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Automatic Railway Track Crack Detection System using Ardunio C (IOT)

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ABSTRACT: This research paper and the resultant prototype are the initial outcome of the work of the authors to apply emerging learning based techniques for identification of rail track anomalies. As a divergence from the existing studies that used sonar or mechanical signals in identification of cracks that too mostly applied on robots or autonomous vehicles, this paper uses optical signals based systems mounted under the trains as an alternative approach. Deviations in the reflected optical signals are measured and interpreted on the potential cracks and appropriate alerts are generated. The system can be mounted under the train, is easy to maintain and to manage.

KEYWORDS*:* Differential Sensor, Vibration, photodiodes, detection system.

I. INTRODUCTION

Railways are regarded as one of the most suitable mass transport modes of modern times and assume critical significance in a vast country like India as it has been the backbone of the country's mobility and economy. Indian railways is the fourth largest railway networks in the world comprising 121000 KM (as at March 2017) of track length and it were to be laid out, can encircle 1.5 times of the earth. Such a huge track length poses enormous challenges for maintenance without cracks. Although we have seen recently considerable reduction in the number of rail accidents, the rail mishaps continue to exist and to proactively respond to the incidents, efforts are in progress to modernize the railways so that it will be equipped to provide uninterrupted services. Way forward is to keep pace with the emerging technologies; as has been evident from the ensuing review of the literature, there are studies that have brought forward automated technologies for fault detection. Amongst the reasons of the accidents such as collusion, derailment, signal related issues, human error, level crossing related accidents, fire, carriage related, sabotage etc., the predominant reason continues to be derailments. By recognizing the importance of minimizing derailments due to cracks and breaks of the railroads, and also to replace the cumbersome manual inspections, electronic technologies are introduced in a gradual manner. Though the initially introduced manual inspection is being replaced/complemented by single or double tester cars which use the ultrasonic waves, scope for looking into alternative technologies still exist. In this direction, the paper introduces a novel approach as an addition to the existing knowledge base for detection of railway cracks. The device that is being introduced in the paper can be attached to the train unlike many a systems that require robots and other autonomous vehicles.

II. A REVIEW OF THE LITERATURE

The key elements of the crack detection system are the core technology of crack detection, and device or the platform in which the technology is implemented, either as robot/autonomous vehicle or on the train. The studies that discussed the implementation of robot based anomalies of rail tracks are quite a few in number. A study carried out in 2014 [1] used a comparatively cost effective ultrasonic sensor where PIR sensor was used to avoid manual checking both in the day and night time. Since the system works through a robot, the GPS (global positioning system) location of the crack can be sent to the nearby railway station. Another study, microcontroller was interfaced [2],with Robot, ZigBee, GPS, Liquid Crystal Display and crack sensor and IR sensor senses the voltage variations from the crack sensor and then it shares the signal to the microcontroller. The microcontroller checks the variations in the voltage of the measured value with the threshold value. The co-ordinates were displayed using the .NET software. An autonomous vehicle was developed [3] wherein ultrasonic sensor was used to detect the crack in the railway track by measuring distance from track to sensor. During the checking process, the robot can identify the incoming trains through the vibration sensor and can shrink the size of the robot in between the tracks, conversely, the robot would be performing the tasks after the crossing of the train. An ultra sonic crack detection [4] vehicle by integrating the ultrasonic crack detection method by integrating GPS module, GSM modem, IR sensor and PIR sensor to bring into operation the crack detection, communication, and identification of any

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living being crossing the railway track were attempted. It integrated an ultrasonic-based non-destructive testing (NDT) and wireless sensor networks (WSNs). The PIR sensor was executed to keep away manual patrolling and finding of living beings across the tracks and could operate during the night as well as the daytime. Neural network (NN) classifier was used for detecting cracks in rail track [5]. A combination [6] of detection methods for alerting the unmanned gate crossing and faulty rail track detection was attempted, where in, in case of unmanned level crossing, a IR sensors base system was used and crack detection was performed through a dynamic approach which combines the use of GPS tracking system and GSM modem to send geographical coordinate of location with the support of IOT technology. In another approach, a system which consists of a guage to record the stress at the time of passing of the train was introduced, which continuously monitors the rail stress, and provide rail break alerts such as bending, buckling, other impacts etc. with the support of ultra sonic metal detecting sensors. The outputs from independent modules fed to the microcontroller based control module which processed the signals and evaluated the existence of rail fault. The system also has a component connected to train, as an anti-collusion devise [7]. Through simulation, a system was implemented [8] to stop the train 4-5 KM prior to the detected crack; also the device stops the train to avoid collusion of the train comes on the opposite side. Once the crack is detected, the train slows down and the exact location of the crack is shared with the control room. The study has used ultrasonic metal detecting sensors with the support of blue tooth technology, which were fitted on the front of the locomotive and in case of derailment happens, the alert goes to the driver, and also applies the automatic braking. The system made use of UV rays with the UV transmitter and receiver connected to the signal lamp and supported by the CAN controller. Attempts were made to use LDR (Light Dependent Resistor) to detect the cracks as the LED attached to one side of the rails and the LDR to the opposite side[9]. After falling of the LED light after LDR, LDR resistance gets reduced and the reduction of the amount of light intensity found to be nearly proportional. As a consequence, when light from the LED deviates from its path due to the presence of a crack or a break, a sudden decrease in the resistance value of the LDR ensues. The robot has a speed of 0.5m/sec.

