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HIGH ORDER AUTONOMOUS GEOSYNCHRONOUS ORBIT DETERMINATION USING SPACE-BASED MEASUREMENTS

Abstract

The dilemma between a limited number of ground tracking stations and an unprecedented amount of satellites motivates the improvement of satellite autonomous orbit determination techniques. This paper explores the possibility of precisely geosynchronous orbit estimation via the usage of sparse space-based relative range and bearing measurement information of a known beacon satellite. A set of nonlinear high-order extended Kalman filters (HEKFs), adopting different expansion orders, are proposed. In order to calculate the high order Taylor expansions of the flow associated to the perturbed dynamical model in a fast, simple, and accurate way, jet transport (JT) technique is employed. The motion of a geosynchronous spacecraft is subject to four dominating perturbations: solar radiation, Earth's non-spherical gravity, solar and lunar gravitational forces.

The performances of the proposed HEKFs, implemented at different expansion orders, are assessed by comparing the estimation results with the high-precision numerical propagation of the "true" trajectory. Five different measurement acquisition periods (10, 20, 60, 120, 180 minutes) and two levels of measurement accuracy (0.2 and 0.64 arc-sec) are considered in the numerical simulations. The results show that the HEKF using higher expansion order outperforms that adopting lower expansion order, meanwhile the former one is more robust against the magnitude of the initial state error and the measurement acquisition period. In other words, the initial state error and the measurement acquisition period do not have an evident effect on the estimation accuracy of the HEKF using higher expansion order. In contrast, these factors highly deteriorate the linear prediction accuracy, and mismatch the real measurements in the filter procedure, resulting in the low estimation precision of 1-st order HEKF even when a very good measurement performance is assumed. For a special simulation case considering the measurement acquisition period 10 minutes and measurement accuracy 0.2 arc-sec, the average position and velocity errors of 1-st order HEKF are of the order of 10^2 meters and 10^{-2} m/s respectively, while those of 2-nd order HEKF are of the order of several meters and 10^{-4} m/s.

Besides, the proposed high order filtering algorithms enable to improve the autonomy of geosynchronous orbit determination procedure and lessen the dependence on ground facilities via the consideration of space-based relative measurement information. Moreover, the newly developed filtering approach can be easily extended into other orbit regimes.