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AI based Solar Powered Railway Track Crack Detection and Notification System with Chatbot Support

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***Abstract*—India is one of the fastest developing countries with significant advancement in the field of the railway network. There have been several incidents of railway accidents due to derailments caused by cracks in the railway track. These cracks generally go unnoticed due to irregular maintenance and manual track monitoring. In this work, we have proposed an solar powered autonomous vehicle called "Rail- Rakshak" for inspecting and detecting cracks in the railway line. The proposed robot moves along the path and detects the cracks. The exact location of the cracks is sent to the concerned authorities. The proposed robot leverages the concepts of Cloud Computing and Natural Language Processing (NLP) for better visualization and interaction with the robot.**

***Index Terms*—Railway, Solar Powered, IoT, Ultrasonic sensor, Arduino UNO, GSM Module, Chatbot Client.**

I. Introduction

The Indian Railway network is the fourth largest in the world with a route length of 67,368 Kilometers (41,861 mi), a total track length of 121,407-kilometre (75,439 mi) and 7,349 Railway stations. In comparison to the international standards, the Indian railway networks lacks the safety infrastructure causing frequent derailment resulting in severe loss of human lives. In the year 2016-17, India has seen the highest death toll in the decade due to derailments and out of which 90% were due to cracks in the railway tracks[1]. Henceforth, there is a necessity to address this issue of crack detection in railway tracks with the utmost care due to the frequency of the usage of railway lines.

Due to the manual railway line monitoring and irregular maintenance, there is a high chance that these cracks are generally overlooked. Hence, there is a need for automated systems to inspect and detect the cracks in the railway lines. Most of the existing systems are equipped with Light Dependent Resisor(LDR) and Light Emitting Diode(LED), the drawbacks with these kinds of systems are the sensors need to be aligned opposite to each other to detect the cracks. In our work, we have used a single module ultrasonic sensor, which has both transmitter and receiver solving alignment issues. We have extended the utility of the proposed system by providing remote monitoring and controlling capabilities via a Chatbot. The main objective of our work is:

- To send and receive messages from Arduino using GSM Module.
- To send location coordinates taken from GPS Module to the user using Arduino and GSM Module.
- To build Chatbot for visualising and interacting with Arduino from a remote location using a mobile phone.
- To build solar-powered 4 wheeled robot with an attached ultrasonic sensor.

The remaining part this paper is organized as follows, Section II highlights various national and international works done in the domain of railway track crack detection and provides a basic idea on problem and its variety of solution solutions. Section III, discusses details of proposed system and expected outcome, while Section IV provides details on implementation of proposed system with respect to required hardware, connection and algorithms. Section V highlights the results of implemented system and its working under different scenarios is tested. Finally Section VI provides conclusion and future work to enhance to the proposed system.

