Distributed Sensor Nets and Environmental Field Facilities

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CLEANER Challenge

Networked infrastructure of environmental field facilities.

- Geographically dispersed
- Many interacting and dynamically changing variables
- Complex models for analysis and prediction

Create a sensor network, database, and visualization environment to support research, modeling, simulation, education, and outreach.
Environmental Monitoring

DATABASE AND VISUALIZATION

MODELING AND SIMULATION

SENSING
Distributed Sensor Nets

DATABASE AND VISUALIZATION

MODELING AND SIMULATION

Sensor Network

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Distributed Sensor Net Technologies

- DATABASE AND VISUALIZATION
- MODELING AND SIMULATION
- SENSOR NETWORK TECHNOLOGIES
- COMMUNICATIONS PROTOCOLS
- EMBEDDED COMPUTING
- NETWORK ARCHITECTURE
- POWER
Distributed Robotic Sensor Nets

- DATABASE AND VISUALIZATION
- MODELING AND SIMULATION
- SENSOR-ACTUATOR NODES
  - Robotic Sensor Network

Network diagram showing interconnected sensor-actuator nodes.
Distributed Sensor Net Tasks

TRACKS

EVENTS

FIELDS
Distributed Sensor Nets

Key Technologies – Devices and Hardware

Integrated Sensor Microsystems
   Systems on a chip
   Specific chemical and physical sensitivity

Pervasive Computing
   Local processing
   Signal compression
   Low power

Wireless Communications
   Transmitter, Receivers, Protocols
   Electromagnetic, Ultrasound

Node Mobility and Robotics
   Locomotion principles – land, water, air
   Degrees of freedom
   Power
Distributed Sensor Nets

Key Technologies – Architectures and Algorithms

- Local Sensor Signal Processing
- Communications Protocols
- Network Architectures
- Distributed Computing Algorithms
- Model-Based Data Analysis
- Adaptive Control of Robotic Nodes
- Collaborative Localization and Mapping
- Multisensor Fusion
Distributed Sensor Nets

Multisensor Fusion

Integrating sensor information to estimate model-based distributed variable fields.

\[
\max_{x \in \chi} \psi(x) \quad \chi \subset \mathbb{R}^n \quad \psi : \chi \rightarrow \mathbb{R}_+ 
\]

R. Joshi and A. Sanderson

*Multisensor Fusion: A Minimal Representation Approach*

World Scientific Press, 1999
Cooperative Sensing and Navigation

Distributed Network Architecture
Distributed Sensor Nets

Distributed Model Estimation and Control

Dynamic eq. of $i$-th module

$$F_i = [\hat{\theta}]_{i}^{-1} \{ M_i (\ddot{n}_i + \hat{\theta}) + \Sigma \hat{\theta}_a F_d \}$$

Network

**nonlinear compensation**

Feedback

Forward Kin.
Hudson River and Estuary

Major U.S. river resource
   Economic
   Environmental
   Cultural

Total length: 315 miles
   New York City – Troy (tidal): 154 miles

Complex and Diverse Ecosystem

Critical Environmental Challenges
   PCB remediation
   Industrial development
   Expanding population

Planned core sampling grid for remediation study, started October, 2002. 30,000 samples
Hudson RiverScope Project

Collaborative team of RPI and Columbia University scientists

Establish a linked network of monitor nodes on the Hudson River.

Facilitate real-time monitoring of valuable information related to the River and predicted behavior.

Create a network, database, and visualization environment to support research, modeling, simulation, education, and outreach.
RiverScope Instrumentation

NETWORK NODES

Base Node
Instrumentation for real-time monitoring of basic physical, chemical and biological parameters.

Extended Node
Extended measurements and development of new sensors and monitoring technologies

Remote Sensing
Satellite and other remote sources
RiverScope: Demonstration Project

TWO NETWORK NODES

Northern Node: Waterford
- Base
- Extended
  - Particulates
  - Biochips
  - Robotic Experiments

Southern Node:
- Base
- Extended
  - e.g. Particulates
  - Salinity
  - Side scan

Remote Sensing
Database and Visualization
Modeling and Simulation
RiverScope: Project Requirements

Instrumentation

Base Node

1. Fiber optic backbone (or link to existing lines)
2. Base Node
   - RUSS UB-100- (Housing unit, solar powered)
   - CTD (conductivity, temperature, depth)
   - DO/pH/turbidity/ortho-phosphate
   - Fluorometer (chlorophyll A)
   - Transmissometer
   - Precision pressure sensor
   - PAR (photosynthetically active radiation)
   - Optical backscatter sensor
   - Fish sensing (acoustic, imaging array)
   - Technical personnel
3. Data capture, communications, archiving
RiverScope: Project Requirements

Instrumentation

Extended Node - Pilot instrumentation development
1. Automated particle collectors
2. DNA Chip for Zebra Mussel Larvae Detection
   - Microarray chips, format development supplies
3. Robotics – Autonomous underwater vehicle

Modeling and Simulation

1. Real-time predictions of hydrodynamics and water quality
2. Drainage basin modeling: GIS Land-us Analysis

Database and Visualization

1. Remote sensing – image acquisition and analysis
2. 3D Interactive Web-based visualization and dissemination