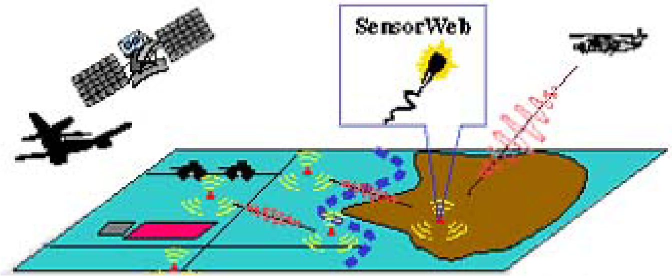
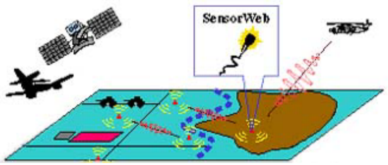


Summary

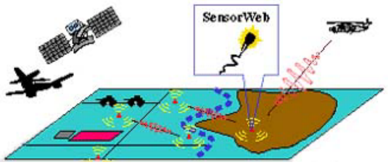
Alan S. Willsky

SensorWeb MURI Review Meeting
June 14, 2002



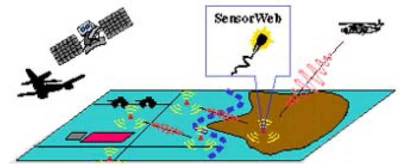
Outline

- Fulfilling the intellectual agenda outlined in our proposal
- Meeting the expectations for MURI research
- Contributions to DoD needs, missions, and activities
- A prospective look: Challenges and plans



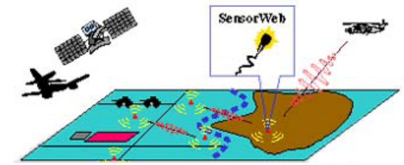
Fulfilling the intellectual agenda outlined in our proposal

- We have maintained course along all three intellectual themes defined in our proposal
  - Focus primarily on intellectual “long-poles”
  - Maintaining relevance to and coverage of the RCA’s,
- We have established strong relationships with other research activities
  - MURI’s, CTA’s,…
  - Ensuring that we capitalize on synergies and complement the work of others
- We have had considerable success
  - Major research results
  - Recognition of our work by the broader community



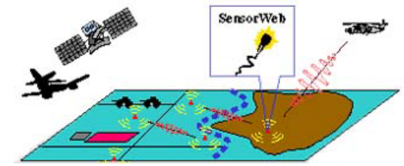
Major Research Results - I

- Network-Constrained Fusion
  - Embedded Trees
  - Recursive Cavity Models
  - Tree-reparameterization algorithms
    - Including distributed optimal data association
    - Initial results on testing these methods
  - Initiating transition to CTA activity (Moses)
- Intelligent Querying of Sensors for Localization and Tracking of Targets
  - Transitioned and successfully tested within the SensIT program



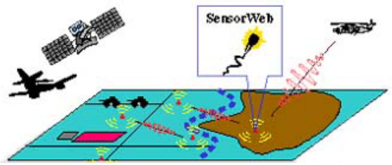
Major Research Results - II

- Stability and Catastrophic Failure Characterization in Large Data Fusion Problems
- Information exchange and querying through collaborative Q&A
- Fundamentals of large-scale distributed sensing and computation
  - Invariants that expose how global tasks may be distributed
  - Error protection and correction through graphical codes



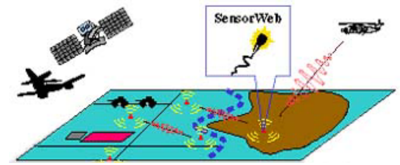
Major Research Results - III

- Information-Theoretic Fusion in Highly Uncertain Environments
  - Multimodal fusion and source localization
  - Efficient methods for estimating information-theoretic measures relating signals measured by different sensors
  - Methods for exploiting such measures for feature-aided data association
  - Experimentation with real and simulated data



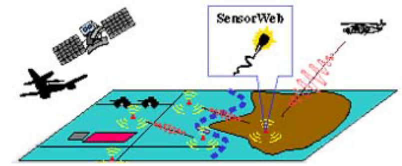
Major Research Results - IV

- Optimization-based Approach to Combined Array Calibration and Source Localization
  - Provides complementary results to those of Moses under CTA funding
- Fundamentals of learning and pattern recognition
  - Less stringent conditions for effective learning (including conditions under which sensor networks must operate)
  - Nonlinear feature extraction based on principal curves



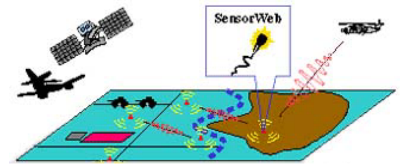
Major Research Results - V

- Fusion of uncalibrated temporal data streams, exploiting correspondences over time
- Development, implementation, and testing of two wireless protocols
  - Power control (COMPOW)
  - Media access control (SEEDEX)



