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VALIDATION ON FLIGHT DATA OF A NOVEL RELATIVE NAVIGATION APPROACH FOR SPACEBORNE GPS RECEIVERS FLYING IN FORMATION OVER LARGE BASELINES

Abstract

Formation flying is a topic that is receiving great attention from the international scientific community. Remote sensing applications might require the satellites to fly at large distances, i.e. the baseline can range from a few kilometers to hundreds of kilometers during a single orbit or keep large values during the whole mission. Many applications require the determination of the satellite separations with accuracy at the centimeter level, especially when they come closer as a result of the relative orbital path, or at the sub-centimeter level to achieve challenging scientific goals. This paper presents a filtering approach relying on Carrier-phase Differential GPS (CDGPS) for precise real-time relative navigation of LEO formations. The focus is on formations with large separations between the satellites (order of hundreds of kilometers). In this case, the finite spatial correlation of GPS error sources, most notably ionospheric delays and ephemeris errors, can seriously impact the quality of the relative navigation solution if not properly modeled and predicted. Previous works have developed various filtering approaches prevalently for formations of two or more satellites characterized by baselines of a few kilometers. Only a few works can be found concerning the real-time relative navigation of large-baseline formations. In these cases, measurements on both frequencies are processed to achieve high accuracy. Nevertheless, performance is demonstrated only by numerical simulations. This paper investigates performance of CDGPS for real-time relative navigation of a formation of two satellites in applications where the inter-satellite distance is large. Specifically, the proposed approach uses an Extended Kalman Filter (EKF) for computing the "float" baseline estimate assuming that the integer ambiguities are real-valued. The EKF is combined in cascade with an integer estimation step, which is performed using the LAMBDA method. The integer estimates are used for correcting the float baseline with accuracy in the order of the carrier-phase measurement noise. To allow real-time applications, the filter state dimension is limited by using a nonlinear Keplerian model of the satellite relative dynamics to predict the relative state. A simple kinematic algorithm estimates the satellites' absolute positions. In order to maintain accuracy and robustness in the float estimate of double-difference integer ambiguities over large baselines the ionosphere delay terms are included in the filter state. The proposed relative navigation filter scheme is validated using the flight data from the GPS. receivers of the Gravity Recovery and Climate Experiment (GRACE) mission.