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China, jyuan@nwpu.edu.cnHIGH ACCURACY ORBIT DETERMINATION OF GEO-STATIONARY SATELLITES USING
DIFFERENTIAL ALGEBRA AND HIGH-ORDER EXTENDED KALMAN FILTER**Abstract**

Aiming at using optical sights, this paper studies an accurate orbit determination procedure for geostationary satellites under the influence of four perturbations: solar radiation pressure (SRP), Earth's non-spherical gravity field, and third-body gravitational forces of the Sun and the Moon. The procedure combines differential algebra techniques (DA), and a high-order extended Kalman filter (HEKF). Using DA one gets (arbitrarily) high order Taylor expansions of the vector field (including perturbations), and of the trajectories. By means of polynomials in the state variables, these expansions provide accurate information of the neighborhood of any nominal trajectory that allow the propagation of orbits in the neighborhood in a fast, simple, and accurate way.

In the paper we analyze the orders of the expansions required in the evaluations of each perturbation, as well as in the orbit propagation, that keep an optimal accuracy at a minimum cost. Several orbit integrators and coordinate frames are discussed. In particular, using a set of hybrid orbital elements well suited for the problem, we propose a novel dynamic model to simplify the modeling of perturbations. Furthermore, the slowly-varying hybrid elements are beneficial to increase the size of the time step during the integration, reducing this way the computational cost. To validate the accuracy of orbit evolution using DA, point-wise state propagations of the sampling points in the initial state neighborhood are done, and used as the "true" trajectory. For the propagations of two periods of geostationary orbit, the position error is of the order of centimeters, and the velocity error of the order of 10^{-6} m/s.

The consideration of the DA scheme clearly reveals the high order information of the nonlinearity of the motion, which improves the accuracy of state prediction of usual EKF. According to this, a new implementation of HEKF can be done. Compared to the accuracy of EKF used in the process of geostationary orbit determination, the accuracy of HEKF is improved by some orders of magnitude.