Direct Multitarget Tracking and Multisensor Fusion Using Antenna Arrays

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The estimation of the state (i.e. source positions, velocities, etc.) of multiple emitting sources using passive sensors is a widely investigated problem encountered in various fields like wireless communication, radar, and sonar. This problem is commonly referred to as the Target Motion Analysis (TMA) problem. We consider a three-dimensional scenario with multiple moving targets and multiple (fixed or moving) observers, each equipped with an antenna array. Each array collects batches of antenna outputs. The scenario is assumed to be stationary during one batch and non-stationary from batch to batch.

Within the traditional approach to the multiple source TMA problem, first of all for each batch of each sensor Directions of Arrival (DOAs) of all sources at all points in space are estimated with a DF method like the subspace-based Multiple Signal Classification (MUSIC) method. The subsequent measurement-to-track (M2T) association step consists of partitioning the DOAs into sets of DOAs, or tracks, belonging to the same source. Then, the DOA tracks of all sensors are fused in a track-to-track (T2T) association step. Finally, the DOAs for each source are used to determine its state with the help of a suitable BOT algorithm.

In the Subspace Data Fusion (SDF) approach, subspaces are formed in a first pre-processing step from the raw antenna outputs. Then, the parameters of interest are estimated directly from a single MUSIC-type cost function, which results from fusing all subspaces. This approach requires only a single low-dimensional optimization and completely circumvents the bearing data association problem inherent in traditional TMA approaches. We use the novel SDF approach and extend it to the multisensor case.

In this paper, we derive the Cramér-Rao Bound (CRB) for the direct multitarget tracking problem. We show that the SDF approach offers the advantage for the multitarget multi-sensor case that the M2T and T2T association problem is circumvented. Furthermore, this approach is computationally efficient, as all source states are assessed from the minima of one common cost function that depends on as many parameters as there are degrees of freedom for a single source. Moreover, the accuracy of the state estimates is much better compared with the traditional TMA approach in situations where the variance of DOA estimates deviates from the CRB, e.g. in the case of a weak source, closely-spaced sources or crossing DOA trajectories. In Monte Carlo simulations we find that the state estimation accuracy can be improved by using additional (fixed) sensors.