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ANGLES-ONLY RELATIVE NAVIGATION IN NEAR-GEOSTATIONARY ORBITS CONSIDERING PERIODIC CORRECTIONS OF LUNISOLAR PERTURBATIONS

Abstract

In order to ensure the success of space missions, it's essential to monitor the space environment around spacecraft accurately in real-time, which makes space situational awareness widely studied in recent years. Among these studies, the space-based relative orbit determination technique has become the research focus because of its high dynamic and full-time observability. For achieving accurate real-time situational awareness, it demands a more accurate relative navigation algorithm. Aiming at the relative navigation problem in the GEO orbit, this paper studies a relative navigation algorithm using angle-only measurements, based on mean relative orbital elements (ROEs). Many scholars have studied the relative navigation problem in the GEO orbit. However, there are few studies considering the effect of the difference between mean and osculating orbit elements in the process of navigation filtering. In the practical application, the measurement parameter is usually expressed in osculating states. However, it's mean states that are estimated by an averaged dynamics model as the state equation. If periodical corrections between mean and osculating states are neglected, the accuracy of the measurement equation will be reduced. Consequently, the accuracy of navigation would be decreased as well. Satellites in the GEO orbit are significantly affected by J2 and lunisolar perturbations. To the best of the authors' knowledge, all research on the relative navigation in GEO orbit ignored the periodic correction between mean and osculating orbital elements induced by lunisolar perturbations. In this paper, the GEO navigation algorithm including an analytical mean-to-osculating orbit elements transformation process is constructed based on the Cabuture Kalman Filter (CKF) frame. The analytical mapping between osculating and mean elements is derived based on the Lie transform theory, which is then utilized in the measurement equation to reconcile the estimated mean states with the angle measurements, thereby improving the accuracy of navigation. In addition, the highly nonlinear measurement equation is also beneficial to improve the dynamical observability of the system. However, the high nonlinearity of the equation brings new challenges to the filtering process. The CKF is adopted to handle this problem, which utilizes cubature points based on the spherical-radial cubature rule to approximate nonlinear functions, instead of linearizing equations as EKF. In the end, numerical simulation results validate the higher accuracy of the proposed navigation algorithm considering analytical corrections between mean and osculating states. Additionally, the robustness of the navigation algorithm is verified by Monte Carlo simulations.