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OPTIMAL CONTROL THEORY TO DYNAMIC SYSTEMS METHODS OF THE BI-CIRCULAR FOUR BODY PROBLEM

Abstract

The application of low energy transfer methods in multi-body regimes allows for significant propellant savings, but typically at the expense of longer transit times. Recent applications of flow control segments, Lagrangian coherent structures, and itineraries from dynamical systems theory have shown that fast transit, low delta-v transfers can be created in the planar circular restricted three body problem (PCR3BP) such that the third body traverses from the exterior to interior of the second primary via invariant manifolds. This can be accomplished by analyzing the overlay of heteroclinic connections on a Poincare section in the rotating frame.

Applications of the aforementioned dynamical techniques have been applied to the bi-circular restricted four body problem (BiC4BP) wherein a similar flight path is sought from exterior of the third primary to orbit about the second primary. Unlike the autonomous PCR3BP, the BiC4BP is non-autonomous and typically modeled as a coupled CR3BP. A feasible solution requires an impulsive maneuver at the Poincare section where the third primary's L1 unstable manifold and second primary's L2 stable manifold overlap. The geometry of the Poincare section and configuration of the primaries at a given epoch can strongly influence the quality of solutions.

This paper will build on current work in the BiC4BP by applying optimal control and primer vector theory to the solution of feasible transfers. Primer vector theory can be used to determine when and where additional burns are warranted to reduce propellant costs. Simultaneously, the costate equations of optimal control theory are propagated along feasible solution arcs such that the sensitivities of the states can be analyzed and the adjustment of coast arcs extended or shortened. It is possible that the use of such methods will allow for a better determination of where to analyze heteroclinic connections in the BiC4BP and therefore better placement of an impulsive burn to reduce not only propellant usage, but also transit times. A discussion of the applied methods, an example problem, and concluding remarks will be give.