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Arduino based Crack Detection on Railway Track

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ABSTRACT: Train accidents, though less common compared to road incidents but can result in serious injuries and even fatalities. Often, these accidents stem from minor cracks in railway tracks or missing track. Therefore, the goal is to establish a system capable of proactively detecting these issues to prevent potential disasters. The project focuses on detecting faults in railway tracks, aiming to create a system proficient in identifying cracks or other irregularities. An ultrasonic sensor, operated by an Arduino UNO board, is utilized for this purpose. When a defect is detected, the sensor sends a signal to the Arduino UNO board, activating the relay module to apply brakes and halt the train engine promptly. Simultaneously, the GSM module sends a notification to the control room and transmits the precise location using GPS. This project aims to enhance railway safety by proactively detecting faults and keeping the railway department informed about the track's condition. The integration of advanced technologies, such as ultrasonic sensors and real-time communication modules, emphasizes a preventive approach to improve railway safety.

KEYWORDS: Arduino UNO board, Ultrasonic sensor, Crack detection, Cost effective, IoT.

I. INTRODUCTION

The recent Indian railway network has a track length of 113,617 kilometers (70,598 mi) over a route of 63,974 kilometers (39,752 mi) and 7,083 railway stations. It is the fourth largest railway network in the world [1]. However, in terms of the reliability and safety parameters, we have not yet reached truly global standards [2]. Despite its vast reach, there are areas where improvements are needed for reliability and passenger safety. Utilizing new technologies could help mitigate the risks associated with railway hazards. With frequent use, cracks have begun to appear on the tracks, often going unnoticed due to insufficient monitoring, potentially leading to serious accidents. Recent studies reveal that more than a quarter of the tracks require replacement due to these cracks. Manual detection of tracks is cumbersome and not fully effective owing to much time consumption and requirement of skilled technicians [3]. Thus, there is a need for an automated system capable of detecting cracks and missing sections, promptly notifying railway authorities to facilitate quick maintenance and ensure passenger safety. The aim is to design a detection system for crack in railway track using Microcontroller, ultrasonic Sensors which detects the cracks along its path. Ultrasonic sensor detects the crack and objects and sends this information to the microcontroller and stop the train immediately [4].

So, here we have an automated railway crack detection system. It operates using an ultrasonic sensor to spot cracks along the tracks. When a crack is identified, the Arduino UNO board triggers the relay module to apply brakes, swiftly stopping the train engine. Next, the Arduino sends a message to a designated number, saying "crack detected," with the help of GSM module along with the current location obtained from the Global Positioning System (GPS). This section mainly consists of GPS module which is used to find the exact position of the crack and GSM modules for transmitting the information to railway authority [5]. The system halts either when manually stopped or when a crack is detected.

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The proposed system uses ultrasonic sensors to detect cracks on railway tracks, the ultrasonic sensor transmits the ultrasonic waves constantly from its sensor head on every occasion an obstacle comes ahead of it, the ultrasonic waves are reflected lower back from an item and that facts is passed to the microcontroller [6].

II.PROBLEM OCCURING

The main problem was the lack of cheap and effective technology to detect problems in the tracks and of course the lack of proper maintenance of the tracks, which caused the formation of cracks in the tracks [7]. Similar problems were caused by antisocial factors threatening the safety of railway traffic. In the past, this problem has caused several derailments resulting in many casualties and property. In the past, railway track cracks were identified as the main cause of derailment, but there were no cheap automated solutions available for testing.

Derailment is one of the most common causes of the most expensive and dangerous derailments in the world. Considering derailments in general, the United States alone averages more than one major derailment every three days, consistently for more than a decade.

Fig. 1 Crack in Railway Track

III.PROPOSED SOLUTION

This system involves the design of a crack detection robot that looks for cracks in railways. This system uses a sensor to interact with the track and detect cracks. The sensor detects fluctuations in the period of returning of wave representing crack which then sends a signal to the microcontroller. The microcontroller monitors the difference in returning period to the set value of time to ensure the existence of crack. Our concept addresses one cost effective method to prevent train accidents by formulating solutions to find cracks in the railway.

