Study on Structural Seismic Monitoring Using IoT Sensing Devices

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1. INTRODUCTION

Bridge structural monitoring has been paid more and more attention over the last few years as reviewed by Kim et al. (2016). Since most of the bridges in developed countries were constructed during the fast economic development period decades ago, many problems are appearing in recent years such as ageing and deterioration. There are not enough experienced bridge inspectors for periodic inspection. In addition, this kind of conventional inspection is high cost and low efficiency and the analytical reports are normally produced several days after the inspection. With the advancing sensor and information technology, the concept of Internet of Things (IoT) was adopted in this study for speeding up the workflow and decreasing the cost for bridge structural monitoring. A low-cost, high-accuracy, long-term and real-time acceleration monitoring system was proposed in this study. The measurement unit was composed of a 3-axis ADXL355 MEMS accelerometer and a Raspberry Pi 3 microcomputer. The measurement system was developed under Python open-source environment to handle data acquisition, data storage and data synchronization in real time. Shaking table tests were conducted to verify the measurement accuracy of the proposed method.

2. MEASUREMENT METHODOLOGY

The monitoring system consists of 3 layers in terms of dataflow: sensor, microcomputer, and cloud. The sensor used in this study is a 3-axis MEMS accelerometer, ADXL355, released in 2016 by Analog Devices and worth 6000 JPY. The microcomputer is a Raspberry Pi 3 Model B: a low cost (5000 JPY), credit-card sized computer which can communicate with IoT sensors. The communication protocol between the accelerometer and the microcomputer is a serial protocol I2C. The wiring of the measurement unit is shown in Fig. 1. This measurement application was developed using Python, an open-source general-purpose programming language. Measurement data was written into a local microSD card and uploaded to a cloud server via Dropbox API and to a physical server via SMB networking protocol.

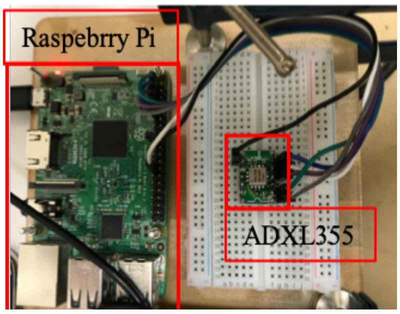

Fig. 1. Wiring demonstration

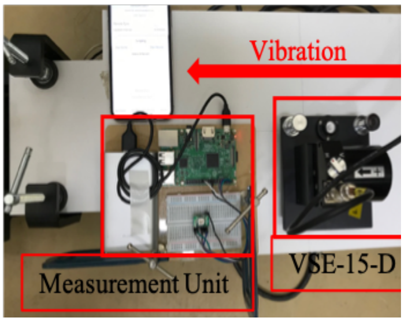

Fig. 2. Shaking Table tests set up


Fig. 3. Reference Data acquisition unit

3. SHAKING TABLE TESTS OVERVIEW

Shaking table tests were carried out on a uni-axis shaking table as shown in Fig. 2. The test setting was the match between various amplitude and frequency as shown in Table 1. The reference sensor was an accurate servo velocity seismometer VSE-15-D. The sampling rate was set at 100 Hz for both sensors, the measurement was started and stopped simultaneously. Then the reference data was acquired through data acquisition unit as shown in Fig. 3.

Table 1. Shaking table tests setting

Amplitude \ Frequency	0.1 Hz	0.2 Hz	0.5 Hz	1.0 Hz	2.0 Hz	5.0 Hz	10.0 Hz
1 Gal	◎	◎	◎	◎	◎	◎	◎
5 Gal	◎	◎	◎	◎	◎	◎	◎
10 Gal	◎	◎	◎	◎	◎	◎	◎
50 Gal	×	◎	◎	◎	◎	◎	◎
100 Gal	×	×	×	◎	◎	◎	◎

4. SHAKING TABLE TESTS RESULTS

The measurement sampling rate is stabilized at 100 Hz for the proposed system. The acceleration time history and its Fourier spectrum are shown in Fig. 4 and Fig. 5, respectively. Comparing the developed measurement system with the

