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LINEARIZED SDE FOR PROPAGATING DENSITY MODEL UNCERTAINTY

Abstract

One of the main tasks of a space objects catalogue is to support routine space operations with accurate orbital information and associated uncertainties. Uncertainties associated with an estimated orbit are provided through a covariance matrix, which in turn is used in estimating the probability of collision between the satellite of interest and other orbiting space objects. The probability of collision estimate is only as good as the quality of the input that is the covariance matrix. In order to make a rightful decision during space operations, the realistic covariance matrix plays an important role. Therefore, a method for estimating realistic covariance will be significant within a space object catalogue maintenance system. Generally, batch least square orbit determination (BLSQ-OD) procedure is used in maintaining a space objects catalogue. With this procedure, the estimated orbit and the confidence of estimation is obtained by fitting the modelled orbit to a given set of observations. Thus the estimated covariance matrix reflects the observation quality and inversely proportional to: the number of observations, length of the observation arc, and the time distribution of observations within the arc. This covariance associated with the estimated orbit in a BLSQ-OD does not take the quality of force models used within the propagator, i.e. an orbit model. This over optimistic covariance might not provide realistic impression of the uncertainty associated with the orbit. Hence, it is required to include all the known knowledge of uncertainties within the estimated covariance. The present study will target uncertainties associated with atmospheric density model and an empirical method to estimate them along the prediction arc lengths. The high atmospheric densities are both spatial and temporally correlated. To estimate or to include an uncertainty of such a system is a non-trivial task. In this study an interpolated Gauss-Markov process (smoothed Brownian motion) is used to approximate the uncertainty within the density models. Later a linearized stochastic differential equation is established to understand the time behavior of the orbital uncertainty due to density noise. The relative equation of motion, in the form of Hill-Clohessy-Wiltshire equations, with stochastic acceleration is used to approach the problem at hand. Monte-Carlo simulations are used to compare the results from SDE formulation and quantify the approach.