Railway Security System based on Wireless Sensor Networks: State of the Art

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ABSTRACT
Railways are large infrastructures and are the prime mode of transportation in many countries. The railways have become a prime means of transportation owing to their capacity, speed, and reliability. Even a small improvement in performance of railways has significant economic benefits to rail industry. Thus, a proper maintenance strategy is required to govern optimization of inspection frequency and/or improvement in skill and efficiency. Accidents happening due to track breaking have been a big problem for railways for life security and timely management of services. This breakage needs to be identified in real time before a train actually comes near to the broken track and get subjected to an accident. In this paper, different kinds of rail defects inspection and maintenance methods are described and a basic algorithm is readdressed that makes use of wireless acoustic sensors for detecting cracks and breakages in the railway tracks.

General Terms
Wireless sensor network, fault tolerant, track gauge inspection

Keywords
Cracks detection, railway security, acoustic sensor

1. INTRODUCTION
Railways comprise a large infrastructure and are an important mode of transportation in many countries. The railways have become a new means of transportation owing to their capacity, speed, and reliability, being closely associated with passenger and goods transportation; they have high risk associated with them in terms of human lives and cost of assets [1]. The poor maintenance of the railways can lead to accidents. New technologies for railways and better safety measures are introduced time to time but still accidents do occur. Thus, a proper strategy is required for maintenance and inspection of tracks.

Detection and maintenance of rail defects are major issues for the rail community all around the world. The defects mainly include weld problems, internal defects worn out rails, head checks, squats, spalling and shelling, corrugations and rolling contact fatigue (RCF) initiated problems such as surface cracks. If these defects are not handled and corrected they can lead to rail breaks and accidents [2] .There are numerous challenges to rail community and the infrastructure maintenance people such as to perform effective inspection and cost effective maintenance decisions. If these issues are taken care of properly, inspection and maintenance decisions can reduce potential risk of rail breaks and derailment.

2. TECHNIQUES FOR INSPECTING CRACKS IN RAILWAY TRACKS

2.1 Long Range Ultrasonic Testing (LRUT)
Authors in paper [4] focus on the limitations of methods in their ability to detect defects in the rail foot, especially in the side edges away from the region directly below the web and how the LRUT method provides a significant improvement for the same.

Long Range Ultrasonic Testing (LRUT) technique is proposed as a complimentary inspection technique to examine the foot of rails, especially in track regions where corrosion and associated fatigue cracking is likely, such as at level crossings. LRUT technique is found to be suitable for examining inaccessible areas of railway tracks such as areas where corrosion occurs and susceptible areas of fatigue cracking. In different parts of the rail section (such as head, web and foot) properties of guided waves are used and are examined for their capability to detect defects in each part.

A suitable array of transducers is developed that is able to generate selected guided wave modes in rails which allow a reliable long range inspection of the rail. The characteristics of ultrasonic guided waves in the rail complex geometrical profile have been identified.

2.2 Vision Based System
A rail track inspection technique using automated video analysis is proposed [5]. The aim of the system is to replace manual visual checks performed by the railway engineers for track inspection. A combination of image processing and analysis methods is used in the paper to achieve high performance automated rail track inspection. This paper focuses on the issues of finding missing clips and finding blue clips which have been recently replaced in place of damaged clips.
The objective of the algorithm is to automatically find clips in video sequences and thereafter recognize whether they are broken and if they are new or old as indicated by their color. Metal clips hold the rail track to the sleepers on the ground. Clips are searched to locate their position. Some clips on the track may be broken or missing due to excessive strain on them as the train moves on the track which may lead to the track failure these missing clips are identified. The clips used may be of different color depending on whether it is new (blue color) or old (grey color). So a video color analysis is done on the clips and the results are given to track maintenance engineers.
The main image pre-processing steps in the recognition of clips include smoothing, edge detection, and short line removal.

