Development of 6-DOF dynamic response measurement system for civil infrastructure monitoring

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The displacement sensors such as LDV and LVDT have limited application in large-scale civil structures like cross-sea bridges due to its installation problems. Instead, GPS-RTK is widely applied to large civil engineering structures, but GPS-RTK is expensive and has low accuracy (1~5mm). A displacement measurement system was developed to measure 6DOF displacement, velocity, acceleration and angular displacement with 2mm of RMS error and 100Hz of sampling frequency by fusing the data obtained from a 3 axes accelerometer and a GPS-RTK through two-stage Kalman filter. Based on the research, 3 SCI papers were published, and 3 patents (2 pending, 1 in the process) and 3 technology transfers ($0.3 million completed) have been accomplished. Through field tests in Yeongjong Grand bridge, Yi Sun-sin bridge and Xihoumen bridge, the performance has been proved and the system is being installed at Yeongjong Grand bridge. Furthermore, the system will be commercialized in national and international market through new construction technology certification and oversea patent. The proposed system can improve the precision and reliability of structural health monitoring, precise construction and load carrying capacity evaluation.

1. Background

The dynamic displacement of a structure is the most important dynamic response in structural integrity evaluation. Linear variable differential transformer (LVDT) is commonly used for measuring dynamic displacement. However, LVDT requires high cost and long time due to the installation of additional temporary structures for reference point. Global positioning system-real time kinematic (GPS-RTK) is another technique for monitoring dynamic displacement, but GPS-RTK has low sampling rate (20 Hz) and precision (10~50 mm). Therefore, it is necessary to develop dynamic displacement sensor capable of measuring dynamic displacement more precisely than existing techniques, and also the localization of the sensor and measurement system is urgent. The developed dynamic response measurement system integrates an accelerometer and GPS into a single system so that it can simultaneously monitor 6-degrees-of-freedom (DOF) dynamic response with high sampling rate (100 Hz) and precision (2 mm). Finally, reliable structural integrity monitoring system can be achieved by the developed dynamic response measurement system.

2. Contents

This research develops world first/best dynamic response measurement system with high sampling rate (100 Hz) and precision (2 mm) by integrating a precise/high sampling rate 3-axis accelerometer and low price GPS-RTK module. The 3-DOF accelerations from the 3-axis accelerometer and 3-DOF displacements from the low price GPS-RTK module are fused by the two-stages Kalman filter. The developed two-stages Kalman filter can decrease the computation time by processing multiple

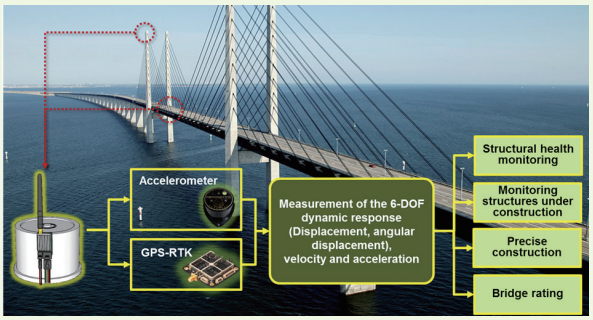

Fig. 1. Overview of 6–DOF dynamic response measurement system

variables in parallel, and also reduce the accumulated bias from the 3-axis accelerometer. Therefore, 6-DOF displacements, velocity, acceleration and angular displacement can be calculated in real time with high precision/sampling rate. By the performance validation tests in Yi Sunsin Grand Bridge and Yeongjong Grand Bridge in South Korea and Xihoumen Bridge in China, the developed dynamic response measurement system shows higher precision (1~2 mm) than those of GPS-RTK modules installed on the bridges (10 mm).

3. Expected effect

The reliability of the structural inspection and integrity will be improved due to the outstanding performance of the developed dynamic response measurement system compared with existing techniques. Social demand for the structural safety will be satisfied. In addition, it is expected to be commercialized at a lower price (15,000 USD) than existing displacement sensors (GPS-RTK, 30,000 USD). Currently, two patents are registered, and one patent is scheduled to be registered. In addition, three technology transfers (total 300,000 USD) were completed. Based on this, the developed dynamic response measurement system was applied for new excellent technology certification in construction and it will be applied to Yeongjong Bridge according to the "Manufacturing/Purchasing of Incheon International Airport Expressway Bridge Measurement System" project, which was announced in November 2016.

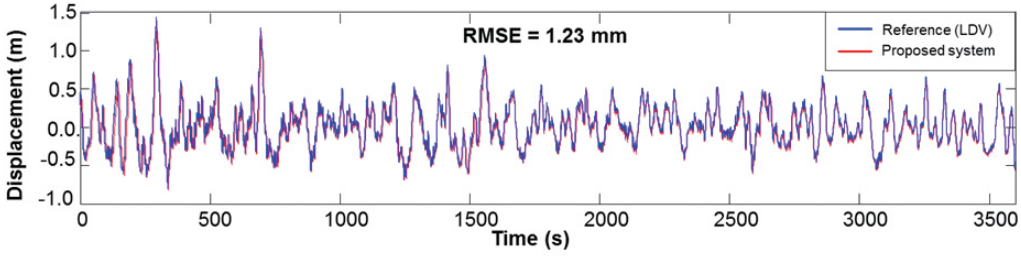

Fig. 2. Performance validation test result in Yi Sunsin Grand Bridge

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Research Outcomes

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- Junhee Kim, Kiyoung Kim, Hoon Sohn, "Autonomous dynamic displacement estimation from data fusion of acceleration and intermittent displacement measurements,"Mechanical Systems and Signal Processing, Vol. 42(1–2), pp. 194–205, 2014