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TOWARDS THE MAINTENANCE OF GAUSSIANITY ON STATE VECTOR UNCERTAINTY PROPAGATION

Abstract

Space Situational Awareness (SSA) refers to the ability to view, understand and predict the physical location of natural and manmade objects in orbit around the Earth. While the ability to view is made possible thanks to ground and space based sensors (e.g. Radars, Telescopes or Lasers) the ability to understand and predict the physical location of objects needs the determination of their orbital state vectors.

In addition to the state vectors determination, many applications need to know the state vector uncertainty and its evolution with time. Cataloguing of the space debris population, collision risk assessment in orbit, collision risk assessment at launch or space object identification are some of the applications that need a fine characterization of state vector uncertainty and of its evolution with time.

A common assumption that is done by the community is that state vector uncertainty remains Gaussian with time. Such assumption is a key requirement in order to apply the simplified mathematical formulations commonly used in the applications described above. To overcome the error induced by such invalid assumption, some researchers have developed in the past Gaussian-mixture models. These allow approximating any distribution by a mixture of Gaussian laws and therefore adapting mathematical formulations without changing the underlying assumption of Gaussian uncertainties. Other researchers have decided to work on a generic Bayesian framework where no assumption is needed concerning the nature of the uncertainty of the state vector. Both approaches, even if mathematically valid, induce an important increase on the computational time and therefore remain non-used within the operational framework.

In this paper we present a non-linear local orbital frame transformation that allows working on a dimension closer to the curvilinear abscissa and thus taking into account the effects of the curvature of the trajectory. As a result, this transformation guarantees the Gaussianity of the state vector uncertainty. In the paper we prove, with several examples, that the covariance remains Gaussian for propagation periods on the order of several tens of days and in the presence of big orbital maneuvers with non 100