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IOT Platform for Structural Health Monitoring

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ABSTRACT

Structural Health Monitoring (SHM) is becoming a crucial research topic to improve the human safety and to reduce maintenance costs. However, most of the existing SHM systems face challenges performing at real-time due to environmental effects and different operational hazards. Furthermore, the remote and constant monitoring amenities are not established yet, properly.

To overcome this, Internet of Things (IoT) can be used, which would provide flexibility to monitor structures (building, bridge) from anywhere. In this paper, a complete IoT SHM platform is proposed. The platform consists of a Raspberry Pi, an analog to digital converter (ADC) MCP3008, and a Wi-Fi module for wireless communication.

Piezoelectric (PZT) sensors were used to collect the data from the structure. The MCP3008 is used as an interface between the PZT sensors and the Raspberry Pi.

The raspberry pi performs the necessary calculations to determine the SHM status using a proposed mathematical model to determine the damage's location and size if any. The All the data is pushed to the Internet filter using Thing Worx platform. The proposed platform is evaluated and tested successfully.

I. INTRODUCTION

SHM is a non-destructive evaluation technique to monitor the integrity of civil structures such as bridges, aircraft, etc. Since the gradual deterioration of structures can happen for different reasons, such as continuous exposure to the inclement weather, overloading, etc., SHM is a vital tool to be implemented in old buildings, bridges, etc., to ensure the safety of human beings.

Although researchers from different discipline took different approaches for SHM, most of the works in this field were done using civil and mechanical engineers' approach. Their works involved mostly to analyse natural frequencies of structures to make decisions.

However, in this paper, the chosen approach was to develop a technique to analyse signals (electrical) and implement the proposed technique on an embedded platform.

Generally, to perform SHM, firstly, data needs to be collected using sensors. Different types of sensors such as ultrasonic, piezoelectric etc. can be used for SHM to generate signals traveling through solid configurations. Later, data collected from the sensors needs to be analysed by applying different signal processing techniques, because a minor variation within the system triggered by different factors such as noises, temperature changes, environmental effects, might cause significant changes in the response from the sensors, concealing the potential signal changes due to structural defects.

Various signal processing techniques have been used to improve the SHM performance such as Wavelet noising, 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. Fast Fourier transform and wavelet transform are usually used to get the frequency spectrum of sensors' output signal, and these spectrums also can help to design appropriate filters to remove noises. On the other hand, CC is the degree of similarity between two signals.

For SHM applications, the signals to be compared are the base signal and the real-time signal. Another useful signal processing technique used in SHM is PCA, which uses orthogonal transformation to establish the linear relationship between input and output. The linear input/output relationship developed for a targeted structure can be exploited for an SHM process.

II. PROPOSED METHODOLOGY

The proposed IoT platform consists of Wi-Fi module, Raspberry Pi, ADC, DAC, buffer, and PZT as shown in Figure 1.

The two piezoelectric sensors are mounted on the structural and connected to a high speed ADC. In the real case implementation, we will deploy the sensors in a way to catch all the possible damage. A buffer is used as a level conversion and to protect the Raspberry Pi. The Raspberry Pi generated the excitation signal and the DAC converted it to analog. In addition, the Raspberry Pi, using the proposed SHM technique, is used to detect if the structure has damage or not and the location of the damage if it is existing.

Moreover, the Raspberry sends the structure health status to the Internet server. The data is stored on the Internet and can be monitored remotely from any mobile device. Moreover, the Internet server sends an alert if there is a damage in the structure.

WIFI MODULE

Wi-Fi Module. Miniature Wi-Fi (802.11b/g/n) Module is a USB module that has 2.4 GHz ISM band. It has a data rate up to 150 Mbps (downlink) and up to 150 Mbps (uplink). It uses IEEE 802.11n (draft), IEEE 802.11g, and IEEE 802.11b standards. The Wi-Fi module is used to send the data to the cloud.

RASPBERRY PIE

The Raspberry Pi 2 is a single-board computer. It features a full Linux operating system with diverse programming and connectivity options. The on board 900 MHz quad-core ARM Cortex-A7 CPU allows for swift computation and analysis of data obtained from several nodes and transducers.

The operating system of Raspberry Pi is Linux 3.18.5-v7+ and has 4 processors in one chip which is CPU ARMv7 Processor rev 5 (v7l). It has a RAM of 1 GB and maximum clock speed 900 MHz Normally, current drawn by Raspberry Pi 2 is 200 mA. The Raspberry Pi will be used to collect the structure health and push it to the cloud using Wi-Fi module.

