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GNSS Gyroscopes of Angular Speed and Acceleration Types

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Although global navigation satellite systems (GNSS) have been routinely applied to determine attitudes, there exists no literature on determining angular velocity and/or angular acceleration from GNSS. Motivated by the invention of Xu (2023, https://doi.org/10.21203/rs.3.rs-2575585/v1) and following the success of accurately recovering translational velocity and acceleration waveforms from very high-rate GNSS precise positioning by Xu et al. (2021, J Geod, 95, article 17, https://doi.org/10.1007/s00190-020-01449-6), we propose the concept of GNSS gyroscopes and reconstruct angular velocity and acceleration from very high-rate GNSS attitudes by applying regularization under the criterion of minimum mean squared errors (MSE). The major results from the experiments can be summarized in the following: (i) angular velocity and acceleration waveforms computed by applying the difference methods to high-rate GNSS attitudes are too noisy and can be physically not meaningful and numerically incorrect. The same can be said about inertial measurement unit (IMU) attitudes, if IMU gyros are not of very high accuracy; (ii) regularization is successfully applied to reconstruct the high-rate angular velocity and acceleration waveforms from 50 Hz GNSS attitudes and significantly outperforms the difference methods, validating the proposed concept of GNSS gyroscopes. By comparing the angular velocity and acceleration results by using the difference methods and regularization, we find that the peak values of angular velocity and acceleration by regularization are much smaller by a maximum factor of 1.57 in the angular velocity to a maximum factor of 8662.53 times in the angular acceleration in the case of high-rate GNSS, and by a maximum factor of 1.26 in the angular velocity to a maximum factor of 2819.85 times in the angular acceleration in the case of IMU, respectively; and (iii) the IMU attitudes apparently lead to better regularized angular velocity and acceleration waveforms than the high-rate GNSS attitudes, which can well be explained by the fact that the former is of better accuracy than the latter. As a result, to suppress the significant amplification of noise in GNSS attitudes, larger regularization parameters have to be chosen for the high-rate GNSS attitudes, resulting in smaller peak angular accelerations by a maximum factor of 37.55 percent in the angular velocity to a maximum factor of 6.20 times in the angular acceleration in comparison of the corresponding IMU results. Nevertheless, the regularized angular acceleration waveforms for both GNSS and IMU look more or less similar in pattern or waveform shape.

To conclude, we invent GNSS gyroscopes of angular speed and acceleration types and propose a regularized solution to reconstruct angular speed and accelerations. When the invented technology is applied to gyroscopes of any types and/or inertial measurement units, we expect that these instruments would provide more accurate angular speeds and accelerations.