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DESIGN OF CONDITION MONITORING SYSTEM FOR BRIDGE STRUCTURE USING REALTIME DAMAGE DETECTION ALGORITHM

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ABSTRACT

This paper shows application of wireless sensor network for monitoring the structural health of bridge. Many evidences of damaging the bridges had been found in under developed Asian countries before their expiry period. Wireless sensor network can be proved to be a reliable solution for early detection of damages so that early precautions can be taken. In this paper we aim to provide a solution based on WSN system, in which sensors like accelerometers shall be used and located at different predetermined positions of the bridge. The sensors shall be interfaced with wireless nodes for monitoring and transmitting the sensed physical properties of the bridge. The master station located at few meters will compare the results with database in good condition and decision regarding the condition shall be taken.

This paper focuses on requirement gathering issues, system design and development issues, design challenges and implementation algorithm.

***KEYWORDS:** wireless sensor networks, structural health monitoring, bridge conditioning monitoring, accelerometer, WSN etc.*

I. INTRODUCTION

The purpose of this system is to understand the features of a Structural Health Monitoring (SHM) scheme, and how it can be useful to bridge structures. The Structural Health Monitoring system based on accelerations and is carried out to know the impacts of vibrations on a bridge to find damage. It is done by making a study of bridge model and dangerous points on model structure like weak bridge parts and joints of bridge. These dangerous points provide the important information to provide the accelerometer placement for continuous monitoring of the bridge very effectively. This project will provide the applications of sensors (mainly accelerometers) as well as their correct location to protect the bridge from damage and give accurate collected data and give awareness to the rising field of structural health observing. The aim of this system is to apply my study into a structural condition monitoring system.

Structural Health Monitoring is an important factor to structural engineering application. The need to monitor the health of our structure and maintenance of it is very important in these days. So in order to monitor the health of a structure a structural health monitoring system must be applied to fully understand how the bridge is responding to various conditions of loads and find out bridge is weak enough to failure or not.

The main objectives of the SHM are to monitor the bridge under various loading conditions, measure its performance under various provided loads, to detect its damage or weak parts, and to give its inspection result to maintenance team. It is very important to understand the effects of loads or moving loads on a structure because it will decide the design rules for a structural system. When structures are designed, such as bridge structures, properties such as load can be calculated with a high level accuracy.

The advantages of using wireless monitoring systems are

1) Easy installation,
2) Accuracy with wireless data collection,
3) Highly reliable,
4) Widened coverage.

In the proposed work, wireless sensing system will be designed and implemented for health monitoring of structure like bridge to detect early damage of constructions. This system will provide a real time and complete structural health monitoring system consisting of sensors, ADC, ARM microcontroller, PC for monitoring the signals which are coming from actual structures after vibrations. Sensors are data acquisition subsystems which are located at distant place and it is able to connect to PC wirelessly through Zigbee protocol, while continuously working in all environments.

II. LITERATURE REVIEW

Saniie J. et al have presented [1] a method in which Critical structures such as aircrafts, bridges, dams and buildings require periodic inspections to ensure safe operation. It tells us Reliable inspection of structures can be achieved by joining ultrasound non-critical challenging techniques with other sensors (for example, temperature sensor and accelerometers).

Qin Yuan et al have presented [2] a system in which the average CT number is used to analyse the damage and crack process of physical example, and the concept of damage and fracture process is improved. This study provides a suitable and fast way to observe the concrete with quality and quantity in the engineering practices.

Bhuiyan et al [3] presented paper which told, Sensor placement plays a vital role in deploying wireless sensor networks (WSNs) for bridge monitoring powerfully and successfully. Existing civil engineering approaches do not seriously consider WSN limitations, such as load, type of network connectivity, and error acceptance.

Wen-Zhan Song et al [4] have presented method which gives information about sensor nodes, that since we are using sensor nodes we are getting highest detection information very accurately compare to other traditional methods.

