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Author: Mr. Zhaowei Wang
Tsinghua University, Beijing, China, zhaowei-17@mails.tsinghua.edu.cn

ANALYTICAL ORBITAL EVOLUTIONS TECHNIQUE FOR LOW-THRUST SPACECRAFT BASED ON THE PERTURBATION THEORY

Abstract

Benefitting from the significant development of the low-thrust electric propulsion, space exploration missions of low-thrust spacecraft are increasing rapidly because of the large fuel-saving. Compared with the traditional impulsive propulsion system, the low-thrust electric propulsion is more efficient. Nevertheless, the other side of the double-edged sword of low-thrust propulsion is that difficulties for orbital design and optimization are increased significantly because large amount of orbital evolutions are needed but the orbits are not holonomic. Meanwhile, the computational burden in orbital optimization is too large to bear though the modern computational ability is excellent. Therefore, an efficient method should be established to increase the efficiency of the orbital evolutions in orbital optimization. As the numerical integration is inadvisable sometimes, some semi-analytical methods have been established to improve the efficiency in orbital optimization, such as the orbital average method and methods for the prediction of velocity increment. Both of these methods are applied in orbital optimization successfully. However, the short-term items are ignored in orbital evolutions. Hence, a further method should be developed to provide more attainable information in orbital evolutions and improve the efficiency for orbital optimization as well.

In this paper, an analytical orbital evolutions technique for low-thrust spacecraft is developed based on perturbation theory. The perturbation theory has the benefits that it can provide an approximation solution for complicated nonlinear system. Method for orbital evolutions of low-thrust spacecraft is established analytically. Meanwhile, the analytical formulas for orbital evolutions are derived with the fuel consumption for low-thrust spacecraft considered. In the end, scenarios for different magnitudes of low thrust are tested using the proposed method and the numerical integration. Compared with the purely numerical integration, the proposed method coincides well with the numerical integration of orbital evolutions and shows its high efficiency with large amount of computational consumption saved.