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RAPID CONJUNCTION SCREENING BASED COLLISION AVOIDANCE FOR MEGA-CONSTELLATIONS WITH COVERAGE AND THRUST CONSTRAINTS

Abstract

In recent years, low Earth orbit (LEO) mega-constellations, composed of hundreds to thousands of satellites to provide global broadband even including the most rural areas, have been designed and launched by commercial aerospace companies, such as OneWeb and SpaceX. For these mega-constellations, however, one of the most significant threats to the safe operation is the collision of constellation to the active/inactive satellites, rocket bodies, debris, etc. Such collisions may result in catastrophic damage to the spacecraft operating environment. Therefore, the collision avoidance maneuver (CAM) strategy must be considered for the safe operation of the constellation. In order to properly conduct the CAM, conjunction screening is the first and essential step, which is to distinguish the satellite that need to be maneuvered. However, compared with the conventional CAM strategy of a single satellite, that of the mega-constellations is much more complicated, mainly because of the enormous quantity of satellites. This leads to conjunction screening incredibly slow even infeasible for online purpose application. What is worse is that mega-constellations have limited maneuverability, and the coverage of the satellite is sensitive to its position, compared with traditional navigation satellite constellations. To this end, a rapid conjunction screening based collision avoidance method considering coverage and thrust constraints is proposed. In view of global coverage, constellations are generally distributed in several orbital planes with dozens of satellites. To expedite the conjunction screening step, the threatened orbital planes are screened out firstly by evaluating the minimum miss distance between the danger space object and the orbital planes. Then, the satellites in the plane that need to perform CAM can be determined by the orbital period and the time of closest approach. Consequently, the computational complexity is related to the number of orbital planes rather than to that of satellites contained in the constellation, which significantly reduces the online computational burden. Furthermore, to meet the convergence requirement of online CAM algorithm, a continuous low-thrust CAM problem with mega-constellation coverage constraints is transformed into a convex form. For ease of the convexification, the coverage quantification indicator with satellite orbital altitude and angles of coverage geometry is introduced, and the coverage constraint is converted to the satellite maneuvering position constraint. As a result, the CAM problem is solved through sequential convex programming algorithm, making it applicable online with the limited computing resource.