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FIELD DEPLOYMENT VALIDATION OF A LOW-COST AND HIGH-PRECISION DISPLACEMENT SENSOR COMBINING MILLIMETER-WAVE RADAR AND ACCELEROMETER

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ABSTRACT

Abstract: Although displacement measurements are critical for many civil infrastructure applications, accurate monitoring of structural displacements remains a challenge, especially for medium/small-scale structures with only millimeter-scale vibrations. The authors previously proposed a structural displacement estimation technique using collocated accelerometer and millimeter wave radar measurements, and the technique can achieve sub-millimeter accuracy [1]. Based on this technique, this study developed a displacement measurement sensor that integrates a low-cost millimeter-wave radar, an accelerometer, and a microprocessor unit. With a total cost of less than 1000 USD, the developed sensor still measures displacement well with a low error (< 0.5 mm) and a high sampling rate (100 Hz). In addition, the developed sensor achieves wireless data transmission based on a wireless local-area network (WLAN), which makes it more convenient for practical applications. To fully validate the performance of the developed sensor, field tests were conducted on nine different structures, including four highway bridges in San Jose, USA, a parking structure in Stanford, USA, a highway bridge in Daejeon, South Korea, and three highway bridges in Weifang, China. For all structures, the developed sensor was able to accurately measure displacements with a maximum root mean square error (RMSE) of less than 0.06 mm, compared to the ground-truth displacement measured by a laser Doppler Vibrometer.

Keywords: Displacement measurement, millimeter wave radar, accelerometer, data fusion.

Reference
[1] Ma, Z., Choi, J., Yang, L., & Sohn, H. (2023). Structural displacement estimation using accelerometer and FMCW millimeter wave radar. Mechanical Systems and Signal Processing, 182, 109582.