Vibration Based Structural Damage Detection in Multipoint Environment using PSD Algorithm

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***Abstract*— Civil engineering infrastructure is generally the most expensive national investment and asset of any country. In addition, civil engineering structures have long service life compared with other commercial products, and they are costly to maintain and replace once they are erected. All civil structures age and deteriorate with time. The deterioration is usually the results of aging of materials, continuous use, overloading, aggressive exposure conditions, lack of comfortable maintenance, and difficulties encountered in correct review ways. All of those factors contribute to material and structural degradation as internal and external damages emerge and coalesce, then evolve and progress. The project aims to develop autonomous systems for the continual watching, inspection, and harm detection of structures with minimum labor involvement.**

Using sensor technology, signal processing methods the project aims to develop a smart method to detect damage in the structure. To increase the accuracy and reliability of the system the project uses a multipoint sensor networking technique. Damage detection in the structure with more efficiency is the goal of this project.

I. Introduction

Vibration based Structural Health Monitoring (SHM) is a vital tool to improve the safety and maintainability of critical structures such as bridges and buildings. SHM provides period and correct data regarding the structural health condition. it's a method of non-destructive evaluations to find location and extent of injury from the multiple nodes, calculate the remaining life, and predict forthcoming accidents. SHM method incorporates several sensors e.g. accelerometer is that the commonest used sensor; the method usually includes observation of entire structure over a amount of your time victimization sensors, extracting injury sensitive options from the measurements given by the sensors. Later, information collected from the sensors must be analysed by applying completely different signal process techniques, as a result of a minor variation inside the system triggered by various factors like noises, temperature changes, environmental effects, might cause significant changes in the response from the multiple sensors nodes, concealing the potential signal changes due to structural defects. Various signal processing techniques have been used to improve the performance such as: Wavelet denoising, Fast Fourier Transform (FFT), Wavelet transform, Cross-Correlation (CC), Principal Component Analysis (PCA), etc. Wavelet analysis can be used to remove noise from the signal and detect damage in the structure. Power Spectrum Density (PSD) is a function of frequency which will plot power of the signal with respect to frequency. PSD is a normalized technique compared to other methods and computing and manipulation of PSD data is easier and simpler. On the other hand, CC is the degree of similarity between two signals. For SHM application all the signals after processing we will localize the point where the damage occurs and this data used to avoid any damage or failure of structure that may occur in its life span.

II. Literature Survey

In this paper [1], A recent video-based motion magnification method was developed to measure and visualize small structure motions. This new approach presents a possible for low-priced vibration measure and mode form identification. Pilot studies victimisation this approach on easy rigid body structures was rumored. Its validity on complicated out of doors structures haven't been investigated. the target is to research the capacity of video-based motion magnification approach in measure the modal frequency and visualizing the mode shapes of complicated steel bridges. a unique methodology that will increase the performance of this motion magnification for economical structure modal analysis is introduced. This method was tested in both indoor and outdoor environments for validation. The results of the investigation show that motion magnification can be an efficient tool for modal analysis on complex bridge structures.

With the developed method, mode frequencies of multiple structures are simultaneously measured and mode shapes of each structure are automatically visualized.

In this paper [2], authors propose a system that uses low-frequency magnetic fields to conduct 3-D displacement measurement directly from within concrete, with a median displacement error of 0.5 mm in all directions, with a maximum separation distance of 50 mm between the transmitter and the receiver. The sensors can be attached to the concrete surface after the building is erected, or can be included in the concrete mix at manufacture, to monitor displacement between gaps in enlargement joints, perform crack detection in concrete ties for railroads and in pavements, additionally as aid position measure for the assembly of premanufactured concrete blocks. Embedment in concrete permits operation throughout the life of a structure, providing early warning of imminent disaster and serving to to tell repair operations. The sensor can be used for the structural health monitoring of civil structures, such as roads, railroads and bridges, helping to warn of impending failure and informing repair operations for improving safety conditions. Future work will include miniaturization of the sensors, as well as field trials.

In this paper [3]. authors propose an efficient vibration-collecting method using wireless sensor networks (WSNs) that minimizes the need to perform modelling, making the SHM system easy to deploy on any structure with little to no modification. In our algorithm, we employ a two-layer stacking technique, similar to protocol stacking in networking. At the core of the algorithm is a frequency domain pattern matching technique applied to observed vibrations that is executed by each sensor node in the bottom layer of the algorithm. An energy management scheme for attaining the desired lifetime of the WSN is also proposed. The scheme is based upon a novel energy management circuit that decreases current for inactive sensor nodes, such to increase the lifetime of the nodes up to 90-fold. Upper bounds on system lifetime are determined experimentally using sensor nodes based upon the Zolertia Z1 mote. Finally, the pattern matching technique is validated on an experimental structure.

