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Author: Mr. Huan Huang
National University of Defense Technology, China

Prof. Leping Yang
National University of Defense Technology, China
Dr. Yanwei Zhu
National University of Defense Technology, China
Mr. Yuanwen Zhang
National University of Defense Technology, China
Mr. Haitao Liu
College of Aerospace Science and Engineering, National University of Defense Technology, China

BEHAVIOR-BASED DISTRIBUTED MOTION PLANNING FOR SATELLITE SWARM WITH ELECTROMAGNETIC FORCE

Abstract

Satellite swarm presents a broad prospect of application due to its significant advantages over a single large satellite such as flexibility, robustness, redundancy and cost-effectiveness. One of the key requirements of a satellite swarm is to maintain formation flight while being capable of avoiding collisions among each other and external threats. Therefore, it is of great significance to design a distributed motion planning scheme to make the satellites behave safely in a coordinated manner. Additionally, small satellites in the swarm face crucial issues of propellant consumption and plume contamination. An attractive operational approach is applying the inter-satellite electromagnetic force to effectively offset above shortages and offer continuous reversible and synchronous controllability. This study presents a behavior-based distributed motion planning approach for satellite swarm to achieve a given configuration, and explores the possibility of integrating the inter-satellite electromagnetic force into this scheme. Based on the motion planning algorithm inspired by collective robotics dubbed "equilibrium shaping", we model the satellites in the swarm as agents, and define the desired velocity of each satellite as coming from three different behaviors following biological rules: "gather" to maintain the satellite swarm, "avoid" to prevent collisions, and "dock" to maneuver towards the pre-defined target position. The desired configuration of the satellite swarm is associated with the equilibrium points of the pre-designed kinematical field. Furthermore, a 6-DOF coupled dynamic model is required since inter-satellite electromagnetic force/torque is a nonlinear function of relative distance and relative attitude. However, only the relative trajectory motion is the focus of a motion planning problem, hence minimizing the sum of magnetic moments is additionally considered to deal with variable redundancy. In this way, such motion planning problem is translated to a parameter optimization problem. Numerical simulations of three satellites are illustrated to verify the validity of the proposed algorithm, and the satellite swarm performance enhanced by inter-satellite electromagnetic force is discussed at last.