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# A GEOMETRICAL APPROACH TO THE DESIGN OF MULTI-GRAVITY ASSIST TRAJECTORIES

**Abstract**

Gravity-assisted trajectories take advantage of the gravity pull of celestial bodies to change the velocity of a spacecraft and limit the use of the propulsion system. In this way, propellant is saved and high-$\Delta$V targets can be reached. Traditionally, the preliminary design of a trajectory of this kind relies on two-body dynamics, patched conics and impulsive maneuvers, and the engine of all calculations is a Lambert's problem solver in connection with an optimizer that searches for the event dates (departure, arrival, and intermediate encounters) that minimize fuel consumption. This approach is certainly robust but it is a brute-force method and can be computationally heavy (the transfer time equation is transcendental and always requires an iterative method for its solution). In this contribution, we propose a geometrical approach to the problem. For a given encounter sequence, discrete sets of conic sections connecting the orbits (assumed circular and coplanar) of the encounter bodies are generated and then matched at the several flyby bodies. The matching can be done by either imposing that the corresponding gravity assist is natural or allowing an instantaneous velocity variation at the pericenter of the hyperbola. Multiple solutions are found for the full transfer without requiring any numerical approximation or iterative procedure. The solutions are analytical, hence very fast to compute. The time matching with the actual planetary configuration is done a posteriori and is only executed on the subset of solutions that satisfy any additional requirements set by the user. By construction, the method aims at providing optimal (i.e., minimum-$\Delta$V) solutions. It is equally applicable to interplanetary trajectories and transfers within multi-moon systems. This tool is useful for mission planning as it is capable of mapping all the possible trajectories with a prescribed itinerary. Its capabilities and performance will be shown against a number of known trajectories.