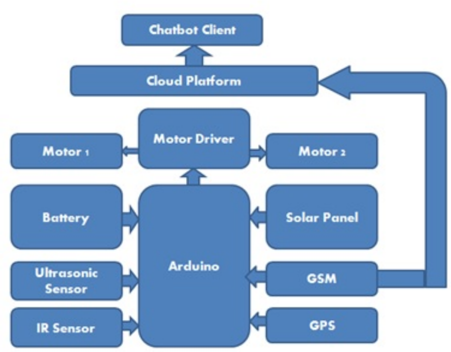


Fig. 1: Proposed System for Rail- Rakshak: Railway Track Crack Detection

[1]https://www.news18.com/news/immersive/indias-train-mishaps.html

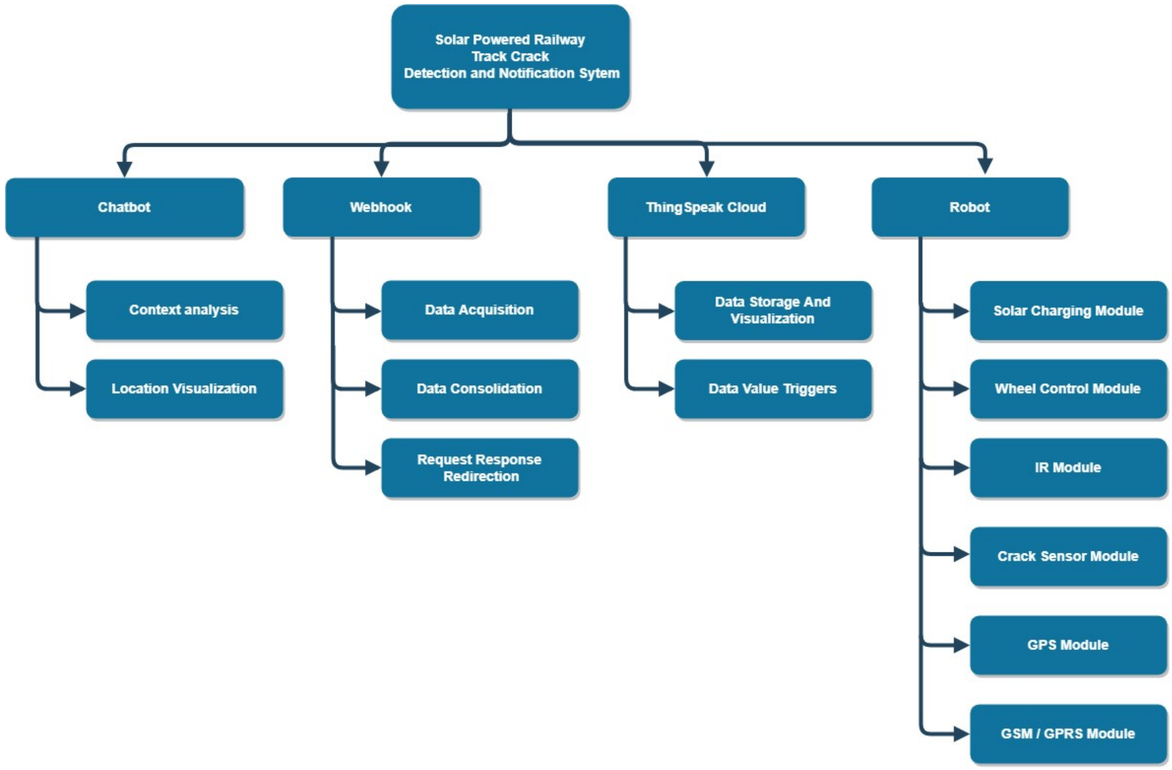


Fig. 2: Modular Architecture of Proposed System

II. Literature Survey

Over the period, there has been a significant contribution by researchers in building up a system for tracking the cracks in the railway tracks. Krishna et al. [1] proposed a system for monitoring the cracks by applying IR Technology and send the details through Bluetooth. But, the Bluetooth technology is not practical for long-range communication. Few researchers have used the GSM module for sending the information and infrared IR module for inspecting the cracks [2] [3] [4]. Nevertheless, there is a chance that the IR sensor might detect minute cracks which may not be dangerous for the trains and causing an unnecessary burden. Anand et al. [5] used the operational amplifier for detecting cracks by varying the output voltage in the operational amplifier. However, there is a chance of false alarm due to the noise in the railway line. Mohan et al. [6] surveyed on Image detection based railway crack detection. The image detection method is useful to detect the cracks. But, there is a necessity of higher-end cameras for detecting cracks in the night.

Benefits from popular technologies such as IoT and Cloud Computing [7] can be leveraged to design more robust and flexible Railway Track Crack Tracking Systems. By using web services [8] exposed by various platforms can be integrated to build quick solutions for complex problems. Paper [9], provides an insight on building chat-bot for desired IoT application. The design and implementation of the proposed system is inspired from these works and an attempt is made to bring best of these works together.

