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Author: Mr. Bohao Du
School of Astronautics, Beihang University, China

Mr. Junfeng Yuan
Beihang University, China
Mr. Hailiao Wang
Beihang University (BUAA), China
Prof. Ming Xu
School of Astronautics, Beihang University, China
Prof. Jizhong Liu
Lunar Exploration and Space Engineering Center, China
Mrs. Lusha SHI
Deep Space Exploration Laboratory (Tiandu Laboratory), China

FMASND: AN ENHANCED FLOQUET MODES APPROACH FOR EFFICIENT STATION-KEEPING OF LIBRATION POINT ORBITS

Abstract

In recent years, libration point missions have become a hotspot in deep space exploration, offering significant value. However, the dynamical properties of libration point orbits are inherently unstable, requiring station-keeping strategies. For spacecraft carrying special payloads, long periods of strictly vibration-free environments are required, which can be disrupted by any form of maneuver, including electric propulsion. This necessitates a pulse maneuver-based station-keeping strategy for libration point orbits. The Floquet Modes Approach (FMA) is one such strategy, but it has significant drawbacks. The traditional FMA suffers from low control efficiency and even risks failure due to its inability to suppress the gradual accumulation of components other than the unstable component. Additionally, FMA is only applicable to periodic orbits or quasi-periodic orbits that are very close to periodic. These limitations collectively restrict the practicality of FMA.

To address this issue, this paper proposes an improved FMA strategy. The concept of the collateral effect of non-divergent components (NDCs) is introduced, demonstrating that it is a contributing factor to the failure of traditional FMA but can also be leveraged to enhance control performance. First, the most critical NDC is identified for suppression, the timing of the next maneuver is predicted, and a maneuver overshoot factor v is introduced. By actively utilizing the collateral effect, the “type” of the next maneuver is selected, achieving suppression of excessive NDCs, referred to as the Floquet Modes Approach for Suppressing Non-Divergent Components (FMASND). Next, by applying techniques of reduction to the central manifold and symplectic transformation, the six Floquet modes of the central manifold corresponding to the quasi-periodic orbit are decomposed, thus avoiding the need for solving single-valued matrices and eliminating the limitation of periodic orbits. Combined with the FMASND method, this significantly enhances the practicality of the FMA. Finally, simulations are conducted to validate the new method, including Monte Carlo simulations with real errors for both periodic and quasi-periodic orbits to demonstrate the effectiveness of FMASND.

Simulations demonstrate that the FMASND algorithm significantly reduces fuel consumption compared to the traditional FMA, while also exhibiting better robustness in error-prone environments.

FMASND has also been successfully applied to station-keeping in quasi-periodic orbits, achieving excellent fuel efficiency.