Wireless Sensor Network Based Crack Detection on Concrete Bridges/Buildings

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Abstract—*As wireless smart sensor networks (WSN) 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. 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. This paper presents an autonomous wireless sensor network system to monitor structural health in highways bridges. Analysis of testing results and comparisons with existing monitoring systems are also discussed. Operators can access the bridge real-time data through mobile phone. The system is cost effective and user –friendly.Advancements in micro-electromechanical-systems made it feasible to deploy low-cost, self-configuring wireless sensor networks to monitor an area of interest with fine granularity. Due to its commercial potential, monitoring of large public buildings is a significant emerging application area for wireless sensor networks. Wireless sensor networks can be deployed to monitor the response of structures to strain and ambient vibration (e.g., wind, earthquakes), monitoring and controlling of indoor environment (e.g., lighting, heating, air quality), and helping in extreme event response (e.g., detecting congested exits, finding safe routes during an evacuation). Here we provide a brief summary to investigate the feasibility of monitoring large public buildings using wireless sensor networks, and list some of the open research problems in this domain.*

Keywords— *WSN, Raspberry pi, MEMS, Vibration sensor, GSM*

I. INTRODUCTION

Structures including pipelines, aircraft, ships and civilInfrastructures 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 network but they are expensive to build and maintain. Bridges suffer overall structural deterioration due to aging, Overloading and lack of proper maintenance. For example, more than 36%, or one in four, of the TN's bridges is either structurally deficient or functionally obsolete. 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[1]. The rapid development in the use robotics is being free humans from heavy and dangerous work, greatly improving the working efficiency, reducing the cost. And sometimes it can even realize tasks human beings cannot complete.

We develop a bionic climbing robot which can climb on rough surface due to its smart structure and bionic design. After loading simple camera, wall images can be acquired wirelessly in real time, which is suitable for health detection of bridge structure. But, due to the small load of the robot, both the size and precision of its camera are limited, which leads to the lower quality of obtained pictures.

The goal of our system is to obtain crack pictures of bridge surface, use algorithms to make up for the deficiency of hardware precision through a series of image processing methods, divide complete crack samples. Based on the visual and geometrical characteristics, a decision-tree-based multiclass support vector machine algorithm is applied to classify crack target.

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 inadequate to ensuring bridge safety because it doesn't provide enough information to prevent the structure's failures [1].

As Wireless Sensor Networks (WSNs) 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[1][2]. Many recent studies were focused in developing wireless sensor nodes and platforms for highway bridges. Among others, a Raspberry Pi and Code division multiple access (CDMA) prototype wireless sensor based systems for bridge health monitoring are designed and tested.

A structural health monitoring system of bridges using wireless sensor network for large bridges was developed [1][2]. This system consists of a build-in Micro-Electro Mechanical Systems (MEMS) accelerometer signal conditioning circuit, microcontroller chip, and central station. MEMS sensors will have very small devices with 1 µm-100 µm size. An MEMS sensor will have atleast one mechanical element or functionality.Gyro sensors and Accelerometer type of MEMS sensors are used for calculation of angular motion or displacement. The main principle behind these sensors is measurement of angular movement with respect to time (i.e. X-Y-Z axial measurements). These sensors also act as temperature sensors. These sensors are used in many different applications such as digital compass, gravity sensor, GPS tracking etc [1].

The bridge vibration frequency was measured using vibration sensor which works on the range of frequency specified. In-house software algorithm is developed to analyse the accelerometers that reflect the structure vibration.

Several others wireless sensor networks-based monitoring systems centred on Raspberry Pi as short-range communication and other long-range communications were repeated [3]. 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 applied 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 paper. The system collects the sensor’s data from an in service bridge; evaluates the bridge health status using a fuzzy logic based system to evaluate the bridge’s 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 wide popularity of wireless sensor networks and their quick adoption for several applications can be attributed to their:

- **Ease of deployment:** Since sensor nodes communicate wirelessly, there is no need for a communication infrastructure set-up. Using energy-conservation techniques (putting nodes to sleep when they are idle), the nodes can last for months on a pair of AA batteries without the need for any wall-power. Furthermore, wireless sensor networks can be programmed to be self-configuring, enabling an ad-hoc mode of deployment. Therefore, deployment can be as simple as dropping nodes at certain locations in the area of interest.
- **Low-cost of deployment**: Sensor nodes are built using off-the-shelf cheap components. The nodes complement what they lack in reliability/quality with redundancy as they are deployed in large numbers. With mass production, a sensor node will cost as low as a couple of dollars in the near future. Even in this early phase, a sensor node is competitively priced for about $150 (exact pricing will vary based on the sensing modalities requested).
- **Finer grain of monitoring:** Traditionally, structural monitoring systems have been designed using coaxial cables to transfer data from sensors to centralized data repositories. The extensive lengths of coaxial cables not only drive the cost of wired monitoring high and limit the extent of monitoring to less number of sensors than desired, but they also complicate the deployment since routing the cables and protecting the cables is a very labor-intensive task. Wireless sensor networks offer an economical, simple method for real-time and fine grain to monitor the structures during ambient vibrations and seismic disturbances. Such monitoring of a structure starting fromthe construction phases throughout the actual use could enable us to perceive what is happening in detail and will potentially provide new insights about construction quality and performance of critical structural components in a building throughout its service life.

