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LOW THRUST MINIMUM FUEL OPTIMIZATION TO LIBRATION POINT ORBITS USING VARIABLE SPECIFIC IMPULSE ENGINE

Abstract

In this paper, low-thrust minimum fuel-optimal transfer trajectories are studied in the Earth-Moon restricted three-body model with variable specific impulse engines. The trajectory optimization problem brought by the use of low thrust propulsion in conjunction with lunar flybys and libration point, L1 and L2, is researched. In order to cope with the strong nonlinear and multiple constraint optimal control problem caused by the initial value and the optimization methods, a hybrid technique is proposed.

First, the costate equations are brought by the Pontryagin maximum principle. An adjoint control transformation is used for converting costate variables to other variables which possess actual physical meaning and also treating the variables as optimization variables. Then, according to the differential equations and the constraints that include path constraints, specific nodal constraints and control constraints over the entire path, an hp-adaptive pseudospectral method, which is a global optimization method, is used to find a global solution via using collocation to discretize the state and control variables. An hp-adaptive mesh refinement algorithm in the pseudospectral method is used to determine iteratively a mesh that accurately distributes the collocation point. The problem is then solved directly by sequential quadratic programming (SQP), which is a local optimization method, to find the accurate optimization solution using the feasible solution from the hp-adaptive pseudospectral method. Meanwhile, the hybrid technique is not convergent when upper and lower bounds on design variables especially angles of thrust vectors in the initial search vector are selected unsuitably. So the sensitivity of design variables is analyzed quantificationally. At the same time, during the solving process of a traditional optimization method, integration time is significant, and hundreds of iterations are necessary, with typical run-times of two or more hours. And the solution is found by using finite difference which reduces the computational accuracy. Therefore, in order to reduce the high computational burden and improve the accuracy which significantly impacts the capability to produce results, analysis gradients derived for objective function are incorporated to the algorithm.

According to the coasting phase, invariant manifolds are exploited and the locations for insertion along the entire manifold surface are considered. Meanwhile, the effect of lunar flybys with different altitudes is analyzed in the design of transfer trajectory. Therefore, the research includes some sample libration point transfer trajectories including L1 halo orbits, L2 halo orbits that transfer with and without arcs along invariant manifolds and lunar flyby.