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DESIGN OF A PROXIMITY FLYBY TRAJECTORY USING OPTIMAL CONTROL THEORY AND GENETIC ALGORITHM

Abstract

Over the years small bodies have drawn more and more attention by many reasons, such as, planetary protection or the study of early solar system dynamics. Up to this day there is only a few asteroid dedicated missions; however, past missions, e.g. Galileo and Rosetta, took advantage of the proximity of the main trajectory to an asteroid to add it as a secondary objective. By performing a small change on the original trajectory, an asteroid flyby was obtained increasing the mission's scientific return at the cost of a small propellant addition. In such cases, the asteroid selection and trajectory planning is a challenging task due to the large number of variables and unknowns present in the problem.

This study presents a method for trajectory design based on optimal control coupled with genetic algorithm for the case of a mission using low-thrust propulsion system. The objective is to perform the smallest possible change on the main trajectory to allow a flyby on a neighboring asteroid while maintaining the initial and final conditions, required for achieving the main mission objective. The optimal control theory is applied to provide a comprehensive method to define the direction and magnitude of the thrust that minimizes the propellant consumption. However, the optimal control is able to identify necessary conditions for the local minimums which are close to the initial estimation (main trajectory); therefore, for some target asteroids the obtained solution may not be globally optimal or even be feasible. In order to improve the local search and considering that the problem may possess different local minimums, the use of the thrust conditions defined by the optimal control are allied with a genetic algorithm for cost minimization and compliance with the final and midcourse conditions. Finally, a probabilistic optimization method is used to explore a larger space for the solutions provided by the optimal control. A multi-objective parallel genetic algorithm is applied to obtain a trade-off between parameters such as total propellant usage and flight time, represented as Pareto-fronts of optimal trajectories. The difficulty is to adapt the parameters of the genetic algorithm to the system's complex dynamics, as there are a lot of different options available. In particular, attention is given to the balance between the objective function and the non-linear constraints to a certain tolerance. We present numerical examples of a small spacecraft on a nominal Earth resonant trajectory to visit asteroids in its neighborhood.