Monitoring of indoor environmental quality can vary from monitoring, controlling, lighting, heating conditions and air quality to detecting presence of bio-chemical agents. Again, using wireless sensor networks a finer-granularity monitoring and a timely response can beachieved. Moreover, since wireless sensor networks are easy to deploy they are unaffected,unlike wired networks, by the interior configuration changes of offices in large buildings.

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II. LITERATURE SURVEY

The method of Detection and Recognition of Bridges' Cracks Based on Deep Belief Network adopts Raspberry Pi to collect and pre-process images, to transmit images data by the GPRS / 3G or wired networks. And it uses high-level image servers to make image analysis. According to the characteristics of bridges cracks ' images, this method selects and improves the best processing algorithm, as well as detects and recognizes the true bridges cracks. Finally, bridges cracks are classified by use of the Deep Belief Network (DBN). By the analysis of the experimental data, the system can find all bridges cracks beyond the maximum, and can effectively identify the type of fractures. The recognition rate is above 90%, which meets the accuracy requirements of engineering.

III. DESCRIPTION

A. POWER SUPPLY:

The power supply section is a essential one.It is a device that provides electric power to the Raspberry pi Microcontroller.It should deliver constant output regulated power supply to(5-7)volts DC power supply and that is given to the microcontroller.

B. RASPBERRY PI:

The Raspberry Pi 3 Model B is the third generation Raspberry Pi as shown in Fig.1. This powerful credit-card sized single board computer can be used for many applications and supersedes the original Raspberry Pi Model B+ and Raspberry Pi 2 Model B. While maintaining the popular board format the Raspberry Pi 3 Model B brings you a more powerful processer, 10x faster than the first generation Raspberry Pi. Additionally it adds wireless LAN & Bluetooth connectivity making it the ideal solution for powerful connected designs.

Figure 1: Raspberry pi Microcontroller

C. VIBRATION SENSOR:

Accelerometers operate on the piezoelectric principal that a crystal generates a low voltage or charge when stressed. (The Greek root word “pieze in” means “to squeeze”.) Motion in the axial direction stresses the crystal due to the inertial force of the mass and produces a signal proportional to acceleration of that mass. This small acceleration signal can be amplified to measure acceleration or to convert (electronically integrated) within the sensor into a velocity or displacement signal. This is commonly referred as the ICP (Integrated Circuit Piezoelectric) type sensor. The piezoelectric velocity sensor has a wider frequency range, and can perform accurate phase measurements. Most industrial piezoelectric sensors are used in vibration monitoring.

Figure 2: Vibration Sensor

D. MEMS SENSOR:

Micro electro mechanical systems (MEMS, also written as microelectromechanical, MicroElectroMechanical or microelectronic *and* micro electro mechanical systems and the related micro mechatronics) is the technology of microscopic devices, particularly those with moving parts. It merges at the Nano-scale into Nano electromechanical systems (NEMS) and nanotechnology. MEMS are also referred as micro machines in Japan, or micro systems technology (MST) in Europe.

MEMS are made up of components between 1 and 100 micro meters in size (i.e., 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micro meters to a millimeter (i.e., 0.02 to 1.0 mm), although components arranged in arrays (e.g., digital micro mirror devices) can be more than 1000 mm^2. They usually consist of a central unit that processes data (the microprocessor) and several components that interact with the surroundings such as micro sensors. Because of the large surface area, forces produced by ambient electromagnetism (e.g., electrostatic charges and magnetic moments), and fluid dynamics (e.g., surface tension and viscosity) are more important design considerations than with larger scale mechanical devices.

Figure 3: MEMS Sensor

E. USB CABLE:

Arduino use the USB port to simulate a serial port .So we have to use a USB cable to connect the Arduino USB port to computer USB port.

Figure 4: USB Cable

F. GSM MODEM:

GSM is a mobile communication modem. It is widely used for mobile communication system in the world. GSM is an open and digital cellular technology used for transmitting mobile voice and data services operates at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands. 2G networks are developed as a replacement for first generation (1G) analog cellular networks, and the GSM standard originally described as a digital, circuit-switched network optimized for full duplex voice telephony. GSM system was developed as a digital system using time division multiple access (TDMA) technique. GSM digitizes and reduces the data, then sends it down through a channel with two different streams of client data, each in its own particular time slot. The digital system has an ability to carry a data rate of 64 kbps to 120 Mbps.