III. Proposed Methodology

The proposed vehicle detect cracks in its path and is able to identify the location of crack through the GPS Module. The micro-controller is used as a controlling functions to orchestrate communication between sensors, actuators and cloud. The proposed system has to be mobile and hence usage of dedicated on-board rechargeable Li-ion battery is proposed. As the system has to sustain for longer operational time, it has to have capability to harness Solar Energy. The movement of proposed robot is controlled by motor driver connected to the micro-controller. IR sensors are used to detect the obstacle as well as to provide theft alert. Ultrasonic sensors are deployed for detecting distance between track surface and robot, which is used for finding abnormalities in track. Once identified, the proposed robot must halt and communicate to cloud the location co-ordinates obtained by GPS module. Following which the location coordinates are sent in the form of telegram message to the predefined mobile number using the on-board GSM Module. The Cloud platform is used to communicate all the sensor data and GPS coordinates to the Chat Bot. The proposed system for the Railway Track Crack Detection is shown in Fig. 1. Name of the proposed system is ”Rail-Rakshak” meaning ”the protector of railway tracks” which combination of ”Rail” referring to the system of train tracks and ”Rakshak” which stands for protector in Sanskrit.

As shown in Fig. 2, the proposed system is divided into 4 sub-modules. Namely as Chatbot, Webhook, Cloud and Robot. The chatbot will handle message context understanding and intelligent replies, as well as; it would provide an interface to visualize the location coordinates of the robot. Webhook will request respective services either from chatbot or from cloud depending on nature or request, and It works as a bridge between Cloud and Chatbot. The Cloud is IoT Cloud Service provided by Mathworks, Inc. This platform will be used to store data from the robot and also to initiate requests to the user based on conditions. The Module is Robot, which would have several sub-components such as managing solar power and regulating its power across the robot. It will also have sensors such as, Infrared Sensor, Ultrasonic Sensor, Positioning Module and Communication Module, which all will be interlinked to form the complete robot.

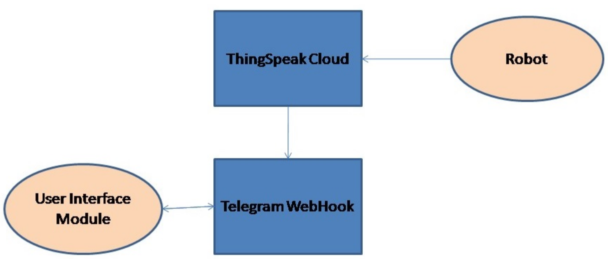


Fig. 3: DFD of the overall system

Fig. 3 shows Data Flow Diagram (DFD) for the overall system. It consists of main modules of system. User Interface Module (Chatbot), Webhook, Cloud Platform and Robot. Each module is further divided into sub modules out of which sensing and processing of data at robot is of major importance.

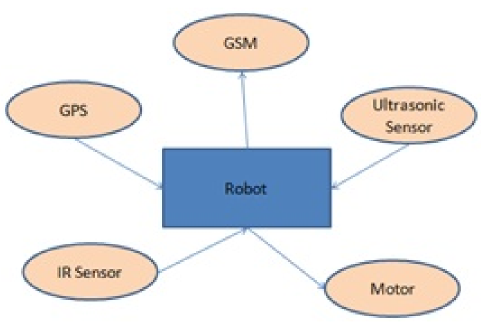


Fig. 4: DFD of Sub-Modules

Fig. 4 shows sub modules of Robot module and their workflow. Here the Robot Processing Module takes input from IR Sensor, Ultrasonic Sensor and GPS Location. It processes the data and responds to motor and updates data over cloud using GSM module.

In this section we have explained the proposed sequence of events that would happen in our system. The sequence can be understood in two sub sequences, each as a part of different type of scenarios.

- **Robot Initiated:** The sensor data received by robot will be continuously compared with standard value of distance between robot and track. In case if this distance is more, specific value would be sent to Cloud Channel Field. Based on the value a request will be generated and posted to webhook which depending on type of request will redirect related message to user via telegram.
- **User Initiated:** At any time, if user requests for getting current status of robot a request will be sent to webhook. Which will reframe the request in format and request for providing the most recent value of the request field.

The proposed system flow is divided into three interactions. Sensors-Robot Interaction, Robot-Cloud Interaction and Cloud-Chatbot Interaction

- **Sensor - Robot Interaction:** As shown in Fig. 5, the arduino will be connected to various sensors and actuator. The entire system will be powered by external power source which will be connected to solar panel. As soon as Arduino starts it will run Setup() to initialized all the variables and functionalities of each pins. Under Loop() function, the arduino will keep checking values of IR Sensor and Ultrasonic Sensor. If the IR sensor is block because of some obstacle, robot will stop, a flag will be set and same will be updated on cloud. Similarly if Ultrasonic sensors detects variation in track pattern then robot will stop a flag will be set and will be updated on cloud. If both cases fail then robot will keep moving forward.

