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IMPACT PROBABILITY COMPUTATION FOR NEO RESONANT RETURNS THROUGH A POLYNOMIAL REPRESENTATION OF THE LINE OF VARIATIONS

Abstract

When a Near Earth Object (NEO) experiences a close encounter with a major planet, nonlinearities rise dramatically and the uncertainty on the object's state quickly expands, opening the door to potential resonant returns: depending on the ratio of the orbital periods, the two may come to a new encounter that can involve a collision. The reliable assessment of the impact probability in this scenario is a challenging task and a major concern for the scientific community.

The standard NEO impact monitoring methodology relies on the concept of the Line of Variations (LOV), according to which the uncertainty region of newly discovered objects can be approximated to a 1D curve. This method offers a remarkable solution to two problems shown in this frame by classical techniques: the insufficient accuracy of linear approaches and the computational burden of nonlinear Monte Carlo simulations.

This work investigates the introduction of differential algebraic approaches in the standard LOV method. By relying on the implementation of an algebra of Taylor polynomials, Differential Algebra (DA) allows to compute arbitrary-order derivatives of any function in a computationally efficient way. When applied to dynamics propagation, DA provides the Taylor expansion of the ODE flow, which can be profitably used for uncertainty propagation. In highly nonlinear dynamics and for large uncertainty sets, DA is endowed with an Automatic Domain Splitting (ADS) procedure, adopted to split the initial set in subdomains that can be accurately propagated with the resulting polynomials.

In the DA framework, the LOV is not sampled as in its standard implementation, but it is rather described with a high-order Taylor polynomial. The LOV is then propagated forward in time by propagating its polynomial representation in the DA framework. Whenever the polynomial truncation error reaches a predefined threshold, the LOV is automatically split using ADS. The resulting procedure is expected to guarantee an efficient splitting of the LOV by automatically increasing the number of domains in areas that experience higher nonlinearities.

At the epoch of the resonant return, the LOV projection is composed of small fragments, some of which impacting the Earth. As a Gaussian probability density function (pdf) is associated to the subdomains, it comes straightforward to exploit the polynomials and compute the impact probability by integrating the pdf over the portion of LOV that crosses the Earth. The performance of the resulting method is assessed on test cases taken from standard internet platforms providing NEOs data sets.