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OPTIMIZATION OF CHASER TRAJECTORY FOR ACTIVE DEBRIS REMOVAL MISSIONS

Abstract

Recent increment of space activities is causing a rapid growth in the number of space debris which threaten ongoing and future missions. Given the number of debris already in orbit, the only effective solution to the problem is the Active Debris Removal (ADR), in which an active (chaser) spacecraft is tasked with performing a rendezvous with multiple designated passive (target) debris to carry out deorbiting operations. To this end, the design of an optimal trajectory for the chaser is mandatory, in order to minimize required propellant and allowing it to reach and remove the highest possible number of objects.

The proposed paper aims to study the optimal planning of ADR missions in which the goal is to find the sequence and the epochs in which the selected debris are visited, while a certain performance index is maximized (which may account for mass and/or area or danger of the targets). The problem can be formulated as a variant of the well-known Traveling Salesman Problem (TSP). This similitude allows one to rely on a rich bibliography generated over the years for the classical TSP, where the objective is to minimize the path necessary to a salesman to visit a given set of cities. Here, each city is represented by a single debris and the cost for moving from the current debris to the following one of the series is estimated by means of a numerically efficient yet accurate and reliable heuristics. If there are no constraints on mission duration, the transfer cost can be considered equal to the cost of a Hohmann transfer between the starting and arrival debris. Subsequently, a novel optimal ADR mission planning method is presented, in which an Ant Colony Optimization (ACO) algorithm is used in order to find an optimal configuration of debris to visit (encounter sequence and epochs) selected from a wide set of potential targets. In a more complex scenario, it is possible to extend the method to the case in which multiple chasers act simultaneously to speed up the debris cloud cleaning process. The basic version of the ACO algorithm is modified using appropriate heuristics to speed up the search process while enhancing the performance of the algorithm. Numerical results are provided for a case study concerning the removal of a set of debris composed by dozens of objects, in order to analyze the efficiency of the proposed algorithm and heuristics.