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LOW-THRUST CONTROL FOR IGSO SATELLITE CONSTELLATION USING CONVEX OPTIMIZATION

Abstract

Small constellations of satellites in Inclined Geosynchronous Orbits (IGSO) provide an alternative to the increasingly crowded Geostationary Earth Orbit (GEO) belt and an extension to the global navigation satellite system. Some space missions, including Beidou- (China, 2019), aim at a further exploitation of the IGSO resources. Selected Highly Elliptical Orbits at geosynchronous altitude provide the additional advantage of low delta-V budget due to their frozen parameters. Furthermore, with the advance of electric propulsion systems, low-thrust control strategies present a key tool to further reduce mission costs. However, new challenges arise despite the obvious benefits of the use of low-thrust systems in IGSO constellation. The maneuvers planning assuming a completely electrical platform requires further study to obtain optimal mission scenarios. According to the phase space study of the long-term orbit propagation, the eccentric and inclined geosynchronous satellite constellation, which moves slowly relative to the Earth around perigee points, shows a potential in replacing the role of geostationary satellites. To reach this goal, our paper aims to present an efficient control algorithm. Additionally, the convex optimization tool is introduced due to two main benefits. Firstly, convexity shows fast and reliable computational efficiency compared with the traditional optimization method. Moreover, the local solution can be guaranteed to be a global optimum. Based on the doubled-averaged dynamical model and assuming a virtual expected satellite constellation, the equations of motion in terms of mean relative orbital elements are formulated in the first step. Afterwards, The system dynamic behaviors and boundary conditions are analyzed such that the original problem can be transformed into a convex problem. Inequality and equality constraints are modified through different linearization method. Afterwards, the original problem is solved by a successive-solution process, where a sequence of convex problems as well as a second-order cone programming approach is formed. Two simulation scenarios are designed to validate the efficiency of the proposed method. The first scenario focuses on the comparisons between the convex optimization algorithm and the traditional indirect method. The robust analysis of the proposed method is implemented in the second scenario, where orbit determination errors, thruster errors and modeling uncertainties are fully considered. Results of this work can demonstrate key factors in the mission design for autonomous IGSO constellations. The contributions are of great significance to achieve sustainable exploitation of the inclined geosynchronous orbits.