ADC

The CA3306 is a CMOS parallel ADC designed for applications demanding both low-power consumption and high speed digitization. It is a 6-bit 15 MSPS ADC with a parallel read out with single 5 V supply. The power consumption is as low as 15 mW, depending upon the operating clock frequency.

It may be directly retrofitted into CA3300 sockets, offering improved linearity at a lower reference voltage and high operating speed with a 5 V supply. The high conversion rate of this ADC is ideally suited for digitizing high speed signals in SHM application. If a higher resolution is needed, the overflow bit makes the connection of two or more CA3306s in series possible to increase the resolution. Also, two CA3306s may be used to produce a 7-bit high speed converter that doubles the conversion speed; this will increase the sampling rate from 15 MHz to 30 MHz.

DAC

The MCP4725 is a low-power, high accuracy, single channel, 12-bit buffered voltage output DAC with non- volatile memory (EEPROM). It's on board precision output amplifier allows it to achieve rail-to-rail analogy output swing. The MCP4725 is an ideal DAC device where design simplicity and small footprint are desired and for applications requiring the DAC device settings to be saved during power-off time.

BUFFER

The 74HC4050 is a hex buffer with overvoltage tolerant inputs. Inputs are overvoltage tolerant up to 15 V which enables the device to be used in high-to-low level shifting applications.

PIEZOELECTRIC SENSOR

PZT transducer converts mechanical energy to electric signals or vice versa. They can work as an actuator to excite an elastic lamb wave based on the electrical signal applied to the PZT crystal. It can also be used as a transducer to transform the responding elastic lamb waves into an electrical signal. Two PTZs sensors are mounted on structure: PZT1 (excitation) will send the excitation signal and PZT2 (receiver) will receive the signal. The CA3306 is operating at 5 V, which means that we cannot connect it directly to the Raspberry Pi which operates at 3.3 V. Accordingly, a level converter in between is needed. The simplest way to do level conversion is to use a buffer such as CMOS 74HC4050. As the buffer runs at 3.3 V, so it is necessary to place a pull-up resistor to 5 V behind the clock buffer.

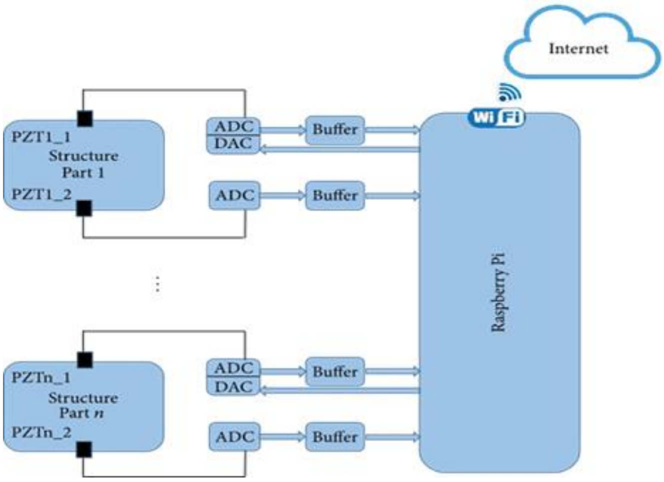

Fig. 1

PROPOSED MATHEMATICAL MODEL

In this model, two sensors (PZT) were used, which were able to generate, as well as receive signals. The generated signal by the PZT1 travelled through the structure, and PZT2 receives the signal (pitch-catch) as shown in Fig.1. When the signal gets reflected at the edges, it travels back to PZT1 (pulse-echo). The wave velocity of the signal, generated by PZT1, and the signal travel back to the PZT1, Ws needs to be determined, needs to be determined

$Ws=(L/T_h/2)$ eq -1

L is the distance between two PZT sensors, and is the peak Ws damage location, L to peak time difference. By utilizing found using the eq. (2).