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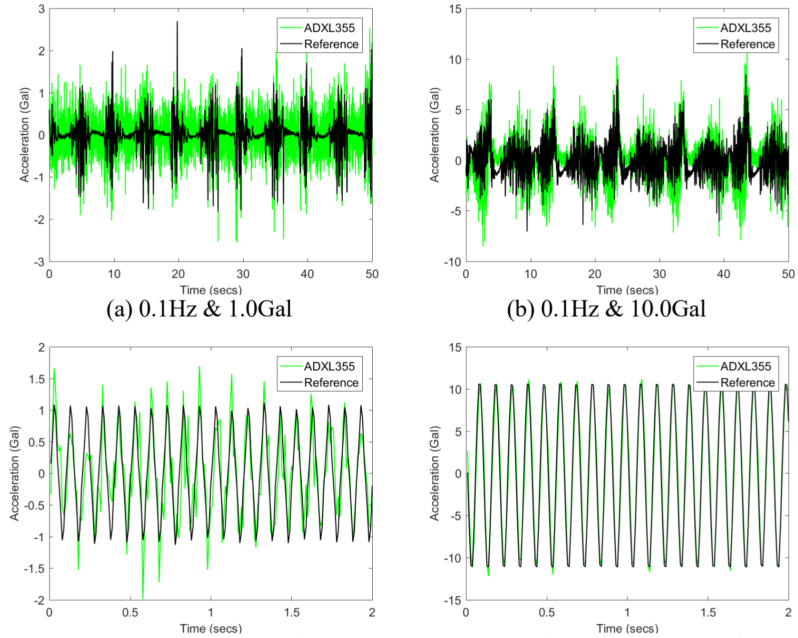
reference sensor, it can be seen that the noise in IoT sensor's result is significant when the frequency is low, e.g. 0.1 Hz. But its performance gets slightly better when the amplitude increased. The waveform matches better with the reference in Fig. 4(b) and (d). As can be seen in the Fourier spectrum, the predominant frequency can be easily captured. It can be inferred from the reference sensor that random errors become obvious when the frequency and amplitude is low due to the limit of equipment capability. In general, the measurements from the IoT sensor agree well with the reference sensor's result. Although the acceleration waveforms obtained from the IoT sensor does not precisely overlap with that of the reference system, the frequency domain spectrum matches with the reference system very well.

5. CONCLUSIONS

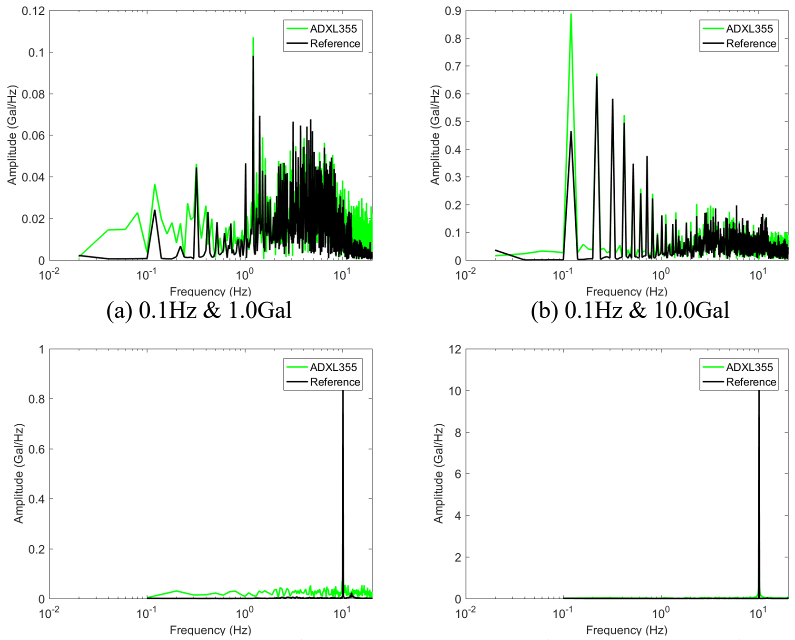
This paper discussed the application of IoT sensors into structural seismic monitoring. Integrated with the function of data acquisition, data storage and data synchronization, IoT devices dramatically reduce the cost of structural seismic monitoring with uncompromised performance. The physical size of IoT devices are smaller than the conventional measurement equipment, which means it will be easier to install IoT devices on site in practice. And the low power consumption shows the advantage, considering maintenance of monitoring equipment in long run. The accuracy is confirmed through shaking table tests, it is reasonable and competitive. No filter has been applied to the data obtained from IoT sensors in this test, it can be the way to improve the accuracy in following study. IoT devices make the dense deployment of structural seismic monitoring systems possible, and the massive volume of real-time structure vibration information obtained in real time is the fuel of near-real-time infrastructure maintenance and post-earthquake quick assessment.



(a) 0.1Hz & 1.0Gal (b) 0.1Hz & 10.0Gal

(c) 10.0Hz & 1.0Gal (d) 10.0Hz & 10.0Gal

Fig. 4. Acceleration waveform comparison



(a) 0.1Hz & 1.0Gal (b) 0.1Hz & 10.0Gal

(c) 10.0Hz & 1.0Gal (d) 10.0Hz & 10.0Gal

Fig. 5. Acceleration Fourier spectrum comparison

REFERENCES

Kim, J., Sim, S., Cho, S., Yun, C., and Min, J. (2016).: Recent R&D activities on structural health monitoring in Korea. Structural Monitoring and Maintenance, Vol. 3, No. 1 (2016) 91-114