In a paper [10] which has reviewed the practice being followed by Indian railways and also based on a review of the studies carried out expressed the need for developing an alternative approach which uses a 4 wheel robot that one person can operate. The robot prototype used MC LPC2148 and 2 IR censor modules for detection of the cracks and messages along with GIS locations were sent. A combination of tools of image processing and sensors were used [11] with the support of the devices like Raspberry Pi 3. The information relating to the cracks are taken from the image data by using high resolution camera. The connectivity was established through Wi Fi. Recently, IOT based robot was introduced which uses ultra sonic sensors, by analyzing the echo from the track [12]. The output of the ultrasonic sensor is given to the microcontroller, which is connected to the GPS, GSM and motor driver IC. Further, the cracks observed through the support of microcontroller takes the location from GPS and send to a control station.

The review shows that, there are continuing investigations into various methods and alternatives that can facilitate crack detection in the railways. As a departure from the existing systems, we propose to introduce a device taking advantages of the vibration of the railway tracks. The premise is to take advantage of the changes in the vibration pattern through remote process. Although studies on remote accessing of motor vibrations exist[13], we observe that most of the prevailing technologies on crack detection uses sonar and ultrasound based systems and in general makes use of autonomous systems for the track monitoring. This paper postulates that, there is scope of exploring other alternatives such as optical and vibration signals in the crack detection and in case the devices can be fitted on to the train itself, the data can be easily gathered without manual intervension.

III. METHODOLOGY

In variance to the existing process of monitoring the cracks with the support of sonar, UV rays etc. we propose that cracks on railway tracks can be detected by changed reflectance of the rails. Further, we also presume that there is near zero probability of developing cracks on both rails at the same place and in the same way. In addition, the methods based on mechanical or ultrasound rays based detection of cracks will not be accurate and reliable because the movement of the train interferes with the process of measurement itself. These conjectures led us to come up with a design based on the following ideas:

- ξ Use optical signals instead of mechanical or sonar signals for identification of the cracks.
- ξ Determination of the presence and extent of crack can be measured by the deviation from normal reflectance.
- ξ Cracks cause vibrations and deviations from normal reflectance, even at a distance, and the deviation is maximum at the crack.
- ξ Concluding based on individual measurements may not be reliable, so we analyze all measurements over a time-period (example: 50 temporal samples).
- ξ Environmental conditions will influence the reflectance characteristics of the rails, but since there are two rails, the influences on the two rails is statistically same if there is no crack encountered.

If there is a crack or even a potential crack encountered, the reflectance characteristics of the two rails will not be statistically same, and the difference is a measure of the extent of crack. The proposed solution is an embedded system that

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can be mounted under the train unlike the autonomous vehicles/robots, as illustrated in Fig 1.

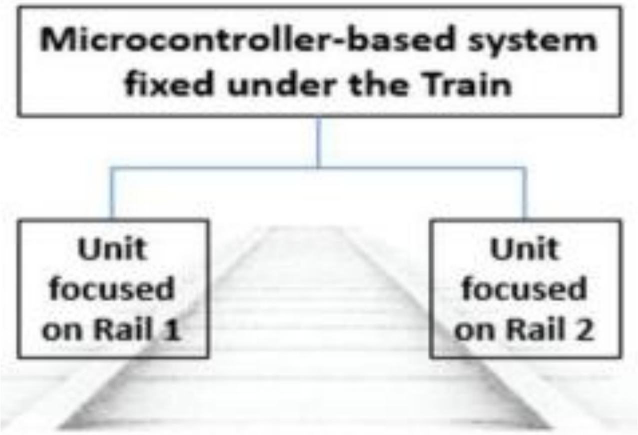

Fig. 1. Illustration of the detection units mounted under the train

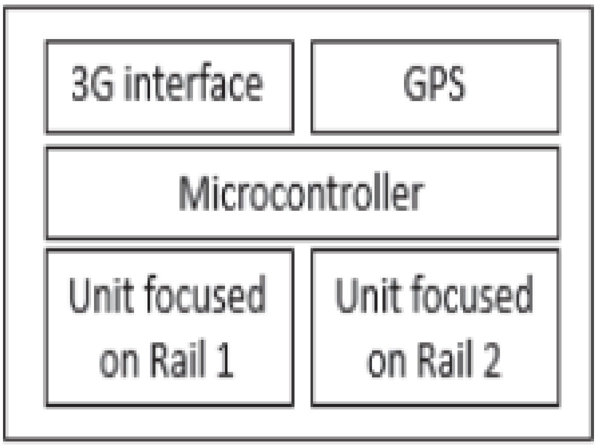

Fig. 2. System architecture of the proposed system \

As shown in Fig 2, the system comprises of a microcontroller, connected to the unit focused on each of the two rails, a GPS system to sense the location of the train and a 3G interface to communicate with the central station. Each unit consists of a laser source, from which the laser beam tracks incident on the rail. The reflected beam is caught by photodiodes placed along with the laser source. The photodiodes are organized in multiple concentric circular arrays, centered at the laser source. As shown in Fig 3, if there is no damage to the rail, the reflected beam goes right back or is caught by photodiodes which are very close to the center. On the other hand, if there is damage to the rail, the reflected beam deviates from the expected or desired path, and the extent of deviation depends on the extent of damage to the rail.

