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TACKING THE ASSOCIATION AND TRACKING PROBLEMS USING DIRECTIONAL STATISTICS TO MODEL UNCERTAINTY

Abstract

One of the main concerns in space situational awareness is to keep track of the large number of resident space objects (RSOs), both satellites and debris, orbiting the earth. Observations typically take the form of angles-only measurements from ground-based telescopes. Two specific tasks are the identification of objects and the tracking of objects. Ideas from directional statistics have been developed recently to help tackle both of these problems. The first contribution is a new "Fisher-Bingham-Kent (FBK)" distribution on the unit sphere, which often can be used to describe the predicted angular position and its uncertainty at a specific time of an RSO. A key property of the distribution is that it can describe uncertainty tightly spread along an arc of a great circle. The FBK distribution has proved very useful for the association problem in which an observation at a particular time might be compatible with the predicted positions (plus uncertainties) of two or more objects in a catalog or library. It is desired, if possible, to associate the observation with just one of the objects.

A second problem is tracking or filtering. The objective is to update successively the prediction of the state (plus uncertainty) of an RSO as new observations are made. Under an assumption of Gaussianity, the problem can be tackled using Kalman filter ideas. Unfortunately, the Gaussianity assumption can fail badly using standard coordinate systems in astrodynamics (such as earth-centered inertial, Keplerian and equinoctial). A new "Adapted STructural (AST)" coordinate system has been developed, under which approximate Gaussianity hold under a wide range of circumstances. An unscented Kalman filter in AST coordinates (UKF-AST) has been successfully implemented. Further, the AST-UKF is computationally much faster than particle filters.