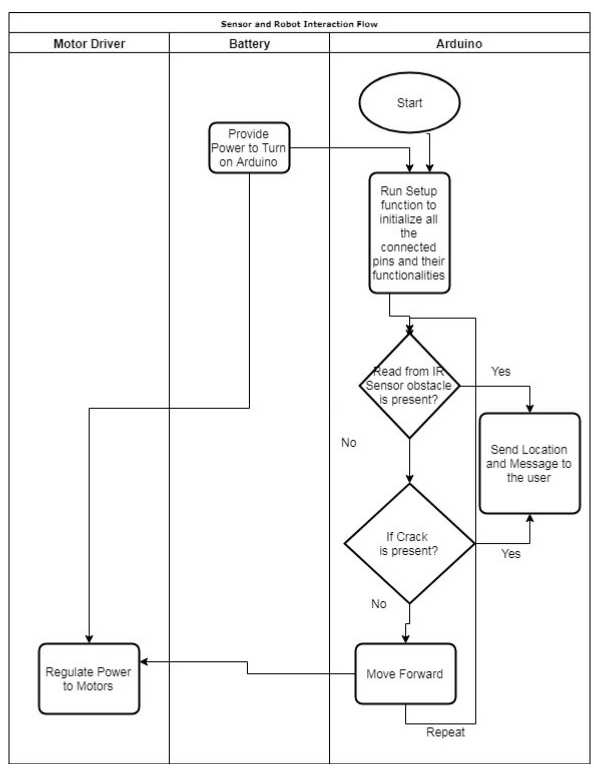


Fig. 5: Sensors-Robot Interaction Flow

- **Robot - Cloud Interaction Flow:** As shown in Fig. 6, As soon as the robot is power on, the GPS module and GSM module will also turn on. GPS module will perform initialization to connect to GPS Satellites. And

GSM Module will try to connect to subscriber service provider. The received data from previous interaction will sent to Cloud via GSM. A specific HTTP request will be generated with the observed value of sensors and location provided by GPS. This HTTP request is then sent to Channel where each field will get updated with the received values.

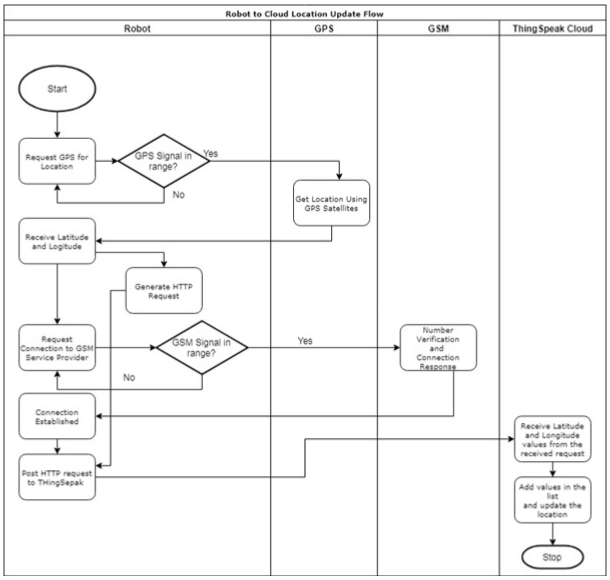


Fig. 6: Robot- Cloud Location Update Flow

- **Cloud-Chatbot Interaction Flow:** There are two possible ways of interaction flow. It could be Robot Initiated or User Initiated. In both case User and Robot can presume the role of both subscriber and publisher. As Shown in Fig. 7, if crack or obstacle is detected by robot, a specific flag will be set and it will be updated on cloud. It will then request user for further instructions and only based on instructions provided by user new values will set on Channel. On the other side, since robot is subscriber of this channel, it will read the specific value and perform predefined operation. In other scenario if user wants to know any information regarding robots location or values detected, a request will be sent to Cloud via webhook which will in turn respond with request values in the format defined by webhook.

