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HYBRID NONLINEAR SEMI-ANALYTICAL UNCERTAINTY PROPAGATION FOR CONJUNCTION ANALYSIS

Abstract

Every Resident Space Object (RSO) is tracked through occasional observations from radars and other satellites; and on-board GPS. Orbit determination methods applied to each tracked object provide its associated state and uncertainty. Accurately propagating this uncertainty is crucial in getting useful future state and uncertainty information for Guidance, Navigation, and Control (GNC) models for these RSOs. GNC models with accurate propagated uncertainty have several applications, one of which is conjunction assessment. Given the uncertain nature of statistical models of orbit determination, Monte Carlo analysis is often used to compute a future state and uncertainty, and to perform conjunction assessment between RSOs. In this analysis, millions of points are taken from the initial RSO uncertainty and are individually propagated to give the final uncertainty distribution. Although extremely accurate, this method is also very computationally expensive. To reduce this expense and maintain accuracy, several analytical and semi-analytical methods of uncertainty propagation have been proposed.

Previous work has shown the accuracy of a Gaussian Mixture Model – State Transition Tensor (GMM-STT) method in nonlinearly propagating uncertainty in space for conjunction assessments. This method in previous papers has evolved from using simple two-body dynamics (2BP) to using a complex Simplified Dynamical System (SDS) model. The SDS used includes a simplified version of dynamics including the 2BP, J2, and Solar Radiation Pressure. This simplification comes from eliminating the short period variations to allow for a faster propagation over longer periods of time.

The novel work with this paper is to investigate the effect of adding these short period variations back to the mean dynamics near the conjunction time. This is done using the Deprit-Lie transformation of the system Hamiltonian, the same method that is used in eliminating these short period variations in the SDS. This transformation splits our dynamics into the averaged dynamics (including secular and long period variations) and short period dynamics, the computation of which allow short period dynamics to be added. This will provide a better view of the conjunction and should lead to a more accurate probability of collision from the GMM-STT method. As done in previous works, the final probability of collision is compared to the Monte Carlo results to confirm accuracy.

This hybrid method will be useful in more realistic application because it leverages the speed of averaged dynamics from the SDS in the GMM-STT method, along with the accuracy of adding the short-period variation near the conjunction time.