INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

A New Novel Control Algorithm/Scheme To Detect Cracks/Damages In Railway System By Using GPS Module

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Abstract:
This paper proposes a cost effective yet robust solution to the problem of railway crack detection utilizing a method that is unique in the sense that while it is simple, the idea is completely novel and hitherto untested. Because of the lack of cheap and efficient technology to detect cracks in the rail tracks so many accidents are taking place. This paper discusses the technical and design aspects in detail and also provides the proposed robust crack detection algorithm and exact dislocation of the track .The paper also presents the details of the implementation results of the RRCDS utilizing simple components inclusive of a GPS module, GSM Modem and PHOTO ELECTRIC RAYS-LDR based crack detector assembly. The proposed scheme has been modePhoto Electric Rays for robust implementation in the Indian scenario.

Key words: *Railway Cracks, Arduino, PHOTO ELECTRIC RAYS-LDR assembly, GSM, GPS, Robot.*

I.Introduction

In today's world, transport is a key necessity because in its absence it would be impossible for products to be consumed in areas which are not in the immediate vicinity of the production centres. Throughout history, transport has been a necessity for the expansion of trade. Economic prosperity can be achieved by increasing the rationality and capacity of transport systems. The proper operation and maintenance of transport infrastructure has a great impact on the economy. Transport, being one of the biggest drainers of energy, its sustainability and safety are issues of paramount importance.

In India, rail transport occupies a prominent position in quenching the ever burgeoning needs of a rapidly growing economy. However, in terms of the reliability and safety parameters, global standards have not yet been truly reached. The Indian railway network today has a track length of 113,617 kilometres (70,598 mi). over a route of 63,974 kilometres (39,752 mi) and 7,083 stations. It is the fourth largest railway network in the world exceeded only by those of the United States, Russia and China. The rail network traverses every length and breadth of India and is known carry over 30 million passengers and 2.8 million tons of freight daily. Despite boasting of such impressive statistics, the Indian rail network is still on the growth trajectory trying to fuel the economic needs of our nation. Though rail transport in India is growing at a rapid pace, the associated safety and infrastructure facilities have not kept up with the aforementioned proliferation. Our facilities are inadequate compared to the international standards and as a result, there have been frequent derailments that have resulted in severe loss of valuable human lives and property as well. To demonstrate the gravity of the problem, official statistics say that there have been 11 accidents in 2011 till the month of July alone, which leaves much to be desired. On further analysis of the factors that cause these rail accidents, recent statistics reveal that approximately 60% of all the rail accidents have derailments as their cause, of which about 90% are due to cracks on the rails either due to natural causes (like excessive expansion due to heat) or due to antisocial elements. Hence these cracks in railway lines have been a perennial problem, which has to be addressed with utmost attention due to the frequency of rail usage in India. These cracks and other problems with the rails generally go unnoticed due to improper maintenance and the currently irregular and manual track line monitoring that is being carried out. The high frequency of trains and the unreliability of manual labour have put forth a need for an automated system to monitor the presence of crack on the railway lines. Owing to the crucial repercussions of this problem.

This paper presents an implementation of an efficient and cost effective solution suitable for large scale application. With the advent of powerful digital signal processors, Image Processing techniques [1] have been explored to formulate solutions to the problem of railway crack detection. Though it provides better accuracy, this method uses techniques like image segmentation, morphology and edge detection all of which take a lot of processing power and an extreme amount of time rendering the robot slow and thereby unsuitable. Recent research has investigated the use of microwave horn antennas for crack detection [2]. This technique was found to produce very accurate results in lab based testing. But, unfortunately it requires spectrum Analyzers which are both costly and also can't be placed on board a moving robot because of their delicacy. Eddy current based methods ([3], [4] and [5]) are used to tide over limitations associated with ultrasonic's and microwave techniques. However they have the problem of very slow overall speed which reduces the usability of the same. A vast majority of the work done in the field of crack detection uses the infrared sensing technique ([6], [7] and [8]). It is a well understood technique so much so that it was initially thought to be the best solution to the problem of crack detection, but later it was found to be prone to external disturbances and hence came to be considered inaccurate. Techniques that employ ultrasonic's ([9], [10] and [11]) tide over some of the problems mentioned earlier, but they can only inspect the core of the track; that is, it cannot check for surface and near surface cracking where most faults are usually located.

