Quantifying and Reducing Orientation Error in Inertial Navigation

Zhao Bob

1 Abstract

Neural inertial navigation systems estimate pedestrian motion from inertial measurement unit (IMU) signals, but their accuracy depends on reliable device orientation estimates for transforming sensor measurements between coordinate frames. This study investigates how orientation estimation failures propagate into trajectory error in RoNIN (Robust Neural Inertial Navigation) and develops methods to reduce that sensitivity. Using the RoNIN dataset and pretrained ResNet model, controlled heading and tilt perturbations are introduced after initial orientation alignment but before gyroscope and accelerometer measurements are transformed into the global frame, allowing orientation error to be isolated while the underlying IMU measurements, ground-truth trajectories, and model remain unchanged. Navigation degradation is quantified using Absolute Trajectory Error (ATE) and Relative Trajectory Error (RTE) across progressively larger and differently structured orientation failures, establishing sensitivity relationships between error magnitude, direction, temporal behavior, and resulting trajectory error. Based on the dominant failure modes identified, the project then develops and evaluates mitigation strategies, including orientation-error-aware training and more orientation-robust input representations, with the goal of reducing dependence on inaccurate orientation estimates and improving the robustness of neural inertial navigation under realistic device motion.