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Railway Track Structural Health Monitoring System

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Abstract: Railway is one of the most used means of transportation. For the railway system to operate flawlessly constant monitoring and inspection of railway tracks is required. Currently railway track inspection and monitoring is done manually which is time taking and not accurate, due to the high chance of human error occurrence. Moreover, practically it is impossible to inspect and monitor the railway track manually as they run thousands of miles. To avoid this we propose a prototype system, designed for continuous monitoring of railway tracks using a combination of sensors. These sensors collect data and through computational analysis faults in the railway tracks are identified. The collected data can help in finding cracks in the tracks and catastrophic accidents can be avoided.
Keywords: Railway track inspection, Structure health monitoring, Data acquisition, Sensor network, Microcontrollers.

1. INTRODUCTION

Railway transportation is one of the most commonly used means of transportation throughout the world. Structural integrity of the rail tracks is of paramount importance in order to avoid accidents. Structural health monitoring (SHM) refers to the process of determining and detecting damage in engineering structures such as buildings, bridges and railway tracks. Once a structure has been observed over time using a combination of sensor nodes, meaningful data can be extracted from the collected sensor data. This helps in determining the health condition of the structure, and ultimately it assists in avoiding disasters related to the structural health.

Figure 1: Damaged Railway Tracks

Problems like cracks, excessive load on the track and thermal expansions of the track can compromise the structural health of railway tracks. Fig. 1 shows pictures of damaged railway tracks. Initially railway tracks inspection was done manually. This approach is least practical as there is a high probability of human error to occur; moreover, the length of tracks is in thousands of miles. Later on some techniques for crack detection were proposed using rotating electromagnetic fields [1], microwave antennas [2] and infrared [3]. Several other methods have also been proposed [4] [5] [6].

In this paper we propose a prototype of the railway track monitoring system that includes various sensors, which monitor variations and vibrations in the track. Cracks being a defect, can cause the normal strain response of a structure to vary [7]. These variations can be measured by using piezo sensors and strain gauge sensor. Data acquired by these sensors is used for railway track monitoring. A smart phone application has also been developed and integrated with the system to provide remote monitoring.

Rest of the paper is outlined as follows. Section 2 describes the system model. Section 3 comprises of software implementation. In Section 4, conclusion and future work is given.

2. SYSTEM MODEL

To investigate the structural health of the railway tracks we propose a prototype system in Fig. 2. The system consists of a miniature railway track, to simulate the actual train on track scenario. The overall system is divided into three parts.

- *Sensor Network:* First part is deployed on the railway track, it contains multiple sensors and microcontroller.
- *Communication Setup:* Second part is the communication system, this part transfers the collected data by the sensors to a remote site.
- *Central Server:* The third part comprises of the receiver and software programs which decode the data and display it in a graphical manner.

The mentioned three parts of system are explained as follows:

2.1 Sensor Network

The first part of our prototype system consists of three piezo sensors, distributed evenly across the track. These sensors can sense vibrations of the slightest magnitude. The piezo sensors are installed underneath the track as shown in Fig. 3(b). The readings from piezo

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sensors have a small amplitude, to overcome this issue amplifiers are interfaced between piezo sensors and the microcontroller.

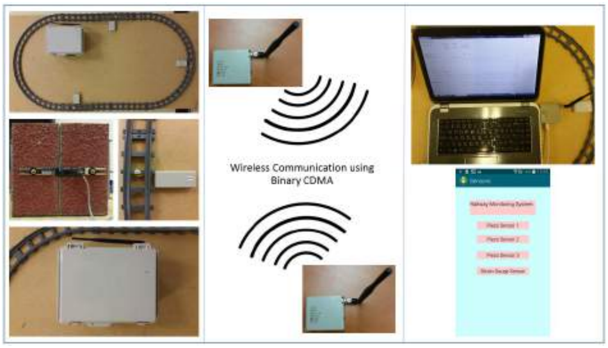

Figure 2: System Model

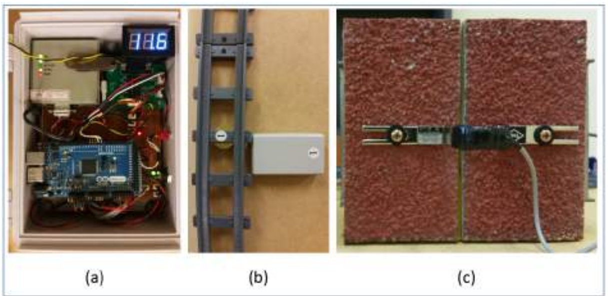

Figure 3: Sensor Network (a) Microcontroller, (b) Piezo Sensor, (c) Strain Gauge Sensor

There is also a strain gauge sensor (TML Displacement Transducer Model PI-5-100) attached to one of the railway track junctions, shown in Fig. 3 (c). This sensor has a simple structure, comprising of a strain gauge and an arch-shaped spring plate. This transducer can measure a crack opening or displacement in various structures, in this case the railway track. The strain gauge sensor is connected to a digital indicator (Cozy International CI–10W). The digital indicator is responsible for displaying minute changes recorded by the strain gauge sensor.

Both of these sensors are interfaced with the Arduino Mega ADK R3. Specifications of the Arduino board are given in Table 1.

Table 1: Arduino MEGA ADK Specifications

Microcontroller	ATmega2560
Operating Voltage	5V
Digital I/O Pins	54(15 PWM output)
Analog Input Pins	16
Flash Memory	256KB(8KB boot loader)
USB Host Chip	MAX3421E
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

The Arduino microcontroller can communicate with the serial devices, in this case the RF transceiver. The logic levels at the port operate on TTL logics. In order to communicate with the RF transceiver the voltage levels should be converted. To convert these voltage levels from TTL to RS232, MAX232 is used. MAX232 is a serial line driver used to establish communication between the RF transceiver and the microcontroller. The voltage levels of the MAX232 are given in Table 2.