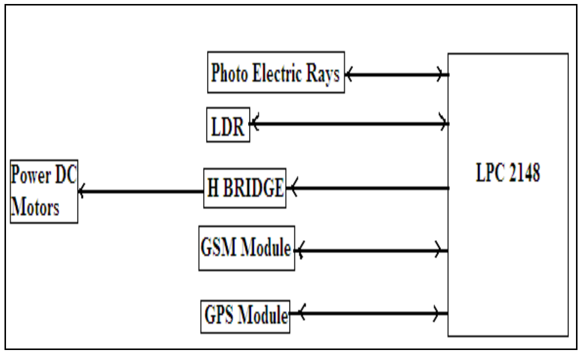


Figure 1: Block Diagram

Several other miscellaneous techniques like observation and analysis of wave propagation via model impacts and piezo actuation [12] have also been developed. The problem inherent in all these techniques is that the cost incurred is high. Hence this paper proposes a cheap, novel yet simple scheme with sufficient ruggedness suitable to the Indian scenario that uses an PHOTO ELECTRIC RAYS-LDR arrangement to detect the crack in railway lines, which proves to be cost effective as compared to the existing methods ([13], [14] and [15]). The important role played by transport in the development of an economy has been studied [16]. In addition, statistics of the number of rail accidents and their corresponding causes have also been studied [17].This paper is organized as follows: Section II discusses the design issues; Section III discusses the proposed RRCD Scheme using an PHOTO ELECTRIC RAYS-LDR arrangement. Section IV elaborates on the electrical design and Section V explains the mechanical design. Section VI gives the implementation of pseudo code, Section VII provides the results of implementation and Section.VII provides the conclusion, IX gives Future scope

2.Design Issues Inherent To Indian Scenario

A literature survey of the existing techniques for crack detection reveaPhoto Electric Rays a number of sophisticated and accurate crack detection technologies. Whilst techniques based on ultrasonic imaging, IR method and electromagnetic detection offer several advantages, when their applicability for large scale implementation in the current Indian scenario was considered, they were found to lack robustness and practicality in a number of aspects. First, in the Indian rails, typically there are small gaps in the rail tracks to provide for thermal expansion during the summer. This design is provided so as to ensure that the track does not twist or crack due to the heat. When the existing technique of crack detection was implemented, it was found that the system was giving false positive signals; that is, it was counting the thermal gaps as cracks. Another issue faced during practical implementation is the presence of railway bifurcations. If the mechanical design of the robot is unsuitable, then it will have a tendency to either get stuck in these bifurcations or in worst case even fall out of the tracks. During the designing of prototype for actual on-field implementation, the problem of presence of debris on the outsides of the tracks was encountered. Though this problem seemed trivial, the effects of dirt on our robot wheels could have been substantial. In addition, as the proposed design utilized a PHOTO ELECTRIC RAYS-LDR based design, the ambient light intensity variations imposed extreme challenges to our design concept.

3.Proposed Rrcd Scheme

In the process of designing the prototype, railway line between Guntur to Vijayawada. This railway line doesn't operate between 10:30 am to 1:30 pm. This gives us a three hour window during which the robot has to traverse the railway line looking for cracks. Figure 1. Illustrates the overall conceptual design of the proposed scheme. To ensure robustness, repeatability and easy implementation, the principle idea has been kept very simple.

The core of the proposed crack detection scheme consists of a Light Emitting Diode (PHOTO ELECTRIC RAYS) -Light Dependent Resistor (LDR) assembly that functions as the rail crack detector. The principle involved in crack detection is the concept of LDR. In the proposed design, the PHOTO ELECTRIC RAYS will be attached to one side of the rails and the LDR to the opposite side. During normal operation, when there are no cracks, the PHOTO ELECTRIC RAYS light does not fall on the LDR and hence the LDR resistance is high. Subsequently, when the PHOTO ELECTRIC RAYS light falls on the LDR, the resistance of the LDR gets reduced and the amount of reduction will be approximately proportional to the intensity of the incident light. As a consequence, when light from the PHOTO ELECTRIC RAYS 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. This change in resistance indicates the presence of a crack or some other similar structural defect in the rails. In order to detect the current location of the device in case of detection of a crack, a GPS receiver whose function is to receive the current latitude and longitude data is used. To communicate the received information, a GSM modem has been utilized. The function of the GSM module being used is to send the current latitude and longitude data to the relevant authority as an SMS. The aforementioned functionality has been achieved by interfacing the GSM module, GPS module and PHOTO ELECTRIC RAYS-LDR arrangement with a microcontroller. The robot is driven by four DC motors. Before the start of the railway line scan the robot has been programmed to self-calibrate the PHOTO ELECTRIC RAYS-LDR arrangement. It is necessary because the LDR has a natural tendency to show a drifting effect because of which, its resistance under the same lighting condition may vary with time. After calibration, the robot waits for a predetermined period of time so that the onboard GPS module starts reading the correct geographic coordinate. This is necessary because any GPS module will take some time to synchronize with the satellites.