The irregularities in the Railway track gauge reduces the service life of rail and vehicle, and even result in vehicle falling off rail or wheel trapping, which causes driving accidents. A dynamic inspection method of track gauge based on computer vision is developed in [6]. The inspection system is constructed by using four CCD (Charge-coupled Device) cameras and two red laser sector lights. The inspection principle and corresponding calibration method of inspection system are analyzed. Several image processing technologies such as image component extraction, differential, adaptive iteration threshold, dilation and thinning are used to extract gauge points.

Experiment results have proved that the proposed inspection method is capable of fast obtaining track gauge value with high accuracy and repeatability, and meets the requirement of dynamic inspection for track gauge.

The method proposed in the paper [6] confirms the calibration method for track gauge inspection by. The method strictly controls the change of railway gauge and provides an effective inspection method with high precision to railway engineers.

2.3 Train-Mounted GPR

A technique based on Ground-penetrating radar (GPR) [7] is used for obtaining quantitative information about the depth and degree of deterioration of the track. This paper aims at automating the processing and interpretation of data to the extent whereby on-site interpretations may be achieved with minimal intervention of the expert. This is done through the development of new image and signal processing tools specifically for GPR data and the range of anomalies found on the trackbed.

For monitoring track conditions and other infrastructure assets the most efficient way is by means of a train, which can collect data for many parameters simultaneously, where possible at normal line speed. A multichannel ground-penetrating radar system is presented in the paper which is capable of operating at speeds of up to 200 kmph. A road-rail variant of the system is also presented which can collect up to 6 simultaneous continuous channels across the track, and can deliver on-site interpretation of ballast thickness and quality, irregularities, weak spots and utilities.

Novel multivariate signal and image processing techniques are used that can automatically detect, quantify and map variations in ballast depth and condition. To enable automatic characterization and classification of regions of interest within the radargrams, multi-resolution texture analysis techniques are applied. The proposed system can probe the ballast both underneath and between the sleepers, thus potential problems can be identified with individual sleepers.

2.4 LED-LDR Assembly

An algorithm for crack detection in rail tracks is uses [9] Light Emitting Diode and Light Emitting Resistor (LED-LDR) assembly which tracks the exact location of faulty track. The design proposed by the authors includes LED which are attached to one side of the rails and the LDR to the opposite side. When there are no cracks i.e. during normal operation, the LED light does not fall on the LDR and hence the LDR resistance is high. Subsequently, when the LED 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. Consequently the light from the LED deviates from its path due to the presence of a crack or a break and there is a sudden decrease in the resistance value of the LDR. 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 robot is driven by four DC motors. If this system is employed only latitudes and longitudes of the broken track will only be received so that the exact location cannot be known.

GPRS module is used to get exact location of the broken rail track. ARM7 controller is also used owning to is low cost and less power consumption it also decreases the time used in detecting cracks.

3. RAIL TRACK INSPECTION USING SENSORS

3.1 Automatic Railroad Track Inspection

The paper [9] presents a technical survey of the automated stationary and mobile track test train systems. An automatic inspection system is proposed in the paper but it is limited to the track bed and the rails. Deployment of the rail track to cover maximum optimum segment is also discussed. Instead of six transducers employed in bi-static mode, a single mono-static mode T-R, transducers is used which offers a significant saving in material, installation, electronics, and space, as well as cost. The proposed system helps in monitoring high risks in track beds by deploying sensors at particular areas and by the use of probabilistic selection method to identify high risk areas.

3.2 Wireless Sensor Networks Based on Fuzzy Logic

The concept of fuzzy logic is used by author’s deployed sensors. A model for placing sensors on the railway track is described in the system [10]. There are many base stations or control centers which collect the data from the numerous sensor nodes distributed on the railway tracks. Multi-layer routing is used to transmit the sensed data to control station. The sensor nodes transmit the data to their nearby cluster heads. Multi-layer routing is used; the nodes in lower layer transmit their data to higher layer instead of transmitting it directly to base station.

