

Instantaneous Positioning and Attitude Determination with Multi-Antennas for Large-Span Bridges

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SUMMARY

High-precision positioning and attitude measurement are fundamental to deformation monitoring, navigation, and engineering safety assessment. However, the conventional two-step GNSS-based attitude determination approach first estimating baselines and then computing attitude parameters- often suffers from error propagation and weak coupling effect between displacement and attitude information, especially under dynamic or low-satellite-visibility conditions. To address these limitations, this study proposes a novel one-step positioning and attitude determination method with multi-antennas. It unifies displacement, attitude, and carrier-phase ambiguity estimation within a single observation model. The attitude is expressed using a unit quaternion to avoid singularities and maintain computational stability. An Unscented Kalman Filter (UKF) framework is developed to handle the nonlinear characteristics of the quaternion-based system, while Lie group theory is incorporated to constrain the updated attitude parameters within the Special Orthogonal group $SO(3)$, ensuring geometric consistency. Additionally, double-differenced carrier-phase ambiguities between antennas are fixed within the same processing procedure, further improving measurement accuracy and robustness. The proposed approach is validated using real multi-antenna GNSS data collected by the GeoSHM system on the Forth Road Bridge in the UK. Experimental results demonstrate that the integrated one-step solution significantly improves positioning precision, attitude stability, and overall measurement reliability compared with conventional two-step methods. The findings highlight the potential of the proposed technique as a general framework for high-accuracy GNSS-based positioning and attitude measurement in structural monitoring, navigation, and other engineering applications.

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