Accurate numerical orbit propagation using Polynomial Algebra Computational Engine PACE

Emmanuel Bignon [(1)], Romain Pinède [(1)], Vincent Azzopardi [(1)], Pierre Mercier [(1)]

ISSFD 2015 congress, Germany

Dated: March 30, 2015

Keywords: *Taylor differential algebra (TDA), Orbit propagation, Monte-Carlo*

ABSTRACT

Space mechanics problems are extremely sensitive to uncertainties management: small differences on initial conditions can lead to large errors on a predicted phenomenon such as orbit propagation. To cover the whole range of possible trajectories of a given object, one may analyze the evolution of the covariance matrix, which is not very accurate for highly non-linear systems, or use statistical methods like Monte Carlo methods for numerical integrations, which are very time-consuming.

A new way to deal with uncertainties on orbit propagation is the use of Taylor Differential Algebra. Research in this field has been carried out over the past 20 years, including studies on Apophis asteroid close encounters, interplanetary transfers, or particle accelerators [1][2]. A single integration using Taylor Differential Algebra will propagate the reference initial state x_0 along with a full neighborhood of states around x_0 whereas a usual integration will only propagate x_0. This method has several advantages. It reduces the study of uncertainties to a single propagation, decreasing the computation time with respect to Monte-Carlo methods for which many integrations are needed. It also provides an analytical result which possesses some interesting properties and can be manipulated, while usual methods are statistical and only give numerical results.

The purpose of the present study is to implement a full propagator, for any Earth-orbiting objects using Thales Polynomial Algebra Computational Engine PACE. This leads to carefully and accurately model in Taylor Algebra main perturbations such as high order Earth zonal and tesseral potential, Sun/Moon perturbations, Earth atmospheric drag, solar radiation pressure, etc.

The theory requires functions to have specific properties but we show that it is possible to extend the range of available functions to include discontinuities or some piecewise functions.

This propagator has been heavily validated against Thales reference numerical propagator to operate in industrial applications. Even for complex force models, our implementation of a 5^{th} order TDA orbit propagation runs as fast as two hundred classical propagations. Even if some limitations still remain concerning intermediate evaluations, and improvements are still achievable on computation times, the Taylor Differential Algebra is under way to become a classical and powerful tool for space mechanics applications.

References

[1] R. Armellin. Asteroid close encounters characterization using differential algebra: the case of Apophis, 2010.
[2] M. Berz. From Taylor series to Taylor models, 1997.

---

(1) THALES SIX/CIC/CS3 Space Flight Dynamics department,
3, avenue de l'Europe 31400 Toulouse, France, 33562887553, *pierre.mercier@thalesgroup.com*