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ROBUST MISSION DESIGN USING INVARIANT MANIFOLDS

Abstract

After the success of several spacecraft missions like ISEE-3 and GENESIS, invariant manifolds became a paramount tool in space mission design. Understanding these dynamical structures enables several opportunities like the realization of low-cost transfers or the achievement of bounded relative motion.

When a deterministic system is considered, any initial condition on an invariant manifold generates a trajectory that entirely lies on the manifold itself. However, owing to modeling assumptions and uncertainties in the dynamical environment, e.g., gravitational models and solar radiation pressure, the evolution of trajectories on the manifold will generally drift from the nominal path in a real-life scenario.

In this paper, invariant manifolds are exploited to tackle mission design in the presence of possibly-non-Gaussian uncertainties in the dynamical environment. In a Lyapunov stability perspective, our objective is to find a volume of the phase space such that the flow emanated from this set is guaranteed to evolve in a prescribed bounded region for all possible realizations of the uncertain quantities. This concept is formulated as a semi-infinite optimization problem aimed at maximizing the volume of the feasible region. Then, the formalism of positive polynomials is used in conjunction with the scenario approach to achieve a numerical solution that is guaranteed to be feasible for a desired portion of the uncertain set.

The methodology is illustrated through two applications in the framework of the circular restricted three body problem, where uncertainty in the mass ratio of the attractors is considered. First, a planar transfer from the primary to the secondary body is considered. Second, the design of a two-dimensional quasi-periodic invariant torus populating the center manifold about a periodic orbit is tackled. A sensitivity analysis is also carried out to gain insight into the influence of the uncertainty sources on the manifolds, and the maximum amount of uncertainty that can be tolerated to have a feasible solution of the optimization problem is assessed.