Extended Object and Group Tracking: A Comparison of Random Matrices and Random Hypersurface Models

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Abstract: Based on previous work of the authors, this paper provides a comparison of two different tracking methodologies for extended objects and group targets, where the true shape of the extent is approximated by an ellipsoid. Although both methods exploit usual sensor data, i.e., position measurements of varying scattering centers, the distinctions are a consequence of the different modeling of the extent as a symmetric positive definite random matrix on the one hand and an elliptic random hypersurface model on the other. Besides analyzing the fundamental assumptions and a comparison of the properties of these tracking methods, simulation results are presented based on a static tracking environment to highlight especially the differences in the update step for the extension estimate.

Short Summary

The explicit consideration of target extents is becoming more and more important in the development of modern tracking systems, where an object is considered as extended if it is the source of multiple measurements at the same time. The specific set of problems arises from different scattering centers, named measurement sources, which give rise to several distinct radar detections varying, from scan to scan, in both number as well as relative origin location. In order to improve robustness and precision of estimation results, it is felt desirable to track the target extent in addition to the kinematic state of the object. More than these quantities cannot safely be estimated as well in the (opposite) case, where limited sensor resolution causes a fluctuating number of detections for a group of closely spaced targets and thus, prevents a successful tracking of (all of) the individual targets. In this case, it is suitable to consider this group of point targets as a *single* extended object.

Several suggestions for dealing with this problem can be found in literature. For an early work, see [DBP90]. An overview of existing work up to 2004 is given in [WD04]. In general, implicit and explicit models for the scattering centers, i.e., the measurement sources, can be distinguished. Explicit target models [VIG04, VIG05, IG03] aim at estimating the location of the measurement sources in addition to kinematics of the object. These approaches require data association and are not treated in this paper. An implicit model for the target extent assumes that the measurement sources are generated independently according to an internal state of the object that reflects the extent. An example for an implicit model is a so-called spatial distribution model, where each measurement source is assumed to be an independent random draw from a probability distribution [GGMS05, GS05].

In this paper, we discuss two different tracking methods for extended object tracking, where the measurement sources are modeled implicitly and the true physical extension is approximated by an ellipsoid. Ellipsoidal shapes are highly relevant for real world applications, as an ellipsoid provides useful information about the target orientation and spatial extent. Here, the focus is on track maintenance, while estimation under uncertain observation-to-track association in the possible presence of missed detections and false alarms is considered out of scope.

The first tracking method considered in this paper is based on the use of symmetric positive definite (SPD) random matrices and has been introduced in [Koc08]. Therein, an SPD random matrix to describe the ellipsoid is the counterpart of a random vector representing the centroid. The decisive point for tracking of extended objects in [Koc08] is the special interpretation of usual sensor data, whereupon each measurement is considered as a measurement of the centroid scattered over object extension. This implicit neglect of any statistical sensor error has caused some further investigations and developments to honor the fact that both sensor error and extension contribute to the measurement spread [FF09]. Hence, we employ two approaches: the original one of [Koc08] as well as the advanced one of [FF09]. The second tracking method is based on a random hypersurface model (RHM), which has been introduced in [BNH10]. An *Elliptic RHM* specifies the relative Mahalanobis distance of a measurement source to the center of the target object by means of a one-dimensional random scaling factor. In order to avoid the treatment of an SPD matrix for the ellipsoid, the kinematic state of the extended object is supplemented with the non-zero entries of the Cholesky factorization of the inverse SPD matrix. By this means, all parameters describing the corresponding ellipsoid are contained in one random vector.

This paper analyzes the fundamental assumptions of these three tracking approaches and provides a comparison of the properties of the two different methods. It is completed by simulation results based on a static tracking environment to highlight especially the differences in the update step for the extension estimate.

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