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GENERAL APPROACH TO SOLVE LOW-THRUST MULTI-TARGET SPACE LOGISTICS PROBLEMS

Abstract

This paper presents a general approach to solve multi-client space logistics path optimization problems in the case of low-thrust propulsion. The methodology is able to take into account the main time-dependency factors such as orbital perturbations (secular J_2 and drag), eclipse propulsion constraints, and servicer fuel mass depletion. A low-thrust transfer strategy composed of three phases (thrust-coast-thrust) which exploits a drift orbit to correct the Right Ascension of the Ascending Node difference is adopted. Drift orbit parameters are optimized by a Non-Linear Programming algorithm in order to minimize the fuel cost needed for the transfer and satisfy the maximum time of flight constraint for the well-posed problem.

An optimization is run for all possible transfers between the satellites of the dataset on a bi-dimensional discrete grid of initial servicer masses and departure times. This procedure creates two four-variable discrete matrices representing the cost of each possible visitation in terms of fuel consumption and time of flight. The distance matrices are then interpolated to quickly solve a general path optimization problem by means of heuristics.

Two application cases are analyzed for a dataset composed of twenty satellites in Low Earth Orbit. The first considers an optimal open tour problem where the servicer must visit all satellites once by minimizing the total fuel consumption. The second concerns an on-orbit refueling problem where the servicer must refuel as many satellites as possible. The mission scenario is generalized to the case where a priority index is associated with each client; servicing time and fuel mass constraints are also taken into account.

The derived methodology is well-suited to parallel programming which permits its application to large datasets in reasonable computational times. Furthermore, the same discrete matrices can be used to quickly evaluate multiple mission scenarios providing with a broader view of the architecture's flexibility.