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MANY-TO-MANY GEO ON-ORBIT REFUELING MISSION OPTIMIZATION UNDER TIME-VARYING FUEL DEMANDS VIA MODIFIED DIFFERENTIAL EVOLUTION

Abstract

As a kind of on-orbit servicing technology, on-orbit refueling (OOR) has essential significance in prolonging the lifetime of satellites and decreasing the generation of space debris, especially for the expensive satellites located in geosynchronous orbit (GEO). Recently, several one-to-one mode-based OOR missions have been successfully conducted in space. To further reduce the economic cost, the mode of using several refuel satellites (RS) to refuel some dozens of client satellites (CS) in one mission has been proposed, that is, the many-to-many OOR mode. To maximize the efficiency of this mode, the mission optimization problem that determines the refueling sequence and refueling time should be further investigated.

The mission optimization is usually carried out before the OOR mission starts, and the fuel demand of CS is obtained in advance. However, the OOR mission for multiple CSs usually takes a long time, and some temporarily unrefueled CSs may perform orbit maintenance by consuming the remaining fuel, leading to a time-varying fuel demand change. In this case, performing the initial mission optimization results may lead to efficiency reduction or even mission failure.

To address this problem, in this paper, a many-to-many mode-based OOR mission optimization model is established considering the time-varying fuel demands, and a differential evolution (DE) based algorithm is designed to solve the problem. Firstly, a remaining fuel varying law is obtained according to the periodic orbit maintenance strategy of GEO CSs. Based on that, the mission profit model is further established. Then, by additionally considering several constraints like RS fuel capacity, mission duration, and orbital maneuver duration, the mission optimization model is established. Next, by taking the refueling sequence, the instant of refueling begins as the design variable, and a modified DE is designed to solve the problem. Unlike existing DE, a greedy-search-based mechanism generates high-quality initial individuals, and an adaptive penalty function method is used to handle the constraints to speed up convergence. Finally, the proposed algorithm is tested by optimizing the OOR mission by choosing 20 currently operational GEO satellites as CSs. Compared with the results generated by the orbit-wise sequential order, the optimized results have a better mission profit, showing the effectiveness of the proposed method.