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THE TRANSFERS BETWEEN NEAR RECTILINEAR HALO ORBITS AND DISTANT RETROGRADE ORBITS IN THE EARTH-MOON SYSTEM

Abstract

The establishment of cis-lunar space station has become a near-term goal for space agencies. The periodic orbits with favorable stability characteristics in the vicinity of the Moon, such as near rectilinear halo orbits (NRHOs) and distant retrograde orbits (DROs), are considered as potential parking orbits for the cis-lunar space station. The NRHOs belong to the halo orbit families associated with libration points L1 and L2, and the DROs are planar orbits in retrograde motion around the Moon. The transfers between NRHOs and DROs will be routine operations of space facilities in these staging orbits.

In this study, the transfer orbits between NRHOs and DROs are obtained through a search and optimization procedure. The search phase is to find trajectories from the NRHOs that could approach the DROs, possibly multiple times, after an impulse. In order to obtain initial guesses with different transfer time, each time the trajectory reaches less than 5000 km from the DRO, the initial state and the time of the minimum distance are recorded as initial guesses. Then, the initial guesses are optimized by using the direct transcription and multiple shooting strategy applied in the Earth-Moon transfer. However, unlike the Keplerian orbits around the Earth and Moon, NRHOs and DROs cannot be described by closed-form algebraic expressions. Thus, the state variables of NRHOs and DROs are fitted by six time-dependent Fourier series of order eight. When the curve fitting technique is used for an entire DRO, the errors of the Fourier series for position and velocity are about 10m and 0.01m/s, respectively. When one segment of the orbit with about a quarter of the period is fitted, the errors for both position and velocity could be less than 0.1m and 10^{-6}m/s, respectively. By combining with the curve fitting technique, the nonlinear programming (NLP) problem with analytic gradients is constructed.

By solving the NLP problem, thousands of transfer orbits between DROs and NRHOs are obtained, and the NRHOs associated with libration points L1 and L2 are both considered for comparison. The transfer orbits with favorable characteristics are selected and compared with known solutions. Properties of both the transfer orbits from NRHOs to DROs and from DROs to NRHOs are investigated. Although this study is focused on the transfers between the NRHOs and DROs, the method is also well applicable for other transfer problems. The results about the transfer orbits will be useful for future exploration of cis-lunar space.