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A HEURISTIC STRATEGY TO COMPUTE ENSEMBLES OF TRAJECTORIES FOR 3D LOW-COST EARTH-MOON TRANSFERS

Abstract

The problem of finding optimal trajectories is essential for modern space mission design. In order to obtain low-cost solutions, the models employed in mission analysis have become more realistic, considering multi-body gravitational dynamics, enabling orbits that do not exist in two-body dynamics. Besides that, the missions have increased in complexity, exploiting both low-thrust and high-thrust, including alternative forms of propulsion such as solar sailing.

In this context, sets of good initial guesses are fundamental for the convergence to local or global optimal solutions, using both direct or indirect methods available to solve the optimal control problem. Thus, this paper deals with producing trajectories in the patched three-body approach that are designed to be good initial guesses as input to search optimal low-energy short-time Earth-Moon transfers with ballistic capture.

We introduce a more realistic modelling in which the restricted four-body system Sun-Earth-Moon-Spacecraft is decoupled in two patched Planar Circular Restricted Three-Body Problems (PCRTBP). Contrary to previous works that consider these two systems as coplanar, we take into account the inclination of the orbital plane of the Moon with respect to the ecliptic by considering that the PCRTBPs are tilted with respect to each other, with the line of the nodes of the orbit of the Moon being the intersection of the orbital planes of the pairs of primaries.

First, we present a heuristic strategy to obtain ensembles of ballistic capture orbits around the Moon relying on the hyperbolic invariant structures associated to the Lagrangian points of the Earth-Moon system that fulfill specific mission requirements. Then, we propose a patching procedure between the two three-body systems that takes into account that the motion of the primaries is not coplanar, but allows to exploit the fundamental solutions of the planar dynamics as a starting point for the search of optimal fully refined three-dimensional transfer orbits. Finally, we exploit quasi-periodic orbits of the Sun-Earth system to produce good initial guesses for the departing stage aiming optimized solutions, with low, high, and hybrid thrust.

Given that setup, we exploit the proposed algorithm in order to obtain a diverse set of good low-cost and short-time initial guesses for different strategies of thrust. An assessment of these solutions will be performed as a function of chosen relevant parameters.