Tang Yu-liang Luo Yu et al proposed a system [5] which provides a new online structural damage detection method called N-stage Kalman Filter Algorithm.(NS-Kalman) Its main theme is to segment a big structure into several sub-structures. Every substructure will collect sensor data within its range and process that data with the NS-kalman. Finally, we will get detection result.

III. BACKGROUND

a. STRUCTURAL HEALTH MONITORING

Structural Health monitoring is a method of determining the health of a structure, and in terms of this project a bridge structure. The way to determine the health of the structure is almost like to determine the health of people's heart. A variety of sensors are placed at predetermined positions. These sensors are connected to various nodes via wireless connections and finally a structure connected with various computer programs and then structure's behaviour is developed. Monitoring this behaviour gives us the current state of the bridge.

The key component to structural health monitoring is the development of a network of sensors that will continuously monitor the health of a structure. This proposed system does not only take feedback from various connected sensors but also take decision on parameters provided sensors in real time. Finally SHM tells us how the structure is responding to various loading conditions, vibrations and environmental effects.

b. PROBLEM FORMULATION

In the proposed project, we have aim to design and develop a structural condition monitoring system based on wireless sensing network. In the system two tiers, time series damage detection and identification algorithm is implemented for early damage detection. Bridge parameters like vibrations are monitored and compared with database of undamaged bridge. This is smart sensor which will transmit the information related to structural health to the master station. The master station is equipped with PC; it will collect the obtained information and process those signals in MATLAB to show real time graph of vibrations and will draw the conclusion regarding the structure. The data will be acquired from these sensors, processed and will be analysed at master station and will be displayed on PC in form of graph. The day to day records can be maintained and compared. In case of more vibrations on bridge ARM controller will take the appropriate decision regarding the damage of bridge in form of indication like green or red led signals along with audio signals.

The implemented prototype has wide applications in areas where earth surface is weaker and is affected by frequent earthquakes, over load etc. Moreover it can also be implemented for other structures like roads, dams etc. In the prototype system a two-tier time series prediction based algorithm is implemented for obtaining the damage of the structure in real time.

IV. OBJECTIVES

1) Development of structural damage detection system.
2) The wireless sensor network located at different locations will send the information to master station.
3) Master station wills record the readings, analyse and will take the decision regarding damage or weakness of structure.
4) User/ owner will be alerted in case of swings in readings.

V. DEIGN CHALLENGES:

• The various values from sensors to be monitored, such as temperature, wind, displacement, and corrosion.
• The Practical value and expected ranges of the parameters should be compared accurately in kinds of weather conditions.
• Location of the measuring instruments like sensors and ICS.
• The requirement of power to connected network.
• The type of network for array of sensor.
• The duration of the monitoring.

VI. DESIGN OF SHM SYSTEMS FOR BRIDGES

To begin the design process one must first understand the different components to a structural health monitoring system and how they work and come together. A SHM system generally consists of the following modules namely, sensor node, data acquisition, data processing, transmission system, control system, data management system, and structural evaluation system. The sensory system along with the data acquisition, data processing and transmission system are actual located on the structure, were the others are offsite and help in the monitoring the bridge and data analysis part of SHM. How it all works: Sensors are placed throughout the bridge to measure data at critical points in the structure from vibrations. The data acquisition and data processing then capture that data and process it with help of ADC and ARM microcontroller then transmit that data offsite to the control system. The control system then stores and displays the data with help of PC. Now that data is collected for maintenance team and is now ready for introduction into the structural condition monitoring system.

a. SHM SYSTEM PROCESS

The design of a bridge SHM system requires the designer to understand different aspects about the bridge structure and the events involved with the bridge. The first to be considered is the features of the bridge and the environment that it will be in. for example what type of weather will the bridge experience over its lifetime and also whether or not it will be in water or not. It is very important to understand these parameters because each individual bridge project has unique demands and characteristics and must be understood before a system is designed for it. The following considerations should be implemented into the design process:

