18th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Modeling and Risk Analysis (2)

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AN EVIDENCE-BASED MACHINE LEARNING APPROACH TO AUTONOMOUS COLLISIONS RISK ASSESSMENT AND COLLISION AVOIDANCE EXECUTION

Abstract

In previous work, the authors proposed a new Evidence-based quantification of collision risk and a classification approach that integrates the Probability of Collision (P_C) with the confidence in the correctness of its calculation. The proposed classification approach addresses the existing paradox with the dilution of probability that is affecting the estimation of the collision risk.

The P_C is a common metric used in conjunction risk assessment and Space Traffic Management to identify high-risk events when a potential conjunction between space object is likely. It is also well known it suffers from dilution of probability, leading to smaller values of probability when the standard deviation associated to position uncertainty increase beyond a certain point. The root of this problem can be found in the underlying assumption that all sources of uncertainty are aleatory. The consequence is that the lack of knowledge is modelled with an increase of the standard deviation which leads to a paradoxical reduction of the risk metric and a false confidence to operators' decisions. The remediation proposed by the authors was to include a proper model of the epistemic uncertainty (lack of knowledge) using Evidence Theory. This Evidence-based approach takes into account information relating to the reliability of the data sources (i.e. sensors…) and yields intervals of confidence on the correctness of the values of Probability of Collision.

The key assumption was that the encounter was fast and that the orbit of one of the two objects was fully known. Underneath these assumptions the P_C could be calculated as a simple two dimensional integral on the impact plane of the known object. While short-term encounter models well describe a number of scenarios in LEO, there are situations where they do not apply and results cannot be trusted, like swarm conjunction or encounters in GEO.

In this work, we extend this methodology to deal with situations in which the position and velocity of both objects is uncertain and close encounters are slow. In this framework some of the assumptions underneath short-term encounters are not applicable anymore. We also propose an AI system for collision avoidance manoeuvre (CAM) planning that exploits the collision classification approach to make autonomous decisions on CAM execution. The paper will present the classification of risk events in GEO and how the AI system can autonomously allocate CAMs following the classification of the events.