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EFFECT OF LINEAR AND NONLINEAR PROPAGATION OF UNCERTAINTY ON OPTIMAL COLLISION AVOIDANCE MANEUVERS

Abstract

The increasing number of space missions is fueled by our rising reliance on them. Alongside all the benefits this has to offer, growing number of space missions has also led to growing number of space debris. So, collision avoidance maneuvers have become crucial to ensure the safety of the operating satellite. The satellite uses control thrusts to temporarily deviate itself from the nominal orbit to avoid any risky encounter with another approaching space object. In real-world scenario, the problem gets a little more complicated due to the absence of certainty in the values of the states of the space objects. Also, the uncertainty distribution assigned to a given state variable evolves over time. This lack of accurate knowledge about the state variables might lead to a collision between the space objects even when their nominal orbits are not expected to collide. So, incorporation of this uncertainty is essential when optimizing collision avoidance maneuvers. This paper studies the effects of linear and nonlinear propagation of the uncertainty distributions on the collision avoidance maneuver optimization results of the complete problem, consisting of avoiding the encounter and returning the satellite to its nominal orbit in a timely manner. In the method using nonlinear propagation of uncertainty distribution, the uncertainty of the passive object is evolved using Monte Carlo samples while that of the operating spacecraft is evolved using Unscented Transform. The sigma points from the Unscented Transform of the operating spacecraft are required to lie outside the 6-σ debris error ellipsoid formed from the Monte Carlo samples of debris uncertainty. The second method uses linear covariance propagation and a combined error ellipsoid along with a hard body to ensure the maintenance of a desired Mahalanobis distance of the hard body from the uncertainty distribution to ascertain safety. Both the methods consider the nonlinear state dynamics while incorporating the perturbing forces to find the optimal thrust profile and the corresponding steer angles. The methods vary by implementing different error ellipsoids with differing sizes and orientations. In this paper, it has been observed that, using nonlinear uncertainty propagation to maintain sigma points of the satellite to lie outside the debris error ellipsoid requires a much lower optimal Δv than maintaining the hard body outside the combined error ellipsoid, using linear uncertainty propagation.