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AUTONOMOUS CONTINUOUS LOW-THRUST RECONFIGURATION CONTROL FOR MEGA CONSTELLATIONS

Abstract

Low-Earth-Orbit (LEO) mega constellation is a newly emerging concept aiming at providing high-speed and full-coverage telecommunication services. Mega constellations usually hold hundreds even thousands of satellites running in predetermined configuration. The large number of satellites impose challenges in terms of failure satellite replacement and end-of-life disposal, In that regard, the ground infrastructure shall continuously monitor, track, and command hundreds of satellites, yet it is almost beyond the capacity of the existing ground facilities. Therefore, autonomous satellite replacement and deorbiting are necessary for mega constellations. Technically, they can be simplified as autonomous reconfiguration control problem. Meanwhile, electric propulsion has great potential in mega constellation satellites. Compared to conventional chemical propulsion, electric propulsion satellites consume renewable electric energy and thus much more efficient. In this case, it is not essential to minimize the fuel consumption, while low calculation burden and real-time adjustment capacity are two main requirements for electric propulsion control. Moreover, continuous low-thrust becomes a new constraint in constellation reconfiguration control. This paper focuses on autonomous replacement and deorbiting issues using electric propulsion for mega constellations. Artificial Potential Function (APF) control method is introduced to solve the autonomous continuous low-thrust reconfiguration control problem. Trajectories based upon APF control are not planned explicitly but rather are shaped by the potential field in reaction to the changing environment. Cartesian coordinates are usually used as APF variables in past literatures, while they do not take advantage of the dynamics associated with the orbital environment. Relative orbital elements (ROEs) generated from HCW equations are also used instead in APF control, but past ROEs can describe close relative motion only, which is not applicable to large-range orbit transfer. This paper innovatively introduces classical orbital elements into APFs for autonomous reconfiguration control. In-plane and out-of-plane control using APFs are analyzed respectively. The stability of the proposed APFs are proved in detail based Lyapunov theory and Gauss variational equations. Finally, the initial control phase is calculated to make satellite converge to target phase angle. Results indicate that the proposed control strategy is stable, distributed, near optimal in fuel consumption and minimum in computation. Thus, it is suitable for replacement and deorbit tasks for mega constellations, and it is applicable to all other reconfiguration tasks in large space systems.