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FAST NUMERICAL COMPUTATION OF LISSAJOUS AND QUASI-HALO LIBRATION POINT TRAJECTORIES AND THEIR INVARIANT MANIFOLDS

Abstract

Over the last years, the use of libration point (LP) trajectories and their invariant manifolds has become a flexible and powerful tool in the design of space missions. They provide a way to take advantage of 3-body dynamics in order to obtain complex trajectory designs with small Δv budgets, compared to the ones required by 2-body approximations. Their use is not limited to missions having a single nominal LP trajectory (as in SOHO, WMAP, Herschel-Planck), but homoclinic and heteroclinic connections can be used to obtain low-energy trajectories connecting different LP regimes (as in Genesis and Artemis). Up to present, both Sun-Earth libration orbiters (all the missions previously mentioned) and Earth-Moon orbiters (the Artemis mission) have been or are in operation.

A difficulty common to all LP trajectories is that they cannot be described by closed formulae like 2-body trajectories, and are inherently unstable, so they cannot be generated for long time spans by direct numerical integration. In order to simplify preliminary mission design, it is convenient to have sufficiently fast methods to generate LP trajectories as to display entire families, or interactively plot extremal properties of LP trajectories and their invariant manifolds as to select the best trajectory satisfying mission requirements.

Semi-analytical procedures based in the algebraic manipulation of multivariate power series allow to do this, and provide good approximations in a neighbourhood of the libration points large enough to include the LP trajectories of all the missions previously mentioned except Artemis. Numerical techniques allow to reach larger trajectories (including this last case), but require a continuation procedure that, depending on the energy of the trajectory sought, can last from some seconds to some minutes.

The goal of this paper is to overcome this last drawback by precomputing numerically sufficiently fine meshes of LP trajectories in order to obtain from them intermediate ones by interpolation. The orbits of these meshes include periodic orbits, quasi-periodic orbits (Lissajous and quasi-halos), as well as the linear approximation of their invariant manifolds. In this way, given some parameters such as planar and vertical amplitude, or energy and rotation number, a call to a single routine produces a Fourier expansion of the desired trajectory. Results will be presented for Lissajous and quasi–halo trajectories in both the Sun-Earth and Earth-Moon environments.