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SPACE DEBRIS SYMPOSIUM (A6)
Space Debris Detection and Characterisation (6)

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ANALYTIC ASSESSMENT OF SENSOR UNCERTAINTY FOR APPLICATION TO SPACE OBJECT TRACKING AND CORRELATION

Abstract

Reliable tracking and correlation of observed space objects is a key objective of space surveillance. An acceptable accomplishment of this responsibility is predicated upon the correct assessment of how measurement uncertainty affects the observed object's state estimate and *a posteriori* density function. The nonlinear mapping of space object observations, often range and angle pair, to the object states, Keplerian elements, can render the Gaussian assumption of state uncertainty invalid, requiring state estimation methods to account for the shape distorting effect of the nonlinear transform. This research applies the transformation of variables technique to map the measurement error probability density function directly and exactly from sensor frame to Keplerian element frame. This mapping enables direct application of Bayesian estimation techniques for object state estimation and allows for a hypothesis testing framework to correlate object tracks. Comparisons with existing architectures for state estimation, such as particle filtering, and alternative methods of track association will be presented to discuss the utility of the proposed method.

Analysis of the impact of measurement error on object state estimation and track correlation is a key issue since objects are observed using spherical coordinates but, Cartesian coordinates allow for a more intuitive visualization of tracking performance and Keplerian elements enable efficient and accurate state and covariance propagation to the next epoch. The measurement noise associated with conventional radar and optical sensors is commonly assumed Gaussian, which is valid for most situations of interest. However, the distortion effect of the nonlinear transformation between the measurement and propagation coordinate frames needs to be understood in greater detail. By incorrectly accounting for measurement error in the propagation frame, either Cartesian or Keplerian element space, overconfidence or doubt in the object state estimates can result. Overconfidence assumes small error uncertainty which can lead to filter divergence during tracking or rejection of tracks that should be correlated with the object if they lie outside the propagated uncertainty. Lack of confidence in the uncertainty modeling can lead to false object detections and incorrect track correlation.

To test our approach we consider a single ground station utilizing range with an angle pair or angles-only observations of space objects assumed to be non-maneuvering. We develop key elements of the probability density function transformation through nonlinear mapping for application in a Bayes' filter to allow for a more reliable uncertainty assessment of object states during tracking and for correlation of object tracks.