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ANALYTICAL OPTIMAL SOLUTION OF REACHABLE DOMAIN FOR LOW-THRUST TRAJECTORIES BASED ON MINIMUM PRINCIPLE

Abstract

Electric propulsion systems with low thrust are favored by engineering applications and has drawn increasing attentions of researchers due to their high propellant efficiency. To guarantee securities and feasibilities of the missions propelled by low-thrust, solutions for reachable domain of spacecraft trajectories should be studied, and the collision in the docking and formation tasks can also be avoided in advance. The existing solutions for reachable domain usually deal with reachable domain for spacecraft trajectories with finite impulses using geometric methods or parameter optimization methods. Meanwhile, in response to reachable domain for low thrust trajectories, numerical indirect methods were usually applied to solve the problem. However, these methods suffer from large time consumption and computation complexities. To address these issues, an analytical method is proposed using the Minimum Principle to achieve fast and accurate acquisition for reachable domain of the low-thrust trajectories.

The reachable domain of low-thrust noncircular orbit with fixed allowable transfer time is considered in this study. First, the linearized differential equations of relative motion are used to simplify the complex nonlinear problem because of the nonlinear orbital dynamic equations and the long-time integration. Then, based on the Minimum Principle, analytical solutions are derived for solving the low-thrust reachable domain problem. Consequently, the corresponding co-states and controls can be obtained directly during the transfer. Benefitting from the analytical solutions, an integral expression is developed for the reachable domain of low-thrust trajectories without solving the nonlinear shooting functions comparing with the numerical indirect method. Comparing with traditional indirect methods to solve the reachable domain problem, the computational consumption of the proposed method is significantly saved, while the prediction accuracy is also guaranteed. Two numerical examples show that the reachable domains coincide well with the ones obtained by indirect method and demonstrate the usefulness of the proposed methods.