19th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Operations in Space Debris Environment, Situational Awareness - SSA (7)

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SATELLITE CLOSEST APPROACH CALCULATION CONSIDERING ATTITUDE MOTION

Abstract

This paper deals with a satellite closest approach calculation considering both satellite's attitude and orbit, which enables more accurate predictions of minimum miss distance and collision probability. The satellites' relative position and attitude are expressed with dual quaternions, and two sets of them are interpolated to obtain the minimum miss distance. The accuracy of the proposed method and conventional one is compared. Furthermore, the necessary accuracy of orbit determination when the proposed method provides a significant difference from the conventional one is also discussed. The increase of space objects yields the congestion of space environment around the Earth, and collision avoidance must be implemented to suppress the space objects' increasing rate. For collision avoidance maneuvers, close approach analysis between multiple satellites, calculating the minimum relative distance and its time, has a significant role. The precise prediction of the minimum relative distance not only enables collision avoidance but also prevents unnecessary maneuvers. Conventional methods of close approach analysis consider satellite relative position only and calculate the minimum relative distance by cubic spline interpolations. Satellite's shape is modeled as a sphere whose diameter is its maximum length, which determines the threshold to judge the necessity of avoidance maneuvers. However, such a threshold determined without considering the satellite attitude motion would yield conservative results. For example, suppose that the relative attitude is almost constant, and the longitudinal direction of the satellite does not direct to another satellite. In that case, the threshold using the maximum length of the satellite, i.e., the longitudinal direction, is too conservative because the actual relative distance should be smaller than the longitudinal direction of the satellite. The closest approach calculation considering attitude motion is challenging, because the interpolation between two sets of position and attitude is not unique when Euler angles or other attitude parameters are used. To avoid this non-uniqueness, this paper employs dual quaternions to express the satellites' position and attitude. The dual quaternions enable identifying the unique interpolation between two arbitrary sets of position and attitude. In the proposed calculation, the satellites' body-fixed frames are defined so that their maximum length is along one axis of the frames. This definition means that minimizing both relative position and attitude yields the minimum relative distance. Numerical examples

for various types of orbits and satellite shapes are conducted to verify the effectiveness of the proposed method.