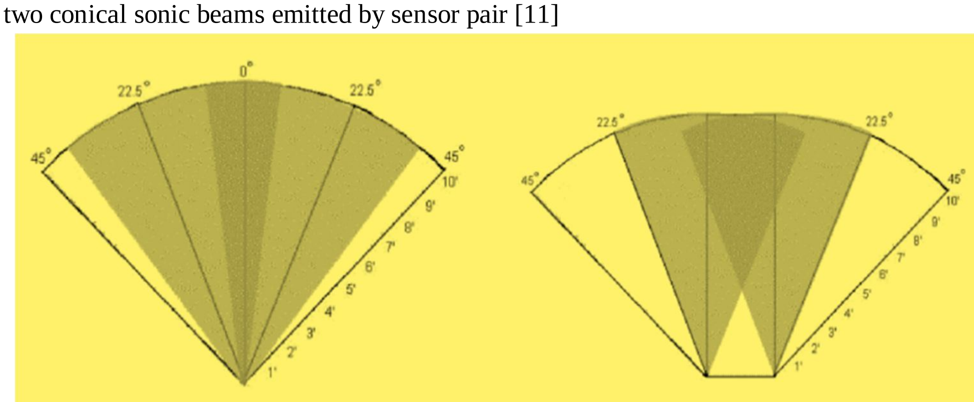



Fig. 7 – Overlapping of sonic beams of two ultrasonic sensors

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com*

## V. RESULT & DISCUSSION

The prototype of the proposed system using high precision ultrasonic sensors has been constructed as shown in figure 8. This system has been tested by implementing the crack on plastic casing used as track. The detection work was carried out for 4 different sizes of crack, 3mm, 6mm, 10mm,16mm (figure 9) with 4 different time delay as 500ms, 300ms, 100ms and 80ms respectively. The proposed detection System works as per procedure given in methodology (figure 10,11). Target location is marked on the goggle map, see figure 12.

