Dynamic structural health monitoring

Tuesday, 08.04.2025, 14:20 - 15:35, Room Haller

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Integrated GNSS Positioning and Attitude Determination for Structural Health Monitoring of Large-span Bridges

Attaining accurate displacement and attitude information is essential for structural health monitoring of large-span bridges, as they provide critical information regarding the condition and stability of structures. Integrated determination of bridges displacement and attitude with Global Navigation Satellite System (GNSS) enables early detection of potential structural issues and produce a more effective maintenance plan for informed decision-making. The traditional method of GNSS-based attitude determination could be split into two steps: calculating the baseline first, and then deriving the attitude information from the baseline solution. This paper integrates GNSS positioning and attitude determination within one step. Firstly, this method combines the GNSS observations from multiple antennas located on the bridge, utilizes a unit quaternion to express the attitude, and parameterizes the displacement, attitude and carrier-phase ambiguities in one observation equation. Then, the Unscented Kalman Filter (UKF) is adapted to achieve the optimal estimation of the quaternion-based nonlinear systems. Finally, the double-differenced ambiguities between the stations are resolved to integers to improve the accuracy of positioning and attitude determination. As an example, this method is used to process the data gathered with the GeoSHM system on the Forth Road Bridge in the UK and the accuracy of the developed GNSS positioning and attitude determination method is evaluated and analyzed.

Keywords: GNSS integrated positioning and attitude determination, Structural health monitoring, Unscented Kalman filter

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Feasibility analysis of smartphone GNSS data for low-frequency cm-level motion monitoring

In the last few years, to get better positioning performance, smartphone industry has developed mobile phones capable of dual frequency carrier phase measurements, leading to many well-known globally manufacturers

incorporating this feature in their latest models. Although expectedly noisy Global Navigation Satellite System (GNSS) measurements due to the linearly polarised smartphone GNSS antenna and chipset GNSS receiver, the dual frequency carrier phase plus GPS, Galileo, GLONASS, Beidou (BDS) multi-constellation observation capabilities have made them potential candidates for precise location and positioning applications. In this paper, we aim to explore the feasibility of these smartphone antenna/receiver in monitoring low-frequency periodic cm-level motion, for evaluating the possibility of employing them in structural health monitoring related applications. We have conducted two controlled oscillation displacement experiments in the lab with mobile phones for displacement detection. It was found that motions as small as 2-cm amplitude and frequencies as low as 0.05 Hz could be monitored, with an accuracy of 5-8 mm from displacement measurement, and a maximum 6% deviation from dominant frequency derivation, respectively.

Keywords: Smartphone, GNSS, Deformation monitoring.

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Incorporating Low-Cost GNSS Receivers for Deformation Monitoring in High-Rise Buildings

Deformation monitoring of high-rise buildings is crucial for ensuring structural integrity and safety. Traditional methods including conventional surveying techniques, while effective, often involve high costs and operational challenges. This research explores the feasibility of utilizing low-cost Global Navigation Satellite System (GNSS) receivers in monitoring deformations of high-rise buildings. This study focuses on examining deformations of slow movement, such as that due to temperature and solar radiation, and dynamic movement such that due to wind load and seismic activities. A series of controlled experiments assess the performance of low-cost receivers compared to high-precision geodetic equipment, for static, slow-motion and dynamic motion. We analyse the GNSS data of the low-cost GNSS receivers and compare them against geodetic GNSS receiver and independent high-precision Robotic Total Station (RTS) data. The study focuses on the assessment of the performance of the u-blox F9P dual frequency low-cost GNSS receiver when conected with three different types of antenna; with Leica AS10, Tallysman TWI and u-blox patch antennas. The results of the study show the impact of the antenna type and the GNSS satellite constellation

on the performance of the low-cost GNSS receiver. However, it is revealed that the low-cost GNSS receiver, even with a low-cost antenna and the appropriate GNSS satellite constellation, has significant potential in providing reliable and accurate GNSS measurements, suitable for a sustainable monitoring network for high-rise buildings.

Keywords: High-Rise Buildings, Deformation Monitoring, Low-Cost GNSS