Unscented Kalman Filtering for Simultaneous Estimation of Attitude and Gyroscope Bias

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Abstract—We present an unscented Kalman filtering (UKF) algorithm for simultaneously estimating attitude and gyroscope bias from an inertial measurement unit (IMU). The algorithm is formulated as a discrete-time stochastic nonlinear filter, with state space given by the direct product matrix Lie group $SO(3) \times \mathbb{R}^3$, and observations in $SO(3)$ reconstructed from IMU measurements of gravity and the earth's magnetic field. Computationally efficient implementations of our filter are made possible by formulating the state space dynamics and measurement equations in a way that leads to closed-form equations for covariance propagation and update. The resulting attitude estimates are invariant with respect to choice of fixed and moving reference frames. The performance advantages of our filter vis-à-vis existing state-of-the-art IMU attitude estimation algorithms are validated via numerical and hardware experiments involving both synthetic and real data.

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