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SEMI-ANALYTICAL APPROACH FOR LUNAR CAPTURE UNDER SOLAR GRAVITY PERTURBATION IN THE ELLIPTIC RESTRICTED THREE-BODY PROBLEM

Abstract

Over the past few decades, the dynamics of capture have been extensively discussed as a key issue in celestial mechanics. Indeed, the capture of a spacecraft by the gravity of the target central body is a crucial factor in space missions. In recent years, lunar exploration has been expected to progress primarily through NASA's Artemis program, leading to numerous studies on spacecraft capture by the Moon as the secondary primary in the Earth-Moon system. However, in general, the region around the secondary primary is highly nonlinear due to large perturbations such as gravitational forces. Consequently, predicting spacecraft behavior near a secondary primary from its initial conditions, particularly when accounting for gravitational perturbations, is challenging. Additionally, solar gravity perturbation also significantly influences the Earth-Moon system. Therefore, establishing the conditions necessary to maintain the capture state is essential for future space mission design.

In the previous study, Shihara et al. (2023) derived an equation that semi-analytically describe how the Jacobi constant of the Earth-Moon system changes due to solar gravity perturbation around the Moon in the Circular Restricted Three-Body Problem (CR3BP). And this previous study assumed circular orbits for the Earth and Moon. Thus, in this research, we semi-analytically elucidate the variation of the Jacobi constant in the Earth-Moon system under the assumption of elliptical orbits for the Earth and Moon, along with solar gravity perturbation. Furthermore, we aim to estimate the conditions for spacecraft capture by the Moon under solar gravity perturbation in Elliptic Restricted Three-Body Problem (ER3BP).

To achieve this objective, we propose a two-step method. First, we derive an equation that semi-analytically describes how the Jacobi constant varies around the Moon due to the Earth and the Moon orbital eccentricity and solar gravity perturbation. Second, we use this equation to estimate the range of variation of the Jacobi constant and to determine an initial condition that must be satisfied for the neck region to remain closed even when the Jacobi constant varies.

These studies elucidate the conditions for spacecraft capture by the Moon under solar gravity perturbation in the ER3BP. This is expected to contribute to trajectory design in the preliminary stages of future lunar exploration missions.