Description of FY 2000 MURI Program: http://www.onr.navy.mil/sci_tech/special/muri2k/

++

FY2000 MURI Topic #1: http://www.onr.navy.mil/sci_tech/special/muri2k/topics.htm#1

Submit white papers and proposals to the Army Research Office

DATA FUSION IN LARGE ARRAYS OF MICROSENSORS (SENSORWEB)

Background: Current designs for remote and unattended sensor arrays usually emphasize functionality of individual sensors and performance of small arrays. However, in a context of a large array of microsensors, each perhaps no larger than a quartz wristwatch and possessing only limited functionality, a new set of design rules is required. The power of such an array is regained in the smart processing of simple signals from numerous throwaway sensors. Distributed sensing by organized or self-organizing arrays of large numbers of geographically dispersed miniature sensors of various modalities is increasingly recognized as a key to battlefield surveillance. The data/information that will be produced by the sensors has to be transmitted, processed and fused in a fashion that provides the commander and soldiers with reliable summary information with high probability of detection and low false alarm rates while using the minimum amount of resources. This involves discovering which set of nodes should be involved in the decision, the method by which data will be fused, the inhibition of other nodes from being involved in the decision and conveying the information to the user within the latency constraint. To date, research on data fusion in distributed sensing has often neglected physical constraints, including those on energy reserves, bandwidth, latency, processing capability and peak transmitter power. Complex information processing systems for large arrays of microsensors will in all likelihood have currently unexpected coherent and emergent behaviors, including those with unforeseen failure modes. Fundamental limitations on data fusion and optimal strategies within those limitations, even under relative mild assumptions, are not yet known. The practical problem is that of devising algorithms that come close to the fundamental limitations with reasonable complexity, latency, etc.

Objective: The objective of this initiative is to develop a quantitative basis for information processing in large arrays of distributed microsensors under strong limitations on the capabilities of each sensor and severe constraints on communication.

Research Concentration Areas: Interdisciplinary research is needed in the following areas:

1. Determine (self-)calibration requirements and algorithms to do such calibration. Must each individual node determine its position using a GPS-like approach or can the positions be inferred (bootstrapped) using communication and processing? Must each node remember its own position, the positions of its neighbors or the positions of a large subset of the array?

2. Determine fundamental limitations on data fusion in multi-modality distributed sensing that take into account constraints on energy reserves, bandwidth, latency, processing capability, peak transmitter power and network topology. A network analogue of Shannon information theory?

Random sensor distribution will probably not allow one to assume anything as simple as Internet-like nearest neighbor connections.

3. Determine the (sub)optimal trade-offs between local processing at the sensor level, processing at other levels and communication capacity, protocols, bandwidth, duty cycle, etc.; determine these trade-offs in the context of hierarchical networks with potentially more than two levels and with different communication capacities between levels.

4. Determine sensitivity and robustness to local variations in sensor density. Determine bounds for, characteristics of and algorithms for identifying the minimum number of nodes and minimum amount of resources needed to detect, estimate, classify and track an event or a collection of events at a given level of fidelity; static multiple-target separation and dynamic multiple-target tracking with network and computational constraints taken into account. Determine the dependence of algorithms on dynamic network characteristics and inter-node communication or lack thereof (as in weather-caused fade-out).

5. Design and implement data fusion algorithms that, in various metrics (perhaps including but not necessarily restricted to probability of detection and false alarm rate), come close to optimality. Compare these algorithms to alternate techniques.

6. Develop principles for describing coherent and emergent behaviors on various levels of granularity. Develop distributed control algorithms that have theoretical guarantees about global behavior. Extend verification methods such as model checking, theorem proving, and monitoring and checking. Develop methods appropriate for systems with the self-assembly, self-stabilization, adaptability, rapid reconfigurability and fault tolerance needed in distributed microsensing. Determine failure modes, especially those not expected based on experience with small arrays.

7. Create suites of events on which data fusion algorithms can be tested for closeness to optimality.

Impact: Advanced data fusion techniques for large arrays of small sensors (distributed from ground vehicles, piloted aircraft, unmanned aerial vehicles and seacraft) are needed for increasingly intelligent, dynamic and precise identification of threats, for battlefield weather/condition prediction and as substitutes for landmines. In particular, replacement of landmines by arrays of acoustic, IR and other small sensors is contingent upon the development of these techniques. Monitoring of military or terrorist activity in urban areas or under heavy foliage canopy will be possible with large intelligent arrays of microsensors. Uses of data fusion in the civilian economy include security, environmental monitoring, monitoring of manufacturing networks and intelligent traffic systems.

Research Topic Chief: Dr. John Lavery, ARO, (919)549-4253, lavery@aro-emh1.army.mil