High-Order Optimal Station Keeping of Geostationary Satellites

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Nominal space trajectories are usually designed by solving an optimal control problem that maximizes the payload launch-mass ratio while achieving the primary mission goals. However, uncertainties and disturbances affect the spacecraft dynamics in real scenarios. This draws the designer towards the development of optimal feedback control strategies that assure the satisfaction of the mission goals in presence of errors and uncertainties.

Classical optimal feedback control algorithms are based on linear methods, whose main advantage is the simplification of the problem. However, their accuracy drops off rapidly for highly nonlinear systems. Thus, nonlinear optimal feedback control is gaining particular interest in recent years, and several strategies have appeared to tackle nonlinearities, such as the state-dependent or approximating sequence of Riccati equations methods [1] and the approaches based on the use of generating functions [2].

A high order method based on the use of differential algebraic techniques is proposed in this work. Differential algebra enables the efficient computation of the arbitrary order Taylor expansion of any sufficiently continuos multivariate function in the computer environment. Following the reduction of the optimal control problem to a two-point boundary value problem, differential algebra is used here to expand the solution about the nominal trajectory with respect to either initial conditions or problem parameters. Consequently, the computation of the feedback control in a relatively large neighborhood of the reference trajectory is reduced to the simple evaluation of high order polynomials.

The method can be used to solve nonlinear optimal feedback control problems with hard, soft, and mixed constraints. Illustrative applications are presented in the frame of the optimal station-keeping of geostationary satellites in a perturbed two-body dynamical framework.

[1] Cimen, T., and Banks, S. P., Nonlinear Optimal Tracking Control with Application to Super-Tankers for Autopilot Design. *Automatica*, vol. 40, pp.

1845–1863, 2004.

[2] Park, C., and Scheeres, D., Solution of Optimal Feedback Control Problems with General Boundary Conditions Using Hamiltonian Dynamics and Generating Functions. *Automatica*, vol. 42, pp. 869–875, 2006.