IV. Experimental Setup

For implementation of proposed system, combination of different programming languages and design skill is needed. Thus, the Implementation is divided in 3 parts namely as Hardware Interfacing and Component Placement, Sensor Calibration and Testing and Data Acquisition and Notification.

A. Hardware Interfacing and Component Placement

This section highlights various hardware components and its interfacing with Arduino UNO. This section can be sub divided based on different hardware components used.

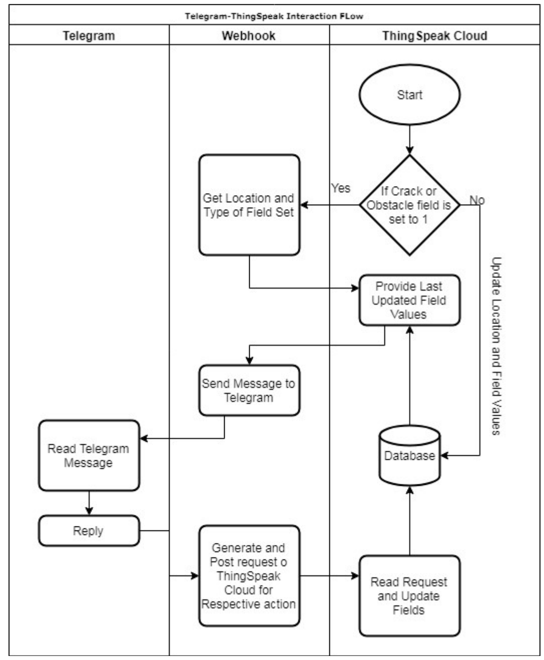
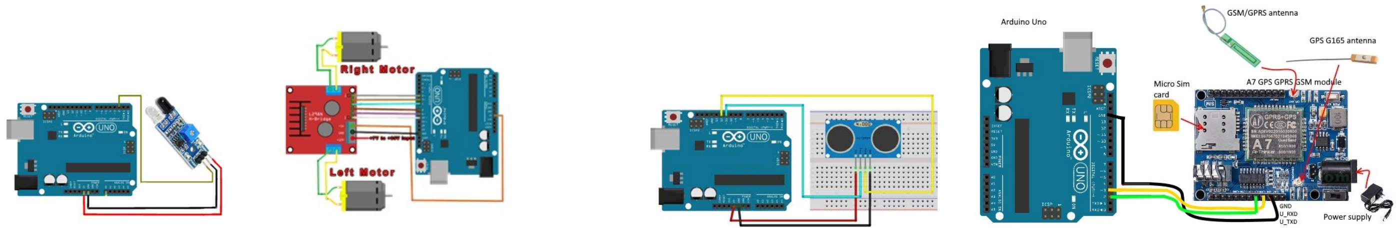


Fig. 7: -Telegram Interaction Flow

- **Arduino UNO:** Arduino is world's most popular open source programmable board due to which it supports lot of customization. For implementing our proposed system arduino will work as Central System for Decision making with respect to Sensed Data by sensors. It will also perform first level of data pre processing which later will be stored on cloud.
- **IR Sensor - Arduino:** As shown in Fig. 8a, an IR Sensor is connected to Arduino UNO. VCC and GND pin of IR Sensor is connected to 5v and GN of Arduino respectively. This completes to circuit and powers IR sensor. IR sensor consists of an IR transmitter and IR receiver. Transmitter transmits IR light and if it gets reflected back then IR receiver will receive it and an obstacle is detected. The output pin of IR sensor is connected Pin 2 of Arduino which is set as input. In the proposed system, IR Sensors are used to detect presence of obstacle in front of the robot and for detecting if the robot is on track or not.
- **Motor Driver - Arduino:** As shown in Fig. 8b, a motor driver is connected to arduino. This allows controlling speed and direction of motor. These connected DC motors require more power for operation compared to output provided by Arduino, hence an external power source is used. Motor driver takes 4 inputs from arduino, 2 for each motor. Depending on which pins are set to high and low the direction of motor changes.
- **Ultrasonic Sensor - Arduino:** Fig. 8c, shows connections for Ultrasonic sensor and Arduino. The working principle of ultrasonic sensor is similar to IR Sensor except an ultrasonic sensor provides distance between obstacle. It uses a trigger and echo pin to send and



