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STUDY ON RESONANT FLYBY TRAJECTORY DESIGN USING SYMBOLIC REGRESSION IN CRTBP

Abstract

While Keplerian motion has been studied extensively in mission analysis, actual missions require the use of a realistic dynamical model. In the case of EQUULEUS, one of the CubeSat launched with Artemis-1, a realistic dynamical model is directly used to design the initial guess trajectory and parameters are explored by grid search. Such conventional trajectory design methods are inefficient, lack logical support, and it is unclear whether the trajectory is optimal. Therefore, these methods are not adequate for future missions, which will be more diverse and complex.

To consider realistic dynamical models, the three-body problem is used. One method for efficient trajectory design involves using dynamics on a Poincaré map at the surface of the section corresponding to the periapsis in the planar restricted three-body problem. Dynamics on the Poincaré map allows the motion of particles to be calculated analytically, which in turn allows the change in trajectory to be calculated analytically. The analytical calculation of the trajectory change not only facilitates the design process but also provides logical support for it. In a previous study [Shane D. Ross, SIAM, 3, 6, (2007)], an analytical approximate solution for the dynamics on the Poincaré map in the planar circular restricted three-body problem was derived. However, a comparison of the map-derived approximate solution, known as the Keplerian map, with the full propagation map has revealed some differences in the approximate solution, such as a break of Hamiltonian symmetry.

This study attempts to estimate the dynamics on the Poincaré map directly from the numerical data obtained from full propagations. While conventional methods use approximations to estimate the dynamics, this study estimates the dynamics directly from the results of full propagation. As a result, the dynamics are estimated more accurately with a realistic dynamical model. In this paper, as an initial attempt, we estimate the dynamics of the Sun-Earth system on the Poincaré map in the planar circular restricted three-body problem using Symbolic Regression. Symbolic Regression is a type of function identification that uses numerical data. We then compare these estimates with the results from full propagation. The map, calculated using the estimated dynamics, is compared with the full propagation map to verify its validity. The location and width of the resonant islands appear to agree. Moreover, the dynamics estimated can preserve the Hamiltonian symmetry. Finally, we aim to design an initial guess trajectory using multiple gravity assists in the planar restricted three-body problem.