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Structural displacement estimation using a low-cost sensing system combining millimeter-wave radar and accelerometer

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ABSTRACT

Displacement plays a vital role in structural health monitoring, but the accurate estimation of structural displacement remains a challenging task. Millimeter-wave radars are promising tools for measuring accurate displacements, and they are low-powered, cost-efficient, and suitable for any extreme weather. However, the radar-based displacement estimation requires a cumbersome initial calibration for target selection and conversion factor estimation. In addition, phase wrapping becomes an issue for large displacement estimation. To better exploit the potential of millimeter-wave radars, this study proposes a novel sensing system that combines a low-cost millimeter-wave radar and an accelerometer for accurate displacement measurement. The system achieves automatic initial calibration and adaptive phase unwrapping. To validate the performance of the proposed system, a laboratory test was conducted on a four-story building model, and a field test was conducted on a pedestrian steel box girder bridge. In both tests, the proposed system was able to estimate displacements accurately with a root mean square error of less than 1 mm compared to the displacements measured by laser-based displacement sensors.

Keywords: Displacement estimation, millimeter-wave radar, finite impulse response filter, accelerometer, data fusion

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