This network of microcontroller and sensors is also equipped with a rechargeable battery. The system can run for 12 hours on this battery without being recharged.

2.2 Communication Setup

The second part of the system consists of communication between the microcontroller and the central server receiver. Binary CDMA is used to transfer data from the microcontroller to the receiver. Binary CDMA is a low cost, full duplex, and high-speed access technology. The salient features of the technology are given in Table 3.

Table 2: MAX232 Logic Voltage Level Conversion

RS232 logic level	RS232 voltage	TTL voltage to and from MAX232
Data transmission logic 0	+3 V to +15 V	0 V
Data transmission logic 1	-3 V to -15 V	5 V
Control signals logic 0	-3 V to -15 V	5 V
Control signals logic 1	+3 V to + 15 V	0 V

Table 3: Binary CDMA Salient Features

Connection method	Point-to-point
Range	500m
Transmission speed	55 Mbps
Security	AES-128

A custom protocol SJ-10ch, was designed to fulfill the task of transporting the data from microcontroller to the central server. SJ-10ch protocol command is sent over the Binary CDMA with a baud rate of 9600 bps. SJ-10ch protocol command structure is of 22 bytes. This means that it can accommodate the data of 10 sensors at a time. The first and last bytes are reserved for start and end sequence while the remaining 20 bytes hold the data of 10 sensors. Each sensor occupies 2 bytes of data. This protocol command is depicted in Figure 4.

Start	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	End

Figure 4: SJ-10ch Command Protocol Structure

The RF transceiver used is KIB-2000M/S/R, it comprises of a Binary CDMA modem and a USB to UART bridge controller (Silicon Labs CP210x). The transceiver specifications are listed in Table 4.

2.3 Central Server

The central site contains the RF transceiver which receives the Binary CDMA signal and forwards it to the server at a baud rate of 115200 bps with the help of UART to USB bridge controller installed in the RF transceiver. After the server receives the signal, a custom written program in visual studio C# decodes the data and presents it in a readable graphical form. In addition to this, the server also acts a HTTP server which sends the data over internet and LAN to remote laptops and smart phones for real-time monitoring and signal analysis. The software implementation is discussed in the next section.

Table 4: KIB-200M/S/R Transceiver Specifications

Frequency	2.4 GHz ~ 2.4835 GHz
Data Rate	5 Mbps
Transmission power	19 dBm
Service Area	800 m
Interface	RS232, RS485
Power	12V DC
Temperature	-25 °C ~ + 70 °C

3. SOFTWARE IMPLEMENTATION

The software program is divided into two parts.

- The decoding and monitoring program.
- Smartphone android application.

The first part of the software is implemented in visual studio C#. The purpose of this program is to receiver the data form the RF transceiver and decode the SJ-10ch protocol command. The first and last bytes of the protocol command are the start and end sequence. The middle 20 bytes contains the data of the 10 sensors. The program is designed to read the data encapsulated in the protocol command and display it in a graphical manner. Figure 5 shows the graphical user interface of the application. The user can select multiple sensors, their data will then be displayed.

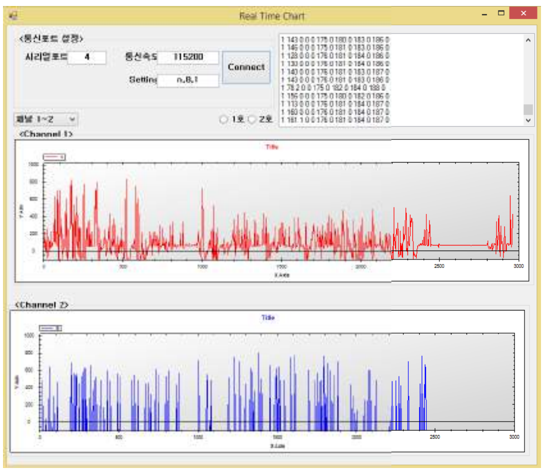

Figure 5: Computer Sensor Analysis Program

In addition to this, the user can also zoom in and out of the graph to note slightest changes in the readings. The program also creates a HTTP server to send the data collected by the server to remote sites. This data can be sent over internet or LAN.

The second part of the software is the android smartphone application. The sole purpose of the application is for the engineer on duty to monitor the reading on the android based smart phone. The application structure is simple. The main menu displays the option to choose from the sensors whose reading is to be displayed on the screen. The smart phone application directly connects to the central server to acquire data and displays it on the screen. Figure 6 shows a screen shot of the data received by the smartphone app.

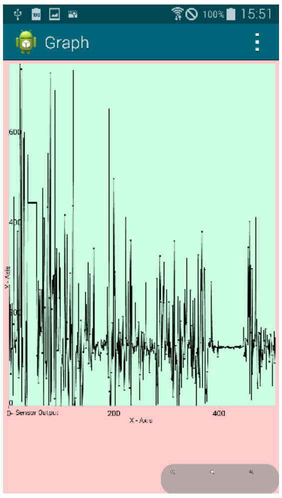

Figure 6: Android application for remote monitoring

4. CONCLUSION

This paper presents a prototype for monitoring the structural health of the railway tracks. The prototype is still under development with many new sensors to be incorporated for efficient study and monitoring of railways tracks. We plan on incorporating an IR module and camera for visual inspection. After the system is fully developed a standalone monitoring program will be made to efficiently interpret and predict any faults in the railway tracks before any collateral damage occurs. Complex computational techniques can be applied to sense any abnormal behavior in the structure of the railway tracks.

5. ACKNOWLEDGMENTS

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