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SIP0: CENS Sensor Information Processing Research Overview

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CENS Signal Processing Research: Overview

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Introduction: Five signal processing problems in sensor networking are presented below

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| 1. Understanding and Controlling Instrumented Physical Systems: Modeling is Complex, but Optimization is Easy (M. Potkonjak) | Images (S. Soatto) |
| 2. Iterative Sampling of the Sunlight Field (G.J. Pottie) | 4. High Integrity in Sensor Networks: Models, Techniques, and System Support (M. Srivastava) |
| 3. Towards Automated Analysis of Minirhizotron | 5. Acoustic Source and Wireless Sensor Node Localizations (K. Yao) |

Problem Description: Brief descriptions of the five problems considered here

1. Inherent unreliability of sensors often collect data with errors, faults and missing samples. We address the data integrity and computational sensing problems in sensor networks.
2. Measuring sunlight values under a forest canopy has basic values in biological applications. Sensors equipped with mobility, (e.g. NIMS nodes), can selectively sample the 2-D sunlight random field.
3. The ability to do robust meaningful research with minirhizotron images is currently limited by the amount of time that can be spent by a human expert classifying the data.
4. Data integrity is vulnerable to faulty and malicious behavior in sensor networks. It is necessary to detect and handle faults and malicious data before they cause problems in an integrated sensor system.
5. Localization of an emitting acoustic source as well as sensor nodes is needed in sensor network applications. The AML estimation and the distributed Gauss-Newton algorithms are used to solve these problems.

Proposed Solution: More details on the five problems considered here

Problem 1

- Data integrity and computational sensing are two canonical problems in sensor networks
- Generic approach for both tasks includes three phases: statistical modeling, prediction, and fusion and analysis
- Phase 1: Statistical data-driven models; unique features of computational sensor modeling
- Phase 2: Constraint manipulation
- Phase 3: Formulate data integrity as an optimization problem; minimize the discrepancies between the sensor readings and the models; model constraints and users specified constraints

Problem 2

- Besides its value in biology and energy harvesting, sunlight under forest canopy constitutes a good realization of 2D random field
- Sensors equipped with mobility, e.g. NIMS nodes, can selectively sample the field based on current information
- Reconstruct the field based on scattered samples – thin plate spline
- Candidates for next round sampling are generated by circle fitting
- Statistical model and local roughness based sampling point pruning
- Bending energy increase is used to gauge the approximation convergence

Problem 3

- The ability to do robust, meaningful research with minirhizotron images is currently limited by the amount of time that can be spent by a human expert classifying the data
- Classifying the images is a hard problem for humans; there is variability between experts. In addition, there is large within-class variability of the

scale, appearance, and color of the objects in the images

- An application is being developed to aid in the classification of the images
- Algorithms are also being explored to completely automate the process, although this is a much harder task than it at first seems

Problem 4

- System support for analyzing a remote outdoor testbed of motes in the presence of various faults
- Reconfigurable support modules through SOS
- Provide a user-level interface for customizing the behavior of RFSN
- Reputation Based Framework for Sensor Networks
- Can handle malicious and faulty behavior.
- Can handle misbehavior in networking, sensing as well as data processing.

Problem 5

- Localization of acoustic source uses the Approximate-Maximum-Likelihood (AML) methodology
- In virtual array method, the AML est. direction-of-arrival (DOA) can be used to localize the source under controlled reverberant scenarios
- For localization of an impulsive acoustic source, whitening of the observed data before the AML operation is shown to be effective
- For wireless sensor node localization, the locations of the anchor nodes are assumed to be known
- Range information among neighborhood sensor nodes as well as from sensor nodes to neighborhood anchor nodes are also available
- Dist. Newton-Gauss algorithm is used to find the sensor node loc.