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SHAPE-BASED APPROACH BASED ON FAST NUMERICAL APPROXIMATION OF INVARIANT MANIFOLDS FOR CISLUNAR LOW-ENERGY LOW-THRUST TRAJECTORIES TRANSFER

Abstract

In this paper a shape-based approach for the design of low-energy, low-thrust trajectories transfer from high earth orbit (HEO) to cislunar invariant manifolds in the framework of the circular restricted three-body problem (CR3BP) is presented. Firstly, modified exponential sinusoid of shape functions are analytically determined; Secondly, using a fast numerical approximation of invariant manifolds to compute attainable sets; Finally, differential evolution algorithm is used to determine suitable values for the design variables of modified shape function parameters. Result shows the approach can efficaciously design optimal trajectories which need a great number of manifold insertion points have to be evaluated online.

Finding a reasonable initial guess, possibly represented by a suboptimal solution, is an important (and often time-consuming) part of mission design, which plays a decisive role for convergence, especially in the presence of local minima. In this paper, transfers from high earth orbit (HEO) to invariant manifolds associated to Lagrangian point L1 of the Earth–moon system are considered, assuming the two primary masses on a circular relative orbit. Provided that a significant portion of mission time is spent in a region where gravity pull from the moon and Earth is equivalent, a shape-based method is developed, where the exponential sinusoid includes an additional term that deforms its shape in the direction of the line joining the two primary masses m1 and m2 m1. Solutions obtained for the modified spiral result in reduced V, if compared with solutions obtained on the basis of the classical formulation for the same boundary conditions. The modified spiral can be used as is also for preliminary design of transfer trajectories to invariant manifolds associated to Lagrangian point L2 and L3.

In order to obtain the global optimal solution, a great number of feasible solutions associated to a set of admissible initial conditions have to be rapidly evaluated online for the optimization algorithm. The fast numerical approximation method of invariant manifolds to compute attainable sets is efficiently evaluated for the problem. Differential evolution algorithm is used to determine suitable values for the design variables of modified shape function parameters, which result in acceptable values of thrust profile and mission performance in terms of fuel consumption and transfer time for low-energy, low-thrust transfer trajectories. Result shows the approach can efficaciously design the optimal low-energy, low-thrust trajectory in the earth-moon circular restricted three-body problem system.