A General Theory of Signal Integration for Fault-Tolerant Dynamic Distributed Sensor Networks

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RESEARCH SUMMARY
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**Brief Introduction:**

The computational issues related to information integration in multisensor systems and distributed sensor networks has become an active area of research. In recent years a number of significant advances in the field of sensor integration have been made. This interest in the development of Distributed Sensor Networks (DSNs) for information gathering has partly emerged because of a) the availability of new technology which makes the DSNs economically feasible to implement and b) the increasing complexity of today's information gathering tasks to which they are applied.

From a computational viewpoint, the efficient extraction of information from noisy and fault signals emanating from many sensors requires the solution of problems related to a) the architecture and fault-tolerance of the distributed sensor network, b) the proper synchronisation of sensor signals, c) the integration of information to keep the communication and the processing requirements small, and d) the design of efficient computational techniques to abstractly represent and integrate sensor information.

**Wavelet based sensor integration:**

Multiresolution analysis can be used in filtering out robust peaks in the overlap functions obtained from abstract sensors to produce fault tolerant sensor estimates in Distributed Sensor Networks. This technique is most effective when the number of sensors is very large and the number of tame sensors is also large. The idea essentially consists of constructing a simple function from the outputs of the sensors in a cluster and resolving the function at various successively finer scales of resolution to isolate the region over which the correct sensors lie.
Topics of current research:
The following issues have been the subjects of our current research:
1) Wavelet based distributed sensing and fault tolerant sensor integration.
2) Computational frameworks for distributed sensing and fault tolerant sensor integration.
3) Design of fault-tolerant architectures for distributed sensor integration.
4) Computational complexities of the problem of distributed detection.
5) Issues related to recording of events and synchronization in distributed sensor networks.

Attached to this report is a list of publications resulting from this research.

Books

1. Distributed Sensor Integration: S.S.Iyengar, Hla Min and L.Prasad (To appear)

RESEARCH PUBLICATIONS

List of papers accepted/published in refereed journals:


3. L. Prasad and S. S. Iyengar "An Asymptotic equality for the number of
neclaces in a shuffle exchange network". Journal of Theoretical Computer

4. S. S. Iyengar, D. N. Jayasimha and D. Nadig " A versatile Architecture for
the Distributed Sensor Integration Problem", To appear in IEEE Trans. on
Computers (June 1993).


using Distributed Data structures". Journal of Parallel and Distributed

7. S. S. Iyengar and F. B. Bastani, "Self-organizing Knowledge and Data
Representation in Distributed Environment: An Introduction", IEEE
Transaction on Data and Knowledge Engineering". Vol 4, No 2, April 1992,
pp 105-107.

Paper under revision:

1. L. Prasad and S. S. Iyengar " A General Computational Framework for
Distributed Sensing and Fault-Tolerant Sensor Integration", Submitted to
IEEE-SMC.

List of Papers submitted to refereed journals

1. V. G. Hegde and S. S. Iyengar " An efficient Distributed Algorithm to find
Biconnected Components of an Asynchronous Network", Submitted for
publication to Information Processing Letters. Also, technical Report TR-92-
015, Dept. Of Computer Science, LSU.


6. W. Deng and S. S. Iyengar "A New Probability Relaxation Scheme and its applications to Edge Detection", Submitted for publication to IEEE-PAMI.

List of Papers in refereed conference proceedings:


**Invited Talk:**

Indo-US Workshop in Computer Science, August 4-6, 1992, Bangalore, India.


**Research Papers in progress:**


2. Wavelet Based Distributed Sensing and Fault-Tolerant Sensor Integration.

3. Scaling and Temporal Characterization of Sensor Integration Problem in Distributed Environments. This is an extension of Dr. Madan's work on Maximum Entropy techniques.


5. Distributed Conferencing System for 2D graphics Design.

**Graduate Students involved (Ph. D Program).**

1. L. Prasad

2. D. Thomas (EPSCOR - DOD Program)

3. W. Deng

4. S. Trivedi
Distributed Sensor Networks
(Professor Bush Jones contribution)

The research performed thus far consists of three components. The first component is a system model with a maximum entropy characterization. For a complex system, the characterization becomes nonlinear, and it becomes necessary to solve a set of nonlinear equations for all roots in a prescribed region. There is no current methodology to effectively isolate such roots, so the second component of the research is a new technique to isolate roots of a nonlinear system of equations. The third component is a by-product of this research. A more accurate representation of statistical interactions is proposed and compared to statistical interactions.

Three papers have been prepared. The system model has been published by Jones and Iyengar in the ISSS conference proceedings. The root isolation technique is a definitive work with broad application by Jones and Iyengar that is currently being revised for publication in Computers and Mathematics. The interaction concept is an invited paper by Jones and Gouw for the IJGS journal. All three papers acknowledge ONR support.

Part I. System Model

This research provides a system's model for a network for a network of sensors. A set of sensors with associated information processing nodes is viewed as an overall system. Within this overall system are subsystems of sensors and information processing nodes. An arbitrary overall behavior function (which may or may not be analytically provided) describes important reactions of the systems to inputs at the sensors. From the overall behavior function, functions for the subsystems are generated. Analysis using entropy mathematics makes possible the identification of important subsystems and their characterization. The analysis uses information theory, and measures the information theoretic contribution of a subsystem to the overall system.
A program has been written which will take as input a description of a sensor network, and will output the information theoretic importance of the major subsystems based on linear mathematics. Subsequent work treats nonlinearities.

Part II. Nonlinear Equations

This research provides methodology and a program for isolating the real roots of nonlinear systems of equations. The technique developed requires only function values, and can be applied to any nonlinear system. The technique has broad application wherever nonlinear equations arise. The technique and program have been empirically tested for effectiveness and efficiency. This research constitutes a definitive work in nonlinear equations.

Part III: Interaction Concept

This research provides a more accurate representation of interactions than is found in classical statistics. A description of the interaction concept is given, and it is compared to the classical statistical interaction that is based on linear mathematics. An example is given which reveals wide disparities in interaction results.