ON-SITE APPLICATION OF SMART DEVICE BASED BRIDGE DISPLACEMENT MONITORING SYSTEM

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1. INTRODUCTION

The performance assessment of some of the key bridge components such as rubber bearings has emerged as an important research issue raised by several damages to the rubber bearings found after the 2011 Great East Japan Earthquake and 2016 Kumamoto Earthquake. Displacement monitoring in bridges using high-density instruments is one of the straight forward measures to eliminate difficulties and uncertainties to estimate the damage process. However, due to high cost and heavy on-site installation, conducting displacement measure using conventional sensors are not easy in practice. While recent improvement of image sensors in smart devices can provide an opportunity to measure displacement with ease and low cost. In this study, bridge displacement monitoring system was implemented using smart devices. Previous study (Shrestha etal 2016) investigated the feasibility of built-in camera in smart devices for image process based displacement measurement by conducting shaking table tests. In this study, on-site application and stability of the proposed system has been demonstrated through one day field measurement on a bridge. To test accuracy and viability, displacement due to traffic and temperature obtained using proposed system was compared with accurate displacement sensor.

2. MEASUREMENT APPLICATION: METHODOLOGY

A measurement application has been developed that interacts with smart phone hardware and operating system features to make built-in camera sensor components available and acquire, analyze, store, and transfer data to the cloud. This measurement application was developed using the Objective-C programming language in the Xcode integrated development environment. The application uses the Dropbox API to connect to a data-restoring cloud server. QR code tracking algorithm has been proposed and implemented for displacement measurement. The basic procedure of the algorithm is shown in Figure 1. Every incoming image frame obtained from the camera is passed through different filters implemented under the Core Image framework in order to detect the target feature and localize the centroid of the target. From the next frame, the location of new centroid is tracked. Hence, the difference between the pixels' position in the corresponding frames gives the displacement response of the target and after multiplying the pixel value with a suitable scale factor real displacement measurement is obtained.

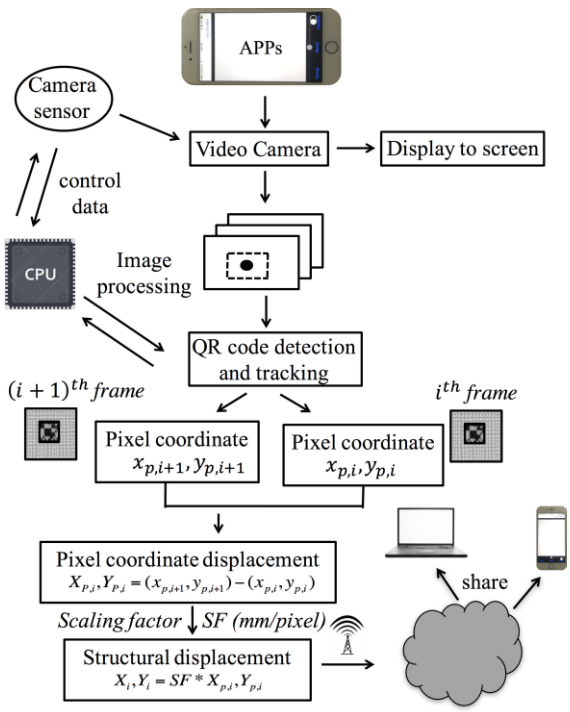

Fig. 1. Displacement measurement flowchart

3. FIELD MEASUREMENTS OVERVIEW

Field measurements were carried out on Nakano bridge located at Kawaguchi, Saitama, Japan. The bridge is a single span I-girder bridge, 34.4 m long and with high density rubber bearing at the abutments as shown in Figure 2. Out of the 11 main girders, 8th girder was selected for assessing the long-term movement of rubber bearing and effect of traffic load on the bridge. In addition to longitudinal movement of rubber bearing (LS1) and vertical deflection of the girder on either side of the bearing (LS2, LS3), transverse movement of the bearing (LS4) was also measured using different smart devices (SD) and laser displacement sensors. Therefore, displacement measurement at a total of 4 different points were carried out. A QR code target object was attached on the girder at the measuring points same as that of the laser measurement points. Figure 2 and Figure 3 shows the schematic diagram and picture of each of the measurement points and devices at the bridge respectively.

