HIGHWAY BRIDGE MONITORING USING WSN

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Abstract - As smart sensor networks and geographical information systems (GIS) are evolving nowadays, applications of remote monitoring in wide spread geographical areas are becoming cost-effective and possible. An example of such applications is the structural health status monitoring of highway bridges that connect roads in both rural and urban areas. Online, real-time structural health monitoring is a resourceful complimentary tool to facilitate rapid field inspection. Bridge maintenance and infrastructure managers can easily use such application to safeguard the performance and safety of these vital structures. This paper presents an autonomous sensor network system to monitor structural health in highways bridges. The proposed system consists of Accelerometer, flex sensor, load cell, buzzer, GSM module and Wi-Fi. The sensors gather the bridge health signs and transmit them promptly via GSM and Wi-Fi to the management and evaluation middleware for further processing. Based on the national bridge inventory rating scale, an early warning fuzzy logic-based engine is developed to process the status of a given bridge and alert the concerned operator/s regarding any abnormality. A prototype was built in the laboratory to validate the proposed system. Analysis of testing results and comparisons with existing monitoring systems are also discussed. Operators can access the bridge real-time data through mobile phone.

Index Terms— GSM, Wi-Fi, Accelerometer, flex sensor, load cell, buzzer

I. INTRODUCTION

Structures, including pipelines, aircraft, ships and civil infrastructures, such as bridges, buildings, dams, among others, are major parts of society's economic and industrial success. Bridges are one of the critical cross points of a country's transport net- work but they are expensive to build and maintain. Bridges suffer overall structural deterioration due to aging, overloading and lack of proper maintenance. Therefore, bridges are expected to have a higher level of reliable inspection and condition assessment to protect human lives and economic activities from unsafe bridge structures.

At present, visual inspections are the most common practice used to monitor the structural integrity of bridges. Mostly, this basic technique has proven to be in- adequate to ensuring bridge safety because it doesn't provide enough information to prevent the structure's failures. As Sensor Networks are evolving in the past decade and becoming more cost effective; civil engineers with their counterparts in sensing and communications technologies are seizing the opportunity to design, build and implement continuous health monitoring tools for bridge systems. Many recent studies were focused in developing wireless sensor nodes and platforms for high- way bridges. A structural health monitoring system of bridges using bias magnetic field sensor, signal conditioning circuits and impulse radio ultra – wideband transmitter was described. Moreover, a wireless measurement system using wireless sensor network for large bridges was developed. This latter system consists of a build-in MicroElectro Mechanical Systems (MEMS) accelerometer signal conditioning circuit, microcontroller chip, and central station. The bridge vibration frequency was measured using a pendulum. In-house software algorithm is developed to analyze the accelerometers that reflect the structure vibration. Several others wireless sensor network-based monitoring systems centred as short-range communication and other long-range communications were repeated. The differences among these systems are the data processing and the analysis algorithms to determine the health of the structure (damage detection algorithm).

Some of these algorithms are based on the dynamic index method, static displacement, or static curvature. Others ap- plied wavelet analysis, mode shape and neural networks. Others used the expanded damage detection methods to enhance the monitoring accuracy utilized genetic algorithms and Hilbert Huang Transfer (HHT). To complement the above mentioned systems, a real-time online remote wireless bridge monitoring system is proposed in this project. The system collects the sensor's data from a bridge; evaluates the bridge health status. Information with health history data is provided promptly for bridge safety assessment, to help owners and maintenance authorities make decisions in assigning maintenance budgets. The overall proposed health monitoring system comprises of hardware architectures. The hardware architecture is mainly designed for the data collection process, communications, and data storage. These conditions are classified based on the existing National Bridge Inventory (NBI) rating scale, which is a database used for highway management and resource allocation. Another added value to the proposed system is the early warning indicators by using buzzer and sending message.

II. PROBLEM STATEMENT

In bridge monitor system structural integrity of bridge is monitor. It is quite difficult to monitor the health of critical bridge items of maintenance and operations are required. Most of the roads are comprised of bridges when the roads are crossing the sea, rivers and mountains. For the safety, the status of the bridges is very crucial since the traffic accident and the wide might damage the bridges. Thus, the bridge status monitoring is needed to give an real-time evaluation to analyze the bridges.

Motivation:

At least 23 people have been killed after a bit of an under-construction over- pass collapsed in a crowded space of the jap Indian city of Kolkata. Ponte Marandi Motorway Bridge collapse in Italy as a result of structural defect -43 dead. Not just these two but there are numerous mishaps as a end result of structural defects. To avoid these accidents a system is required which will detect the structural defects and ship the details about the defect to the central control system.