1. The parameters to be monitored, such as vibrations on various parts of bridge
2. The nominal value and expected ranges of the parameters
3. Location of the measurements
4. The accuracy requirement
5. The environment condition of the monitoring
6. The duration of the monitoring

Once these parameters have considered then development of a sensor system will start. Sensors should be picked based on the size and complexity of the bridge and also the demands of the monitoring system. Many aspects to consider such as accuracy, durability, effectiveness and cost etc are considered while picking the sensor. Also when picking sensors the environment they will be in must also be considered, things like humidity, temperature, and general weather aspects of the surrounding environment. In terms of this project environment will not be considered because model is developed in a controlled laboratory environment where weather and thermal effects are not takes on the output of data.

b. HOW IT ALL WORKS

Transmitter Side and control section
2148ARM Microcontroller
ADXL-335 (or any 3- axis accelerometer)
ADC0804 (10 bit analog to digital converter IC)

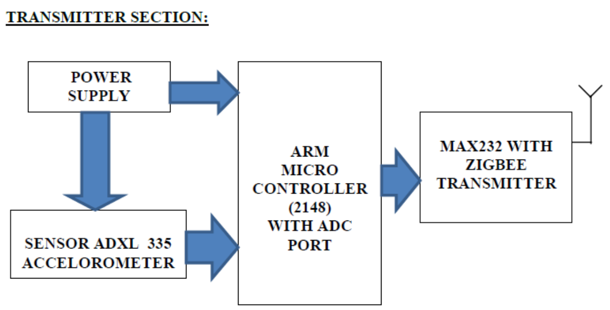
ADXL 335 Accelerometer sensor:
This module provides X, Y and Z axis data. It's very easy to deal with such kind of modules as they just need the VCC and GND supply to get started, rest it is its job to provide us the analog data. These modules work on simple concept like that of force acting on an object at inclined plane. It deals with the Mg (sin Φ) and Mg (cos Φ) part of the force and calculate the angle Φ for further calculations. Now it also notices the change in force from which acceleration will be calculated. These accelerometers do not respond to linear movements they respond to accelerated motions at very small scale.

ADC 0804:
This IC is used to convert analog data from ADXL_335 into a digital output. This was really necessary because microcontrollers only understand digital data. Since this ADC is a 10 bit one, it will provide 1024 different digital values (0-1023).Zigbee Transmitter: [23] It is used to transmit the data to receiver side. It is connected through UART. The output of ARM LPC2148 is transmitted to the master station where it is monitored that whether the bridge is under healthy condition or not.
Receiver side (Master station)

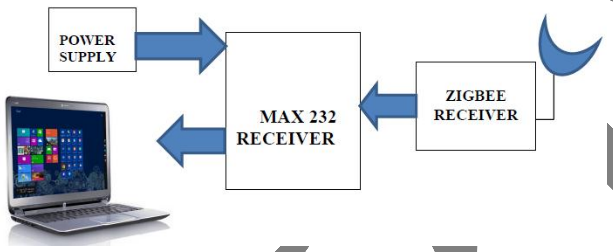
Zigbee Receiver:
It is used to receive the data from transmitter side. The microcontroller ARM LPC2148 decides that whether the bridge is under healthy condition or not. If it is found that the bridge is not under healthy condition then more vibrations like spikes can be send to master station and appropriate decisions are taken like playing the LEDs and buzzer to alert maintenance team. Once it is clear that bridge is not in good condition then on master side it needs to be displayed for maintenance team and that's what exactly we plan to do it on receiver side.

PC:
It is used to store the day by day data regarding the health of the bridge. When bridge is found to be under unhealthy condition, then related decisions are taken like informing the safety team through alarm and indications of LEDS. It is the device mainly connected for providing

message to maintenance team. On PC by using MATLAB we process these entire signals and plot various graphs and accordingly decision is made regarding vibrations on X, Y, Z axis.



