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RELATIVE ORBITAL ELEMENT METHODS FOR CONJUNCTION ANALYSIS

Abstract

Conjunction analysis is typically performed in Cartesian coordinates due to the difficulty of determining relative distances in orbital element space. This difficulty can be overcome through use of the recently developed relative orbital elements (different than those used for relative motion). Previous work has used these elements to provide geometric insights into the collision problem as well as develop new collision prefiltering and conjunction analysis techniques. The present study will expand this work to derive a rigorous upper bound on the probability of collision between two satellites with known initial distributions over a single close approach and as time approaches infinity. Furthermore, a method for computing the probability of collision directly in terms of the relative orbital elements is derived and compared against existing methods on set of test cases.

The upper bound is derived for the case of Keplerian dynamics. The probability of collision function is first shown to be a monotonically increasing function of time ≤ 1. Using the dominated convergence theorem the limit of this function is found in terms of the steady state orbital element distributions. This leads to an expression for inf-norm of the probability of collision that can be evaluated in terms of r and the relative right ascension of the ascending node or directly (albeit in a higher dimension space) in terms of the orbital elements. It is shown that traditional methods for computing the probability of collision can exceed this bound since they do not account for the correlations between close approaches.

Next an upper bound on the probability of collision is presented for a single close approach. In this case general initial distributions and perturbed orbital motion is allowed. The time interval of the close approach is discretized and subsets of the density functions are projected onto the line of relative nodes. This yields a tight upper bound on the probability of collision for the close approach.

Finally a method for computing the probability of collision directly in terms of the relative orbital elements is derived and compared on existing test cases. This represents a major improvement over previous works which have required mapping the orbital element distributions into either Cartesian or spherical coordinates. This result is achieved by breaking the problem down into a series of planar problems and then integrating over all possible planes of collision.