Accurate collision probability calculation using Gaussian mixture in orbital uncertainty propagation

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Abstract:

In the space debris collision warning project, the initial orbital uncertainty is large or the propagated time is long will result in the propagated uncertainty presenting non-Gaussian. And the calculation of two space objects' collision probability is inaccurate due to non-Gaussian orbital propagation uncertainty. In this paper, a new Gaussian mixture uncertainty propagation method is applied to the calculation of collision probability. The Gaussian mixture algorithm is based on particle-filtering algorithm, and the initial Gaussian distribution is fitted by the weighted Gaussian mixture components. Optimization of the linear matrix inequality is implemented to prevent the covariance matrix of Gaussian mixture components to be too small, and the appropriate number of Gaussian mixture components is used to approximate the initial orbital covariance. At the same time, this paper provides a method to calculate the collision probability of two objects in which Gaussian mixture is used to represent the uncertain distribution. The linearization method and the Unscented Kalman Filter(UKF) method for the Gaussian covariance propagation are analyzed. In the numerical simulation, simulation results show that compared with the linear covariance propagation method, UKF method and high precision Monte Carlo covariance propagation method for space object with larger initial orbital uncertainty, the Gaussian mixture method can be well applied to capture non-Gaussian characteristics of predicted nonlinear orbital dynamics uncertainty. Therefore, the calculation accuracy of space debris collision probability is improved.

Keywords: space debris collision warning, collision probability, Gaussian covariance propagation, Gaussian mixture components, Unscented Kalman Filter.

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