DYNAMIC CROP FILTER ENHANCED REAL-TIME VISION BASED DISPLACEMENT MEASUREMENT METHOD USING SMART DEVICES

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1. INTRODUCTION

Displacement measurements have useful information for various engineering applications such as structural health monitoring or on-site deformation function tests for key structural members such as rubber bearings. A waking up call for the engineers and the researcher in both earthquake engineering and bridge engineering was highlighted with few cases of broken rubber bearings during the 2011 Tohoku Earthquake and the 2016 Kumamoto Earthquake[1], but unfortunately with lack of enough instrumental record information. Therefore, the seismic damage and state of structures could not be identified in a short time and proper decisions concerning rational repair and reconstruction was even more difficult. Eventually a lesson was learned regarding the importance of structural displacement response monitoring, especially, the deformation of some key members of bridge structures such as isolation or energy dissipation devices, where the structural response and damage were focused at. However, despite its importance, practical displacement measurement is generally challenging, since most of the existing displacement measurement methods are costly, labor-intensive and difficult to install to very limited spaces such as top of piers.

The vision-based method, attributed to advancement in electronics and optical technology, takes advantage of high-resolution digital cameras for displacement measurement applications. Recent advances in smart devices provide various on-board sensing capabilities and especially, the embedded cameras show great advances in providing higher-resolution and higher speed video features. Moreover, their powerful processors and memories eliminate the need for additional computers to perform extensive image processing. All these features are available in low-cost, compact size, and with low power and maintenance requirements, thus aiding practical application of such system. However, limited studies have been conducted which utilizes the advanced vision and embedded processing capabilities of smart devices for dynamic displacement monitoring applications. In this study, smart device based displacement measurement system was developed. Images captured by the image sensor are processed in real-time to obtain the feature responsive displacement. Shaking table tests based on harmonic loading were conducted so that the reliable domain for frequency and amplitude measurement for different smart devices were identified by comparing with the reference accurate displacement sensor.

2. MEASUREMENT APPLICATION DEVELOPMENT

Application program was developed based on Objective-C programming language and Xcode (version 10.0) for iOS application development. The main flow chart for displacement measurement application is shown in Fig. 1. Every incoming frame obtained from camera is processed for detecting the QR code which is the unique feature used in this study and then localized to track the movement of its centroid (in normalized X, Y coordinates). From the next frame, the location of the new centroid is tracked as the pixels' positions in an image can be treated as a two-dimensional graph. Hence, difference between the frame gives the displacement response of the target. However, this displacement is only in the image domain in the pixel unit; nonetheless, after multiplying with a suitable scale factor, the real displacement measurement is obtained.

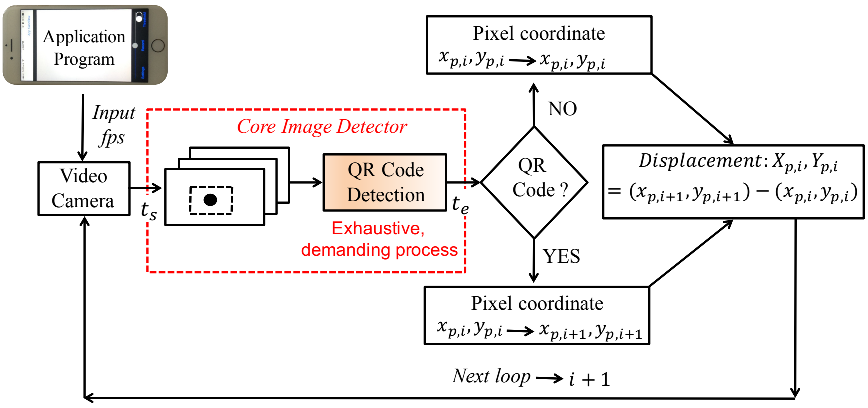

Fig.1 Displacement measurement with Core Image based QR code detection

3. DYNAMIC CROP FILTER ENHANCED METHOD

In the proposed approach, processing image frames to identify a QR code is processed by QR code detection block (shown in Fig. 1) which is basically an exhaustive and demanding task. Processing higher frame resolution (larger matrix of pixels) although yield higher measurement accuracy but is computationally expensive and eventually, yield low sampling frequency. Nevertheless, in order to preserve both the accuracy as well sampling rate, a dynamic crop filter based tracking method has been investigated in this study. Instead of processing the whole frame only a portion of the frame containing the QR code is processed, so that the computation load to process a smaller matrix is much lowered than using the original

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large matrix. Therefore, this method could improve the sampling frequency performance without compromising the accuracy of the measurement. Some of the previous studies used static crop filter for this purpose[2]. However, those methods provided small allowance for larger movement of the target. As a consequence, whenever the target is moving there are chances that the target may go out of bounds of the chosen crop rectangle. Thus, as a solution, instead of assigning a static crop rectangle, the crop rectangle is designed to move along with the movement of the target. Such design eliminates the uncertainty of choosing an appropriate size of crop filter and tracking is possible even with high percentage of crop (with less allowance for movement of target). In this method, first, a crop rectangle is initialized and then the target is tracked with respect to updated crop rectangle every frames as illustrated in Fig. 2.