Figure 5: GSM Modem

IV. BLOCK DIAGRAM

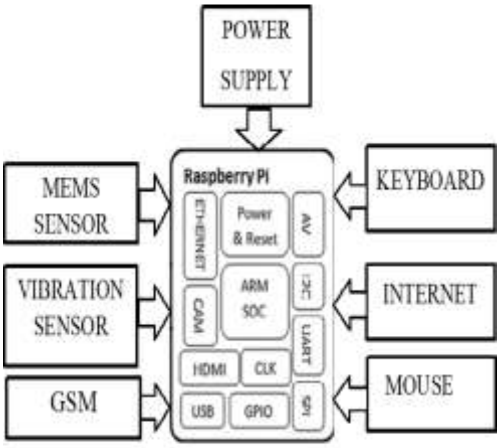

Figure 6: Interfacing sensors and GSM with Raspberry pi

V. WORKING PRINCIPLE

First, the sensors (MEMS and vibration) and GSM are connected with microcontroller as shown in Fig.7. Then, the raspberry pi microcontroller is connected to the mouse and keyboard.MEMS sensors will have very small devices with 1 µm-100 µm size. An MEMS sensor will have atleast one mechanical element or functionality.Gyro sensors and Accelerometer type of MEMS sensors are used for calculation of angular motion or displacement. The main principle behind these sensors is measurement of angular movement with respect to time (i.e. X-Y-Z axial measurements). These sensors also act as temperature sensors. These sensors are used in many different applications such as digital compass, gravity sensor, GPS tracking etc.The bridge vibration frequency was measured using vibration sensor which works on the range of frequency specified.

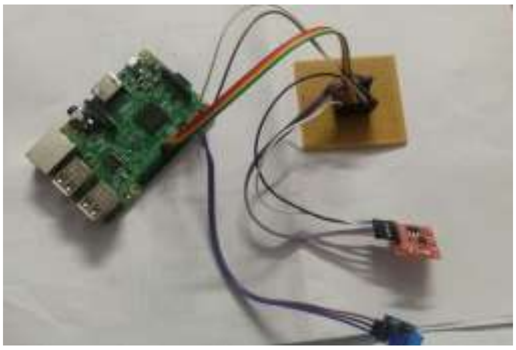

Figure 7: MEMS and Vibration Sensor are connected with Microcontroller

In-house software algorithm is developed to analyse the accelerometers that reflect the structure vibration.The sensor will sense the value for the bridge crack detection and the values are sent through the microcontroller.The GSM will send the message from the bridge cracked in case occurred.

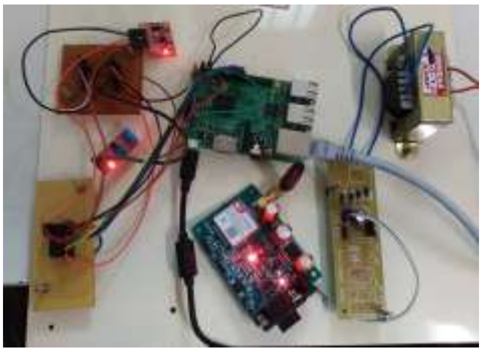

Figure 8: Interfacing GSM and Raspberry pi

The values are transmitted through the web server and the monitored with the web page using internet.The bridge crack detection is measured the crack location based on bridge axis in the MEMS sensor and the vibration sensor to calculated the location in the bridge. The photos and videos are sent directly to a cloud server, when the cloud is not available then the data is stored locally on the Raspberry Pi and sent when the connection resumes.

VI. APPLICATIONS

- ***Ease of deployment:***Since sensor nodes communicate wirelessly, there is no need for a communication infrastructure set-up.
- ***Fine grain of monitoring:*** Since they are inexpensive, it is possible to deploy wireless sensor nodes densely for fine-grain of monitoring.
- ***Low cost of deployment:***Sensor nodes are built using off-the-shelf cheap components.
- The Detectors are used in industrial application to monitor the structure of the buildings like hospitals, hotels, schools and colleges.

VII. CONCLUSION

In this paper we provided a brief survey of the state-of-the-art in wireless sensor networks with an emphasis on structural and environmental monitoring applications. We outlined the challenges and open research problem from the computer science and engineering perspective for these systems to be deployed in real-world scenarios. We believe that to achieve successful real-world deployments, there is a need for collaboration between structural& environmental engineering and computer science & engineering disciplines.The bridge crack detection is detected based on the angle changing and the crack is detected with the location in vibration of the bridge. Then the values are sent through the GSM modem when the bridge is cracked. And also monitored with the web pages through the internet. The bridge crack identification and the angle location traced using raspberry pi microcontroller.

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