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REPRESENTATIONS OF HIGHER-DIMENSIONAL POINCARE MAPS WITH APPLICATIONS TO SPACECRAFT TRAJECTORY DESIGN

Abstract

The Circular Restricted Three-Body Problem (CR3BP) serves as a useful framework for preliminary trajectory design in a multi-body force environment. While the CR3BP offers a simplified model with useful symmetries, trajectory design in this dynamical regime is often nontrivial. It is essential to gain insight into the available solution space in order to generate trajectories that meet a variety of constraints. The Poincare map is a powerful tool that aids visualization of the solution space; it has proven useful to predict available solutions and to compute trajectories with specified characteristics. In combination with a constraint on energy level, Poincare maps allow a reduction in dimension such that, for the planar problem, the system is reduced to two-dimensions and the phase space is fully represented on a plane. In the spatial problem, however, Poincare maps are at least four-dimensional and are therefore challenging to visualize.

In this investigation, a method to represent the information in higher-dimensional Poincare maps is explored and is applied to trajectory design. As an example, higher-dimensional Poincare maps are used to search for transfers between libration point orbits in the Earth-Moon system. Four-dimensional map representations are demonstrated to display the invariant manifolds, and are employed to generate transfers, including heteroclinic connections between three-dimensional periodic orbits. Maps are also useful to evaluate the solution space by propagating a batch of initial conditions and studying subsequent returns to the map. The periapse Poincare map has been employed by several researchers to examine available trajectories in both the planar and spatial problems. Periapse maps are not defined in terms of Cartesian variables; however, planar periapse maps are fully represented by the projection into configuration space. For periapse maps in the spatial problem, the map cannot be represented using four state space variables and the four-dimensional map should be rendered in spherical coordinates. This representation may not be intuitive; however, to transform the map to Cartesian coordinates requires that the map be displayed in the full six-dimensional space. Sample six-dimensional periapse map representations are generated and are compared with two-dimensional maps. Regions of long-term capture emerge within both maps, however, a larger variety of long-term capture orbits exist in the spatial problem. Transit trajectories, examined by several previous researchers, also appear within the periapse maps. Long-term capture orbits and transits are computed, and sample trajectories are demonstrated in the Earth-Moon system.