For detecting cracks on rail tracks ultrasonic method is used. Ultrasonic waves are injected into the rails by special transducers. High-energy signal is sent in two directions at predetermined intervals. The transmitted signal is propagated in the rail and is received by receivers. The nearby transmitters send ultrasonic waves with the same frequency but with different period’s .In this way, the receivers will be able to recognize the direction (left or right) from which they receive the signal. If there is a break or chafe in the rail, the amplitude of the waves received by receivers will be reduced and an alarm signal will be sounded.

To track cross (horizontal) defects that happen in the crown of the rail, the ultrasonic method is used: power is concentrated in the crown of the rail so that it becomes possible to track these defects as the ultrasonic waves are maximized. Ultrasonic sensors are alternately installed 1.75km apart from each other in the inside wall of the rail and they must be in complete contact with the crown of the rail, in this way by increasing the number of the rail which needs to be investigated.

Collision in the tracks can be avoided using sensors and a technique based on IR Rays & Sensors [11]. Collisions are avoided by fixing the sensors in the train wheels and transmitting the rays in the track. The trains coming from opposite direction also have the same option. If two trains are on same track, the rays will get collided and get reflected back to the respective engines and the LED or Alarm will blink that will help in stopping the train.
The detection of Cracks is done using IR rays with the IR transmitter & receiver.IR receiver connected to the Signal Lamp or Electrified lamp with the IR sensor. CAN controller is connected to the main node and it sends the information via GSM and transmit the message to engine and to the nearest station. The detection of Cracks can be identified using IR rays and IR sensor.IR receiver is connected to the signal lamp and to the CAN controller. The electrified lamp is nothing but it sides of the tracks the electric lamp which is current flowing for the engines transportation.
A failure tolerant (FT) algorithm is proposed [12] for monitoring the rail lines. The algorithm is based on the simultaneous use of movable and fixed sensor network design and has the ability to send information as online-offline.
The proposed algorithm reduces fault tolerance and energy consumption in the network thereby increasing network lifetime. The algorithm has two parts fixed and movable. The fixed algorithm works for sensor networks that are in places such as bridges, tunnels and special points. This algorithm collects information about seismic data and the bridge balance and Cracking in the foundations of bridges and Pressure on the bridge and investigates this information. Movable algorithm, displays how to collect information of fixed sensor network by installed networks on the locomotive or monitoring cars , it also check the balance point line and register in a data position. In this system, GPS will detect coordinates of points that their data is registered.

3.3 Track Surveying with Sensors

For Track surveying with sensors the authors have proposed an architecture which has sensor nodes deployed along a railway track as shown in Fig 1. The network consists of numerous control centers (sink nodes) that are connected through a wire lined connection, and the sensor nodes are deployed along the railway lines [13].The sensor nodes collect the necessary data and forward the data back to the sink.
An innovative railway track surveying procedure is described that uses sensors and simple components like a GPS module, GSM Modem and MEMS based track detector assembly [14]. The surveying system proposed in this paper can be used for both ballast and slab tracks. The railway geometrical parameters which are Track axis coordinates are obtained with integrated Global Positioning System (GPS) and Global System for Mobile communication (GSM) receivers.
The authors have proposed a cheap, and simple scheme with sufficient ruggedness which is suitable in the Indian scenario that uses an LVDT arrangement to survey track geometry by using multi sensor, which has proved to be cost effective as compared to the existing methods. This sensor very accurate detection and it will send information immediately by using GSM. The system can be operated in tunnels without interruption

