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ADAPTED SYZYGY FUNCTIONS FOR THE PRELIMINARY DESIGN OF MULTI GRAVITY ASSISTS TRAJECTORIES

Abstract

In the design of Multiple Gravity Assisted (MGA) trajectories, the most critical and time-consuming phase is the definition of the sequence of planets at which to perform the flybys. A general approach tackles the MGA problem using a "branch and bound" technique to resolve the combinatorial problem arising by the possible sequences of planets to be flown in order to reach the destination in reasonable amount of time. It is clear how, depending on the associated launch window and the total time of flight, not a unique optimal configuration exists. Possible solutions are searched selecting each planet at a time, resolving the associated Lambert problem for a specific time of flight and choosing the minimum delta-v solution. Such an approach is extremely expensive from a computational point of view: depending on the orbital distance to be reached and the associated number of planets that could be flown, the process requires at each stage the evaluations of the remaining possibilities in cascade and for different encounter epochs. The goal of this paper is to provide a quick estimate of the possible planet configurations for the preliminary design of suboptimal MGA trajectories. For such purpose, the Syzygy function, commonly used in astronomy for the identification of planet alignment, is mimicked and adapted to satisfy the needs of trajectory design. Different strategies to exploit this approach are presented. At a first stage, a simple modification of the classical Syzygy function is considered: the alignment condition is maintained but with a time shift, ensuring that, between one planet and the following one, the time of flight between two planets is an odd multiple of the Hohmann semi-period. The limitation of this approach, which always enforces a Hohmann transfers between one planet and the following, is resolved by the use of a shape-based approach for the trajectory model, which modifies of the Syzygy line condition into a conic section condition, with an assigned variation in semi-major axis between two consecutive planets. Such condition also allows selecting the time of interception by resolving the time equation. The use of additional constraints on the relative velocity at fly-by of the planet belonging to the defined sequence is considered to further limit the number of preliminary solutions. The proposed approaches are tested on two different case scenarios: a MGA trajectory for an interplanetary mission to Saturn, in the flavour of the Cassini's mission, and a Jovian tour mission.