(a) IR Sensor - Ardino Connection (b) Arduino - Motor Driver Connection (c) Arduino - Ultrasonic Sensor Connection (d) 5.5 GPRS+GSM+GPS A7 Ai-Thinker module - Arduino Connection

Fig. 8: Hardware Interfacing

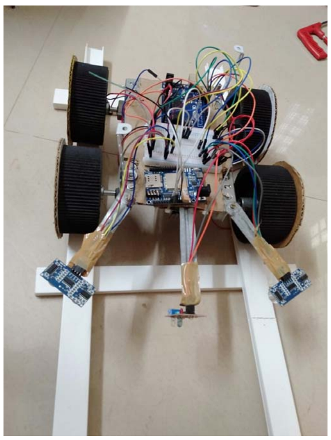


Fig. 9: Final Assembled Robot

Name:	ObstacleDetected
Condition Type:	Numeric
Test Frequency:	On data insertion
Last Ran:	2019-03-23 02:54
Channel:	RailwayCrackTracker
Condition:	Field 1 (Obstacle) is greater than 0
ThingHTTP:	ObstacleDetectedMsg
Run:	Each time the condition is met
Created:	2018-09-06 1:25 am

Fig. 10: React (Obstacle Detected) for FrontIR Field

receive ultrasonic pulses. Based on the time taken to receive pulses and speed of sound in air, distance from the obstacle is calculated. This is really useful to determine cracks in the railway track.

- **A7 Module - Arduino:** Fig. 8d shows connections between GPRS+GSM+GPS A7 Module with Arduino UNO. Once the module is powered it registers the SIM card over the subscribed network and is ready for communication. Set of AT commands are used to request and respond to subscribers network. It also houses a GPS module which allows to track the location of module.

Name:	ObstacleDetectedMsg
API Key:	1A7GOB59CT202SLW Regenerate API Key
URL:	https://api.telegram.org/bot871259480:AAHT7Wrg2-wln2iQZFsgZZF9Ybq6o9gA8aU/sendMessage?chat_id=756766618&text=obstacledetected
HTTP Auth Username:	
HTTP Auth Password:	
Method:	GET
Content Type:	
HTTP Version:	1.1
Host:	

Fig. 11: ThingHTTP for ObstacleDetected React

Fig. 9 shows the final assembled robot. As there is constraint on driving power of the motors, it was important to keep all the hardware and connection within dimension of the robot. Hence, both sides of the platform are used for battery placement, motor driver, arduino, sensors and GSM module. Following table shows all the pins or arduino and its corresponding connection to different modules.

B. Sensor Calibration and Testing

Each module has to be calibrated and tested based on the requirements. Hence this section is sub divided into IR Sensor Calibration, Ultrasonic Sensor Calibration and A7 GSM+GPS Module Testing.

- **IR Sensor Calibration:** As shown in previous section, and IR sensor detects the presence of an object based on the reflected IR Light. However, the intensity of light has to be adjusted to set the threshold for object detection. Using potentiometer connected to sensor one can calibrate this value. In our proposed work it is set to 5cm. Any object closer to sensor lesser than 5cm will be detected.
- **Ultrasonic Sensor:** Unlike IR sensor, since ultrasonic sensor provides distance between the obstacle and sensor, a hardware calibration is not needed. However, by using

detected distance one can set required threshold in the code. In our proposed work, ultrasonic sensor is used to determine uneven surface of railway track. Hence by performing several trials it was observed that distance of 5.10 cm is normal for even surface and a vibration error of +/- 0.05 is allowable. Which also means that anything greater or lesser than that value will be considered as an anomaly and corresponding message will be generated.

C. Data Acquisition and Notification

In order to communicate sensed data from robot to remote user, use of IoT cloud service called is done. A dedicated channel is created over with fields dedicated for each sensor connected to robot. Field names are ”FrontIR”, ”BottomIR”, ”LeftCrack”, ”RightCrack”, ”Latitude”, ”Longitude”, ”MotorStatus”. However to send data over these fields GPRS functionality of A7 module has to be used. By using relative set of AT commands it can be achieved. Here, ”FrontIR” corresponds to data value obtained from IR sensor attached on the front of robot to detect obstacle, ”BottomIR” values corresponds to status of robot i.e., if it is on ground or lifted, ”LeftCrack” and ”RightCrack” corresponds to data value if left and right ultrasonic sensors has detected distance more than set threshold respectively.

