Real-time video-based displacement measurement system for monitoring the vibrational motion of Goega bridge

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***Abstract*: The real-time video-based remote displacement measurement system for monitoring vibrational motion of Goega Bridge is developed. The data logged during a few days is analyzed and the vibrational motion of the Goega Bridge is discussed.**

Keywords: Structural Health Monitoring, Displacement. video-based measurement system.

I. Introduction

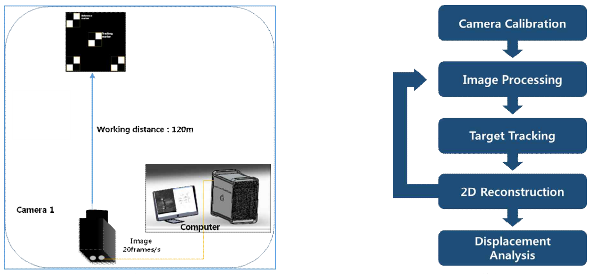
The non-contact sensors such as laser displacement gauge and the contact-type sensors such as accelerometer are popularly used as a method of monitoring the vibrational motion of large scale bridge. The laser displacement sensor using the laser Doppler effect[1], can generally do high precision measurement but measure only the displacement along the specified linear direction at a point and the apparatus is expensive. Furthermore, the installation of additional facilities is necessary for fixing the laser displacement sensor at the target position in the bridge to be monitored. In particular, when measuring the displacement of plural points of the target bridge with the contact-type displacement sensors simultaneously, the same number of displacement sensors as that of the measurement points should be used, which is not cost-effective overall.

In this paper, is studied a new type of the non-contact real-time displacement measurement technology based on remote camera photographing that can measure the multiple displacements of the bridge structure simultaneously and also is economical. The developed system was installed on-site at Goega Bridge in South Korea and the data about the vibrational motion of the bridge was logged during a few days, analyzed and compared with that of the laser displacement measurement system for a comparative performance evaluation of the developed system.

II. Principle and Algorithm of the Proposed Real-Time 2D Monitoring System

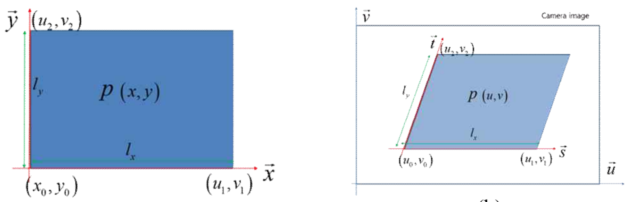
In Figs. 1(a) and 1(b), the schematics of the hardware system and data processing of the developed video-based measurement system are presented, respectively. A single camera of 2048X2048 resolution with a 800mm telephoto lens monitors the binary marker during a day at 20fps. The first step of the displacement monitoring is the camera calibration. In this step, the 2D calibration parameters of the camera which specifies the relation of the 2D object plane (x,y) in which the marker moves to the corresponding tilted object plane (u,v) imaged on the film plane of the camera. In this step, the telephoto approximation (long distance approximation) shown in Fig. 2 is taken in the camera calibration process, which makes the calibration relation to be described by a simple linear matrix transformation given by

$$\begin{pmatrix}x\\ y\end{pmatrix}=\begin{pmatrix}\left(\frac{L_x}{l_x}\right) & 0\\ 0 & \left(\frac{L_y}{l_y}\right)\end{pmatrix}\begin{pmatrix}\frac{u_1-u_0}{\sqrt{(u_1-u_0)^2+(v_1-v_0)^2}} & \frac{u_2-u_0}{\sqrt{(u_2-u_0)^2+(v_2-v_0)^2}}\\ \frac{v_1-v_0}{\sqrt{(u_1-u_0)^2+(v_1-v_0)^2}} & \frac{v_2-v_0}{\sqrt{(u_2-u_0)^2+(v_2-v_0)^2}}\end{pmatrix}^{-1}\begin{pmatrix}u-u_0\\ v-v_0\end{pmatrix}. \qquad (1)$$



(a) (b)

Figure 1. (a) The hardware schematic of the video-based measurement system. (b) Video-based measurement system procedure



(a) (b)

Figure 2. The telephoto approximation in the camera caliration; (a) two dimensional object plane in which the marker moves and (b) corresponding tilted object plane imaged projectively at the film plane of the camera

The camera calibration target is shown in Fig. 1(a), which has three calibration control points at three corners and a binary marker for tacking at the center. The next step is the real-time image pickup by the camera and, in the third step, the 2D position of the marker (u,v) is analyzed from the captured image with the normalized cross correlation (NCC) template matching algorithm. From Eq. (1), the 2D global coordinate of the marker (x,y) is extracted.