Many long-span bridges worldwide have already applied such techniques how- ever excessive preliminary price and maintenance along with wired construction have created severe issues as a outcome of which the desire to utilize traditional methods nonetheless persists.

If there would be a system which will indicate defects in the bridge, the lot of number of mishaps could possibly be avoided.

III. LITERATURE SURVEY

A comprehensive market survey and laboratory evaluation was conducted by Helmicki, Aktan & team for the Ohio Department of Transportation and the Federal Highway Administration to identify the most promising sensors and data-acquisition systems for infrastructure application. A pilot system for highway bridge monitoring was implemented on a typical steel stringer bridge in Cincinnati for high-speed traffic and long-term environmental monitoring. Static tests were performed with known truck loads to contim monitoring results and to calibrate finite-element and section analysis models of the bridge. [1]

To obtain full range, all weather and real-time bridge vibrations, Yingsong & team uses a mm-wave radar for monitoring the micro-deformation data of these bridges. The measured results show that the designed mm-wave radar can well monitor the vibrations of the highway bridges with a super-resolution and high precision [2]. Thus, the designed radar can be used for natural disaster monitoring, such as bridge monitoring, dam monitoring, and debris flow monitoring applications.

Structural health status monitoring of highway bridges that connect roads in both rural and urban areas is done by Radaideh and his team. Many of these bridges are subject to deterioration due to external and internal factors. Online, real-time structural health monitoring is a resourceful complimentary tool to facilitate rapid field inspection. Bridge maintenance and infrastructure managers can easily use this application to safeguard the performance and safety of these vital structures. Here an autonomous wireless sensor network system to monitor structural health in distributed solution based on IEEE-1588 protocol is implemented and its shows high precision synchronization by this protocol [3].

The system consists of a wireless Data Acquisition Unit (DAQ), a mobile public network, a structural health data evaluation, a management middleware, a GIS and graphical user interface module. The sensors in the DAQ gather the bridge health signs and transmit them promptly via the public mobile networks to the management and evaluation middleware for further processing [4]. Based on the national bridge inventory rating scale, an early warning fuzzy logic based engine is developed to process the status of a given bridge and alert the concerned operator/s regarding any abnormality.

Furthermore, an interactive Google map is used to show the status of each bridge along with its exact location. Operators can access the bridge real-time data through mobile phone. The system is cost effective and user friendly.

Fang-liang highlighted on bridge structure monitoring & development of Ethernet technology, the requirement of time synchronization is essential in distributed Ethernet monitoring system. A bridge vibration monitoring device with the vibrating-wire sensor as the basic measuring device is designed to solve some problems in the application of the traditional engineering vibration measuring technologies into bridge monitoring, and a remote monitoring system is established with the wireless network technology, with hardware and software design integrating the single chip, ZigBee and GPRS [5]. The monitoring data is aggregated to the coordinator node via wireless communication and is finally transmitted to the host computer through GPRS module. It is indicated in site applications that the system has such advantages as strong instantaneity, high reliability and easy networking, and can be preferably applied for the remote monitoring of health conditions of dams, highway bridges and other large building structures.

Lu Peng Bridge health monitoring is not only a new technology for traditional bridge detection and structural assessment, but also given the significance of structural monitoring and evaluation, design verification and research and development [6]. The basic data acquisition method is to use the high-precision non-destructive sensing technology in the field to analyze the structural system characteristics including structural response, and achieve the functions of structural monitoring and evaluation, design verification and research and development. However, the sensor faces the challenge of being calibrated as the use time is lengthened during use. It is especially difficult to evaluate the uncertainty in the field calibration process.

Self-Powered Sensors for Monitoring of Highway Bridges makes systems prohibitively expensive. Energy harvesting is a solution capable to alleviate this problem. A novel wireless sensor system is presented that harvests vibrations of the bridge CREATED by passing traffic, which is converted into usable electrical energy by means of a linear electromagnetic generator. Utilization of an electromagnetic generator allows harvesting of up to 12.5 mW of power in the resonant mode with the frequency of excitation at 3.1 Hz, in this particular design. The novelty of the system also includes tight integration of the power generator and a smart algorithm for energy conversion that switches between the low-power mode and the impedance matching mode. [7]

Adam B. Noel focus on Structural Health Monitoring of Bridges Using Wireless Sensor Networks Attention Mechanism. Sructural health monitoring (SHM) using wireless sensor networks (WSNs) has gained research interest due to its ability to reduce the costs associated with the installation and maintenance of SHM systems. [8] SHM systems have been used to monitor critical infrastructure such as bridges, high-rise buildings, and stadiums and has the potential to improve structure lifespan and improve public safety. The high data collection rate of WSNs for SHM pose unique network design challenges.

