Estimation of structural health monitoring parameters using signal processing algorithms

Abstract

The word SHM (Structural Health Monitoring) associates continuous observing of the characteristics of a structure by digital instruments like sensors (e.g. accelerometer sensors and etc.) In another way, SHM includes a selection of sensor data, continuous monitoring and figure out them in real-time. To Estimate SHM parameters, we need to acquire real-time data from the various sensors such as for as temperature, Humidity, Accelerometer, Strain gauge and Ph. From these sensors, data will be collected and undergoes selected suitable Digital signal processing algorithms for noise elimination. As we all know, noise is unavoidable in every signal. In this project, using signal processing algorithms, proper shielding and design can obtain the lowest noise level. Here, the most important technique used for noise elimination is wavelet-based denoising technique secondary notation, instead of the text-based user interface, typed command labels or text navigation[1].

Keywords:

SHM, Wavelet denoising, Accelerometer, Python, PyCharm.

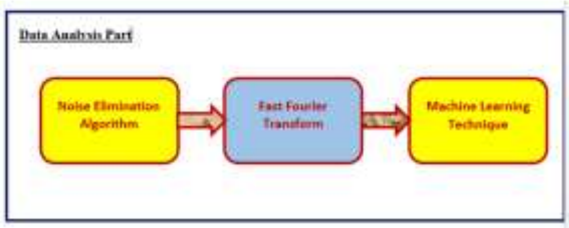
1. Introduction

The word SHM (Structural Health Monitoring) associates continuous observing of the characteristics of a structure by digital instruments like sensors (e.g. accelerometer sensors and etc.) In another way, SHM includes a selection of sensor data, continuous monitoring and figure out them in real-time. To Estimate SHM parameters, we need to acquire real-time data from the various sensors such as for as temperature, Humidity, Accelerometer, Strain gauge and Ph. From these sensors, data will be collected and undergoes selected suitable Digital signal processing algorithms for noise elimination. As we all know, noise is unavoidable in every signal. In this project, using signal processing algorithms, proper shielding and design can obtain the lowest noise level. Here, the most important technique used for noise elimination is wavelet-based denoising technique secondary notation, instead of the text-based user interface, typed command labels or text navigation[1].

Wavelet theory is one of the most modern areas for computing mathematics, developed by French researchers, Yves Meyer, and Albert Cohen. A wavelet is a tool in various areas of technical research, electronics, communications, image processing and many more applications. The main practice of wavelet is Noise elimination called denoising and compression of signals and denoising. The main objective of Structural Health Monitoring (SHM) is to acquire reliable data on the perfect conditions of a building, analysing the appearance and evaluation of damage present in the structure.

2. LITERATURE SURVEY :

To calculate the structural health monitoring parameters, we use accelerometer sensor data which was collected through a ZIGBEE protocol stack using the MSP430F5438A module which is a Texas Instrument. The data rate for ZigBee is maximum of 250 k bits per second. ZigBee is specified for an application that requires nodes to be placed at odd-locations and it is difficult to replace the nodes. %. This means the active time of a sensor node is very less and the device spends most of the time in low power saving mode. In general, ZigBee enabled devices can operate for so many years without replacement [7].



2. Noise Elimination Algorithm- Wavelet denoising: Nowadays, Wavelets analysis has become very popular for signal processing, because it possesses properties as it represents in Spatial, and etc. and it is a dynamic method for the data compression, noise reduction, and fast

computation. The Discrete wavelet transform is capable of removing of noise from 1D and 2D signals i.e, it is used for the multivariant signals. So it gives very efficient results for the elimination of noise in any type of signals.

Experimental Measurements generally contains noise that affects the original data for the further processing of data. The noise in the accelerometer sensor data usually of white noise and also some Environment noises may involve white collecting the data from the structure, and also some noises are due to the instrumental instability [5]. So, Denoising is the first step before further analysis of data and processing. The process of denoising is shown in a block diagram in figure 2. WT decomposes original data into series of wavelets in the spatial domain using windowing technique that has different intensities and scales. Wavelets include symmetric filter banks, the signal is multiplied by a matrix constructed from these filters. The purpose of the filters is to separate the detail and approximate coefficients from the original signal as the first level of the transform.

3. Implementation:

Denoising procedure: Denoising of Experimental data can be seen as a problem of nonparametric regression in which the signal is recovered from the noisy data. The main purpose of denoising is to remove the noisy coefficients from the original coefficients for better estimation of the signal. The flow of the Denoising process is shown in below.

