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OPTIMIZATION OF IMPULSIVE TRAJECTORIES USING CONTINUATION FROM OPTIMAL POWER-LIMITED TRAJECTORIES

Abstract

We propose a new method for the spacecraft impulsive trajectory optimization using the homotopy between an optimal power-limited trajectory and an optimal impulsive trajectory. The method is applicable for any composition of perturbing accelerations, including high-order geopotential gravity acceleration and the gravity acceleration of distant celestial bodies. Particular attention in the method development was paid to ensuring its computational stability. Optimization of impulsive trajectories of spacecraft (SC) is widely used in space missions design and analysis. The analysis of optimal impulsive trajectories is especially important at an early phase of the space mission design, when the main design parameters have not been determined yet. Such an analysis makes it possible to reduce the number of flight profile options and to narrow the ranges of the trajectory parameters considered at the further phases of the space mission design. The theory of impulsive trajectory optimization (the primer-vector theory) was elaborated by D.F. Lawden and has been further developed by many other authors. However, the available methods for calculating optimal impulsive trajectories based on this theory are far from being perfect, and the problem of developing efficient and numerically stable methods for optimizing multiburn impulsive trajectories, especially in problems with high perturbing accelerations, remains relevant. To implement the new method, two auxiliary problems are used. The first one is the problem of characteristic velocity minimization for a trajectory with limited thrust acceleration, in which the magnitude of the maximum thrust acceleration depends on the continuation parameter linearly. The system of differential equations of the second auxiliary problem corresponds to the system of differential equations of motion of the power-limited problem at the beginning of the continuation process and to the equations of coasting motion of the spacecraft at the end of continuation. Velocity increments are introduced at local maxima of the absolute value of the primer-vector calculated while solving the second auxiliary problem. The magnitude of the velocity increment is calculated from the solution of the first auxiliary problem in the vicinity of such local maxima. In the second auxiliary problem, the thrust acceleration decreases with an increase in the continuation parameter, and it becomes zero at the end of the continuation. It is shown that the obtained impulsive trajectory satisfies the necessary optimality conditions. Details of the proposed method implementation and numerical examples of the optimization of impulsive trajectories are presented.