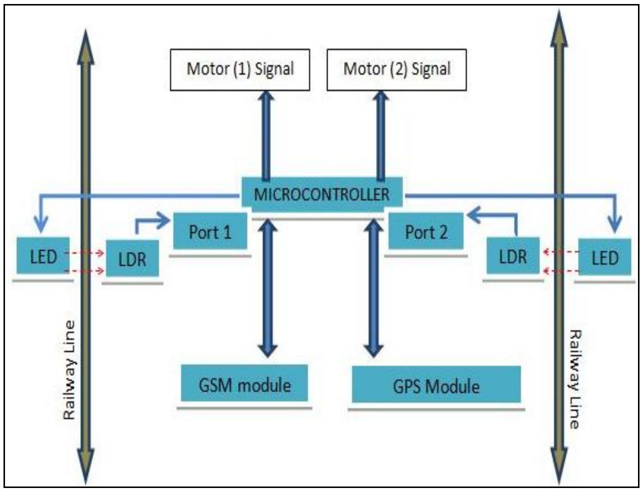
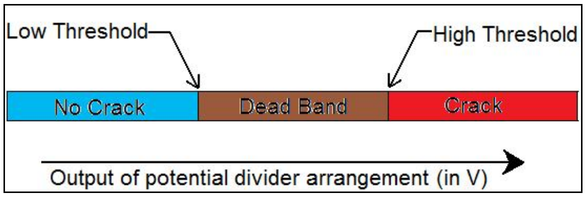


Figure 2: Schematic Representation

4.Electrical Design

- **Microcontroller**
  An Arduino Uno board which has ATMega328 microcontroller forms the brain of the scheme. This board has been chosen for two important reasons other than the fact that it is cost effective. First, the Arduino integrated development environment (IDE) is an open-source project which highly simplifies the coding and debugging process. Secondly it has all the required pins to interface the required peripherals. It has 6 analog input pins, 14 digital I/O pins (of which 6 provides PWM output) and one UART. The detail Photo Electric Rays description about how various components have been interfaced with Arduino is also discussed hereafter.
- **GPS Module**
  EM-406 GPS receiver has been used as the GPS module. It follows NMEA convention. With a baud rate of 9600 bps, 1Hz update rate and 1 sec hot start time, the properties of the said module was found to ideally match the requirements. It is interfaced with Arduino using the UART.
- **GSM Module**
  The SIM 300 GSM module has been chosen to achieve the SMS functionality. Since the Arduino Uno board has only one UART, it was necessary to program 2 of the digital pins (pins 2 and 3 in our case) of Arduino to act like a virtual UART so as to interface the GSM with the Arduino. The overall electrical design of the RRCDS has been shown in Figure 2.
- **DC Motors**
  To traverse a distance of 22 Km in 4 hrs, an average speed of 1.5 meters/sec is needed. The proposed design uses 2 DC motors (Torque Rating: 10Kg and Speed Rating: 100 rpm) interfaced with the Arduino using H-Bridges. With a wheel diameter of 5.2 cm and the total mass of around 5 Kg the approximate speed of the robot is around 0.5 meters/sec. Hence it has been calculated that three such robots would be required to scan the whole Southern Chennai Suburban Railway System.



- **Photo Electric Rays-LDR Assembly**
  The common 5V PHOTO ELECTRIC RAYS and cadmium sulphide LDR was found to be sufficient. The PHOTO ELECTRIC RAYS is powered using one of the digital pin of the Arduino. The LDR and a 45kΩ resistor form a potential divider arrangement. The output of the potential divider is given to one of the analog input channel of the Arduino. The LDR is calibrated every time the robot is used. To compensate for the ambient light we use the concept of dead band.