Major Research Results - VI

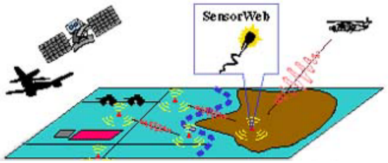
- Network Information Theory
  - Cooperative strategies among network nodes to achieve optimal information transport
  - Scaling laws for network connectivity and transport capacity
  - Optimal power allocation in broadcast channels and optimal power allocation and capacity for multiple relay systems
  - Analysis of networks operating in low power and low spectral efficiency regimes



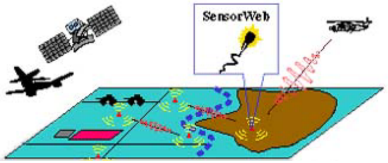
Recognition

- Numerous invited, plenary, and keynote talks
- Organizers of workshops central to the themes of this MURI
- Several key invited papers (Kumar, Willsky, Fisher, et al.)
- Influence on work of others
- Recognition of our students

Meeting the expectations for MURI research

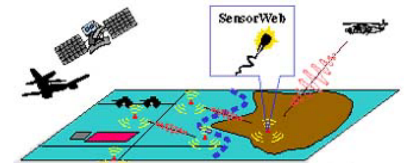


- Multidisciplinary research
  - Links across IT's and RCA's
  - Blending signal processing and information theory
  - Blending fusion/estimation and network comms
  - Bits aren't the ultimate currency and neither are signals: fused information IS
- Creating an activity that is greater than the sum of its parts
  - Productivity
  - Synergy
  - Visitors, colloquia, courses, broad-based website, etc.
  - Leadership
  - Experiments, demonstrations



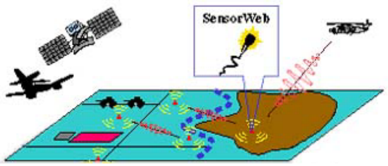
Contributions to DoD needs, missions, and activities

- Coverage of and progress against the RCA’s
- Transitions, ties to partners, interactions with other DoD activities
- Initiative in pursuing collaboration and synergy with other SensorWeb-related efforts
- Responsiveness to EAB/TAC



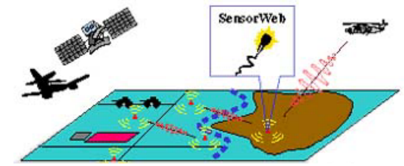
RCA’s - I

- RCA-1
  - Initiated efforts to increase research relevant to this RCA, including work on robustness to calibration/location errors
    - Cetin, (Fisher), (Kulkarni)
    - Ties to and transitions of our fusion methods to work of Randy Moses
- RCA-2&3
  - Fundamental contributions to wireless protocols and network information theory
    - Kumar, Verdu
    - Bridges to this RCA in work of Willsky, Mitter



RCA's - II

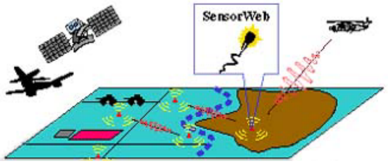
- RCA-4
  - Significant new results on bounds on fusion accuracy and on utilization of dear resources
    - Willsky, Mitter, Jaakkola
    - Collaboration/Synergy with work of Moses
- RCA-5
  - Substantial advances to the state of the art in network-constrained fusion and fusion in highly uncertain environments
    - Willsky, Fisher, Kulkarni
    - Several transitions, including to CTA (Moses)



RCA's - III

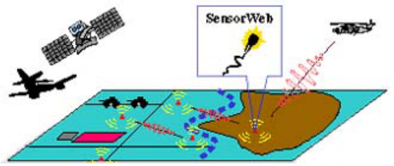
- RCA-6
  - New classes of distributed algorithms & new results on guarantees on global behavior
    - Mitter, Jaakkola, Willsky
- RCA-7
  - A variety of experiments and demonstrations
    - Distributed optimal data association
    - Information-theoretic heterogeneous fusion
    - COMPOW, SEEDEX
    - SensIT transition
    - More in the works…

Transitions, ties to partners, interactions with other DoD activities



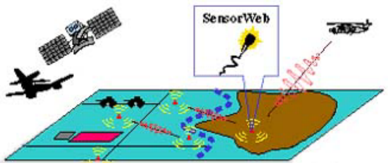
- See the Introduction/Overview

Collaboration and synergy with other SensorWeb-related efforts



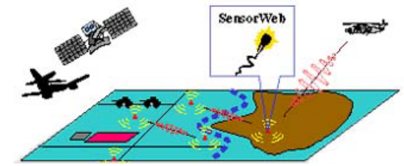
- See the Introduction/Overview

Responsiveness to the EAB/TAC: From last year's review-I



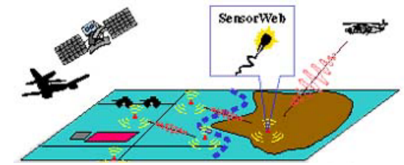
- Work with other programs (e.g., SensIT, CTA's) and DoD activities
  - Transition to SensIT
  - Work with Randy Moses/OSU (Sensors CTA)
  - Initiated additional interactions with CTA leaders (Falco and Learned) at BAE Systems
  - Numerous transitions, interactions, visits (see Introduction/Overview)