On the other side, a telegram WebHook is created which will be called only when some preset triggers like obstacle is present or crack is detected is identified over . To achieve this functionality of React and ThingHTTP is used. React will set a watch over desired field and will trigger a HTTP request if the set condition is met. Following example shows one react trigger set for FrontIR.

As shown in Fig. 10, a react on field1 based on inserted value and for condition of greater than 0 is set. If the condition is met the ThingHTTP called ”ObstacleDetectedMsg” will be triggered. Fig. 11 shows ThingHTTP named ”ObstacleDetectedMsg” which calls a web GET request for the telegram. This will send a message to user saying ”obstacle detected”. Following screenshot shows response for the same telegram url when executed from browser.

V. Results

The final implemented work is tested for three scenarios namely as:

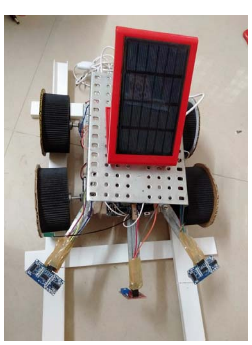
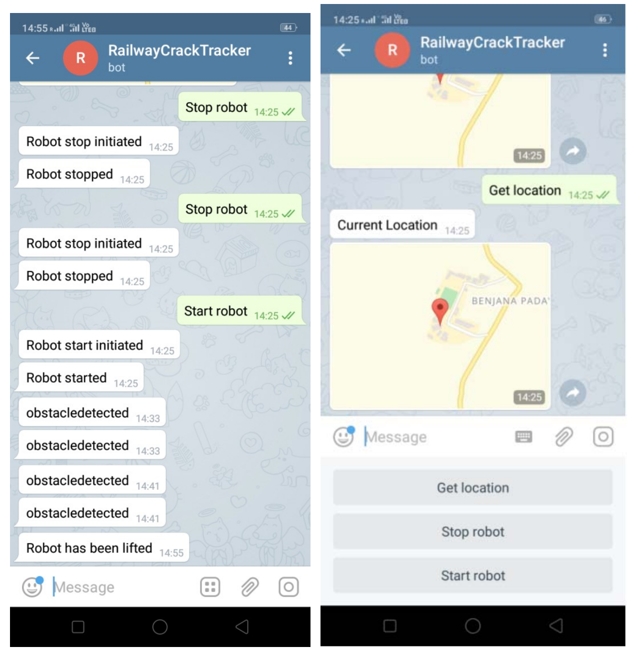


Fig. 12: Normal Working Robot (Moving)



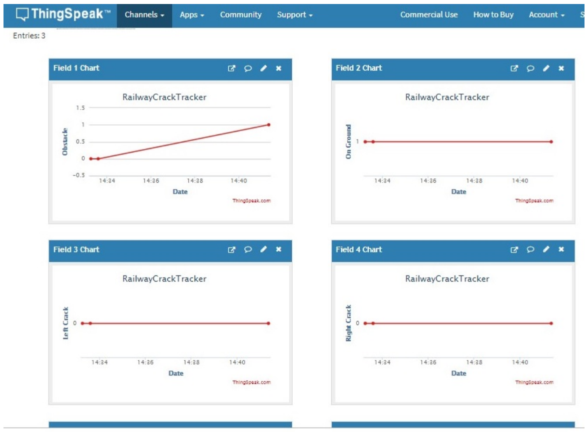
(a) Obstacle detected and Robot Lifted (b) Obstacle Location

