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ON THE USE OF A* SEARCH FOR ACTIVE DEBRIS REMOVAL MISSION PLANNING

Abstract

Several long-term evolution studies recently performed from different space agencies state the crucial importance of space debris mitigation measures to maintain the functionality of the Earth orbital environment. The mere compliance of new satellites with post-mission disposal guidelines will not be sufficient to stop the growth of space debris in LEO, where their density is already critical, and Active Debris Removal (ADR) is deemed the only effective option to stabilize the growth process.

Planning an ADR mission involves the design of a multi-rendezvous trajectory for the “sweeper” (chaser) spacecraft, which has to rendezvous with multiple (target) debris to carry out the deorbiting operations. In order to enhance the effectiveness and reduce the cost of an ADR program, each chaser is expected to remove as many debris as possible in a predefined mission time, making the best use of the on-board propellant.

In this respect, the present paper focuses on the optimization, i.e., the minimization of the total ΔV, of a time-fixed multi-target rendezvous trajectory. The aim of the mission is to remove a set of debris in Sun Synchronous Orbit, carefully selected on the base of their collision probability. The design of this kind of missions can be formulated as a variant of the Traveling Salesman Problem (TSP), a well-known combinatorial optimization problem whose solution is the cheapest Hamiltonian cycle involving all the nodes in a graph. However, in the “orbital” version of the problem, the cost (i.e., the ΔV) of any arc (i.e., from one target to the next one) changes over time, due to their orbital motion, leading to a Time-Dependent TSP. Specifically, two TDTSP variants are considered, assuming either equal duration for any transfer or (possibly) different maneuvering times from one target to another. Transfer costs are estimated by using a fast-computation sub-optimal strategy, that efficiently exploits the J_2 orbital perturbation.

The ADR mission planning is formulated as a tree-search problem and tackled through A*, a best-first graph-search method, broadly employed in Artificial Intelligence. The optimality and time-complexity of A* strongly depend on the heuristic used to guide the search, that must return a lower bound on the cheapest path from any node to the goal. In the present paper, different heuristics for either TDTSP variant are proposed and compared, so as to assess their performance when applied to ADR missions of increasing complexity.