Paper ID: 29180
student

ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (2) (8)

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OPTIMIZED LOW-THRUST RECONFIGURATION MANEUVERS FOR SPACECRAFT FORMATION VIA THE ADAPTED FINITE ELEMENT METHODOLOGY

Abstract

As a key operation of spacecraft formation, reconfiguration has emerged to be a hot topic due to its usage for exerting the merits about scalability and flexibility of formation in space mission.

Numerous literatures about formation reconfiguration focus on impulsive controls from the perspective of such theories as LQR (Alfriend et al., 2010), Lyapunov Function (Vaddi, 2008). The ion thruster possesses the capability of low-mass, high-specific and long-duration, thus low-thrust is considered as promising in reconfiguration. However, few researches are concerned on reconfiguration via this effective thruster. Mauro and Franco (2009) proposed low-thrust reconfiguration maneuvers which see the shortcomings of expensive computation due to the fixed step in the parallel multiple-shooting technique. To overcome this weakness, Garcia-Taberner and Masdemont (2010) applied the finite element methodology (abbr. FEM) which originates from structure dynamics analysis to reconfiguring the formation on a Halo orbit generated in the CR3BP. Nevertheless, they considered much shorter reconfiguration duration (i.e., 8 hours, 24 hours) than the period of Halo orbit near EL2 point in Sun-Earth system, thus this system for FEM is essentially time-invariant. Actually, FEM has difficulty in dealing with reconfiguring the formation of Earth-orbiters. Generally, the duration for this scenario lasts several orbital periods, and the system adapted for the Earth-orbiters formation is therefore time-variant. As the extension of Garcia-Taberner and Masdemont's work, this paper presents a dynamically adapted finite element approach for this time-periodic system about Earth-orbiters formation reconfiguration under J2 perturbation. Specifically, the reconfiguration duration is divided into several smaller intervals (elements) and the initial optimized control value and reconfiguration trajectory based on C-W equation in each element are found by the adaptive steps in an iterative process, where nodes (times at which the maneuvers are performed) of the element change depending on the trajectory obtained. Furthermore, for the application in engineering, the J2 perturbation is added into C-W equation to correct the initial optimal control and trajectory as the final "true" results. The approach is particularly suited for the low-thrust Earth-orbiters formation reconfiguration with many inequality constraints on both states and controls.

A reconfiguration mission which involves potential collision hazard about simultaneously switching the position of spacecrafts orbiting on different relative orbits is illustrated to validate the proposed approach. Afterwards, the performance of this approach is demonstrated to be more effective in the results and computation costs through comparisons with the numerical methods, such as genetic algorithm and multiple-shooting technique.