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FORMATION RECONFIGURATION ON LIBRATION POINT ORBITS BASE ON CONFIGURATION GEOMETRIC INVARIANTS

Abstract

Missions about libration points in the Circular Restricted Three-Body Problem (CR3BP) have a growing interest and the need for corresponding formation flight is on the rise at the same time. Different from the formation for Earth-orbiting missions, the formation on libration points orbits (LPOs) is on non-Keplerian orbits and its reconfiguration considers the time-varying characteristics of relative motions. This paper proposes a formation reconfiguration optimization on LPOs base on configuration geometric invariants. With the help of defined invariants, the trajectory planning problem is turned into an optimal parametrical selection problem, which is significantly simplified and efficiently reduces the computational consumption.

The relative coupled dynamics of formation configuration in a nominal halo orbit is firstly disposed to uncouple linear and periodic motion components. By introducing a time-dependent change of coordinates, a reduced dynamics model has been established and the initial states of the reduced dynamics are defined as the geometric invariant to characterize a formation configuration. General configurations can be regarded as the linear combinations of the essential components in proportion to this invariant. Then, the reconfiguration continuous controller is formulated fully exploiting the instantaneous perturbated change of the invariant. It has been proved that there exists a vector function which parameterizes the reconfiguration trajectory by a functional integral. Hence, the selection of transfer trajectory can be converted into a parametrical optimization problem, whose optimal numerical solutions can be efficiently obtained from optimization methods. The indirect approach is adopted to generate the initial guess of the control and further optimization is implemented by nonlinear programming solver. By taking the hybrid approach, the difficulty in numerical iteration can be further overcome. The proposed trajectory optimization is considered for energy-optimal and time-optimal cases, respectively.

The proposed method can clearly reveal all essential relative motions of the formation on LPOs, which can provide the configuration design reference as well as control strategies. The parametrical optimization based on the reduced dynamics model is superior to the direct trajectory optimization which is typical time-consuming and computationally expensive. Numerical results show that the feasibility of the presented reconfiguration is validated and the optimization algorithm is easily converged with the computation of reconfiguration optimization significantly reduced as much as 50%.