It offers a cost-effective solution for the crack detection using AT mega microcontroller, ultrasonic sensors, relay, IoT tool for reliability, repeatability, and easy implementation. The basic idea remained very simple. ultrasonic sensors are used to detect cracks. An IoT service is used to find the current location of the detected crack and to transmit the received data. Use of this message has been wirelessly sent to the proper authority that a crack has been detected, so they will immediately track the exact location of the track defect to save many lives. The system is connected to the microcontroller using DC relays and transistor.

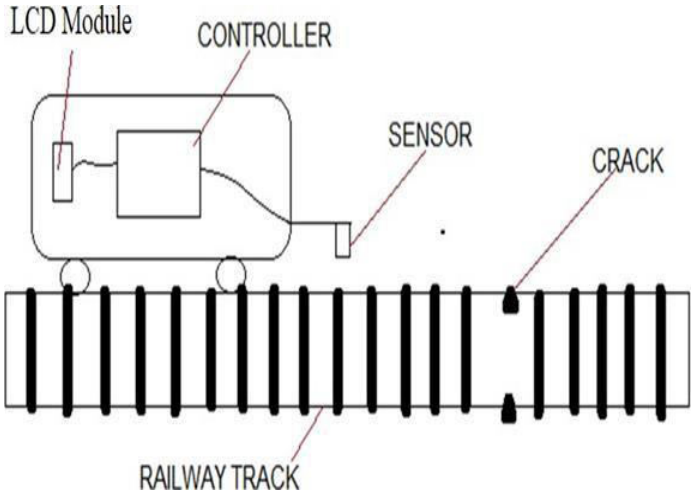

Fig. 2 Experimental Diagram

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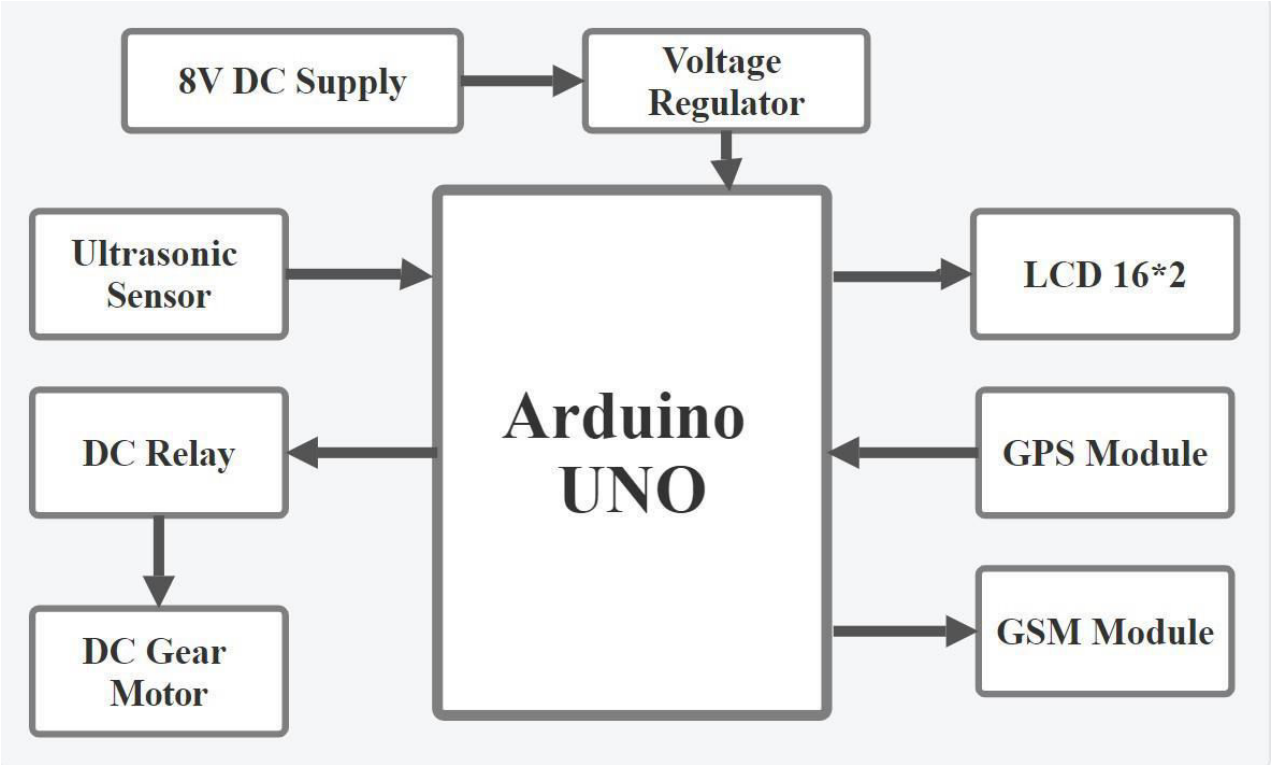

