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OPTIMIZATION OF COLLISION AVOIDANCE MANEUVERS IN THE PRESENCE OF UNCERTAINTY

Abstract

In today's world, services from satellites have become an integral part of people's lives. This has led to a conspicuous increase in the number of satellite missions, which in turn has led to the generation of significant amount of space debris. So, collision avoidance maneuvers by operating satellites have become necessary for ensuring their safety. Collision avoidance maneuvers involve deviating the operating satellite temporarily from its nominal trajectory to avoid the approaching space object using control thrusts. These operations can be relatively easier if there are no uncertainties in the orbital position and velocity of the operating satellite and the approaching space object. However, in practice, that is not the case. Uncertainty can arise in the knowledge of states of the space objects from several sources and it also evolves over time. As the exact knowledge of the state variables associated with the space objects is not available, there arises a need to calculate the collision probability as the bodies may collide even though their nominal trajectories might not be intersecting. So, this paper deals with a novel way of addressing the complete fuel-optimal collision avoidance problem while also incorporating uncertainty propagation, instantaneous collision probability calculation and return of the satellite back to the nominal orbit in a timely manner. The optimization problem is posed as a convex problem so as to find the global optimal solution and avoid getting stuck in local minima, while minimizing the heavy dependence on initial guesses of optimization variables while using direct optimization. As the Gaussian probability density function is the highest entropy distribution for a given mean and variance, it is associated with the uncertain state variables. Thereafter evolution of the probability density function is observed over time under the state dynamics. The growing probability density function results in an evolving non-convex feasible region outside the avoidance region centered around the nominal location of the space debris, and this is tackled by using a modified and conservative Mahalanobis distance and instantaneous collision probability calculation using the Mahalanobis distance. The effects of error covariance and other parameters affecting the magnitude of delta-v required for the avoidance maneuver are also investigated.