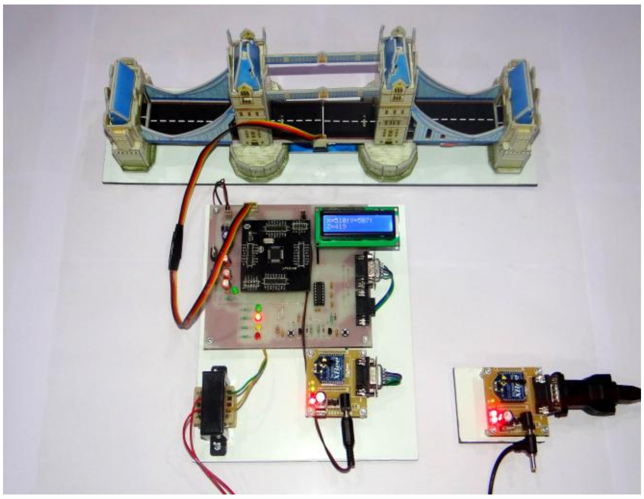
Control section:



VII. VIBRATION MEASUREMENTS SETUP

To determine the vibration on the model, accelerometers are used to measure the vibrations caused by the load or movement on bridge by force. This is accomplished by attaching accelerometers on various parts of the model and then systematically checked the vibrations on various places on bridge. The accelerometers were attached to not only the model, but also a computer with the computer program on MATLAB running to capture the effects of vibrations. The force is placed by hand to surface of bridge, ift the bridge gradually from all angles to check x,y,z movements etc. so that vibrations would be produced from a point and from accelerative movements. A diagram of the setup can be seen in the figure below.

The placement of the accelerometers during testing, were located in these areas to not only make measurements but to understand the impact of the vibrations on the model of bridge also. Once the data was stored in memory, then graphs were produced to get visual ideas of how the movement was taking place of bridge when force was acting on the bridge. Then accordingly we have formed visual graphs which show X, Y, Z coordinates and by using this obtained informed we could find that weaker area of the bridge. These graphs are very important to develop so that later on they can be used as a database to detect damage in the structure. Also knowing what the vibrations should be in certain areas of the model will also give ideas to which area of the model has changing its strength and becoming weaker and weaker. There are so many graphs were produced out of them few shown in figures to indicate X,Y,Z coordinates.



Fully Implemented System

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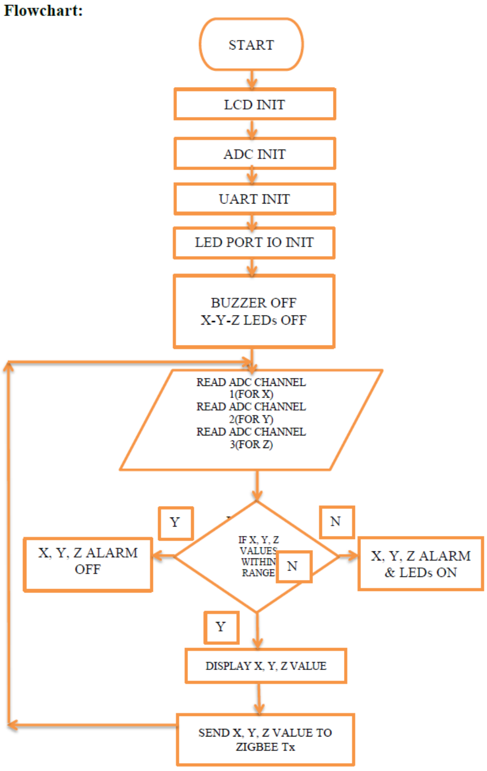
VIII. FLOWCHART :

Algorithm:

1. First Start system supply
2. LCD Initialization will take place
3. ADC Initialization will take place
4. UART Initialization will start
5. LED PORT or I/O Initialization will be visualized by flashing LEDs
5. BUZZER and X, Y, Z LEDs are OFF at initial stage
6. Read ADC channels For X, Y and Z coordinates according to movement
7.If X,Y, and Z values are within specified range in program then 8.X,Y,Z LEDs are off and alarm also off else alarm ON and LEDs will start glowing .
9. Maintenance team will go start observing conditions and will make move ahead.
10. If X, Y, and Z values are within range or not it will be displayed on LCD
11. SEND X, Y, Z Values to Maintenance team for database
12. Repeat procedure continuously in real time.