Fig. 3 Block Diagram

IV. DESCRIPTION OF COMPONENTS

For making the working model to detect cracks on the railway track, following components are used:

i. **Arduino UNO:** The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2010 [8]. It provides the platform for interfacing components with each other. The board has sets of digital and analog input/output (I/O) pins that can be connected to various expansion cards (shields) and other circuits. The board has 14 digital I/O pins (six PWM outputs), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment) via a USB Type-B cable.

Fig. 4 Arduino UNO ATmega328P

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ii. **Power Supply:** The crack detection system is powered by a DC power supply unit that provides stable voltage and current to the Arduino microcontroller and sensors, for these two rechargeable batteries of 4V each is connected in series and for supplying power to DC motors separate battery of 9V is been used.

iii. **Liquid Crystal Display:** This device can be used to display any messages, status or can also be used for debugging. In this project, it indicates the state of the system that track is right condition and will also notify the individual whenever the crack is been detected.

Fig. 5 LCD 16*2

iv. **Voltage Regulator:** LM2596 is a DC-DC step-down converter with the high-precision potentiometer, capable of driving a load up to 3A with high efficiency, which can work with an Arduino nano, Arduino UNO, other mainboards, and basic modules [9]. Here, it is used to step down DC supply of 8V to 5V to provide supply to all components except Arduino uno.

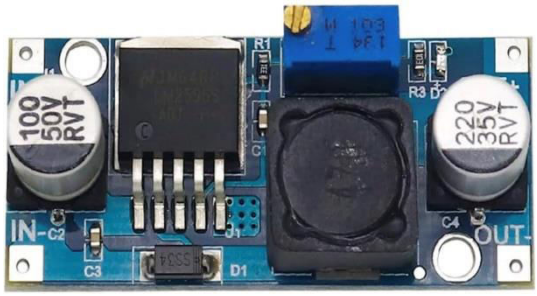

Fig. 6 Voltage Regulator

v. **Ultrasonic Sensor**: Ultrasonic sensor is an electronic device that calculates the distance between the target and the sensor by emission of ultrasonic sound waves. It mainly consists of two components named as transmitter and receiver.

To know the distance between the target and the sensor, the sensor calculates the amount of time required for sound emission to travel from transmitter to receiver. The calculation is done as follows:

D = 1/2 T * C

Where ‘T’ corresponds to time measured in seconds

‘C’ corresponds to sound speed = 343 measured in mts/sec [10]

So, for the crack detection on railway track by using ultrasonic sensor, the distance between track and sensor remains constant including period of ultrasonic wave returning to the receiver, but whenever there is any crack on the railway track, the returning time of ultrasonic wave will exceed the given limit which will indicate the increased distance between track and sensor representing crack on the railway track.

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Fig. 7 Ultrasonic Sensor

vi. **DC Relay:** Relay is a kind of electro-mechanical component that works as a switch. The relay coil is energized by DC such that contact switches can be opened or closed. A single channel 5V relay module generally includes a coil, and two contacts like normally open (NO) and normally closed (NC) [11]. A 5V DC relay is an automatic switch that is commonly used in an automatic control circuit and to control a high-current using a low-current signal. The input voltage of the relay signal can range from 0 to 5V. Role of DC relay in this project is to interrupt the circuit of the DC motor whenever any crack is been detected on the track by the ultrasonic sensor. So, after the detection of crack, the Arduino with the help of PNP transistor will send the signal to the DC relay to trip the circuit for the DC motor to stop the vehicle.