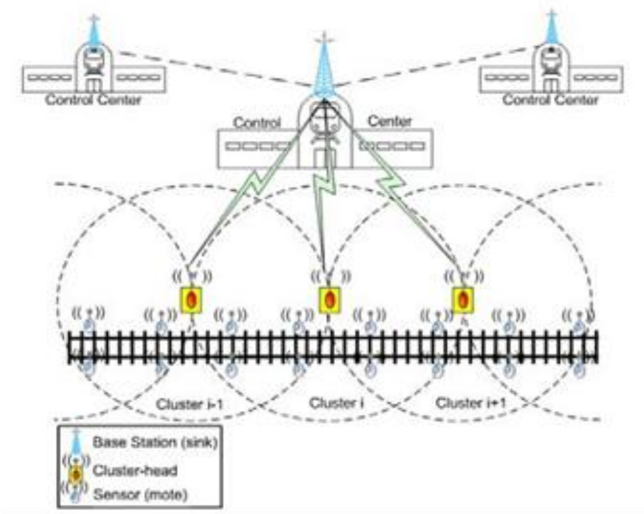

Fig 1. Architecture of Track Surveying with Sensors [13]

Bridge damage status is monitored by the sensor and wireless modules, when the sensor not getting signal, immediately nearby wireless system notifies and alert or informs to the current train on the track. The above task can achieve through microcontrollers, GSM, LVDT.

4. RAIL DEFECT DETECTION PROCEDURE

Rail defect detection is a process for which many different detection techniques have been studied and implemented. In general, for a defect detection system, the following need to be made available: a system of sensors which traverses the rail tracks, a data acquisition system, an algorithm to process the data and classify the signals as those arising from a break or no break and finally a means for notifying the GPS position of the break to authorities so that necessary action may be taken. Figure discusses the flow of the process of fault detection and remediation in case of rail break instances. A schema of the discussed method is given in figure 2.

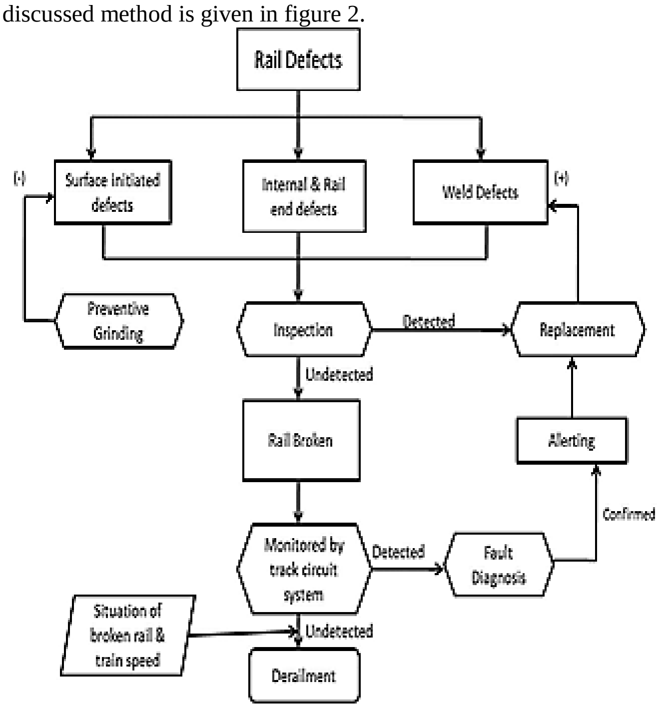

Fig 2 Break Detection procedure [15]

5. CONCLUSION AND FUTURE WORK

Accidents occurring in railway transportation systems cost a large number of lives. Many people die and several others get physical and mentally injured. Accidents are the major causes for traumatic injuries. There is certain need of advanced and robust techniques that can not only prevent these accidents but also eradicate all possibilities of their occurrence. Wireless sensor network which continuously monitors the railway track through the sensors and detect any abnormality in the track. The sensor nodes are equipped with sensors that can sense the vibration in the railway track due a coming train. The geographical positioning sensors are placed on the trains. These sensors send the train's geographic location. The complete process is needed to be real time in nature and should meet the deadlines. Optimization of the communication protocol and real time working network with minimum delay in multi-hop routing from the nodes to the train using a static base station is needed, so that the decision making can be done and the decision is forwarded to the train without any delay.

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