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MANIFOLD-TO-MANIFOLD TRANSFERS USING LOW-THRUST ACCELERATION

Abstract

In the circular restricted three body problem (CRTBP), invariant manifolds associated with periodic orbits exist and enable to design low-energy transfers. On the other hand, low-thrust trajectory enabled by electric propulsion system opens up new possibilities for space missions. Recently, it has been shown that the dynamical structure inherent to the CRTBP also plays an important role in the low-thrust trajectory design.

In previous studies, transfer trajectories using invariant manifolds had been developed. However, such transfers are realized only when the initial trajectory and the final trajectory have the same Jacobi constant, otherwise impulsive maneuver is necessary. Therefore, the purpose of this study is to enable transfer between invariant manifolds with different Jacobi constant by adding continuous low-thrust acceleration during the transfer, combining optimal control with dynamical systems theory.

This paper considers manifold-to-manifold transfers in the CRTBP by low-thrust acceleration where an initial and target states lie on invariant manifolds associated to libration point orbits with different Jacobi constant. The basic idea is to utilize a family of stable and center manifolds that lie arbitrarily close to the target invariant manifold to reduce the cost of transfer. For this purpose, the equations of motion are expressed in the rotating frame whose origin is the libration point. This makes it possible to describe the nonlinear equations of motion in a semilinear form, and linear control theory can be employed via feedback linearization. The linear quadratic regulator is used to design feedback control to transfer to the target manifold. Furthermore, in order to utilize the local stable and center manifolds existing between the target and initial manifolds, this paper proposes to utilize the eigenstructure of the equilibrium point to select the target state for the feedback control. It is shown that the proposed method can reduce the cost of transfer. Furthermore the growth of error due to the nonlinear term for long time transfer can be sufficiently suppressed.

As a demonstration, transfer trajectories are designed to target the unstable manifold associated with an unstable Lyapunov orbit in the Earth-Moon system. It is shown that the proposed feedback strategy is simple but very powerful.