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COMPUTING COLLISION PROBABILITY USING DIFFERENTIAL ALGEBRA AND ADVANCED MONTE CARLO METHODS

Abstract

A method for the computation of the probability of collision between two space object is presented. The method is based on the Taylor expansion of the time of closest approach (TCA) and distance of closest approach (DCA) of the two orbiting objects. These quantities are first computed during the conjunction detection phase by means of a global optimizer based on Differential Algebra, which is implemented in the language COSY Infinity. In this step, analytical solutions are used to describe the dynamics of the objects over the time window of interest, that is one week. When a close approach is identified, a more detailed numerical model of the dynamics is used to calculate TCA and DCA more precisely. Once the nominal values are computed, analytical expansions with respect to uncertainties in the initial states are obtained by means of Differential Algebra. The collision probability is then computed via Monte Carlo simulation, sampling values of initial position and velocity according to their estimated uncertainties. The new value of DCA for the couple of virtual objects is computed evaluating its Taylor polynomial, using the sampled deviation from the nominal initial state. The minimum distance is then compared with the collision threshold, that is the diameter of the sphere that envelopes the two spacecraft. To improve the efficiency and accuracy of the method advanced Monte Carlo Markov Chain techniques are employed.

Two test cases are presented, the first one considers two spacecraft in low earth orbit, and the second one two spacecraft in geosynchronous orbits. For each test case the collision probabilities are computed with both standard and advanced Monte Carlo methods. The computed collision probabilities and the associated computational times are compared.

The method is suitable for a wide range of orbits since no simplifications on conjunction event are assumed, e.g. can be applied to geosynchronous orbits where relative velocity is lower. The effects of main orbital perturbations are accounted for in the computation of the relative distance.