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MGA TRAJECTORY PLANNING WITH AN ACO-INSPIRED ALGORITHM

Abstract

Given a set of celestial bodies, the problem of finding an optimal sequence of gravity assist manoeuvres, deep space manoeuvres (DSM) and transfer arcs connecting two or more bodies in the set is combinatorial in nature. The number of possible paths grows exponentially with the number of celestial bodies. Therefore, the design of an optimal multiple gravity assist (MGA) trajectory is a NP-hard mixed combinatorial-continuous problem, and its automated solution would greatly improve the assessment of multiple alternative mission options in a shorter time. This work proposes to translate the automatic trajectory planning problem into the search for the optimal path on an oriented graph. An algorithm inspired by Ant Colony Optimisation (ACO) is then used to look for the solutions along the oriented graph. We propose the use of a two-dimensional trajectory model in which pairs of celestial bodies are connected by transfer arcs containing one deep-space manoeuvre.

For each transfer arc following a swing-by, the orbit is propagated analytically for a given number of revolutions, then a tangential Δv of a given magnitude is applied in one of the apsides, and the resulting orbit is again propagated forward in time for a given number of revolutions, up to the following planet in the sequence. The problem of matching the position of the planet at the time of arrival is solved by varying the pericentre of the preceding swing-by, or the magnitude of the launch excess velocity, for the first arc.

By using this model, for each departure date we can generate a full tree of possible transfers from departure to destination. Each leaf of the tree represents a planetary encounter and a possible way to reach that planet. The ants explore the tree from departure to destination adding one node at the time: if the solution is feasible, its sequence, parameters and cost value are stored in the feasible list. If it is not, then the unfeasible branch is stored in a taboo-list. Every time an ant is at a node, a probability function based on the lists is used to select one of the remaining feasible directions. This approach to automatic trajectory planning was applied to the design of optimal transfers to Saturn and to Mercury, and solutions are compared to those found through traditional global optimisation techniques using detailed trajectory models.