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Ultra-Tightly Coupled GNSS/INS Based on High Degree Cubature Kalman Filtering

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Abstract : In classical GNSS/INS integration designs, the loosely coupled approach uses the GNSS derived position and the velocity as the measurements vector. This design is suboptimal from the standpoint of preventing GNSSoutliers/outages. The tightly coupled GPS/INS navigation filter mixes the GNSS pseudo range and inertial measurements and obtains the vehicle navigation state as the final navigation solution. The ultra-tightly coupled GNSS/INS design combines the I (inphase) and Q(quadrature) accumulator outputs in the GNSS receiver signal tracking loops and the INS navigation filter function intoa single Kalman filter variant (EKF, UKF, SPKF, CKF and HCKF). As mentioned, EKF and UKF are the most used nonlinear filters in the literature and are well adapted to inertial navigation state estimation when integrated with GNSS signal outputs. In this paper, it is proposed to move a step forward with more accurate filters and modern approaches called Cubature and High Degree cubature Kalman Filtering methods, on the basis of previous results solving the state estimation based on INS/GNSS integration, Cubature Kalman Filter (CKF) and High Degree Cubature Kalman Filter with (HCKF) are the references for the recent developed generalized Cubature rule based Kalman Filter (GCKF). High degree cubature rules are the kernel of the new solution for more accurate estimation with less computational complexity compared with the Gauss-Hermite Quadrature (GHQKF). Gauss-Hermite Kalman Filter GHKF which is not selected in this work because of its limited real-time implementation in high-dimensional state-spaces. In ultra tightly or a deeply coupled GNSS/INS system is dynamics EKF is used with transition matrix factorization together with GNSS block processing which is well described in the paper and assumes available the intermediary frequency IF by using a correlator samples with a rate of 500 Hz in the presented approach. GNSS (GPS+GLONASS) measurements are assumed available and modern SPKF with Cubature Kalman Filter (CKF) are compared with new versions of CKF called high order CKF based on Spherical-radial cubature rules developed at the fifth order in this work. Estimation accuracy of the high degree CKF is supposed to be comparative to GHKF, results of state estimation are then observed and discussed for different initialization parameters. Results show more accurate navigation state estimation and more robust GNSS receiver when Ultra Tightly Coupled approach applied based on High Degree Cubature Kalman Filter.

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