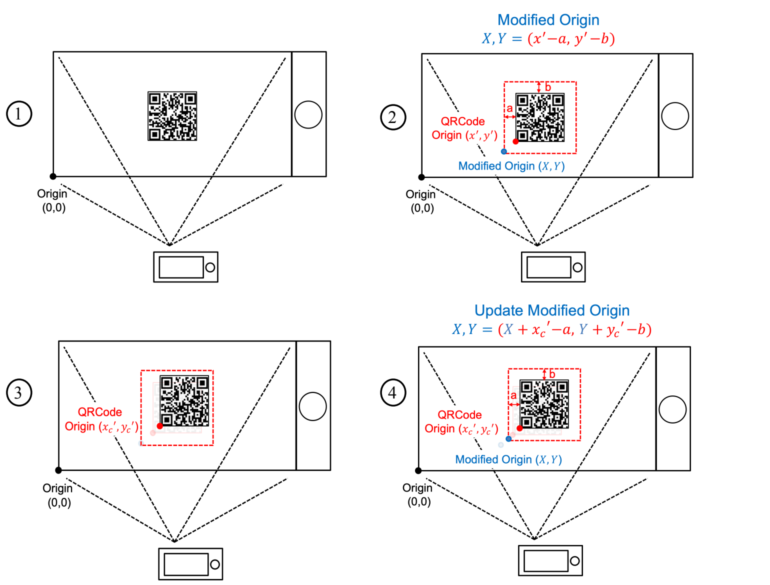

Fig. 2 Flow diagram for designing dynamic crop filter based tracking

4. EXPERIMENTAL RESULTS

Shaking table tests was conducted for experimental verification of the dynamic crop filter based QR code tracking method for displacement measure. Two different model of smart device with different computational and camera capabilities i.e. iPhone 7 and iPhone X were considered for the experiment. An artificially designed target marked with a QR code feature was fixed on the shaking table and driven by harmonic signals of different frequencies ranging from 0.1 Hz to 20 Hz and amplitudes ranging from 0.1 mm to 10 mm. Fig 4 summarizes the test results by quantifying error in terms of correlation scores. It is seen that waveform measured by smart devices generally correlates with laser used as a reference measurement.

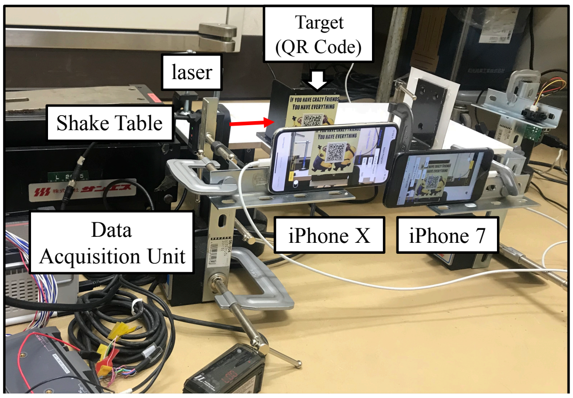

Fig. 3 Experimental set up for the proposed method

5. CONCLUSIONS

The feasibility of smart device for vision based displacement measurement has been investigated in this study. Further, to eliminate the bottlenecks of processing large image and to realize real-time, stable and higher sampling, a novel method using dynamic crop filter was developed and verified. Future works include testing the proposed method in field environment and conducting long-term monitoring tests. Robust implementation of such system can help radically influence advancement for smart, sustainable, and resilient infrastructures.

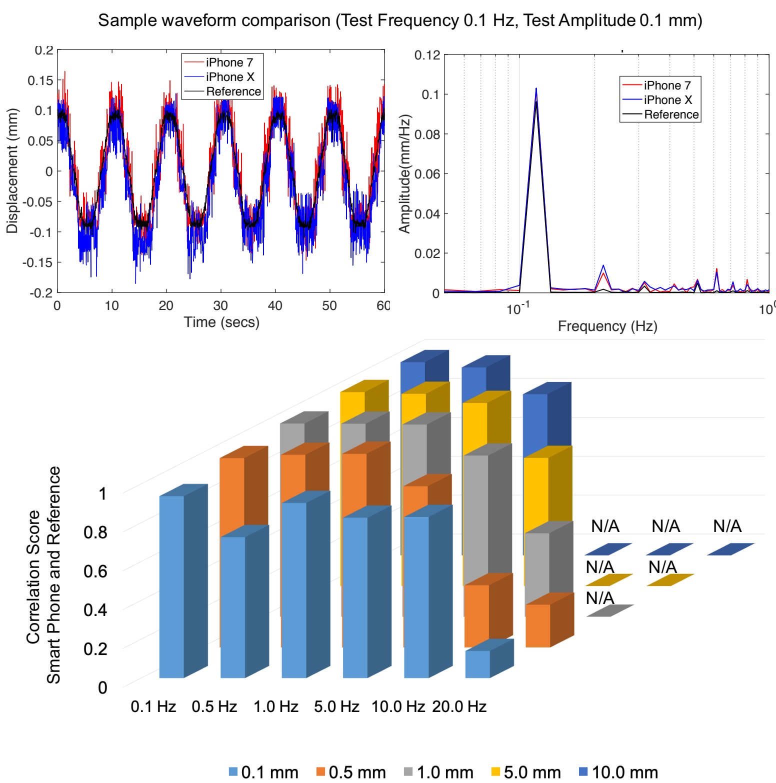

Fig. 4 Correlation scores between smart phone and reference

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