Jan Aldrich R. Gaviña proposed structural Health Monitoring of Existing Concrete Bridges with AASHTO Type IV Girder Using Smart Bridge Sensor Nodes. There are more than 8,000 bridges in the Philippines today, most of which are Concrete Bridges [9]. As the Bridge infrastructure has aged towards the requirement for effective monitoring, the Structural Health Monitoring (SHM) of bridges has become increasingly significant. Currently, in the Philippines, the method for structural integrity evaluation of bridges is limited to on-site visual inspection. Moreover, visual inspections have proven to be deficient in assessing the actual condition of a certain bridge. For this study, Smart Bridge Sensor Nodes were utilized for SHM to further evaluate the health of a bridge. Acceleration readings gathered by the sensor shall aid indicate the actual health of the bridge in which visual inspections are incapable of. To efficiently utilize the sensors, the methods of proper installation and location for placement of sensors on an existing concrete bridge with American Association of State Highway and Transportation Officials (AASHTO) Type IV Girders was determined.

Frank Li presented Urban Highway Bridge Structure Health Assessments Using Wireless Sensor Network. Sensor data were collected on two pre-stressed box beam bridges (PSBB) with eight wireless sensor nodes. The wireless sensor was able to collect one hundred Accelerometer data samples per second without losing any wireless sensor data. Application software was developed to transform the sample data into frequency domain [10]. Sensor data from all eight wireless sensor nodes have shown the similar peak frequencies with multiple trial runs on the same bridge. The peak frequency component was unique to each highway bridge. The signal to noise ratio in frequency domain is greater than seven to one. By comparing the actual wireless sensor data with the predictions from a finite element bridge model, a hypothesis of evaluating the structural health of the bridge was presented.

IV. SYSTEM ARCHITECTURE

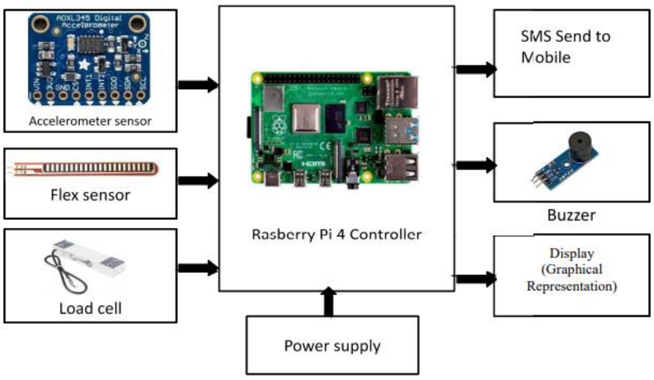

Figure 1.Block diagram System Architecture

When the power supply is given to the circuit the circuit will start and read the values in real time. In the system Accelerometer, flex sensor, load cell are used. When these sensors read the value they send it to the raspberry pi. If the values are beyond the threshold buzzer will turn on all sensors are given as the input to the raspberry pi . System is provided with threshold values for the sensors if the sensor reds the value beyond the threshold, system will send the alert message to the bridge maintenance team. Raspberry process the input and accordingly provide the output. Buzzer is the output device to the raspberry pi. System is provided with threshold values for the sensors if the sensor reds the value beyond the threshold, system will send the alert message to the bridge maintenance team. Raspberry process the input and accordingly provide the output. Here Raspberry Pi acts as heart of the system.