This paper [4] presents development and performance analysis of a sensor node including accelerometer, temperature and humidity sensors for wireless sensor network (WSN) system intended for structural health monitoring (SHM) application. The developed epitome integrates software and hardware supported ARM controller, having glorious process capability in terms of exaggerated on board RAM and higher power management facility. knowledge from sensing element nodes area unit faithfully transmitted to the base station, i.e. sink placed at a distance of concerning 30m. The system is verified mistreatment measuring system knowledge received at the base station through Fast Fourier Transform and found equivalent with that of a typical vibration data logger. Accelerometer data has also been explored in time-frequency domain using wavelet transform. The study also points out the best wavelet basis in the parlance of low frequency SHM applications.

In this paper[5], author discuss our deployment experiences and evaluate the performance of a multi-hop wireless data acquisition system (called Wisden) for structural health monitoring (SHM) on a large seismic test structure used by civil engineers. Our experiments indicate that, with the most recent sensor network hardware, Wisden will dependably deliver time-synchronized tri-axial structural vibration information dependably across multiple hops with low latencies for sampling rates up to two hundred Hertz. This performance was achieved by iteratively processing the system style employing a series of check deployments. Our experiences urged the requirement for careful onset detection so as to preserve the fidelity of the structure's frequency response. Furtheremore, the high damping characteristics of huge structures impelled a research of the process, sampling, and communication limits of current platforms.

In this paper [6], Structural Health monitoring is turning into more and more enticing for its potentialities in several application contexts, because of enhancements brought in by non-destructive check technologies. Among them, Operational Modal Analysis is an efficient tool to assess the integrity of vibrating structures. This work exploits both novel MEMS accelerometers and piezoelectric devices to extract strictly synchronized modal parameters. The advantages of using a combined approach are proved by highly coherent results from an instrumented cantilever aluminium beam, which is able to provide exhaustive structural information.

This paper [7] presents a localized information processing approach for long-term automated online structural health monitoring (SHM) using wireless sensor network (WSN). Feature-based Vibration examination is a powerful diagnostic tool for evaluating the structural performance.This paper presents vibration analysis of acceleration information collected by accelerometers at multiple locations of an old pre-stressed heavily loaded bridge that enclosed healthy also as un-healthy elements. All sensors are joined to create a WSN network. The position for mounting sensors has deliberately been chosen in between the piers of bridge therefore the most impact of vibration are often felt on girders. This deployment demonstrates the potential of WSN networks for structure health monitoring of enormous scale civil infrastructures.

Purpose of the paper [8] is to proposed new method is based on the acquisition and comparison of Frequency Response Functions (FRFs) of the monitored structure before and after an occurred damage. Structural damages modify the dynamical behaviour of the structure like mass, stiffened and damping, and consequently the FRFs of the damaged structure compared with the FRFs of the word structure, creating potential to spot, to localize and quantify a structural injury.

In this paper [9], a prototype for monitoring and detecting the damage for the real bridge using these sensor nodes is built. In this paper [9], a prototype for observance and detecting the damage for the real bridge using these sensor nodes is made. The prototype consists of sensor nodes, shaking table together with its electronic equipment, and real bridge. The sensors are placed on a scaled down concrete bridge model that's mounted on a shaking table. The results are demonstrated in terms of acceleration on different nodes at a particular excitation frequency in the case of normal, single-side damage, and double-side damage.

This paper [10] proposes a novel unsupervised damage detection approach based on a memetic algorithm that establishes the normal or undamaged condition of a structural system as data clusters through a global expectation-maximization technique, using damage-sensitive features extracted from output-only vibration measurements. The proposed approach is compared with state-of-the-art ones by taking into account real-world data sets from the Z-24 Bridge (Switzerland), where several damage scenarios were performed. The results indicated that the proposed approach can be applied in structural health monitoring applications where life safety, economic, and reliability issues are the most important motivations to consider.

III. Design

In this project the main aim is to check the health condition of a structure and monitor its condition. If there are any disturbance or abnormal changes in the structure the system will detect it and detects the pint at which the change has occurred. Figure 3.1 shows the simple block diagram of the proposed system.

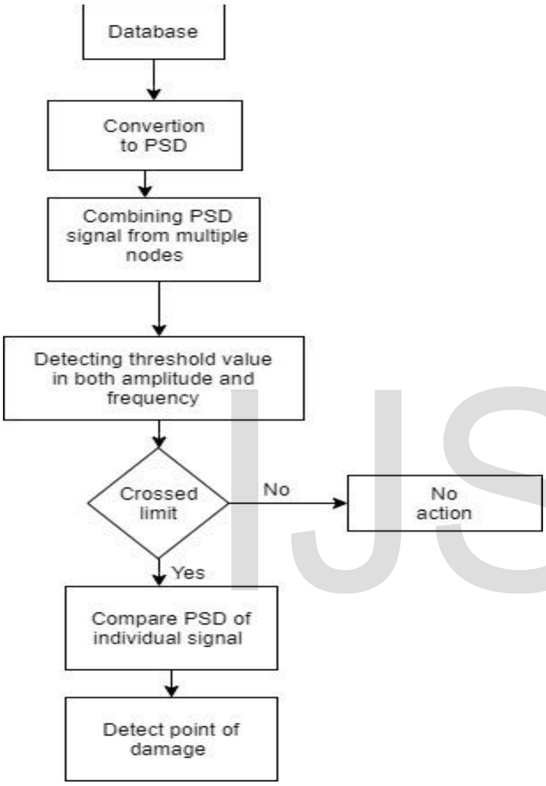

Figure 3.1Block diagram

For a structure there will be many critical points. These critical points or places depend on the architecture of the structure. First we need to identify these critical points and deploy a node in that point. If we deploy one node at a point the accuracy and efficiency of the system will be low. So in this system we need to monitor a point with more than one node.

