High-order Uncertainty Management in Preliminary Orbit Determination

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Orbit determination of minor bodies in the Solar System has recently gained much relevance in the field of planetary defense. During its motion around the Sun, the Earth can be hit by asteroids and comets. Modern techniques and computational resources recently enabled the computation of the impact probability and the potential damages caused by. As a result, we are now more aware about the thread that these objects can pose to human kind. As the consequences of such a collision are so catastrophic, it is prudent to assess the nature of the threat and prepare to deal with it. For this reason most of the national and international agencies have started programs with the goal of producing surveys of all the objects that can represent a threat for the Earth. Within this view, the development of new algorithms that enable the solution of problems associated to orbit determination and that allow the nonlinear propagation of measurement uncertainties is of great interest for the scientific community.

In this paper Taylor differential algebra is applied to:

1. the orbit determination of celestial objects;
2. the nonlinear mapping of uncertainties from the observed variables to the orbital elements;
3. the accurate orbital propagation of the motion of the observed object, including the uncertainty associated to the observations, exploiting the high order expansion of the flow of the dynamics.

Taylor differential algebra allows the efficient computation of the arbitrary order Taylor expansion of a sufficiently continuos multivariate function. The availability of algorithms to perform algebraic and differential operations on Taylor polynomials enables the development of nonlinear algorithms for the solution of the orbit determination problem. In particular, the iterative procedure necessary to refine the preliminary solution obtained by Gauss' method is substituted by a high order method. As a result, the number of iterations necessary for the convergence is drastically reduced, and the

convergence region is enlarged. Furthermore, the uncertainties associated to the observations are analytically mapped into the object orbital elements as high-order multivariate Taylor polynomials. These maps can be then propagated forward in a n-body dynamical system in order to predict the observables at successive epochs. Real asteroids and simulated topocentric observations are used to assess the performance of the proposed method.