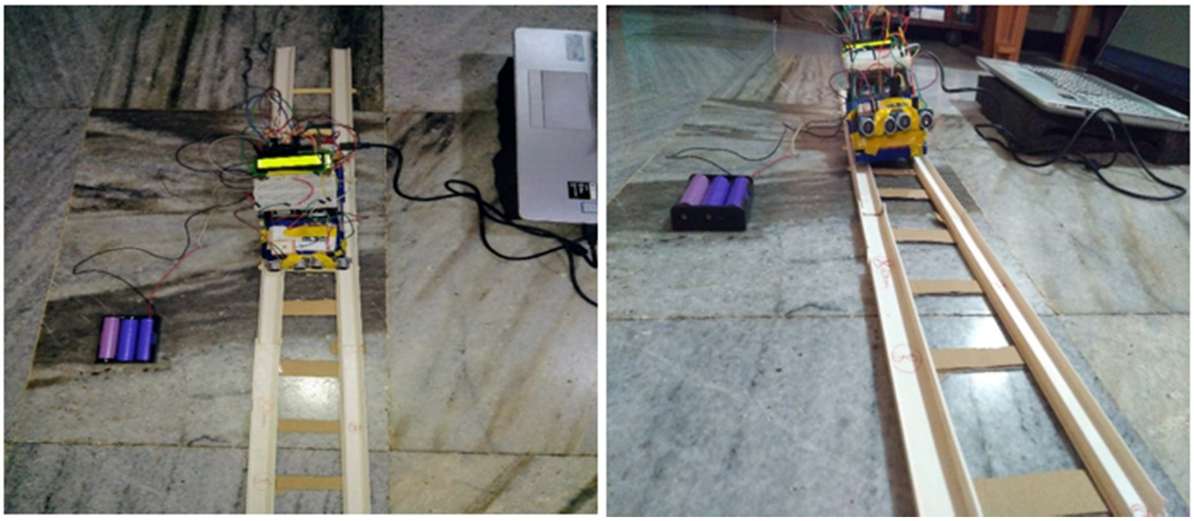


Fig 8: Prototype model of Proposed System

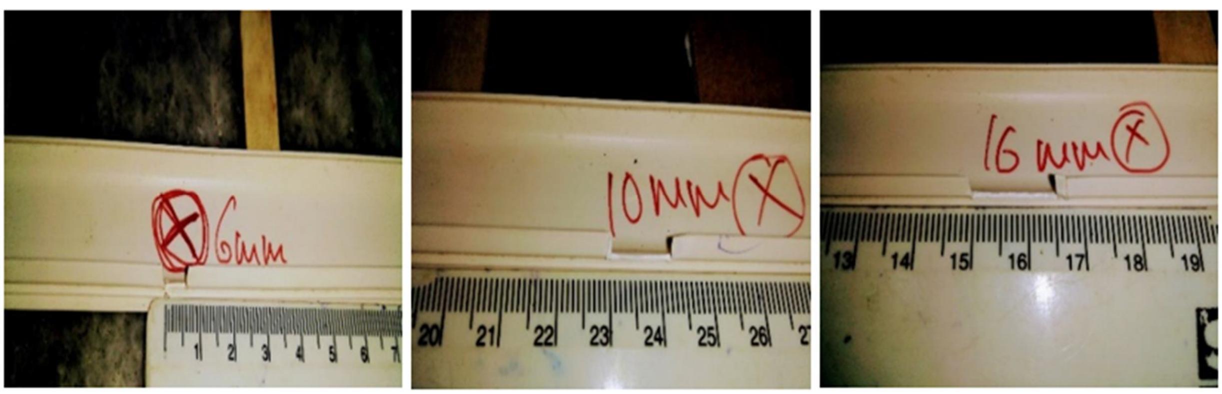



Fig. 9: Different sizes of cracks

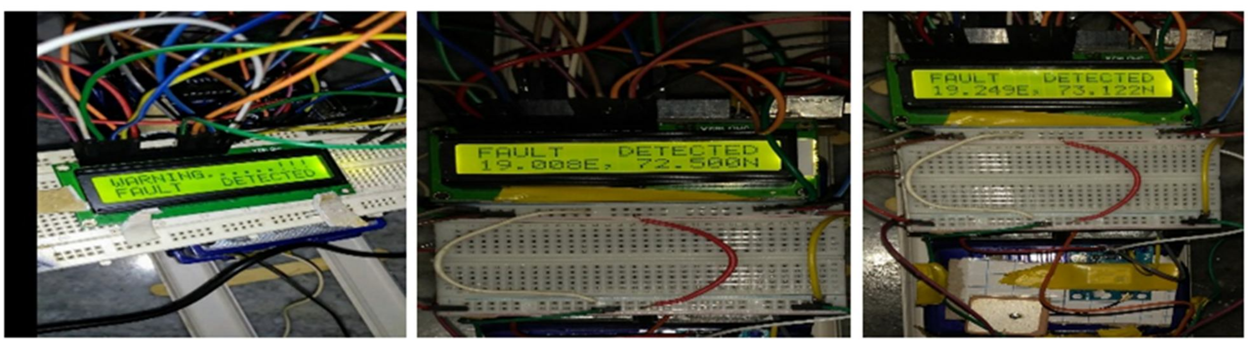



Fig. 10 LCD visual of “warning”, “fault detected” and “location coordinates” after detection.

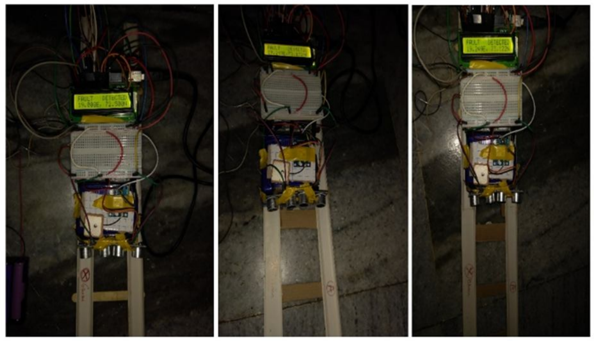


Fig. 11: Crack Detection at various sites

Table I
Detection Time with Different Distances and Different Crack Size, with Crack Location Coordinates.

| Distance of crack to HCSR04 sensor | Crack location coordinate acquisition /detection time (sec) | Crack size | Repetition frequency in terms of time delay between two readings (milli-second) | Location coordinates | |
|---|---|---|---|---|---|
| | | | | Latitude | Longitude |
| 5 cm | 6 seconds | 6 mm | 500 milli-second | 19.002$^0$ | 71.989$^0$ |
| | 4.5 seconds | | 300 milli-second | 19.280$^0$ | 72.981$^0$ |
| | 3 seconds | | 100 milli-second | 19.070$^0$ | 72.844$^0$ |
| | 2.8 seconds | | 80 milli-second | 19.149$^0$ | 72.307$^0$ |
| 13 cm | 10 | 10 mm | 500 | 19.008$^0$ | 72.500$^0$ |
| | 8 | | 300 | 19.249$^0$ | 73.122$^0$ |
| | 5 | | 100 | 19.0110$^0$ | 72.500$^0$ |
| | 3.5 | | 80 | 19.149$^0$ | 73.073$^0$ |
| 46 cm | 16 | 15 mm | 500 | 19.152$^0$ | 72.590$^0$ |
| | 13 | | 300 | 19.318$^0$ | 73.578$^0$ |
| | 10 | | 100 | 19.095$^0$ | 72.749$^0$ |
| | 5.6 | | 80 | 19.135$^0$ | 72.840$^0$ |
| 52 cm | 22 | 3 mm | 500 | 19.090$^0$ | 71.544$^0$ |
| | 16 | | 300 | 19.324$^0$ | 73.010$^0$ |
| | 13.5 | | 100 | 19.152$^0$ | 72.580$^0$ |
| | *4 | | 80 | *4 | *4 |

