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ESTIMATION OF MEAN ORBITAL ELEMENTS WITH UNKNOWN LOW-THRUST ACCELERATION

Abstract

The increase in spacecraft launches since 1957 has led to growing population of satellites, rocket bodies, and debris in orbit around Earth. With a constantly changing population, identifying and tracking these objects is necessary in order to maintain the safety of high value assets in orbit and to predict and detect when collisions occur between objects. Space Situational Awareness (SSA) has been recognized to be important for the safe space activities including these problems. As low-thrust propulsion technology becomes increasingly popular, SSA for low-thrust spacecraft may become an area of increasing interest. More frequently use of low-thrust propulsion to place satellites in orbit create more opportunities for collisions and radio frequency interference as these spacecraft travel slowly through altitude ranges. One of the primary technical difficulties in orbital estimation of low-thrust spacecraft is the instability to accurately estimate the full dynamical state based on observation data.

The purpose of this paper is to develop a method for orbital estimation of S/C with unknown low-thrust acceleration in small-eccentricity low Earth orbits. To overcome the instability of the estimation problem with low-thrust acceleration, we estimate the mean elements instead of osculating elements. By use of the averaging technique, Hudson and Scheeres (2009) proposed an analytical model of secular variations of orbital elements under thrust acceleration. The resulting averaged equation has a nice property in which only finite number of Fourier coefficients of the thrust acceleration appear because of the orthogonality of the trigonometric function. Based on the nonlinear state equation representation for the extended state variable which include not only orbital elements but also unknown Fourier coefficients, mean orbital elements and thrust history are estimated from observation data of osculating orbital elements. Moreover, the mapping from mean to osculating elements is also used as a measurement equation by adding the short-periodic terms to estimate mean elements from observed osculating elements. Proposed method is evaluated through three examples and performance evaluation for both controlled and uncontrolled orbits shows the potential applicability of the method.