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Author: Mr. Shiyu Chen
Tsinghua University School of Aerospace, China, chen-sy16@mails.tsinghua.edu.cn

Dr. Hexi Baoyin
Tsinghua University, China, baoyin@tsinghua.edu.cn
Mr. Haiyang Li
Tsinghua University School of Aerospace, China, lihy15@mails.tsinghua.edu.cn
Mr. Fanghua Jiang
Tsinghua University, China, jiangfh04@mails.thu.edu.cn

COSTATE SCALING FOR MULTI-RENDEZVOUS LOW-THRUST TRAJECTORY OPTIMIZATION

Abstract

In this paper, optimization for multi-rendezvous trajectories with low thrust propulsion is investigated. Indirect method, based on optimal control theory, is applied, which transforms the optimization problem to a multi-point boundary value problem (MPBVP). When the whole trajectory from initial state to the last target is optimized, the number of shooting variables can be very large, which makes shooting method difficult to converge if the initial guesses for the shooting variables are given irrelevantly. Costate scaling has been proposed previously to optimize multi-targets transfers with low thrust among near-circle near-coplanar orbits. The steps of costate scaling are as follows. First, the whole trajectory is split into several legs by estimated rendezvous times. For each leg, near-optimal trajectory is solved and the initial guesses of costates, which are shooting variables of a two-point boundary value problem (TPBVP), are analytically obtained based on the assumption that the initial and final orbits have very small eccentricity, inclination and similar semi-major axis. Second, the obtained costates of each leg are used to derive initial guess of the whole trajectory. Costates of states and switch function are multiplied by a positive scalar k to make the costate of mass continuous at each rendezvous time so that all these legs can be patched together. Finally, homotopic approach is applied to obtain the optimal trajectory. In this paper, initial costates of each leg are guessed randomly after normalization by introducing a positive scalar $\lambda 0$. So each single-leg transfer can be solved without any assumption, that is, costate scaling is adapted to arbitrary cases of multi-rendezvous low-thrust trajectory optimization. In addition, some derivation is implemented to deal with the cases that k is calculated as negative, which is a supplement of costate scaling method. Several numerical examples of fuel-optimization problems demonstrate efficiency of our method.