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FORMATION RECONFIGURATION ON LIBRATION POINT ORBITS BASED ON GEOMETRIC CONFIGURATION INVARIANTS

Abstract

Missions concerning libration points in the Circular Restricted Three-Body Problem (CR3BP) are increasingly garnering interest, while the demand for corresponding formation flight is concurrently rising. Differing from formations for Earth-orbiting missions, formations on libration point orbits (LPOs) follow non-Keplerian trajectories, and their reconfiguration takes into account the time-varying characteristics of relative motions. This paper presents an optimization approach for formation reconfiguration on LPOs based on geometric configuration invariants. By leveraging these defined invariants, the trajectory planning problem is transformed into an optimal parametric selection problem, offering significant simplification and efficiently reducing computational overhead.

The relative coupled dynamics of formation configuration in a nominal halo orbit are initially decomposed to uncouple linear and periodic motion components. This is achieved by introducing a time-dependent change of coordinates, leading to the establishment of a reduced dynamics model. The initial states of the reduced dynamics are defined as the geometric invariant, which characterizes a formation configuration. General configurations can then be viewed as linear combinations of essential components, proportionally related to this invariant. Subsequently, a reconfiguration continuous controller is formulated, fully exploiting the instantaneous perturbated change of the invariant. It has been demonstrated that a vector function exists, parameterizing the reconfiguration trajectory through a functional integral. Thus, the selection of transfer trajectory can be transformed into a parametric optimization problem, with optimal numerical solutions efficiently obtained using optimization methods. The indirect approach is utilized to generate the initial guess of the control, followed by further optimization through a nonlinear programming solver. By employing a hybrid approach, challenges in numerical iteration can be effectively addressed. The proposed trajectory optimization is tailored for both energy-optimal and time-optimal cases, respectively, providing comprehensive coverage for different optimization objectives.

The proposed method effectively elucidates all fundamental relative motions of formations on LPOs, offering valuable insights for configuration design and control strategies. The parametric optimization approach, grounded in the reduced dynamics model, outperforms direct trajectory optimization methods which are often characterized by time-consuming and computationally expensive processes. Numerical

findings validate the feasibility of the presented reconfiguration technique, while also demonstrating that the optimization algorithm readily converges. Additionally, the computational burden associated with reconfiguration optimization is substantially reduced, by as much as 50%, underscoring the efficiency and effectiveness of the proposed methodology.