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BAYESIAN FILTERING USING DIRECTIONAL STATISTICS FOR SPACE DEBRIS TRACKING PROBLEM

Abstract

The problem of space debris tracking from a sequence of observations can be viewed as an example of Bayesian filtering. The state vector describes the position and velocity of the space object, and can be represented as a 6-dimensional vector in Cartesian coordinates. The observation vector consists of an angles-only measurement, possibly plus range, a 2- or 3-dimensional vector. Filtering is simplest if the joint state and observation vectors follow a multivariate normal distribution. However, even if the initial uncertainty of the state is normally distributed, the propagated orbital state several periods into the future quickly becomes non-normal, with the distribution of the position vector having a distinctive "banana" shape in $\mathbb{R}^3$.

One solution to the filtering problem is to use a particle filter, but this approach can suffer from the curse of particle depletion. Another solution is to switch to an "adapted structural" coordinate system, where the joint distribution is much closer to normal. The phrase "adapted" means that the coordinate system depends on the data. The key step is to note that the state vector can also be described in terms of an ellipse (5 degrees of freedom) plus the position of the space object along the elliptical orbit (a one-dimensional angular or directional variable, namely, the true anomaly). In particular, under idealized Keplerian dynamics, the ellipse parameters are constant in time and the true anomaly is an angle travelling around a unit circle. In this paper we demonstrate the usefulness, efficiency and accuracy of this approach for the filtering problem.