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DEFINING ADMISSIBLE MANEUVERS AND RESULTING REACHABILITY SETS IN THE THREE-BODY PROBLEM USING HAMILTONIAN NORMAL FORM METHODS

Abstract

The exploration and utilization of cislunar space–a region 12 the size of the geosynchronous orbit (GEO) radius where the forces on a spacecraft are dominated by the gravity of the Earth *and* the Moon– is a natural next step for the advancement of space technologies. However, one of the most difficult challenges in conquering cislunar space is the dynamics itself.

Compared to the near-Earth space, the orbital elements are no longer nearly integrable in certain regions of cislunar space, therefore they have limited capabilities as features to be utilized by various algorithms. In fact, there exists no known set of globally integrable coordinates even in the circular restricted three-body problem (CR3BP), a simplified three-body model. Useful features in these regions are desirable as dynamics in certain regions are chaotic, especially near the L_1 and L_2 libration points where small perturbations could be the difference between an Earth-flyby or a Lunar-flyby trajectory. However, locally integrable coordinates, or normal form coordinates, may be developed about the libration points of the CR3BP using a Lie series perturbation method. Here, the normal form coordinates separate the different flow properties: the saddle subspace of the normal form defines transport properties of the underlying trajectory, while the center subspace defines periodic and quasiperiodic trajectories near the host libration point.

In these chaotic regions, classifying maneuvers and calculating a reachability set under a bounded, impulsive maneuver and maneuver window are especially complicated. A subset of maneuvers may induce a trajectory onto a periodic or quasiperiodic orbit, another subset will induce a flyby of one of the primaries, while a third subset will induce a flyby of the other primary or even a departure out of the Earth-Moon system. Reachability set calculations will be computationally expensive and approximations will be difficult given the volume of the reachability and the various dynamic regions encompassed therein. Therefore, the objective of this work is to leverage the normal form coordinates of the L_1 and L_2 libration points to define admissible sets of maneuvers in the CR3BP. Through this definition, users will be able to directly generate maneuvers which achieve dynamically similar trajectories, i.e., trajectories which depart to the same region of the phase space. From these generated maneuvers, rapid propagation of a spacecraft's reachability may be approximated through a least-squares polynomial approximation.