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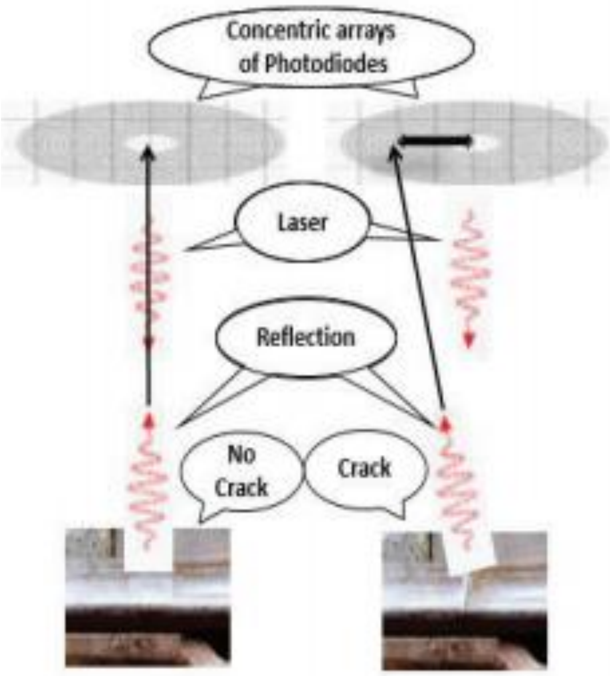

Fig. 3. Illustration of the functioning of the proposed system

Larger damages are, therefore, sensed by the photodiodes which are farther away from the laser source. The signal from each of the two units described must be representative of the extent of the crack sensed. For this signal to be reliable, it must not be just one instantaneous value, because of stray influences from the environment. We need to consider statistical parameters – energy – which iron out these stray influences. Further, the influences of the environment are likely to affect both the rails – statistically equally – resulting in the same energy value sensed from both the rails, if there is no crack. In case there is a crack, there will be a difference between the energies sensed from both the rails, and this difference is a reliable indicator of the crack.

IV. RESULT AND DISCUSSION

The system described as per the methodology elucidated above was prototyped and the results were found to be very encouraging. The energy was measured by considering windows of 100 samples each. The energy profile was plotted for different conditions of the rail. Fig. 4 below depicts the energy sensed during the trail of the prototype. When the quality of the track is good, the plot shows low energy, whereas when there is a loss of quality (simulated by hitting the surface with a hammer), we sense higher values of energy.

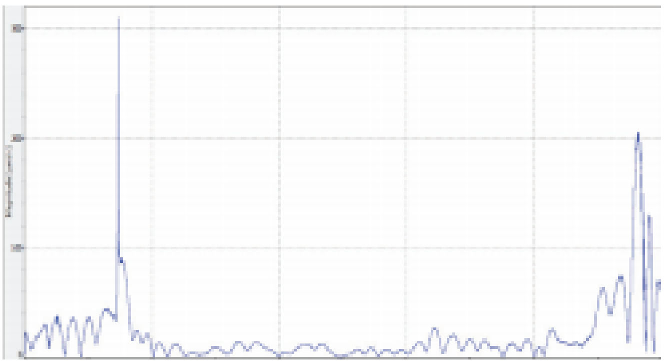

Fig. 4. Energy (value) variations recorded by the proposed system depending on the quality of the surface

There are a few salient points taken into account during the development of the proposed solution. The usage of sensors like vibrometers is possible but is very expensive and sensitive to stray influences from the environment. The proposed solution is cost-effective and reliable and the components used are in-expensive. The proposed solution interprets the

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magnitude of vibration of the rail, and this is seen to be sufficient and effective. In our experiments with vibrometers, we found that the frequency at which there is maximum vibration also shifts when there is a crack, and this needs further investigation. Since the proposed system is rail track independent and can be assembled to the train, the maintenance checks and other inspections can be carried out by the motor men and the yard staff and hence offers considerable convenience.

V. CONCLUSION AND FUTURE WORK

The development of an embedded system to identify and localize potential cracks in railway tracks is introduced in this paper. Based on the data gathered, a machine learning algorithm can be applied, which can detect and localize the cracks with higher levels of accuracy. The approach can be further extended to the on-train motors and other systems with monitors displaying the status at the cabin of the motor man, remotely monitored by the control center, and for preventive maintenance systems.

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