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NOVEL PIECEWISE TRAJECTORY SHAPING IN HILL'S CANONICAL VARIABLES

Abstract

Shape-based methods have been proven to be computationally efficient techniques to quickly estimate the cost of low-thrust interplanetary trajectories. However, in some cases the solution is far from optimal, like in the case of the exponential sinusoid[1], or requires a special treatment when the motion is not completely planar. More recent developments[2][3] allow for a full three-dimensional representation of the trajectory but either constraints need to be imposed on the thrust direction or approximations need to be introduced on the trajectory time-evolution, causing the domain of representable trajectories to shrink. As a consequence, trajectories transferring to highly inclined or highly eccentric orbits can lead to infeasible control laws.

This paper presents a new analytical framework for the quick estimation of the Δv and peak thrust of two-point boundary value low-thrust transfers. The novelty of this method is that it solves an inverse optimal control problem in Hill's canonical variables. The parameterisation in Hill's variables was selected so that the shaping of the in-plane and out-of-plane motions can be treated separately and the boundary conditions can be analytically satisfied. This choice leads to a computationally efficient extraction of the control profile and allows for the integration of known analytical solutions for the in-plane motion. The computation of the value of the objective function (usually the total Δv or the spacecraft final mass) and path constraints is reduced to computationally inexpensive quadratures. The shaping proposed in this paper is piecewise continuous and allows for a flexible full three-dimensional representation of the trajectory. In particular, the out-of-plane motion is represented by piecewise continuous functions so that one can independently maximise both the change of inclination and the variation of the longitude of the ascending node. The method is applied to some well-known test cases, a rendezvous with Mars, asteroid 1989ML and comet Tempel-1, and the results compared to the solutions obtained with exponential sinusoid, pseudoequinoctial elements and spherical shaping.

References

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