These nodes will sense the vibration at that point and will send the vibration signal to the main node or cloud. Vibration of a point is sensed with multiple nodes and multiple signals are transmitted to the cloud.

The data stored in cloud or storage unit have to be processed and analysed for further operation. PSD technique is used for analysing the signal. Since a node is monitored using multiple nodes, the data transmitted from this multiple nodes are combined together to get the clear picture of that node. The health condition of that node is identified and the whole structures health is calculated with the data from signal generated from each point. This processed data is analysed calibrated and displayed with all the health information of the structure..

IV. Implementation

In this project multinode system is used to monitor the structure. The accuracy of the detection increases with increase in the node. The below of results are obtained for specific the number of nodes.

A. Single Node System

In a single node system only on sensor node is used to detect the damage. The range of the damage detection will be the range of the sensor node. Accuracy of the system is low and damaged area cannot be detected precisely. Figure 4.1 shows the results of a single node system.

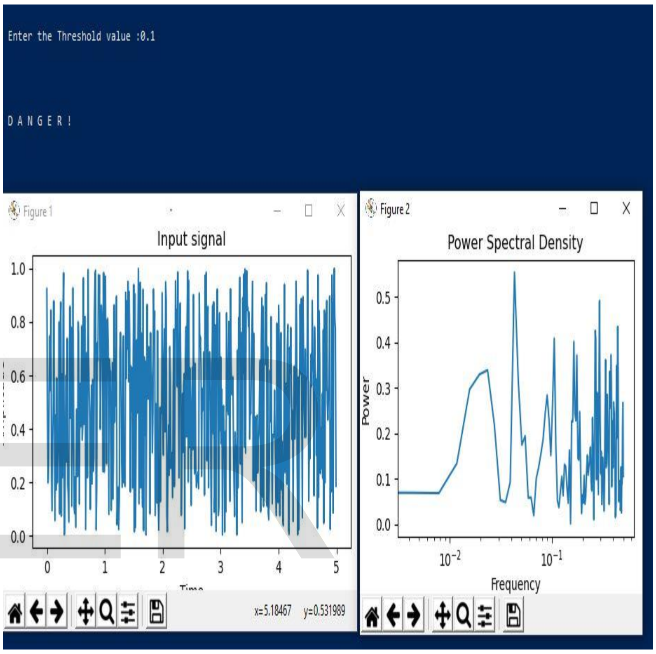

Figure 4.1 Results of Single Node System

B. Dual Node System

In a dual node system only two sensor node is used to detect the damage. The range of the damage detection will be the range of the sensor node. Accuracy of the system is low but better than single node system and damaged area cannot be detected precisely. These are the results obtained from dual node system. Figure 4.2 show the results. The results of multiple node system were found to be better and efficient than for the single node system. By increasing the number of nodes efficiency can be increased.

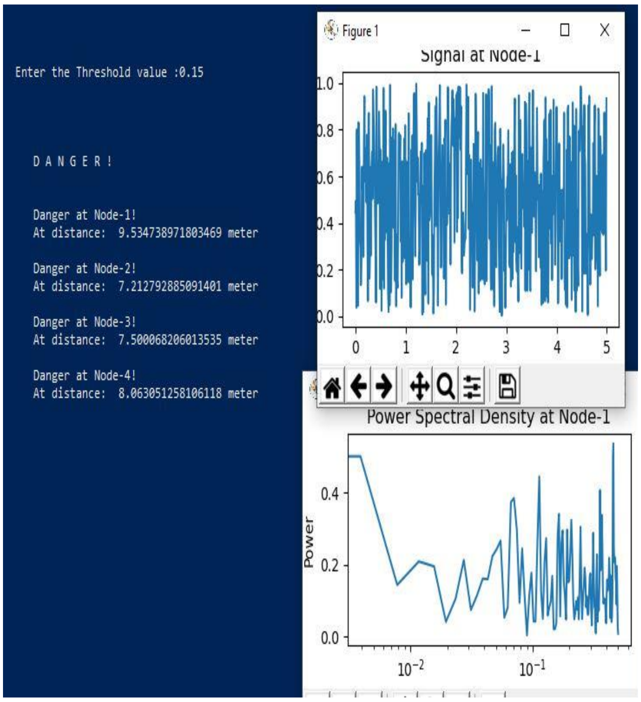

Figure 4.2 Results of Multinode System

V. Conclusion

The Vibration based structural health monitoring system using PSD algorithm project was conducted in simulation environment. Results of the simulation has found various advantages and drawbacks of the system. When implementing in a real time environment the mode and calibration of the system can be improved. Using different developing trends like machine learning, signal processing can take this project to next level.

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