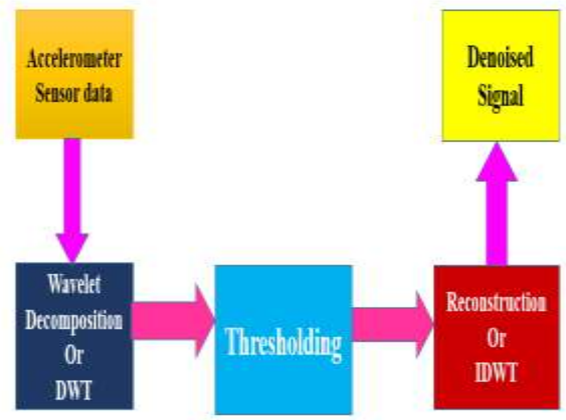


Figure.20. Denoising Process using DWT

Step 1: The Accelerometer sensor PCB393B12 is used for collection of data from the structure with the help of the MSP430F5438A and the Zigbee protocol. This collected data will undergo a denoising technique as shown above.

Step2: The DWT denoising procedure involves three steps:

- The data with the length of the power of two is transformed into the wavelet domain
- Thresholding technique is applied in the wavelet domain, means some coefficients are selected and zero-filling or shrinking of those coefficients can be done according to some criteria
- Reconstruction of those coefficients in their original domain from the wavelet domain[21]

Step 3: The result is obtained as the Denoised signal in its original domain.

4. Related Work:

The brief introduction of different modules used in this project is discussed below:

4.1: *MSP430 Micro-controller*

Figure 25: WSN node with MSP430F5438A and CC2520 RF Transceiver

The full form of the MSP is Mixed-signal processing which is a microcontroller family from Texas Instrument built about a 16-bit CPU. It is designed for low cost and, specifically, low power consuming embedded applications since it supports six low power modes which can disable the clocks and CPU, resulting in current use even less than 1μA.

All of the devices in the family are in-situ programmable via JTAG or a built-in bootstrap loader (BSL) using UART such as RS232. The following figure-15 gives the hardware configuration of the MSP430F5438A evaluation configuration.

4.2: CC2520 RF Transceiver:

The CC2520 is an unlicensed ISM band Texas instrument 2nd generation ZigBee/IEEE 802.15.4 RF Transceiver for the 2.4 GHz

Features of CC2520 RF Transreceiver:

- Adjacent channel rejection: 49 dB and Alternate channel rejection: 54dB.
- Excellent link budget (103dB) 400m line-of-sight range
- Extended temp range (-40 t0 +125 °C)
- Wide supply range: 1.8V-3.8V
- Extensive IEEE 802.15.4 MAC hardware to something that holds upon the micro-controller
- AES-128 security module
- Rx (receiving frame, 50dBm) 18.5mA
- Tx 33.6 mA @ +5 dBm
- Tx 25.8 mA @ 0 dBm
- Receiver sensitivity (-98 dBm)
- RF frequency range 2394-2507 MHz [25]

4.3 *Accelerometer sensor (PCB393B12)*

PCB393B12 is ICP piezo-electric 1-axis accelerometer with good sensitivity. Table-2 represents the specifications of the sensor[23].

S.No	Parameter	Value
1	Sensitivity	10V/g
2	Measurement range	0.5 pk
3	Frequency range	0.10 to 2000Hz
4	Excitation Voltage	18 to 30 VDC
5	Constant Current Excitation	2 to 20 mA

Table 3: PCB393B12 Accelerometer Sensor specification [24]

4.4 Software Components

- IAR embedded workbench IDE for developing ZigBee protocol with embedded C language [25].
- ZStack-EXP5438 Home profile [21].

Z-stack is software which has been implemented by Texas Instrument. It is following the ZigBee & IEEE 802.15.4 standard. The Architecture of Z-stack is shown in figure-16

Figure 26: Z-stack Protocol Architecture

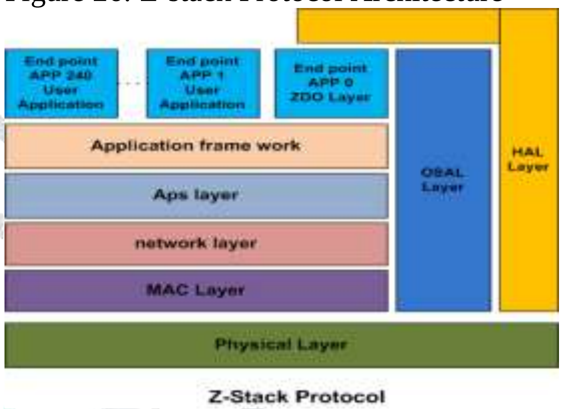


Figure 26: Z-stack Protocol Architecture
Z-stack is having the following layers:

- APP (Application layer).
- HAL (Hardware Abstraction Layer).
- MT ()
- NWK (Network Layer).
- OSAL (Operating System Abstraction Layer).
- Profile (Application Framework development).
- Security (Security provide both NWK & MAC layers).
- ZMac (Sub-MAC layer and SPI protocol Implementation for providing services to CC2520 RF Transceiver (IEEE 802.15.4 Standard)).

