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HYBRID OPTIMIZATION OF LOW-THRUST ORBITAL TRANSFERS WITH COASTING ARCS FOR PROPELLANT MINIMIZATION

Abstract

Electric Propulsion (EP) is among the most efficient technologies for spacecraft propulsion. As compared to chemical manoeuvres, the low thrust force generated by EP thrusters, over time, can equally accelerate a spacecraft using considerably less propellant mass. Nonetheless, the topic of low-thrust spacecraft trajectory optimization remains an active field of research. Many approaches are available yet there is much room for improvement. One of such state-of-the-art techniques combines indirect and direct optimization methods into a hybrid approach. The indirect nature reduces the number of optimization variables whereas the direct nature of the approach provides flexibility for a configurable force and perturbations model as well as handling different operational constraints. This methodology was already shown in literature to be highly reliable for minimum-time trajectories. This paper presents a further development of the hybrid approach that preserves these results while improving the performance for minimum-propellant trajectories through a mechanism that allows for coasting (non-thrusting) arcs. This approach is additionally combined with an orbital averaging scheme to reduce the propagation load. Furthermore, a self-adaptive differential evolution algorithm leads to a flexible global optimization process maintaining practical computational loads. This research is the outcome of a Master of Science thesis at Delft University of Technology in cooperation with GMV, a technology business group with a strong leadership in space engineering. Hence, the specific interest of application lies in planetocentric trajectories, such as an orbital transfer to Geostationary Earth Orbit where there is a growing interest in all-electric propulsion. The resulting software developed using this approach is integrated as part of GMV's Flight Dynamics solution. It allows the user to perform a multi-objective optimization with respect to time-of-flight, propellant expenditure, and operational constraints fulfilment. This research constitutes a significant advancement for space mission design and ground segment operations, because it simultaneously harnesses the advantages of both direct and indirect methods with greater accuracy and enhanced functionality than the hybrid optimization methods previously developed.