20th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Interactive Presentations - 20th IAA SYMPOSIUM ON SPACE DEBRIS (IP)

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A NOVEL METHOD FOR THE COMPUTATION OF SATELLITE COLLISION PROBABILITY BASED ON EXTREME VALUE THEORY

Abstract

Appropriate methods for the conjunction analysis (CA) between orbital objects are at the core of the provision of Space Surveillance and Tracking (SST) services. The increasing number of resident space objects (RSOs) and the associated requirements on safety and automation requires a search for alternative approaches in CA to improve the current state-of-the-art. Recent analysis of the processes for operational CA and collision avoidance (COLA) of the different agencies worldwide, concludes that the current services match the current needs but may not be enough to deal with the new expected requirements and changes in the space environment. These services rely on methods that allow for fast computation of the probability of collision and uncertainty propagation. Nevertheless, several assumptions must be held for the computation to be accurate enough. The shortcomings of the current methods have been pointed out in recent analysis, namely, their inability to tackle non-Gaussian uncertainty representation or low-velocity close encounters. In recent years, there have been proposals to address the limitations of the classical methods. In general, the broadening of the applicability of these new methods comes at the cost of a large computational burden. Exploration of new approaches are required to find a suitable balance between accuracy and computational cost.

From a broad perspective, in-orbit collisions can be considered as rare events because they are seldom observed and have a large impact in the space environment and the evolution of the population of space debris. How to compute accurately the risk of rare events is subject of research in different fields ranging from collisions in air traffic management to heat waves in climatology. One can leverage on the methods proposed and the conclusions drawn in those fields to assess the possibility of using them in the in-orbit context.

The novel method proposed in this communication is based on extreme event theory, extensively used in other contexts such as extreme weather events or traffic crashes. This work explores the possibility of constructing the domain of attraction of a possible collision at any epoch close to the conjunction, i.e.,

the set in the state space that leads to a collision. The domain of attraction is obtained in a convenient low-dimensional projection space. The probability of collision can then be computed from the integral of the probability density function of the state at the given epoch on the domain of attraction.