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Author: Mr. Giorgio Isoletta
University of Naples "Federico II", Italy

Mr. Nicola Cimmino
University of Naples "Federico II", Italy
Prof. Roberto Opromolla
University of Naples "Federico II", Italy
Dr. Giancarmine Fasano
University of Naples "Federico II", Italy

UNCERTAINTY EVALUATION TOOL FOR MEDIUM-TERM LOW-EARTH ORBIT PROPAGATION

Abstract

The circumterrestrial space is becoming a risky environment and is getting increasingly crowded, mainly because of on-orbit breakup events and launches of mega-constellations of satellites. Space Surveillance and Tracking (SST) is in charge of monitoring Earth orbiting objects and related fragmentation events, as well as providing a collision avoidance service. Within the SST framework, orbital propagation is crucial in many activities, as determining the likelihood of a conjunction, since high accuracy predictions of the objects' orbital states is required to be confident enough in assessing collision risk. However, propagation accuracy is affected by several sources of errors, arising from uncertainties depending on many factors, especially in Low-Earth Orbit (LEO) scenarios. Firstly, orbital perturbation modelling represents a major issue, especially concerning the estimation of the Earth's atmospheric density. Indeed, under the same orbital conditions, different atmospheric models output different density values, which can also undergo significant variations also due to the solar activity. Another critical source of uncertainty is related to the accuracy in the knowledge of the physical parameters of space objects, such as the area-to-mass ratio (A/M), typically unknown for debris, also due to the limits of ground-based sensors on the minimum detectable size. Overall, even small errors in the atmospheric density modelling or in the A/M estimation can produce an accumulation of the position error, which is mostly in the along-track direction for LEO propagations. In this context, the uncertainty evaluation process consists in assessing how the input uncertainties on the environment and the objects' characteristics affect the propagation error in output as function of propagation time. Although it can be a nontrivial operation, involving many quantities at the same time, quantifying the effects of the uncertainties on medium-term propagations is important not only to determine which effects are less significant than others, but also to define confidence intervals allowing to support SST functions, such as sensor tasking. This paper tackles the problem of uncertainty evaluation by reviewing analytical and semi-analytical approaches, with the aim to develop a computationally light tool useful to define propagation error boundaries. The performance of the tool is tested for medium-term propagation scenarios in LEO, comparing the estimated errors with those computed by propagating the objects with different A/M or perturbation settings.