### *A. Limitations Found on Detection of Crack*

*1)* For a distance greater than 55 cm between crack and HCSR04 sensor there is no echo/reflected signal from target.
*2)* Another limitation - size of crack below 2.5 mm could not be detected with this sensor.
*3)* This sensor does not work for angle 14$^0$ with respect to horizontal direction. It works very well for angle between 15$^0$ to 25$^0$
*4)* The delay of 50ms was not working Reason is, due to ultrasonic sensor signal limitation with respect to clock timings. Even for the reading of 3mm crack size at distance 52 cm, with delay of 80ms; echo signal was not available.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429*
*Volume 9 Issue VIII Aug 2021- Available at www.ijraset.com*

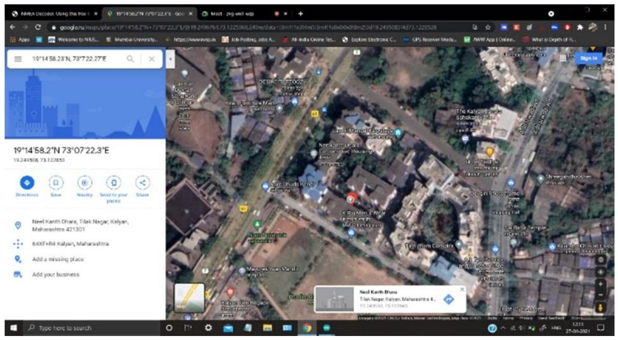


Fig. 12: Target Location Coordinates on Google map

## VI. CONCLUSION

In this study, using low power ultrasonic sensor and microcontroller, it was possible to locate the gaps in the railroad tracks in shortest possible time as sensor system is mounted on the moving locomotive. The process includes crack identification, and GPS system for global position marking and visual alerting. This System enables authority for immediate action of slowing down movement near to this crack, preventing major accident. It will reduce reaction time, sufficient data to make quick decisions due to which large number of human lives could be saved. By using advanced long-range sensing, this system can be incorporated in the regular maintenance by railways.

## REFERENCES

[1] Indian Railways Yearbook 2019-20

[2] Guoqiang, C. , Limin, J. , Liming, Z. , yu, L. , xi, L., "Research on Rail Safety Security System", International Journal of Economics and Management Engineering, 4(8), 1938 – 1943, (2010)

[3] Sharma, K., Kumawat, J., Maheshwari, S., & Jain, N., "Railway security system based on wireless sensor networks: State of the art", International Journal of Computer Applications, 96(25) (2014)

[4] Srivastava, S., Chaurasia, R. P., Abbas, S. I., Sharma, P., & Singh, N. K. ,"Railway Track Crack Detection Vehicle." ,International Advanced Research Journal in Science, Engineering and Technology (IARJSET), 4(2), (2017)

[5] Vijayakumar, K., Wylie, S. R., Cullen, J. D., Wright, C. C., & Ai-Shamma'a, A. I., "Noninvasive rail track detection system using Microwave sensor". In Journal of Physics: Conference IOP Publishing. (2009), Series (Vol. 178, No. 1, p. 012033.

