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OBSERVATION CONFIGURATION CONSTRAINED PREDICTIVE COLLISION AVOIDANCE GUIDANCE FOR LOW THRUST MEGA-SATELLITE CONSTELLATION

Abstract

In recent years, mega-satellite constellations, such as OneWeb, Starlink, have been in operation. With the increasingly crowded low orbit space, one of the most significant threats to the safe operation of constellation is the collision to the satellites, debris and other space objects. In order to improve the safety of the satellites, it is necessary to research low thrust collision avoidance guidance with configuration constraints. Generally speaking, for the mega-satellite constellation, the capability of global coverage, which is usually satisfied through certain observation configuration, is essential for its predesigned function like remote sensing, communication, etc. Such observation configuration, however, can hardly be retained during collision avoidance. As a result, observation configuration constrained collision avoidance would be beneficial for both safety and functioning of the mega-satellite constellation. As far as the authors knowledge, in the satellite collision avoidance method, the state-of-the-art satellite avoidance maneuver is mostly based on impulse thrust, which requires the calculation of the impulse moment, thrust magnitude and thrust direction with high thrust magnitude. At the same time, the constellation observation configuration constraints are usually not taken into account. However, as the electric propulsion technology increasingly adopted by satellite constellations, collision avoidance method based on low thrust will be more beneficial to effectively extend the lifetime of the satellite constellation. Due to the limited control ability of low thrust actuator, collision avoidance maneuver would be a relatively long time duration operation prior to the collision, which requires a longer period of the object's orbit determination, and thus the accumulated error of estimation is larger, which may cause collision avoidance failure. To this end, low thrust based predictive collision avoidance guidance considering observation configuration constraints are proposed. Firstly, according to the minimum coverage elevation angle of the satellite, the maximum distance between adjacent satellites on the same orbital plane can be calculated, which could satisfy continuous coverage to the Earth. Therefore, the observation configuration constraints are transformed into distance and phase constraints. In order to deal with this constrained collision avoidance guidance, a sequence of waypoints satisfying the constraints is planned by using Gaussian pseudospectral method. The guidance between waypoints is used by real-time prediction correction algorithm, which can effectively reduce the accumulated error in orbit prediction. The numerical simulations are conducted to demonstrate the feasibility of the proposed predictive collision avoidance guidance method.