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THE USE OF INVARIANT MANIFOLDS FOR LOW-ENERGY EARTH-MOON TRANSFERS OF LUNAR LANDING MISSION

Abstract

Renewed scientific interest in lunar exploration has been growing over the last decade. Operations on the lunar surface will offer outstanding opportunities for research in the understanding and utilization of lunar resources, as well as for preparation of future deep space missions beyond the moon.

The purpose of this paper is to develop the alternative techniques to minimize the fuel consumption needed for a lunar landing mission. The use of invariant manifolds of periodic orbits is demonstrated in this paper to model, optimize and analyze the low-energy lunar landing trajectories from the Earth to the lunar surface.

With the influence of the Sun, the Sun-Earth-Moon-spacecraft bicicular four-body problem is firstly modeled as two patched Circular Restricted Three-Body Problems (CR3BPs). Low-energy lunar landing trajectories are then constructed using the invariant manifolds of collinear libration points in the CR3BPs. Considering the lunar landing trajectories as the planar collision orbits in Sun-Earth-Moon system, the orbit energies and orbit types vary with the invariant manifolds of different three-body systems. Their interaction has been studied to categorize available low-energy landing trajectories with diverse orientations.

While approaching the lunar surface, the direct descent method is useful to avoid the lunar orbit insertion maneuver. To reduce powered descent maneuver during the direct landing process, the perilune with a low altitude and small arrival velocity is achieved by optimizing the periodic orbits at the collinear point. Meanwhile, the sensitivity of the midcourse maneuver at the intersection of stable and unstable manifolds with respect to the velocity of landing trajectory is analyzed. By adjusting the midcourse maneuver in a proper range, both the perilune velocity and time of flight are minimized.

In the selection of a specific landing site on the lunar surface, the orientation of the landing trajectory, the altitude and velocity of perilune, and the magnitude of midcourse maneuver from the preceding procedures are all involved to obtain the optimal low-energy landing trajectories. As the use of invariant manifolds in the lunar landing mission provides a unique insight into the dynamics, it is greatly helpful to analyze the problem, and find the solution that may be impossible for the other methods.