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HYBRID OPTIMIZATION OF LOW-THRUST MANY-REVOLUTIONS TRAJECTORIES WITH COASTING ARCS AND LONGITUDE TARGETING 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 can equally accelerate a spacecraft over time using considerably less propellant mass. Yet despite the recent advancements in EP technology and the rise of all-electric satellite platforms, the topic of low-thrust spacecraft trajectory optimization remains an active field of research, with many approaches available yet much room for improvement. This paper presents the development of a novel approach for low-thrust trajectory optimization. The underlying formulation employs a state-of-the-art technique that combines indirect and direct optimization methods into a hybrid approach. Its indirect nature reduces the number of optimization variables and its direct nature provides unmatchable flexibility for a configurable force and perturbation model as well as operational constraints fulfillment. This approach is additionally combined with an orbital averaging scheme, to reduce the propagation load, and with a differential evolution algorithm, thus leading to a flexible global optimization process with a practical computational effort. This methodology was already shown in literature to be highly reliable for minimum-time trajectories. This paper presents a further development of the approach that preserves these results while enabling minimum-propellant optimization, through a mechanism that allows for coasting (non-thrusting) arcs. 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. The specific interest of application lies in many-revolution planetocentric trajectories, such as an orbital transfer to Geostationary Earth Orbit, where there is a growing interest in full-electric propulsion. The resulting software, integrated as part of GMV's Flight Dynamics solution, allows the user to perform multi-objective optimization with respect to time-of-flight, propellant expenditure, and final geodetic longitude. This research constitutes a significant advancement for space mission design and satellite operations because it simultaneously harnesses the advantages of both direct and indirect methods, with greater flexibility than the popular indirect approaches and enhanced functionality than the hybrid optimization methods previously presented in literature.