Fig. 13: Telegram Messages

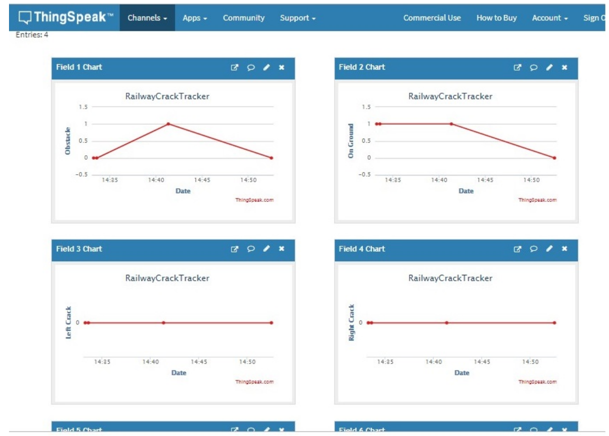
- **Normal Working:** In normal working scenario, once the robot is started it will check if it has been kept on ground or not by using bottomIR sensor. All the values will be uplaoded to cloud with corresponding location after ever 20 seconds. In this scenario the robot will be continuously moving over the track and user can request for getting the location of the robot at any point. The Fig. 12 shows the normal working of the Robot.
- **Detection of an Obstacle / Robot is lifted:** When obstacle is detected or robot is lifted, the robot will immediately stop and send corresponding value to Thingspeak Cloud. As shown in Fig. 14a, the obstacle detected field value is set to 1 when FrontIR sensor of Robot is blocked and Fig. 14b shows fields when robot is lifted. As a React is set on the particular field, a telegram message with location will be sent to user as shown in Fig. 13a and Fig. 13b.
- **Detection of Crack:** If the robot is on ground and no obstacle is present then continuous input from ultrasonic sensors is taken and based on set threshold corresponding value will be updated over cloud. Fig. 14c. and 14d shows values when crack is detected on left or right side respectively.

VI. Conclusion and Future direction

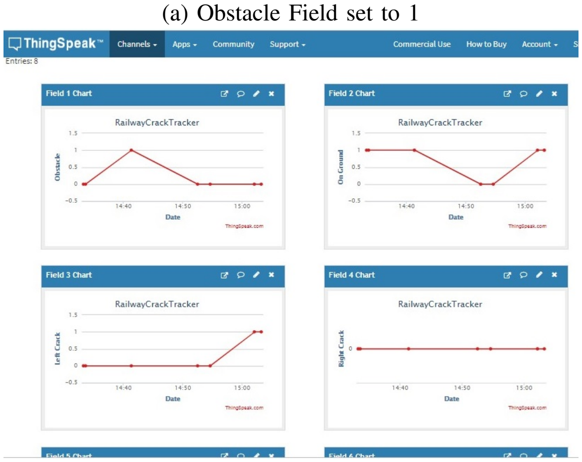
The proposed work provides a proof of concept on a solar-powered railway crack detection system. The main highlights of the proposed system is hardware interfacing of the robot with chatbot integrated into the telegram messenger. The implemented system was tested under three scenarios: normal



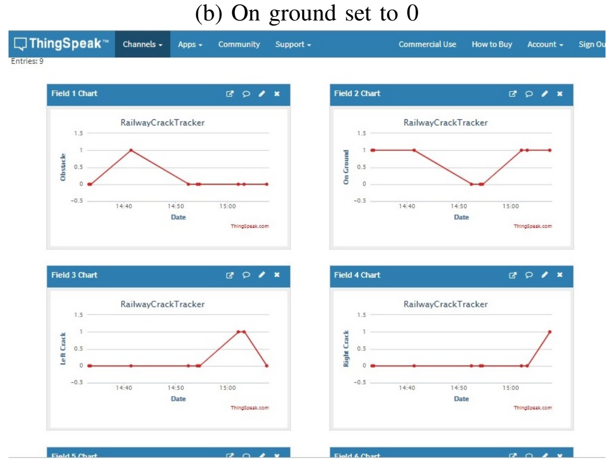
(a) Obstacle Field set to 1



(b) On ground set to 0



(c) Crack Detected on left side



(d) Crack Detected on Right Side

Fig. 14: Thinkspeak Channel Dashboard

working, detection of an obstacle when the robot is lifted, and detection od crack. In all the three situations, the robot has provided an accurate result, and exact GPS locations have been sent to user through the cloud platform.

The design can be improved to detect the damaged tracks on both the lines of the track. The proof of concept can be further scaled up to a life-size system that can be deployed in the real-world scenarios.

Acknowledgement

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