Fig. 8 DC Relay

vii. **DC Gear Motor:** A DC motor is an electrical machine that uses electricity and produces mechanical power. Normally, the output of the motor is the rotary motion of the shaft. The mechanism of a DC motor is like a wire-twisted rod placed between two north and south pole magnets. The stretched wire is energized, resulting in a rotary motion that results in a rotary output. DC is motor in this project is been used to move the vehicle in forward direction for the monitoring of the track. For supplying the power to motor we have used a separate battery of 9 volts other than the battery which is being used for supplying power to the other components.

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Fig. 9 DC Gear Motor

viii. **GPS Module:** The Global Positioning System (GPS) is a satellite-based navigation system. consisting of at least 24 satellites. GPS works in all weather conditions, anywhere in the world, 24 hours a day with no subscription or installation fees. The Global Positioning System works when GPS satellites transmit "a unique signal and orbital parameters that allow GPS devices to decode and compute the precise location of the satellite [12]." The aim of GPS module in this is project is to determine the exact location of the place where crack is been detected, and this is been done by estimating the latitude and longitude of that location while also including the link of the google maps which is then been shared with the necessary authorities.

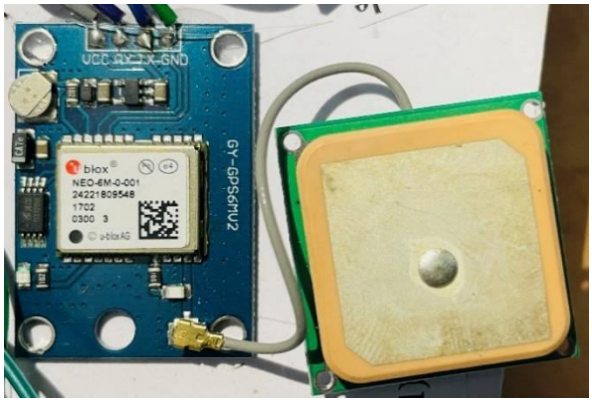

Fig. 10 GPS Module

ix. **GSM Module:** GSM (Global System for Mobile Communications) or a GPRS module is a chip or circuit that is been used to establish communication between a mobile device or a computing machine and a GSM or GPRS system. The modem is a critical part, as these modules consist of a GSM module or GPRS modem powered by a power supply circuit and communication interfaces (like RS-232, USB 2.0, and others) for computers [13]. The main motive behind using a GSM module is to transfer the information of crack detection and the location of crack to the control center wirelessly so any immediate action should be taken to fix the crack as soon as possible to prevent any kind of accident.

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Fig. 11 GSM Module

V. WORKING

The model has an Arduino board that acts as an interface between ultrasonic sensors, GSM, GPS, DC relay and the LCD screen. The entire system is integrated with a four-wheeled LCD robot/vehicle that moves between tracks. The robot is programmed to move forward while triggering ultrasonic sensors attached to the left, right to the front side of the track to detect any cracks on the railway track. The Arduino is programmed with the Arduino UNO and connected to various devices such as the DC relay, GPS, GSM, and the DC motor that is needed to move our vehicle back and forth, GPS module to detect the latitude and longitude of the crack, GSM module to send information of crack and location through SMS to higher authorities, ultrasonic sensor to detect cracks, DC relay to interrupt circuit whenever crack is detected on the track. Block diagram of a project works on the following process: -

1. Initially, the tracks are continuously monitored with the help ultrasonic sensor to detect cracks on the track.

2. When a crack is detected by the ultrasonic sensor, it sends a crack detected alarm to the Arduino microcontroller.

3. After receiving the crack detection warning Arduino sends signal to DC relay with help of PNP transistor to interrupt the circuit to stop the vehicle.

4. As soon as circuit is interrupted the GPS module comes in act to calculate the latitude and longitude of the location where crack is been detected.

5. After the estimation of location of the crack, this location is been sent to the control room with the help of GSM module.

6. After the SMS is sent to the control room, the warning should be heeded and important steps should be taken to avoid future accidents and mishaps which may result in loss of life and serious injury.

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The figure shown below is the circuit diagram of the prototype showing the interfacing of all the components with Arduino and DC motor.