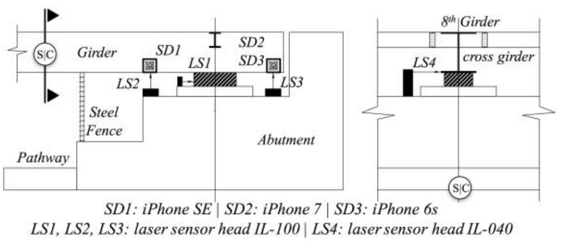

Fig. 2. Schematic diagram showing different measurement points and devices

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4. FIELD DISPLACEMENT MEASUREMENT RESULTS

Fig. 3. Instrumentation set up at Nakano bridge

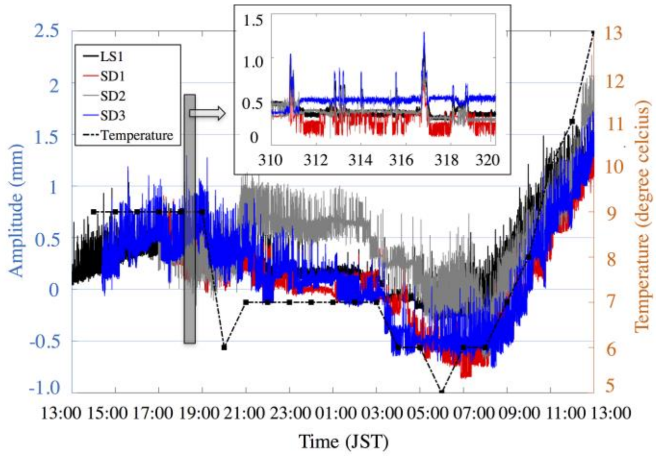

Fig. 4. Longitudinal displacement waveform comparison between reference and smart devices

The displacement pattern of the longitudinal movement of the girder (or the longitudinal deformation of the rubber bearing) is depicted in Figure 4. At first, during the day and night there is negligible longitudinal movement of the bearing depicted by constant displacement amplitude. During early morning, the girder contracts as depicted by drop in displacement amplitude and then as the day progresses the girder starts to expand as depicted by steady increase in displacement amplitude. In addition to long-term displacement characteristics due to temperature fluctuation, horizontal movement of the girder due to traffic can also be observed depicted by many peaks shown in zoomed portion of Figure 4. All such displacement features are accurately measured by smart devices and validated from the displacement plot of laser sensors as reference.

The overall pattern of temperature fluctuation also resembles the longitudinal displacement plot. This shows a strong co-relationship between temperature fluctuation and longitudinal movement of the girder. In addition to longitudinal displacement, vertical displacement of the girder on either side of the bearing measured by smart device was also compared with the reference system. The comparison is shown in Figure 5. In general, the measurements from smart devices agree well with reference system. Although the displacement waveforms obtained from smart devices does not precisely overlap with that of the reference measurement system, measurements from both follows similar displacement pattern and the peak displacement amplitudes (both horizontal as well as vertical) due to traffic are clearly measured by the proposed system. These results illustrate the viability of smart devices for application in displacement monitoring.

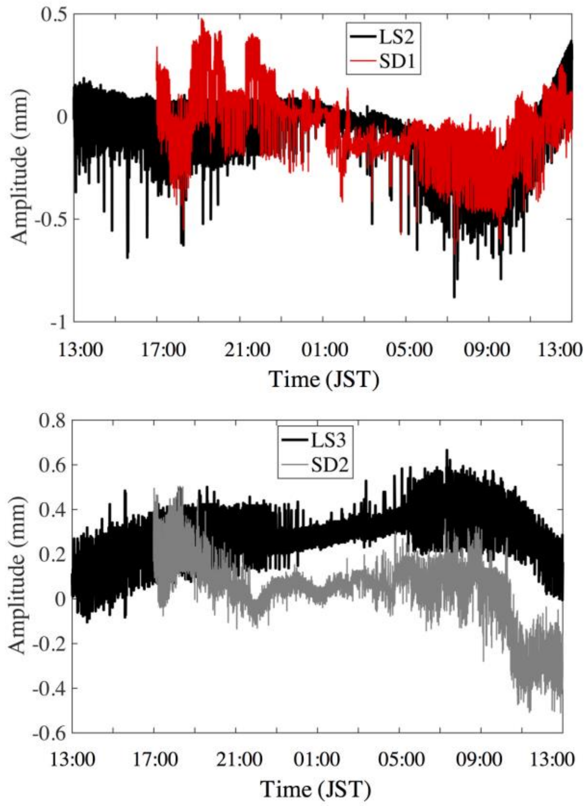

Fig. 5. Vertical displacement waveform comparison between reference and smart devices

5. CONCLUSIONS

In this paper, the feasibility of real-time field displacement monitoring using smart devices is verified. Different from the traditional displacement measurement methods that require expensive sensors and data acquisition components, the proposed method enables the displacement characteristics of structures to be derived with consumer-grade devices like smart devices. In realistic field environment, the performance of the proposed method is confirmed through one day field tests of a road bridge subjected to temperature change and traffic loading. No data loss occurred during the measurement and the displacement characteristics computed with smart device based measurement showed a reasonable level of accuracy as compared to the high precision reference system.

REFERENCES

Shrestha, A., Dang, J., and Wang, X. (2016). "Preliminary study on Image Processing based Real-time Displacement Monitoring Methods Using Smart Devices." *JAEE Annual Meeting* at Eikokuji Campus of Kochi University of Technology.