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Author: Ms. Maria Piera Padula
Politecnico di Milano, Italy

Dr. Roberto Armellin
Politecnico di Milano, United Kingdom
Dr. Pierluigi Di Lizia
Politecnico di Milano, Italy
Prof. Michèle Lavagna
Politecnico di Milano, Italy

A SIMULATION TOOL FOR SPACE SITUATIONAL AWARENESS: NEAR EARTH OBJECTS

Abstract

A simulation tool for Near Earth Objects (NEO) is presented. The peculiarity of the simulator is the use of high order methods based on Differential Algebraic (DA) techniques. State-of-the art tools are mostly based on either linear methods or nonlinear Monte Carlo simulations. The main advantage of linear methods stays in their problem simplification, but their accuracy drops off rapidly for large uncertainty sets. Classical Monte Carlo simulations provide true statistics, but are computationally intensive. DA techniques are used to overcome the above issues. Differential Algebra supplies the tools to compute arbitrary order derivatives of functions within a computer environment. The availability of the high order expansions is exploited to manage problem uncertainties.

The simulator includes DA-based algorithms for NEO preliminary and accurate orbit determination, minimum orbital intersection distance (MOID) computation, and time and distance of close approach (TCA and DCA) identification for potentially hazardous objects. The high order algorithms for orbit determination consider optical observations. The preliminary orbit determination is based on the solution of Lambert's and Kepler's problems and uses the real solutions of the classical 8th order Gauss polynomial as first guesses. A better convergence with respect to Gauss' method is achieved, and the method nonlinearly maps uncertainties from the observation space to the phase space. When more than three observations are available, the tool applies a high order Kalman filter. The solution of the preliminary orbit determination problem initializes the filter. In the propagation phase, the uncertainties related to the preliminary orbit determination are propagated forward in time by exploiting the high order expansion of the flow of the dynamics. Thus, the initial covariance is nonlinearly and analytically propagated up to the next measurement.

The tool for the MOID computation uses a validated global optimizer. This approach enables a rigorous computation of the MOID. In addition, the tool allows us to perform an accurate sensitivity analysis of the MOID using its high-order Taylor expansion with respect to uncertainties.

A technique for the automatic computation of both TCA and DCA for all the virtual asteroids belonging to the initial uncertainty cloud is included in the tool. Being based on the high order expansion of the flow of the dynamics, this technique requires a single DA-integration as opposed to the multiple integrations of the Monte Carlo methods.

The performances of the tool are shown by running all the algorithms on a list of virtual impactors.