4. CONCLUSION:

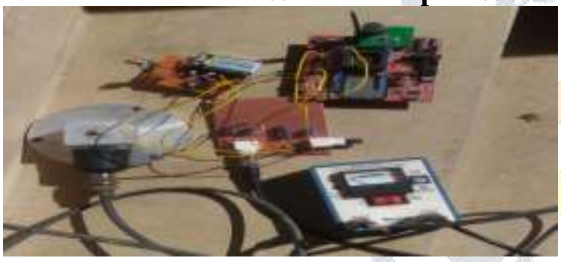
The Structural Health Monitoring system using wireless sensor network of civil buildings health monitoring has been developed successfully Finally deploy the implemented system with optimized design parameters on Tower and developed the GUI (Graphical User Interface) for displaying the each floor of structure response in frequency and time domain along with first three natural frequencies corresponding amplitudes in Python scripting environment. Normally in ambient mode the structure response strongly dominated with the noise. The main challenge is to remove the noise from the noisy signal and monitoring of the damage location on which floor damage will be occurring. We can extract the structure response from the noisy signal of any civil building structures using Wavelet de-noising algorithm Symlet8 with level-5 and minimax thresholding.

5. ACKNOWLEDGEMENT

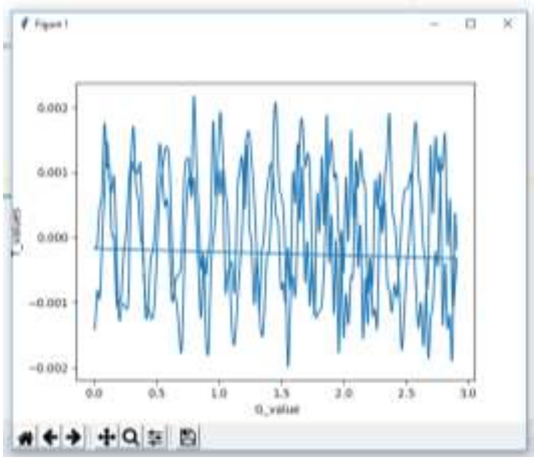
We would like to thank all the authors of different research papers referred during writing this paper. It was very knowledge gaining and helpful for the further research to be done in future.

6. RESULT

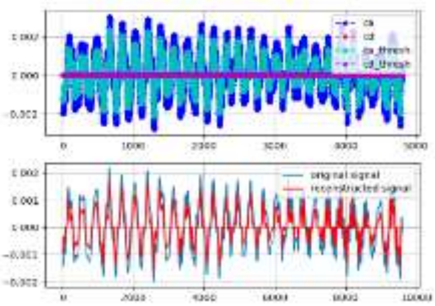
6.1 Real-time SHM With developed WSN system



Data from CSV file



After Denoising



Mathematical equations for computing Signal to noise ratio:

The signal to noise ratio is the ratio between the wanted signal and the unwanted background noise.

$$SNR = \frac{P_{Signal}}{P_{noise}}$$

It is more usual to see a signal to noise ratio expressed on a logarithmic basis using decibels

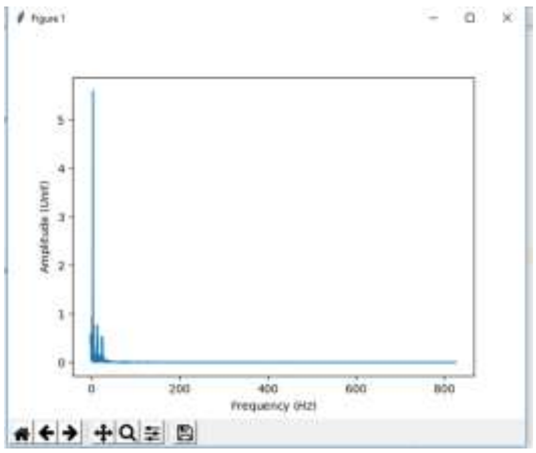
$$SNR_{db} = 10log_{10}(\frac{P_{Signal}}{P_{noise}})$$

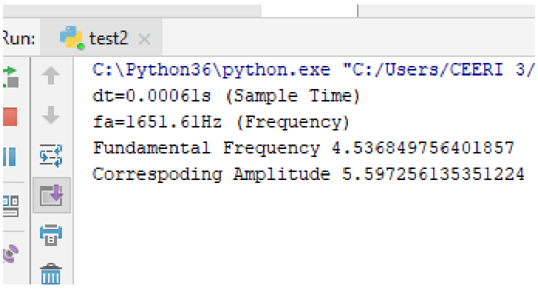
In this case, the increase in the signal content was:

$$increase = \frac{11.9}{2.2}$$

The increment came out to be 5.4 times as compared to previous.

FFT of Denoising signal





Experimental set-up of Coordinator and PC

Final output.

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