Verification and Validation of Sensor Networks

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Abstract

Sensor networks play an increasingly important role in critical systems infrastructure and should be correct, reliable and robust. In order to achieve these performance goals, it is necessary to *verify* the correctness of system software and to *validate* the more broadly defined world and system models. This includes:

- *Physical Phenomena*: PDE models, statistical models, etc.
- *Signals*: Equations of state, physical properties, etc.
- *Sensors*: Physics models, noise models, etc.
- *Hardware*: Failure models, power consumption models, etc.
- *RF*: Antenna models, bandwidth, delay, propagation, etc.
- *Embedded Code*: Correctness, complexity, context
- *Distributed Algorithms*: Correctness, concurrency models, etc.
- *Overall Sensor Network and Environment Models*: Percolation theory, wave theory, information theory, simulation, etc.

We outline some of the V & V issues involved in the various aspects of sensor networks as well as possible approaches to their development and application both in simulation and in operational deployed systems.

1 Introduction

In previous work, we have described distributed algorithms for:

- Leadership Protocol

Dagstuhl Seminar Proceedings 05381
Form and Content in Sensor Networks
http://drops.dagstuhl.de/opus/volltexte/2006/753

- Coordinate frames (relative and absolute)
- Gradient calculation
- Reaction-Diffusion
- Level Sets
- Monte Carlo Sensor Networks

Our organizing scenario is that of a mobile agent (robot or human) roaming over an information field; the sensor nodes organize themselves and extract useful local information. We have experimented with small sets of Berkeley Mica motes (4 to 8) and Telos B motes (we have developed a 90-mote network with North Carolina State University).

However, the insight proposed in this talk were garnered from experience in the realm of high performance computing, in particular, the DOE funded University of Utah Center for the Simulation of Accidental Fires and Explosions (C-SAFE) and we believe that some of the computational engineering and science philosophy is relevant to the design and implementation of sensor networks. The C-SAFE goal is to create a fundamental, science-based numerical simulation of accidental fires and explosions involving highly flammable, energetic materials.

2 Motivation

One way of looking at this approach is: High Performance Computing with Small Devices[1]. The major motivations are:

- The sensor network community is relatively young and moving through standard growth phase,
- Take advantage of lessons learned in more mature disciplines, e.g., computational engineering & physics.

A major debt is owed to Oberkampf, Trucano and Hirsch, and the overarching goal is to *increase confidence in sensor network models, simulations and implementations.* Figure 1 shows the aspects of sensor networks which are involved. Our view is that a sensor network is a computational engine that is trying to find the structure of some phenomenon for which its sensors allow it access. For large-scale simulation projects, the verification and validation steps are off-line, whereas for sensor networks, we believe that both these aspects must be incorporated into the operational sensor net:

[1]This label is the result of the working group: Bir Bhanu, Uwe Brinkschulte, Tom Henderson, Wolfgang Karl and Subhash Suri.

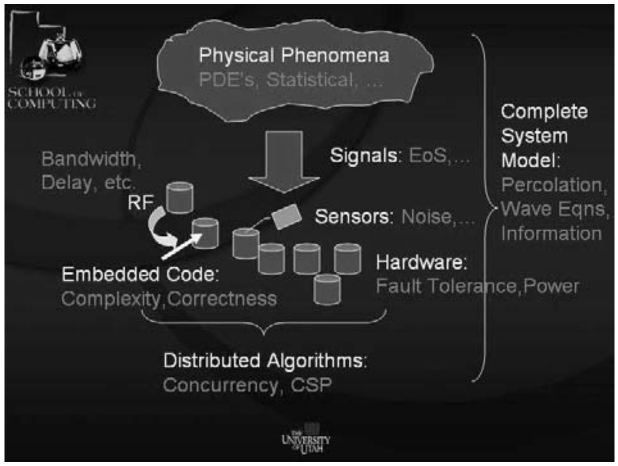

Figure 1: Overview of Sensor Network Aspects.

- A sensor network is a computational physics system embedded in physical space, models the environment and simultaneously validates the model.
- Has all the requirements of HPC scientific computing on the small.
- SNET models: PDE's, probability distributions, etc.
- The challenge is simulation engineering instead of simulation science.

More sensor network models involve computational approaches:

- *Percolation Theory*: Has been used extensively to analyze message traversal of a sensor network.
- *Wave Theory*: Sensors may be modeled as wave function as in quantum mechanics and global energy properties determined as eigenvalues of specific operators.

Oberkampf et al. propose the following activities:

- Phenomena Identification and Ranking Table to Prioritize Activity
- Code verification
- Numerical error estimation
- Hierarchical validation experiments
- Validation metrics.

It is important that sensor network developers follows something like these guidelines since deployed systems will produce results that may be used in autonomous control and human decision making whereas the impact of error in scientific studies is very low!

We hope to develop this paradigm in the context of a snow monitoring project.

3 Acknowledgment

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