Responsiveness to the EAB/TAC: From last year's review-II



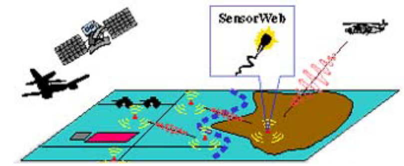
- Correspondence/Data association problems, especially in the context of communication and computation constraints, are of interest
  - Distributed optimal data association algorithm (Willsky)
  - Information-theoretic method for feature-aided data association in uncertain environments (Fisher)
- Make sure to consider the physical layer
  - Power constraints (not just for comms)
    - Allocation/utilization of dear sensor resources (Mitter, Jaakkola)

Responsiveness to the EAB/TAC: From last year's review-III

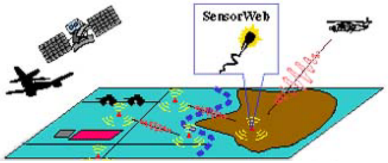


- Make sure work is relevant to myopic sensors
  - Transition to SensIT using acoustic sensors
  - Research described by Fisher, Cetin, Kulkarni (plus fusion algorithms of Willsky, Mitter, Jaakkola)
- Consider more work on RCA-1
  - Initiated optimization-based approach to robust array processing (Cetin)
  - Components of research of Fisher, Kulkarni on uncalibrated sensors
  - Interaction/collaboration with Randy Moses
- Account for degradation in acoustic coherence with distance
  - Research described by Fisher (and Cetin)

Responsiveness to the EAB/TAC: From last year's review-IV

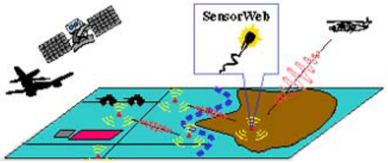


- Consider mobile sensors and dynamic networks
  - Research explicitly in this area is just beginning, although methods/concepts have been developed with this in mind
    - Dynamically evolving graphical models for network-constrained estimation
    - Dynamic resource allocation, sensor querying, and sensor tasking
    - Accommodation and exploitation of mobile sensors in wireless networks



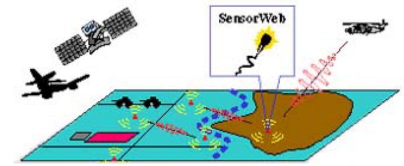
A Prospective Look - I

- Large-scale, distributed, dynamic data association, estimation, & computation
  - New algorithms (trading off memory and computation vs comms) & experiments
  - Application to sensor location estimation
  - Dynamic sensor querying and resource utilization
  - Performance bounds and characterization of potential/incipient instabilities



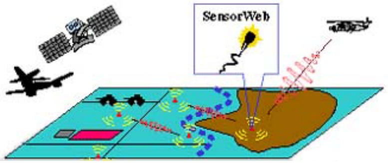
A Prospective Look - II

- Fusion of heterogeneous sensors in complex and uncertain environments
  - Information-theoretic measures for large-scale data association and source localization
    - Can multimodal data (e.g., steerable IR and acoustic) *help* in source *and* sensor localization
  - Exploitation of optimization-based framework
    - To develop limits on required sensor location accuracy
    - To estimate sensor locations *and* the environment



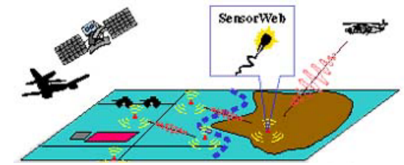
A Prospective Look - III

- Network Information Theory
  - Scaling laws for achievable information rates in complex and dynamic/mobile environments
  - Strategies/algorithms for achieving or approaching these rates
    - What level of node cooperation is required?
    - Optimal power allocation
    - Coding and transmission strategies for general broadcast/relay networks
  - Information theory for low-power networks



A Prospective Look - IV

- Experiments, Demos, Transitions
  - Distributed data association algorithms
  - Large-scale sensor location estimation
  - Fusion of heterogeneous sensors in uncertain environments
  - Optimization-based array processing
  - Experiments with protocols and coding/transmission strategies



A Prospective Look - V

- The holy grail: You toss down a bunch of sensors. They don't know where they are, who they are, what they are looking for. They're myopic, barely have the computational capacity to count to 10, and have tin cans connected by string with which to communicate. And by the way, there are 10 million of them. OK, make it work.
  - How should we distribute computations (and responsibility for maintaining estimates) across a network?
  - Given memory, computation, and communication capacity constraints (e.g., bit-meters/sec), how should we perform network-constrained estimation (not simply source or channel coding or transmission control) to maximize *fusion performance*.
  - Given that we will be working in highly uncertain environments and that communications are limited, how do we decide what bits to exchange in order to *learn* what bits we should exchange?