III. On-site Telephoto Measuremet of the Vibrational Motion of Geoga Bridge

On-site telephoto measurement experiment of the vibrational motion of Geoga Bridge was carried out. In Figs. 3 and 4, the experimental setup and the developed system installed on-site are shown, respectively. For comparative study, the conventional laser sensor system was set up to monitor the markers at the same position in a distance of 120m from the left and right pylons of the bridge. The experimental result of the video-based displacement measurement system is compared with that of the laser displacement measurement system. For this, camera and laser are synchronized using hardware triggering technique. Both systems record the displacement data at 20 fps.

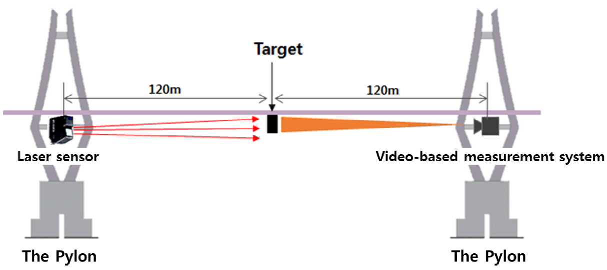
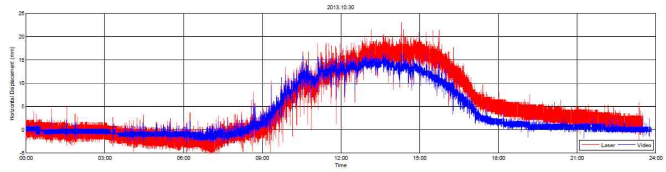


Figure 3. On-site experimental setup of video-based displacement measurement system at Geoga Bridge

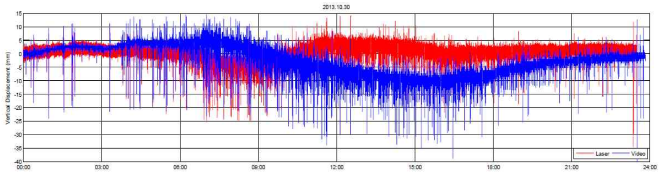
(a) (b) (c)

Figure 4. Video-based displacement measurement system intalled at Geoga Bridge

Figs. 5 and 6 show the displacement measurement data of the video-based measurement system and the laser displacement sensors. The plots compare the time-series data of the video-based measurement system and the laser displacement system during long-term and short-time intervals. Test results showed close agreement verifying the stable operation and measurement performance.



(a)



(b)

Figure 5. Comparison of the data of the video-based measurement and laser measurement system; (a) horizontal displacement data and (b)vertical displacement data measured during a day

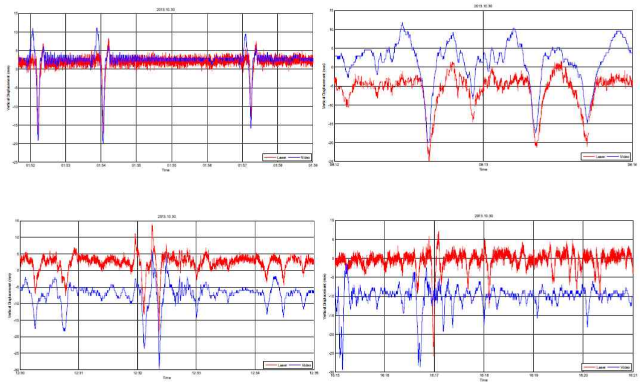


Figure 6. Comparison of shor-time inverval data of the video-based measurement and the laser measurement dynamic displacement system

IV. Conclusion

The video-based measurement system has been developed and shown the feasibility and potential to replace expensive commercialized laser displacement measurement sensors for structural vibration monitoring of large scale bridges.

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