Flowchart:



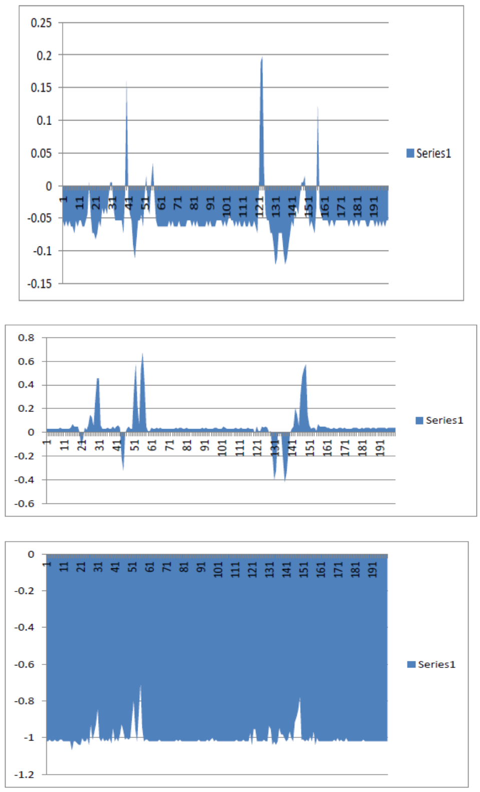
IX. EXPERIMENTAL RESULTS

The accelerometers senses real time vibrations and these vibrations are in form of analog signal. Latter on these vibrations i.e. analog signals are converted into digital signals by using inbuilt ADC of ARM microcontroller. Here these digital signals are compared inside microcontroller with specified threshold values and appropriate output is given out in form of blinking LEDs and making alarm on.

After words these digital signals are send to controlling side which is equipped with PC where these signals are processed on MATLAB software and finally appropriate graphs are generated which indicates movements of bridge parts under forces applied on it that is due to vibrations it moves in X, Y, Z directions.

Below various experimental results are shown. Out of them results associated with positions of actual placements of accelerometer. Some of them are of position1, position2, and position3 of accelerometer in X, Y, Z directions.

Accelerometer Location One and its results



Accelerometer location one results on X,Y,Z axis

1. Wireless sensors mounted on bridge structure to monitor displacement, temperature, vibrations.

2. Proposed plan should work with wireless sensors so very less cable work will require.
3. It is less expensive.
4. Microcontroller always takes quick decision so it is a less time consumable.
5. All this is expected to enable the sensors and nodes to operate for years without needing battery replacements

X. CONCLUSION

During this Project, there was lots of important information and experienced gained. Through the experimental process a structural health monitoring scheme was developed to detect damages that could occur in the real time. This information along with the understanding of different loading conditions that is vibrations due to various kinds of forces applied on bridge parts, gave us important information about the structure. It provided me with a key understanding of how monitoring the different aspects of a structure can lead to the development of a basic monitoring system of structure. This includes not only functions I used to analyse it, but also things like dynamic vehicle loads, difficult analysis caused due to flooding conditions, and a wide variety of different loading conditions which includes natural disasters and manmade disasters. After data is collected it is then post analysed and find out current condition of whole bridge or specific part of bridge that is parts of bridge are become weaker or not and finally it is concluded bridge is healthy or not

Upon completion of this project the key findings were as follows:

Through the study of accelerations and the effects of vibrations on a structure gives us essential information about the rigidity associated with that structure, and how it can be used to detect damage in structure. Vibration based damage detection is a very effective method of monitoring and can be accomplished using very few sensors and be implemented into any structure. Finally we designed and made prototype used to developing an effective and reliable structural health monitoring system.

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