V. PROPOSED METHODOLOGY

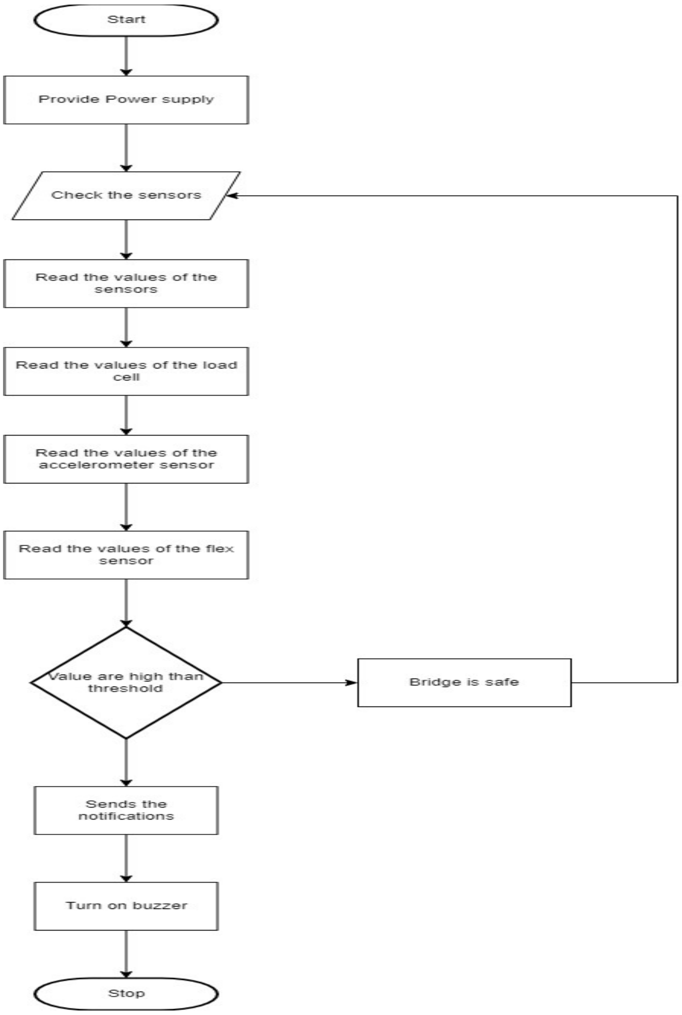

Figure 2. Flowchart of System

Above Fig 2 shows the flow chart of the system. Where sensors sense the input parameters & accordingly give the data to the raspberry-pi. Rasberry –pi processed the data & accordingly gives the notification.

VI. RESULT

Figure 3. Accelerometer X-Axis

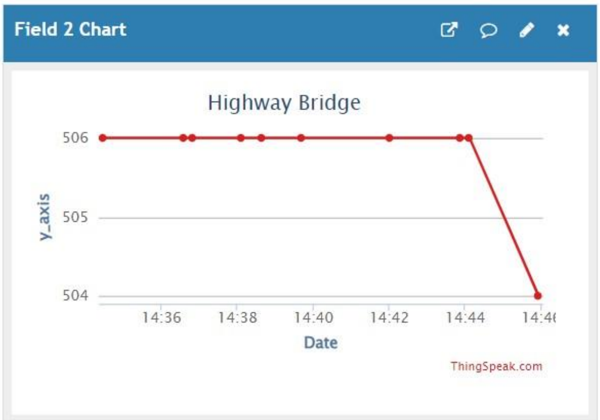

Figure 4. Accelerometer Y-Axis

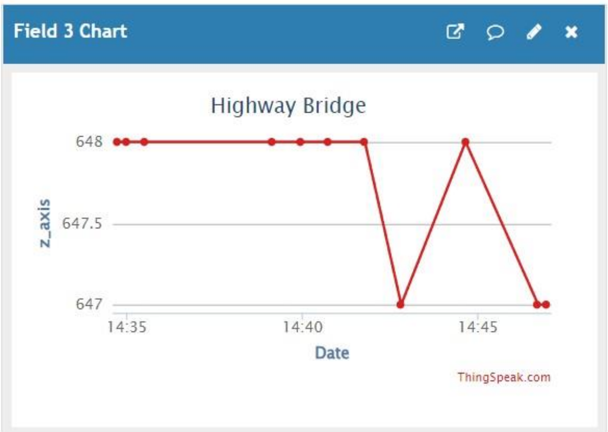

Figure 5. Accelerometer Z-Axis

Figure 6. Flex-Sensor

Figure 7. Load-Cell

- The above graphs shows the analysis of data based on Highway Bridge.
- Graph is the simplest data structure to show the analysis data.
- In the graph point shows the moment occurs on the bridge with respect to time.
- The Fig 3, Fig 4, Fig 5 shows that tilt is occurs on bridge at various time. This is analysis of calibration of tilt at particular time.
- The Fig 6 shows that at 14.40 jerk is occurs on bridge. This is the analysis of calibration of bend at particular time.
- The Fig 7 shows that at 14.50 load raised above the threshold. This is analysis of calibration of load at particular time.

VII. CONCLUSIONS

The system uses a sensor network for data collection and the collected data is also store to the cloud through IOT. In this system obtained results are matched with the threshold value if the obtained values are below or above the threshold value then appropriate action will be taken by management. This method has advantages of real-time alarming and little computation, which provides an efficient and effective algorithm for real-time alarming of extreme events in structural health monitoring.

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