Tracking Algorithms for Bistatic Sonar Systems

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Bistatic sonar has been identified to improve surveillance performance compared to monostatic systems, in particular when exploiting the operational benefit of having a covert receiver. In this setup, the target is loosing the advantage of a stealth design. Operational concepts extend this idea also to the 'multistatic setup' consisting of multiple sources and receivers. However, due to e.g. communication constraints within the multistatic setup, the pure bistatic scenario has also there an important role: Tracking of contacts from a bistatic detection opportunity might lead to tracks which are then sent to a track fusion center. The fusion center collects bistatic tracks from all participating receivers in the multistatic setup. Each bistatic track should be as accurate as possible to ensure at the fusion center a correct association of received bistatic track information to the same target.

From a system design point of view, the accuracy of measured contact and environmental data is limited by the given variability of the underwater sound channel and by budget or feasibility constraints on the quality and number of measurements. By precise modelling and callibrating the underwater sound channel the quality of a bistatic setup can be improved. But in spite of appropriate corrections, some parameters in the multistatic environment may remain imprecise. Thus, from a sequential tracking point of view, it is important to correctly model the uncertainties accompanying the actual measured values, otherwise the tracking filters are not able to fully exploit the presented data.

For bistatic sonar the measurements are described by a non-linear function of the target state, the given bistatic geometry and environmental parameters (like the speed of sound, the source and receiver positions and the receiver heading). The measurement model includes noise describing the uncertainty inherent in the measurement process for all arguments of this non-linear function. In order to apply sequential tracking techniques in the framework of a state-space Kalman filter, approximations of the non-linearity and/or its effect on associated uncertainties have to be applied. A common approach is to transform measurement uncertainties into Cartesian coordinates by linearizing. We will compare this approach with an alternative strategy based on the Unscented Transform (UT). After the transformation, a linear Kalman filter can be used to track contacts. Two alternative procedures are available, known as extended Kalman Filter (EKF) and unscented Kalman Filter (UKF) that can be adapted to account for uncertainties in the environmental parameters.

In this paper, we present a performance analysis for these four methods in terms of Monte Carlo simulations for an operationally relevant bistatic setup. We compare their tracking results to the Cramer Rao Lower Bound (CRLB) of the associated estimation problem.

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