[6] Aswinth Raj(2015) circuitdigest, tech article [Online]. Available: https://circuitdigest.com/article/16x2-lcd-display-module-pinout-datasheet

[7] (2021)store.arduino.cc, arduino-uno-rev3- techspecs, [Online]. Available: https://store.arduino.cc/usa/arduino-uno-rev3

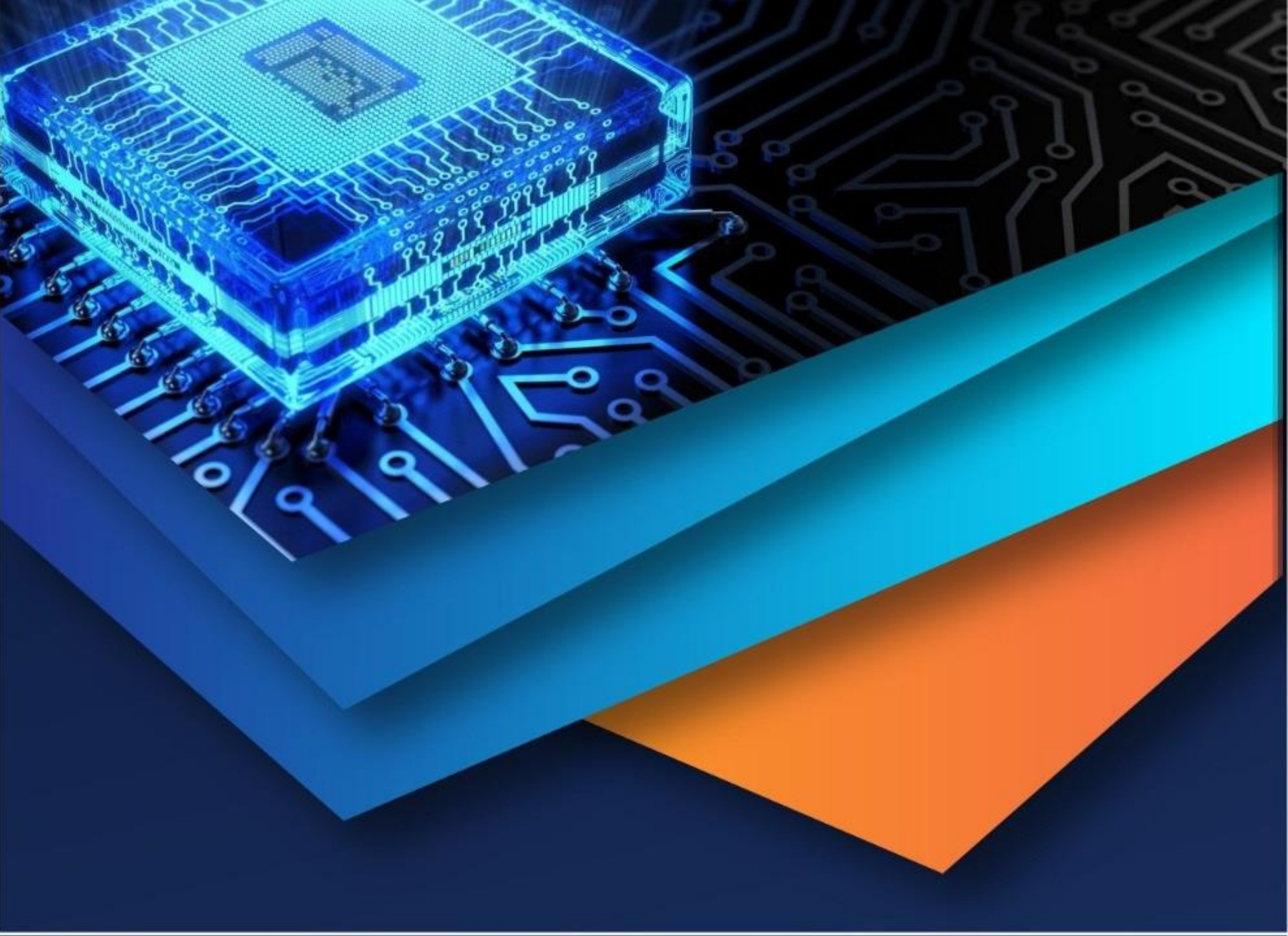
[8] (2021)techspecs, [Online]. Available: https://components101.com/modules/neo-6mv2-gps-module.

[9] Technical Specification and Special Technical Conditions for Procurement of Six numbers Self Propelled Ultrasonic Rail Testing (SPURT) Car (Specification No. TM/HM/SPURT/403 of 2017) by Government of India, Ministry of Railways.

[10] Rao, C. M., & Jaswanth, B. B. "Crack sensing scheme in rail tracking system." International Journal of Engineering Research and Applications, 4(1), 13-18, (2014)

[11] Nathan Kelly(2009) Executive Summary [Online]. Available: https://www.egr.msu.edu › fall09 › group05 › docs-"A Guide to Ultrasonic Sensor Set Up and Testing."

---------------------------------------------x--------------------------------------x---------------------------------------




10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429


# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY