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INTEGRATED STRATEGY OF STATIONKEEPING, AUTONOMOUS NAVIGATION AND REAL-TIME GEODETICAL RECOVERY OF GRAVITY FIELDS: APPLICATION INTO INTERPLANETARY TRAJECTORY CORRECTION MANEUVER OF CASSINI MISSION

Abstract

For the Interplanetary transfer mission as Cassini, the flyby encounters with so-far planets including Venus, Earth, and Jupiter amplify the uncertainties from high-order gravitational perturbations, less-known atmosphere, and autonomous navigation errors, as well as inaccurate parameters of spacecraft in mass and thruster. Thus, a series of midcourse correction maneuvers are required to avoid Cassini away from its nominal trajectory, and also to achieve an acceptable insertion precision into destination orbit around Saturn. The existing strategies to correct transfer trajectory are derived from stochastic control, which are qualified to handle with Gaussian-like navigation errors only, however, fail in unknown but deterministic perturbations. On the other hand, the traditional geodesy theory recovers the gravity field of planet from heavy historical data, which results in post-flight recovery, instead of real-time one. Nevertheless, it does not provide enough planning time for Cassini to start its planet flybys.

An integrated midcourse-correction strategy is proposed in this paper, by combining the functions of autonomous navigation and real-time geodetical recovery. Different from other stationkeeping controllers to estimate perturbation boundaries, a heuristic improvement is given by backstepping control theory, and the adaptive estimator is enhanced by introducing the full orbital dynamics and then leaving the high-order coefficients of gravitational model to be estimated. The asymptomatically-convergent zonal gravitational coefficients are added into the extended Kalman filter to boost the navigating errors, which benefit the ability of stationkeeping maneuvers as well. Besides, to make the proposed strategy available for ION-type propulsion, a saturation algorithm is used to reduce the maximum of thrust by extending working time of thruster. Further improvements of the triggers for the on/off schedule are proposed to remedy the weakness in the capability of estimating for excessively long (infinite) time required to converge. Finally, the controller proves theoretically to be effective in terms of adaptive robust estimation and asymptotic stability from an ingenious Lyapunov function searched by a machine learning technique.

Numerical implementations on the post-mortem of Cassini mission indicate that the proposed strategy not only put all the functions above together to fly by the successive planets by saving 20% fuel consumption totally, but also promote final insertion precision by an order of magnitude.