Orbit Uncertainty Propagation around Non-Spherical Bodies Using the Dromo Formulation

Javier Hernando-Ayuso[1*], Claudio Bomberdelli[2]
[1]*The University of Tokyo, Japan;* [2]*Technical University of Madrid, Spain*
javier.hernando@ac.jaxa.jp

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The capability of efficiently assess how state uncertainties propagate is crucial in many space science and technology applications. In general, any kind of state uncertainty can be propagated using a Monte-Carlo (MC) method with a full nonlinear model. The main limitation of this approach is computation time. This is why MC methods are employed in limited cases or for validating other more computationally efficient methods.

The need to obtain a computationally efficient scheme to propagate has motivated the search of alternative solutions. On one hand, the limitations of linear covariance propagation in Cartesian elements have been mitigated by the use of classical or equinoctial orbital elements [1]. Other authors have employed higher-order Taylor series expansion in Cartesian elements or Gaussian mixture sampling techniques to better track the non-linear evolution of the uncertainty domain.

Following a similar approach to [1] the authors have very recently explored the use of another set of elements for uncertainty propagation: the so called “Dromo elements” derived from a relatively recent orbital motion formulation proposed by Pelaez et al. in 2007 and considerably improved in subsequent works. Using this formulation, the *linear* propagation of the uncertainty of Near Earth Asteroids (NEAs) subject to N-body perturbation [2] was presented recently and shown to drastically improve its Cartesian counterpart. The excellent results obtained for the NEAs case motivated the investigation of an orbit uncertainty propagation scheme applied to Earth-bound orbits.

As a first step, we perform a derivation of a generalized state transition matrix (STM) in Dromo elements accounting for the main geopotential terms and third-body perturbations. Once the time evolution of the STM is obtained the covariance matrix propagation can be carried out analytically bringing a dramatic improvement compared to Monte-Carlo methods.

The key question regarding the range of validity of the proposed uncertainty propagation scheme, depending on the size of the initial uncertainty region and the propagation time interval considered, is addressed by an extensive campaign of numerical simulations.

Results show that the evolution of the uncertainty of satellites can be represented quite well with the proposed method (see fig. 1). As expected, the Cartesian propagation of the covariance rapidly fails to represent the error distribution when propagated away from the initial epoch.

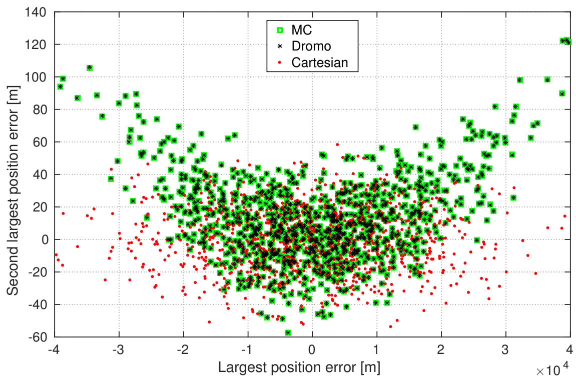

Fig. 1. Position errors calculated with the proposed Dromo method, a linear Cartesian method and a fully numerical Monte-Carlo simulation (MC) (not to scale).

References

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