$L=(T_h/2)\ Ws$ eq-2

After calculating the position, the next step would be determining the damage width. First, the proportion of the damage position to the total length, could be determined by:

$$\frac{Lc}{Lh} = S_1 \tag{3}$$

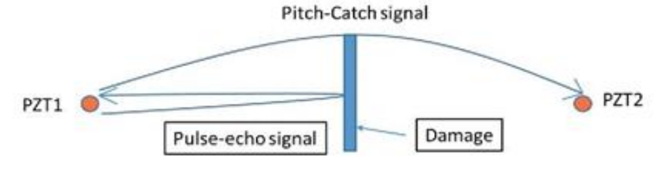

Fig. 1. Proposed Concept

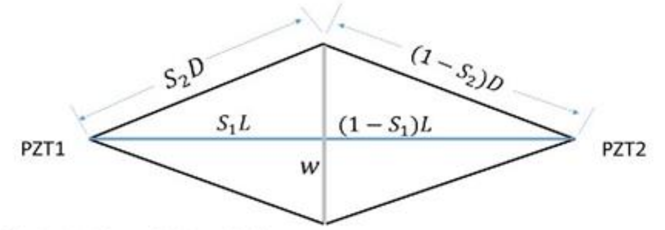

Fig. 2. Mathematical model diagram

Due to a damage being present, the wave takes longer to travel from exciter to sensor, which implies the wave travels a further distance. This distance, H, can be determined by:

Tt*Ws=D

Where, is the total time the wave takes to travel from exciter to the sensor with the presence of the damage. From these equations, a triangle can be made as seen in Fig. 3. is the hypotenuse of this triangle and are the base and very close in value and only equal if is 1⁄2. Whereas can be determined using the following equation:

W= 2*Sqrt of (S_2D) ^2-(Lc)^2

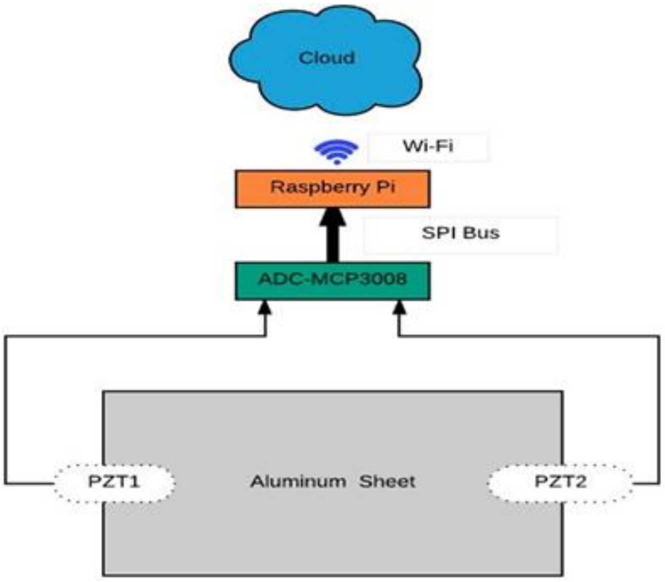

Fig. 3

III. RESULTS AND DISCUSSION

To verify the proposed architecture, as well as the algorithm, experimental set-ups were done for the pitch-catch technique by generating signals using function generators. Noises to these signals were added using other function generators. For the pulse-echo technique, the same setup would be needed.

In order to evaluate the proposed platform, a healthy aluminium sheet and another sheet with damage were used. The unhealthy sheet has damage that is 30 cm far from the exciter piezoelectric sensor and 7 cm width as shown in Figure 11.

The proposed platform is used to check both sheets and send the data to the Internet server. These two sheets are tested separately by the proposed platform.] Figure 12 shows the test bed as located in the lab.

The health status was sent to the Internet server that hosted on ThingWorx. ThingWorx is a technology platform designed for the the excitation signal and the DAC converts it to analog. In addition, the Raspberry Pi was used to detect if the structure has damage or not. Moreover, the Raspberry was used to send the structure health status to the Internet server.

The data was stored on the Internet server and can be monitored remotely from any mobile device. The system has been validated using a real test bed in the lab. Results show that the proposed IoT SHM platform successfully checked if the sheet is healthy or not with 0% error. In addition, the proposed platform has a maximum of 1.03% error for the damage location and maximum of 8.43% error for the damage width.

IV. CONCLUSION

Since IoT is gradually changing the way we used to interact with different devices, as well as applications, the blessings of IoT are appreciated by researchers from different disciplines. In this work, an SHM hardware platform with IoT was proposed.

The hardware architecture consisted of a raspberry pi, an ADC, and a Wi-Fi module. A simple signal processing technique with less mathematical calculation was implemented in this architecture, which used a Butterworth filter (to remove noises) and a mathematical model (to get damage location/size). Later, the SHM information was pushed to the Internet for remote access.

V. REFERENCES

[1]. IEEE explorer
[2]. https://www.hindawi.com/journals/wcmc/2017/6560797/
[3]. https://fardapaper.ir/mohavaha/uploads/2017/09/Fardapaper-Structural-Health-MonitoringFramework-Based-on-Internet-of-Things-A-Survey.pdf