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GNSS BASED NAVIGATION AND CONTROL FOR AUTONOMOUS FORMATION VEHICLE

Abstract

In this study, a relative navigation and formation control algorithm for GNSS-based autonomous formation vehicles was developed, and a hardware-in-the-loop (HIL) simulation testbed was established and configured to evaluate this algorithm. The algorithm presented was a real-time relative navigation estimation using double-difference carrier-phase and single-difference code measurements based on the extended Kalman filter (EKF). Further, the LAMBDA method has been used to improve the performance of the relative navigation by fixing ambiguities in integers for precise relative navigation. In addition, a state-dependent Riccati equation (SDRE) technique was utilized as a nonlinear controller for the formation vehicle control problem. The state-dependent coefficient (SDC) form is formulated to include nonlinearities in the relative dynamics. To evaluate the relative navigation and control algorithms developed, a closed-loop HIL testbed was established; this consists of a GPS signal simulator, GPS receiver hardware, GPS monitoring system, remote control system, and flight control system. To demonstrate the performance of the testbed, a test scenario comprising formation acquisition and keeping in a low Earth orbit (LEO) from an initial along-track separation of 1 km to a target distance of 100 m has been configured (e.g. satellite formation flying mission). Absolute navigation with a 3-dimensional (3D) root mean square (RMS) value of 4 m for position accuracy has been achieved. The relative navigation results from the closed-loop simulations show that a 3D RMS of 0.07 m can be achieved for position accuracy without multipath error. The targeted leader-follower formation vehicle in the along-track separation of 100 m was maintained with a mean position error of approximately 0.2 m and a standard deviation of 0.9 m. The simulation results show that the HIL testbed is capable of successful demonstration of the GNSS-based autonomous formation vehicle.