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ORBIT SELECTION BASED ON AN INTEGRATION MACRO-MICRO COLLISION RISK ASSESSMENT ALGORITHM

Abstract

Space debris has become a global concern with the growing frequency of human space activities. The Space Surveillance Networks have tracked over 36,000 cataloged objects, posing serious threats to on-orbit spacecrafts. Therefore, selecting orbit with low collision risks for spacecraft is significantly important.

Spacecraft collision risk assessment algorithms can be divided into two categories. The first category uses macro variables, such as spatial density, which can provide a macroscopic collision possibility within a certain space and period, but cannot identify each collision event. The second category is the microscopic method, which is based on orbit propagation, providing precise collision parameters. However, it only focuses on individual collision events and cannot assess collision risks from both the temporal and spatial dimensions. Additionally, traditional spacecraft orbit selection does not consider the collision events. This paper proposes an integration macro-micro collision risk algorithm with the consideration of both collision possibilities and specific collision events, designing the optimal spacecraft orbit, with steps as follows:

1. The spacecraft's operational space is gridded based on right ascension, declination, and altitude. The spatial density of the spacecraft and space objects within each grid is calculated. A collision possibility algorithm is proposed by using Kessler's collision probability theory, which adopts the spatial density as a variable state. Then, the orbit with the minimum macroscopic collision probability is selected as the initial orbit before optimization.
2. The objects passing through the operational space of the spacecraft are screened. Then, the relative distance between these space objects and the spacecraft is calculated by orbit propagation. The collision event occurs when the distance is less than the threshold. In this case, collision avoidance is considered, and fuel consumption is calculated.
3. Combining the macroscopic collision probability and the microscopic collision events, an integration macro-micro collision risk algorithm is proposed. This algorithm is essentially a multi-objective optimization problem, which adopts collision possibility and fuel consumption as optimization criteria, incorporating orbital dynamics constraints, mission constraints, and safety constraints.

The innovation of this study lies in simultaneously considering both the macro collision probabilities and micro collision events, providing a theoretical foundation for the safest orbit selection for spacecraft.