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APPLICATION OF HAMILTONIAN STRUCTURE-PRESERVING CONTROL TO CLUSTER FLIGHT FOR FRACTIONATED SPACECRAFT ON AN ELLIPTIC ORBIT

Abstract

Fractionated spacecraft constitutes a new architecture wherein the functional capabilities of a monolithic satellite are distributed among multiple free-flying, wirelessly-communicating modules, and many planned missions have begun to take advantage of the benefits offered by the use of satellite formations. Bounded relative trajectories are expected by this architecture, including the fixed configurations needed in missions with expected baseline vector measurements and required configurations for in-space inspection or repair.

The bounded quasi-periodic relative trajectories on an elliptic orbit are generated in this paper by the Hamiltonian structure-preserving controller **employing only relative positions for feedback without any measurement from relative velocity**, which has potential applications in cluster flight.

The periodic Lawden's equation describing the linearized relative dynamics on an elliptic orbit serves as a nominal reference model for stationkeeping controllers to generate quasi-periodic trajectories near the equilibrium, i.e., the location of the chief. A Hamiltonian structure-preserving controller is derived to stabilize the three-dimensional time-periodic relative dynamics with the feedback from the invariant manifolds. It is proven that the poles of the system can be assigned to any different positions on the imaginary axis by the controller, so that the topology type of the equilibrium is changed by the controller from hyperbolic (saddle) to elliptic (center). However, the equilibrium of the time-dependent system has time-varying topological types and no fixed-dimensional unstable/stable/center manifolds, which are quite different from the two-dimensional time-independent system with a permanent pair of hyperbolic eigenvalues and fixed-dimensions of unstable/stable/center manifolds. The unstable and stable manifolds are employed to change the hyperbolic equilibrium to elliptic one with the poles assigned on the imaginary axis. **So any initial relative position and velocity leads to a bounded trajectory around the controlled elliptic equilibrium**.

In contrast to the singular equilibrium for circular orbit, the equilibrium for elliptic orbit has the transient hyperbolic eigenvalues and the unstable/stable manifolds, thereby making the periodic condition from C-W equation unavailable.

The developed controller stabilizes the quasi-periodic relative trajectories involved in six foundational motions with different frequencies generated by the eigenvectors of the Floquet multipliers, rather than tracks a reference relative configuration. The detailed investigations are conducted on the critical controller gain for Floquet stability, and the optimal gains from the views of local and global optimizations for the fuel cost, respectively. Furthermore, the relationships and the ergodic representation in the (a-i) space are demonstrated between the eccentricity and both of critical and optimal gains.