5.Mechanical Design

The mechanical design of the robot is clearly illustrated in Figure 4. The robot runs on both the railway tracks. This increases its stability preventing it from falling when it moves over a railway bifurcation. In addition, the robot has been designed to be symmetrical. It consists of two wooden frameworks each supporting 2 motors, 1 battery and one PHOTO ELECTRIC RAYS-LDR assembly. Each battery was found to weigh a little over 300 grams giving additional weight on the wheels which also ensured the stability of the robot when it moved over railway bifurcations. These two wooden frameworks were connected by two cylindrical aluminium rods (3/4 inch diameter and 0.25 mm thickness). The length of the aluminium is so chosen that the four wheels of the robot rest exactly on a typical broad gauge railway track. In India, the distance between two rails in a broad gauge railway is 1.676 meters. The circuit box containing mainly the Arduino Uno Board, the GPS and the GSM module is exactly centered on the aluminum rod. Two bunches of 10 wires (2 each for the PHOTO ELECTRIC RAYS, the LDR, the two motor and the battery) each enter the circuit box from its left
and right side. The proper packaging of these many wires is a crucial in the design of the robot. There are few more design criteria which were taken into account: 1) The wheels of the robot will be similar to the wheels of the a train, i.e. a big wheel welded/joined with a smaller wheel. The smaller wheel runs on the track while the bigger one prevents the robot from falling. It is must that the big wheel is on the inner side of the railway track (as shown in figure 4). It is because in the general Indian scenario the stones and other debris are comparatively less on the inner side tracks. If the bigger wheels are placed outside it may brush against the debris causing it to destabilize or in worst case get stuck or even fall. 2) The PHOTO ELECTRIC RAYS-LDR assembly shouldn't go below the rim of the rail otherwise it may get damaged due to the scattered debris. 3) The distance between the front wheel and the PHOTO ELECTRIC RAYS-LDR assembly is a crucial design aspect. The front wheel of the robot should be kept sufficiently behind the PHOTO ELECTRIC RAYS-LDR assembly so that the robot has sufficient distance to stop after a crack is detected. In our case it is 12 cm.

6.Implemented Algorithm

After the robot is powered ON it executes the following algorithm:

- Set LowThreshold = 200, HighThreshold = 800.
- Calibrate LDR:
  - Switch OFF left PHOTO ELECTRIC RAYS
  - Set LOWleft = Average of left LDR signal
  - Switch OFF right PHOTO ELECTRIC RAYS.
  - Set LOWright = Average of right LDR signal.
  - Switch ON left PHOTO ELECTRIC RAYS.
  - Set LOWleft = Average of left LDR signal.
  - Switch ON right PHOTO ELECTRIC RAYS.
  - Set LOWright = Average of right LDR signal.
- Turn ON GSM. Set GSM parameters.
- Turn ON GPS.
- REPEAT
  - Read Latitude from NMEA string
  - Read Longitude from NMEA string
  - UNTIL (Latitude and Longitude not equal Zero)
- Turn ON motors.
- Read left LDR and right LDR signal.