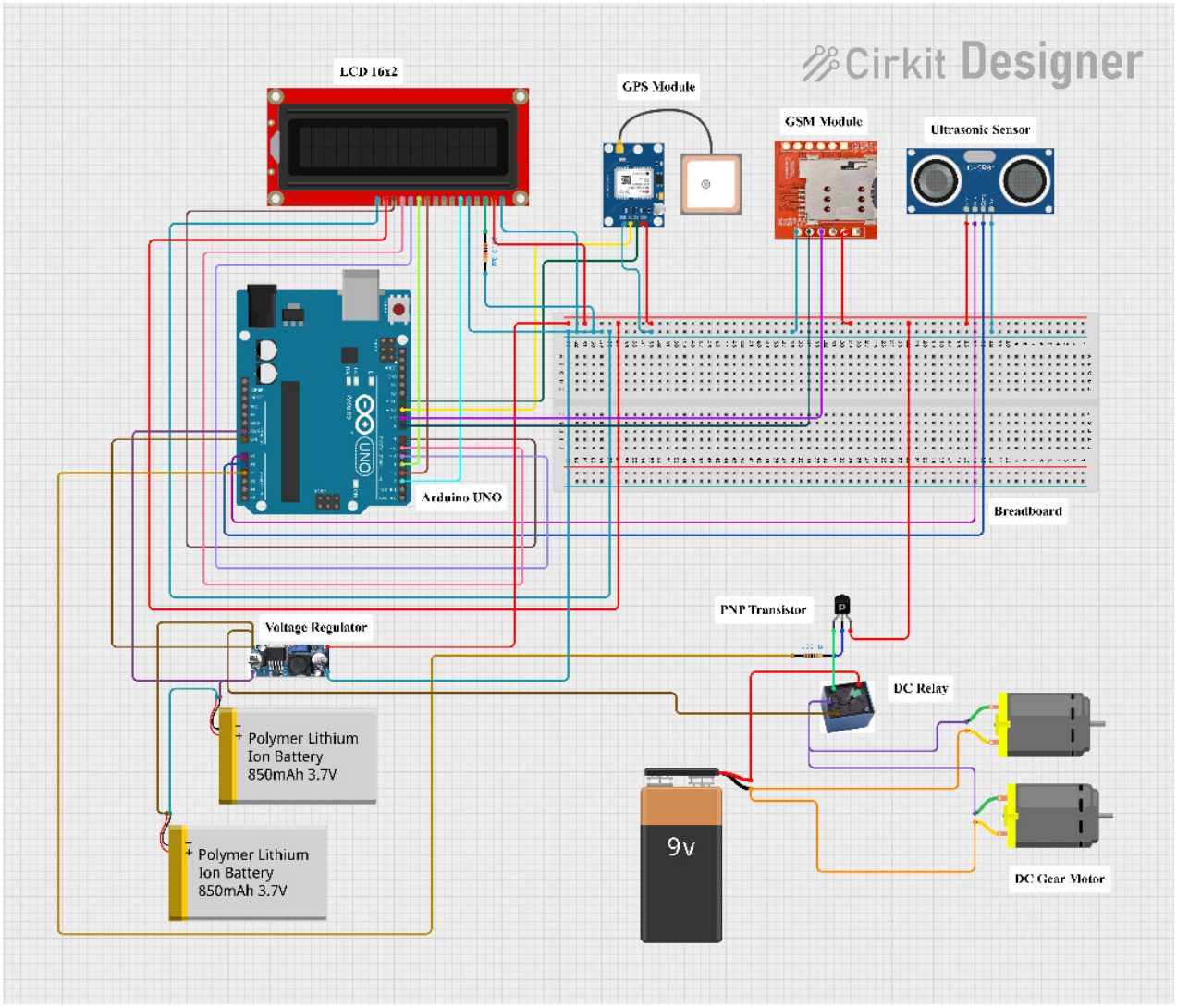

Fig. 12 Circuit Diagram of the Prototype

VI. RESULT

The aim of the "Railway Track Crack Detection using Arduino" project is to detect cracks on the railway with an Arduino microcontroller. The ultrasonic sensor detects the distance between the sensor and the rail, and significant variations in this distance indicate that there is a crack in the rail. The system then informs the Railway Board through the GSM module and informs the exact location of the crack so that they can take necessary measures to fix it and avoid accidents. The project succeeded in detecting cracks with high accuracy and can greatly improve railway safety.

