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A HIGH-ORDER TARGET POINT APPROACH TO THE STATIONKEEPING OF NEAR RECTILINEAR HALO ORBITS

Abstract

Characterized by favorable stability properties, Near Rectilinear Halo Orbits (NRHOs) are the orbits of great interest for the Lunar Orbital Platform Gateway, an international effort led by NASA to expand human presence to the Moon, Mars, and deeper into the Solar System. As nominal trajectories discovered in restricted three-body problems (RTBPs), NRHOs are subject to various perturbations in the real space environment, which necessitates the implementation of stationkeeping.

Among the existing stationkeeping strategies using impulsive control, the target point approach (TPA) enables the analytical computation of corrective maneuvers by minimizing a weighted cost function, which is defined in terms of the maneuver cost (delta-v) and position and velocity perturbations from a nominal trajectory at specified times.

Although widely used in a variety of space mission design and operations, the TPA is restricted by a linear approximation of position deviations. The approximation is based on state transition matrices and provides an analytical expression of optimal maneuvers. However, a resulting neglect of high-order information could possibly lead to inaccurate maneuvers and an accumulation of errors could further influence the performance of this stationkeeping strategy. In addition, previous research on the TPA is often limited to constant/piecewise constant weight matrices. Although some experimentation has confirmed that tailoring the weight parameters can improve the performance of a TPA, an efficient method of designing a robust time-varying control law is still to be investigated.

To maximize the potential of the TPA, a high-order transfer mapping technique enabled by Differential Algebra (DA) is hereby proposed for the stationkeeping of NRHOs. By substituting the classical implementation of real algebra with a new algebra of Taylor Polynomials, with DA, any multivariable function can be expanded into its Taylor polynomial up to an arbitrary order with limited computational cost. In this case, by replacing state transition matrices with polynomial transfer maps, a high-order approximation of the position deviations can be acquired and thus, generates a more accurate delta-v. In addition, as the transfer map can be parameterized with different designing variables, a relationship between the optimal delta-v and weight parameters can be also established. The existence of more locally optimal solutions can be conveniently verified through simple polynomial evaluations. Furthermore, the sensitivity performance of the weight parameters can be directly evaluated with the coefficients of their corresponding maps. The sensitivity information of the weight parameters could be used to formulate a time-varying control law of the TPA.