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Author: Mr. Sergey Trofimov
Keldysh Institute of Applied Mathematics, RAS, Russian Federation, trofimov.russia@gmail.com

Mr. Maksim Shirobokov
Keldysh Institute of Applied Mathematics, RAS, Russian Federation, shmaxg@gmail.com
Prof. Mikhail Ovchinnikov
Keldysh Institute of Applied Mathematics, RAS, Russian Federation, ovchinni@keldysh.ru

METHOD OF VIRTUAL TRAJECTORIES FOR THE PRELIMINARY DESIGN OF MULTIPLE GRAVITY-ASSIST INTERPLANETARY TRAJECTORIES

Abstract

A novel method, called the method of virtual trajectories, is proposed for the preliminary design of multiple gravity-assist (MGA) interplanetary trajectories. Two high-thrust trajectory design problems are considered: the first assumes powered swing-bys and coast heliocentric arcs, while the second deals with unpowered swing-bys and heliocentric arcs each containing at most one deep-space maneuver (DSM). The proposed method differs from the standard approach based on solving Lambert's problem. First, for a given planetary sequence, the orbits of the planets are discretized. A trajectory sequentially connecting the nodes on the planets' orbits with heliocentric arcs (either Keplerian or containing one deep-space maneuver) is referred to as virtual. A database of virtual trajectories (VT) is constructed by computing all the parameters of either powered swing-bys or DSMs for each virtual trajectory. As long as the orbits of the planets are considered to be closed fixed curves (e.g., Keplerian ellipses at some epoch), the database corresponding to a specific planetary sequence remains the same.

At the second step of the method, the iterative procedure of database screening and refinement is applied in the following way. The requirements on the mission duration and the launch date determine the time span of interest. Using the timeline of planetary motion (i.e., the schedule when the planets pass each node on their orbits) during the span of interest, one can divide all the virtual trajectories from the database into two groups, unfeasible ones and near-feasible ones. A spacecraft moving along a near-feasible VT would almost "meet" the planets during its virtual swing-bys. The sub-database of near-feasible trajectories is then improved by making a finer discretization of planetary orbits in the vicinity of nodes contained by a near-feasible VT.

It is worth noting that the first step of the proposed method—constructing a database—requires the most computational effort (80-90% of the total time complexity) and, at the same time, can be done only once for a given planetary sequence. This fact playing a crucial role in bulky computations of MGA trajectories is a key point of the VT method.

The results of applying the VT method to the trajectory design of high-priority missions to the giant planets (Jupiter, Uranus) are given. They clearly evidence a good match between the best trajectory obtained by the VT method and the optimal trajectories computed by other methods. A low computational complexity of the VT method is also proven.