Abstract

The Joint Directors of Laboratories (JDL) data fusion model is a functional and comprehensive model for data fusion and inference process and serves as a common frame of reference for fusion technologies and algorithms. However, in distributed data fusion (DDF), since a node fuses the data locally available to it and the data arriving at it from the network, the framework by which the inputs arrive at a node must be part of the DDF problem, more so when the network starts becoming an overwhelming part of the inference process, like in wireless sensor networks (WSN).

The current state of the art is the advancement as the result of parallel efforts in the constituent technology areas relating to the network or architecture domain and the application or fusion domain. Each of these disciplines is an evolving area requiring concentrated efforts to reach the Holy Grail. However, the most serious gap exists in the linkages within and across the two domains.

This goal of this thesis is to investigate how the architectural issues can be crucial to maintaining provably correct solutions for distributed inference in WSN, to examine the requirements of networking structure for multitarget tracking in WSN as the boundaries get pushed in terms of target signature separation, sensor location uncertainties, reporting structure changes, and energy scarcity, and to propose robust and energy-efficient solutions for multitarget tracking in WSN. The findings point to an architecture that is achievable given today's technology. This thesis shows the feasibility of using this architecture for efficient integrated execution of the architecture domain and the fusion domain functionality.

Specific contributions in the areas of architecture domain include optimal lower bound on energy required for broadcast to a set of nodes, a QoS- and resource-aware broadcast algorithm, and a fusion-aware converge cast algorithm.

The contributions in fusion domain include the following. Extension to the JDL model is proposed that accounts for DDF. Probabilistic graphical models are introduced with the motivation of balancing computation load and communication overheads among sensor nodes. Under the assumption that evidence originates from sensor nodes and a large part of inference must be drawn locally, the model allows mapping of inference responsibilities to sensor nodes in distributed manner. An algorithm formulating the problem of maximum a posteriori state estimate from general multimodal posterior as constrained nonlinear optimization problem, and an error estimate for indicating actionable confidence in this state are proposed. A DBN-based framework iMerge is proposed that models the overlap of signal energies from closely spaced targets for adding robustness to data association. iConsensus, a lightweight approach to network management and distributed tracking, and iMultitile, a method to trade off the cost of managing and propagating the particles with desired accuracy limits are also proposed. iSLAT, a distributed, lightweight smoothing algorithm for simultaneous localization and multitarget tracking is discussed. iSLAT uses the well-known RANSAC algorithm for approximation of the joint posterior densities.