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EXTENDED STATE SPACE APPROACH FOR TRAJECTORY DESIGN IN ELLIPTIC RESTRICTED THREE-BODY PROBLEM

Abstract

This study introduces an extended state-space approach to describe trajectories in the elliptic restricted three-body problem (ERTBP) and invariant manifolds for the application to the low-energy trajectory design. The circular restricted three-body problem (CRTBP) has been well-studied, and various design methods for libration point orbits (LPOs) and low-energy trajectories have been presented based on invariant manifolds. However, because the dynamics of the ERTBP depends explicitly on the independent variable, i.e., the system is non-autonomous, the computation of its invariant manifolds becomes complicated and they cannot be obtained by conventional methods for autonomous systems. Recently, Lagrangian coherent structures (LCSs) are applied as a way to obtain invariant manifolds for non-autonomous systems. However, because computations of LCSs is complicated and LCSs are obtained as a subspace consisting of intersections of an invariant manifold and a cross-section in phase space, it is hard to use them directly for trajectory design.

First, we introduce a higher dimensional autonomous system which can describe the ERTBP system as an autonomous system. By introducing a two-dimensional autonomous system which generates a periodic function of the true anomaly and integrating it to the ERTBP system, we can obtain an autonomous extended system. Invariant manifolds of the ERTBP system can be regarded as being embedded in those of the extended system. Therefore, the time-dependent invariant manifolds of the ERTBP system are sought via those of the extended system.

Next, we present a design method for low-energy transfer trajectories. The computation method for LPOs in the CRTBP based on the center manifold theorem proposed by Akiyama et al. (2017) is applied to the extend ERTBP system and LPOs and their invariant manifolds are found. We show various LPOs in the ERTBP by changing design parameters in the proposed method. The state-space approach shall be used to generate various periodic and quasi-periodic solutions and invariant manifolds in the ERTBP and enables the design of low-energy transfers. The specific examples in the Earth-Moon system are also demonstrated.

In conclusion, we reveal that the proposed methods can significantly reduce efforts to obtain LPOs and transfer trajectories utilizing invariant manifolds of the extended system.