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FORMATION FLYING CONTROL OF THE RELATIVE TRAJECTORY SHAPE AND SIZE USING LORENZ FORCES

Abstract

Propellantless control approaches for small satellite formation flying represent a special interest and an important advantage for space industry nowadays. A formation flying control algorithm using the Lorentz-force for Low-Earth Orbits to achieve a trajectory with required shape and size is proposed in the paper. The Lorentz force is produced as the result of interaction between the Earth's magnetic field and an electrically charged spacecraft. Achieving the required trajectories represents a challenge since the control is the variation of the satellite's charge value. Because of its simplicity, this control mechanism cannot ensure full controllability. A Lyapunov-based control function is developed for elimination of the initial relative drift after launch; it aims at reaching a required relative trajectory with pre-defined shape and size. The Lyapunov-based control algorithm is constructed to correct different parameters of the relative trajectory at different relative positions. The required amplitudes for close relative trajectories for in-plane and out-of-plane motion as well as the relative drift and shift of elliptical orbits are controllable using this Lorentz force algorithm. Due to the absence of full controllability, the algorithm is incapable to correct all the parameters of the relative trajectory. The proposed control allows to converge to the trajectory with required shape and size, though with some oscillating errors in the vicinity of the required trajectory parameters.

Centralized and decentralized control approaches are implemented and their performance is studied. The centralized approach considers a two-satellite cluster formed by an electrically neutral leader satellite moving on a circular LEO and a follower which actively controls its orbital motion by changing its charge in order to remain in close vicinity of the leader. Formation flying consisting of more than two satellites with charge-changing capability can also be controlled by the proposed algorithm using a decentralized approach. This work also considers the control of satellite swarm trajectories in a sphere-shaped formation. Numerical simulation of the relative motion is used to study performance of the control algorithm. It implements the model of the geomagnetic field as a co-rotating tilted dipole. The repulsive collision avoidance control is proposed for the case the system elements are inside a dangerous proximity area. The convergence time and final trajectory accuracy are evaluated for different algorithms and satellite parameters.