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COLLISION PROBABILITY EXPLICIT EXPRESSION AND MAXIMUM COLLISION PROBABILITY FOR SPACE OBJECTS

Abstract

The calculation of collision probability between space objects is the foundation of collision risk assessment and avoidance maneuver. In this paper the explicit expression of collision probability in the case of circular orbit based on the analytical calculation method is presented. The maximum collision probability and the corresponding positional covariance are then analyzed by the means of the explicit expression, an analytical method for determining probability upper-bound for arbitrary shape and orientation of covariance matrix is obtained. Collision probability analysis can be accomplished using a simple Gaussian probability model where the objects are assumed spherical. At the point of closest approach, each object's positional uncertainty is combined and their radii summed. The resultant is projected into a plane perpendicular to relative velocity where the collision probability is calculated as a 2-dimensional Gaussian distributed probability density function (PDF) over the region of a circle. Through the space compression, the integral of anisotropic PDF over the region of the circle is transformed to the integral of isotropic PDF over the region of an ellipse. The ellipse region can be approximated by a circle region which occupies the same area. This integral can be expressed as infinite series whose recursion is known. The partial sum of the infinite series could be taken as the approximation of the integral. Based on the first term of the infinite series, an explicit expression of the collision probability is deduced under the assumption that the orbit is a circle, the collision probability is expressed as an explicit function of the encounter geometry (crossing altitude difference and time difference of the line of the intersection of the two orbital planes, orbital planes included angle) and positional covariance in the RSW coordinates. With the help of the explicit expression, the influencing factors of the collision probability are analyzed, some significant conclusions are obtained. The explicit expression can used to analyze the maximum collision probability and the corresponding position covariance, an analytical method for determining probability upper-bound for arbitrary shape and orientation of covariance matrix is obtained. In the end, the U.S. and Russian satellite collision event in February is analyzed using the collision probability analytical method presented previously. The results indicated that the method is accurate and efficient, and could be used in engineering practice.