- LED screens show relevant information about situations according to the reaction of the controller.
- Control facilitates the driver's work and allows the engines to move.
- The GPS module successfully estimates the correct location of the crack after its detection.
- The GSM module is activated and it sends a message to the nearest stations, instructing them to take the necessary actions including the location of crack.
- The sensors are switched on and can reliably detect cracks or obstacles.
- If a crack is found, the word "Crack detected" appears on the LED display.

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The following figure shows the cracks detected or estimates found on the Arduino display screen as follows:

Fig. 13 Display showing crack detected by ultrasonic sensor including its depth

The following figure shows the text messages, carrying information about the location of the crack is successfully been received at the other end where they were designated to be received.

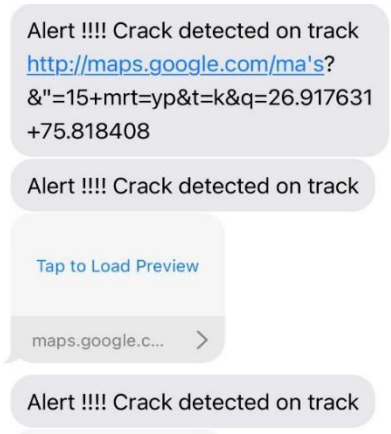

Fig. 14 Information received via SMS

The next figure shows the final model compromising of all the hardware mentioned above. All these hardware has been interfaced with each other through the Arduino and works as per the requirement. The figures shown above concludes the successful functioning of the project.

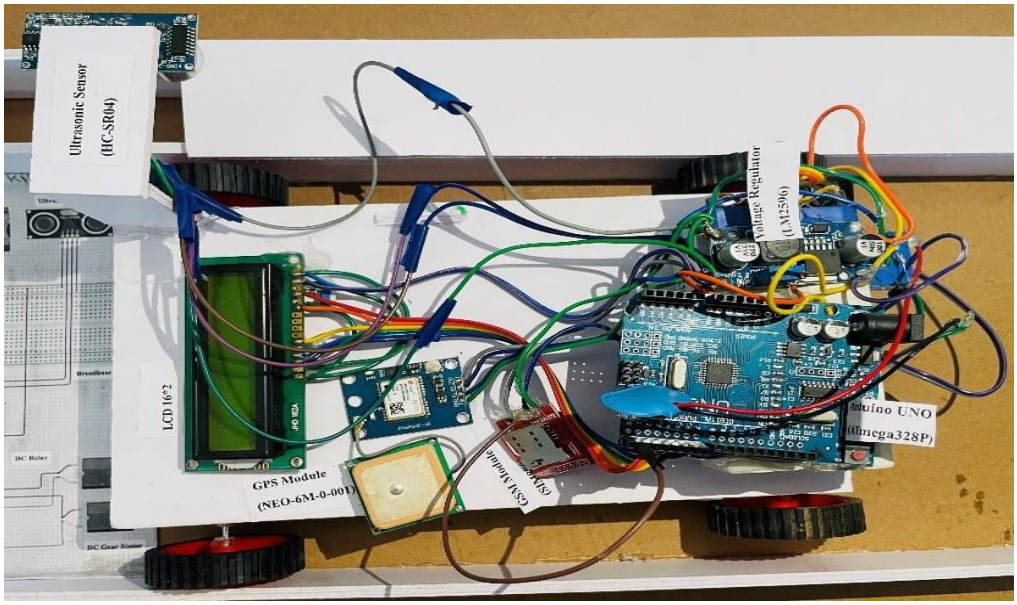

Fig. 14 Working Model

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VII. CONCLUSION

The proposed Arduino-based railway track crack detection system can detect rail cracks, including small cracks, automatically without human intervention. The proposed system has many advantages over traditional detection techniques. Advantages include a fast detection and reporting system, lower cost, low energy consumption and shorter analysis time. Also, the easy availability of components and the simplicity of the idea make the proposed system ideal for large-scale implementation with very small initial investments. Therefore, it can work effectively and efficiently under working conditions. With this proposed structure, we can easily avoid the accidents caused by rail side crack, which will help us save many lives. As part of this project, we developed a cost-effective, low-power embedded system that enables tracks to achieve better safety standards to prevent accidents caused by cracks and obstacles. The prototype railway model under test can effectively detect cracks and obstacles in the rails. The result shows that this new innovative technology increases the reliability of railway safety systems. By implementing these functions in a real-time application, we can avoid accidents up to about 70%.