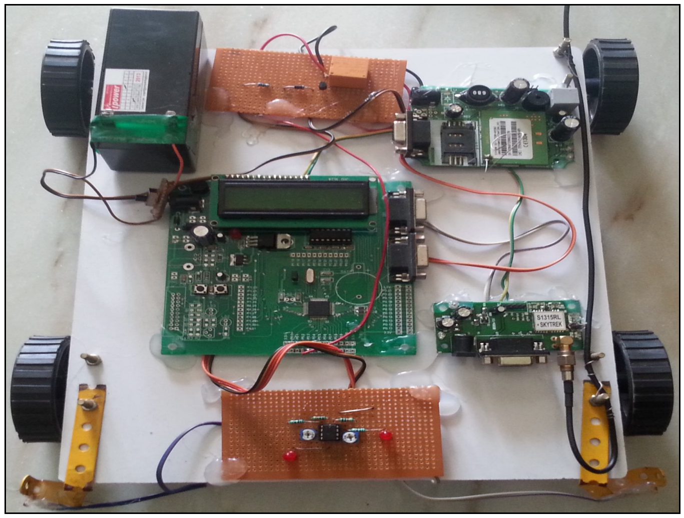


Figure 3: Kit Diagram

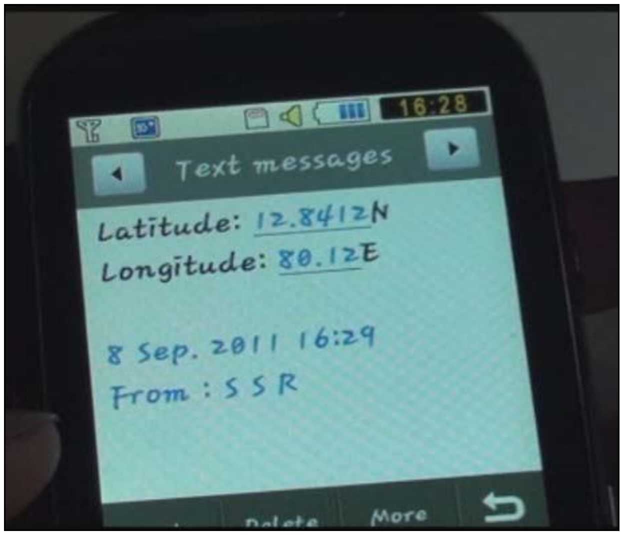
- **Map Left And Right LDR Signals Between 0 And 1000**
  using following formulas
  Intensity left = (analog read (LDR left-low left)/high left – Low left)*1000.0
  Intensity right = (analog read (LDR right-low right)/high right – Low right)*1000.0
  Analog Read (LDRleft) and
  analog Read(LDRright) ⟶ Signal from LDRs
  INTENSITY left and INTENSITY right ⟶ Mapped values
- **If Intensity left < Lowthreshold And**
  INTENSITY right < LowThreshold then,
  Motors are powered ON.
- **If Intensityleft < Highthreshold And Intensityright < Highthreshold Then,**
  Motor is powered OFF.
  Read robots coordinate using GPS.
  Send robots coordinate to a mobile as SMS using GSM1
  Send robot co-ordinates to GSM2 as SMS using GSM1
- **Jump To Step 7.**

7.Implementation And Results

As a part of this project, the proposed novel crack detection scheme has been tested by placing the robot on an actual rail track. The testing was carried out at two different lighting conditions: daytime (4.30PM) with irregular lighting along the railway lines, between Guntur and Vijayawada railway stations (Andhra Pradesh, India), covering 30 kilometres along the track.

The field trials gave negative results for the presence of crack in the length of the tested track-length due to the absence of cracks in the tested area. These results were tested over and again and no false outputs were obtained as the Photo Electric Rays-LDR arrangement was recalibrated before each startup. However, calibration failure (identified by the false output before the testing stage starts) was found to have occurred in the ratio of 1:25 which could be rectified by resetting the entire setup. In order to test the functionality of the crack detection system as well as the GPS and GSM modules, a mechanical arrangement to simulate an actual crack was created and the system was found to accurately detect the presence of it and the GSM module successfully transmitted the current coordinates obtained from GPS. The accuracy of the GPS system was tested by comparing the obtained co-ordinate locations using Google maps.

An SMS sent by the GSM modem (with an Airtel Sim Card) to a mobile phone indicating the co-ordinates of the artificial crack. The crack was detected exactly at a distance of 200 meters from the start of the course of the robot, which is exactly the distance at which the crack was created. These tests were also conducted in uniform and un-uniform lighting conditions and no false output was detected in either case. The crack detection was also tested for different distances of the created crack with no false



Output Values:
Latitude = 1614*π/180 = 28.16
Longitude = 8039*π/180 = 140.24
Output detected. Insufficient GSM and GPS signal, has however been a problem during simulated tests, while this problem was not observed during the field tests due to the open area of the track lines without much obstruction to signals.

8.Conclusion
In this paper, we have presented the rationale, design of our robust PHOTO ELECTRIC RAYS-LDR based railway crack detection scheme. The exact location of crack area will be intimated directly to the user mobile through GPS module simultaneously it sends the detail of the location to the Google maps through GSM/GPS module through this the person can directly view the location. This idea can be implemented in large scale in the long run to facilitate better safety standards for rail tracks and provide effective testing infrastructure for achieving better results in the future.

9.Future Scope
In the future it can be implemented by using single GSM/GPS service it gives signals (corresponding crack location) to the respective control rooms nearby railway stations and user mobiles.

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