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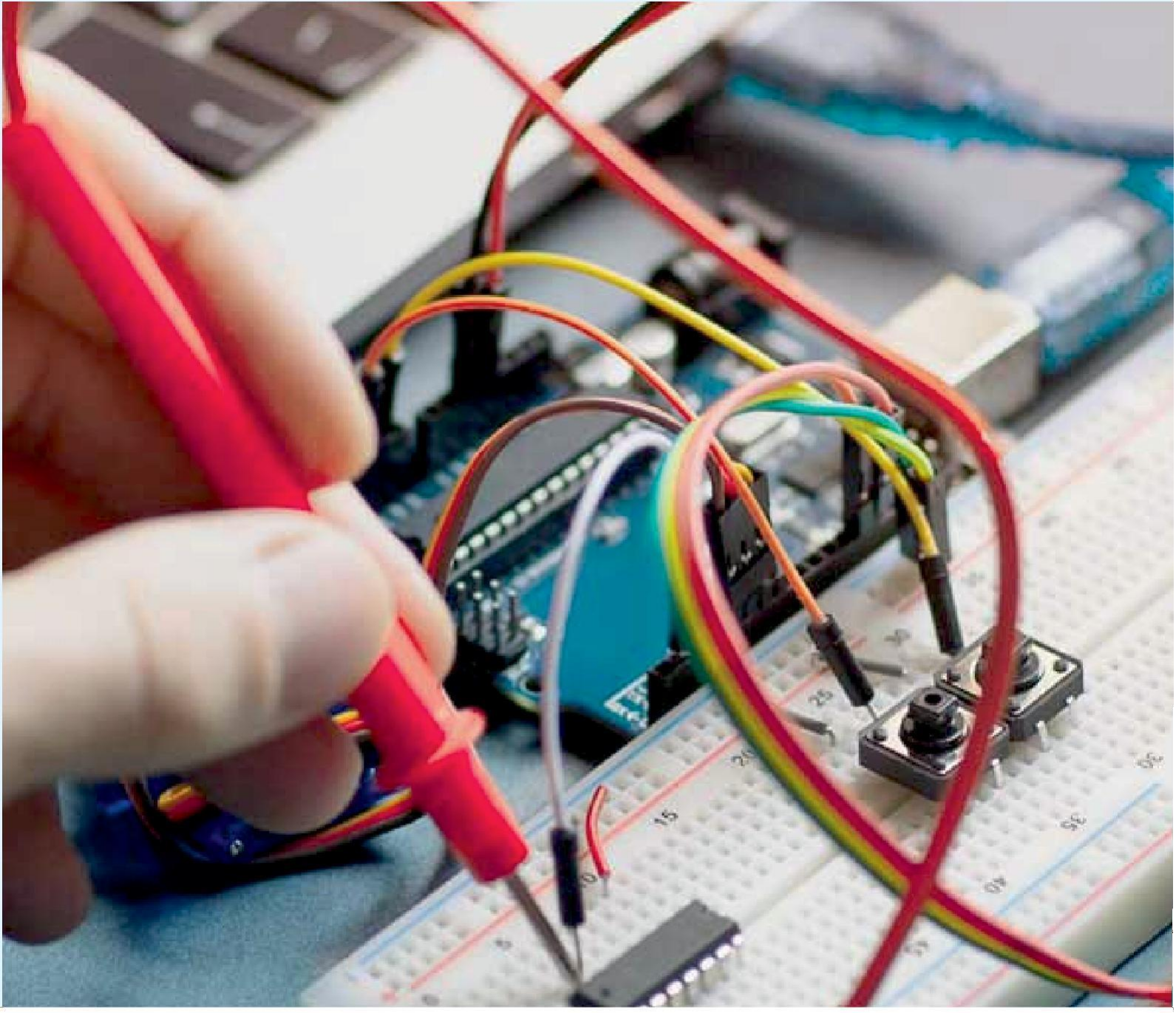

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