Welcome to the UCB NEST Retreat

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Newcomer note:

What retreats are about

• 6 month project checkpoint
  – milestones, accomplishments, directions, shortfalls
  – course correction

• Students refine communication and investigation skills
  – interested benign audience, lots of feedback

• In depth exchange with collaborators
  – discussion and feedback
  – close with feedback session

• Build team and cement connections

Please join my table for project background over dinner
Who are we?

• introductions...
Where are we in the project?

- 3 of 4.5 years (June 01 - Aug 05)
  - got a 1 year head start (Smart Dust, Endeavour)
  - Open Experimental Platform
    » provide platform and challenge application
    » rest of the projects provide middleware
- Delivered 1000 motes in 14 kits in Jan 02
  - mica + general microtracker
- 12 Teams demo’d at June 02
- Demo turned into applIn framework at Jan 03
- Mica => xbow Dot and Mica2
  - Spec feasibility study of OEP 3
- 250 Mote groups, 5,000 units
- Mid-Term demo partially shifted to SOCOM demos
- Mid-Term demo 7/03 ==> OEP2
- Final demo plan should be in hand
Open Experimental Platform to Catalyze a Community

TinyOS

- WeC 99 “Smart Rock”
- Rene 11/00
- Dot 9/01
- Mica 1/02

Small microcontroller
- 8 kb code,
- 512 B data

Simple, low-power radio
- 10 kb

EEPROM (32 KB)

Simple sensors
1/14/2004

Designed for experimentation
- sensor boards
- power boards

DARPA SENSIT, Expeditions

Crossbow

Demonstrate scale

NEST open exp. platform
128 KB code, 4 KB data
50 KB radio
512 KB Flash
comm accelerators

nest Retreat

- DARPA NEST
Problem: detect vehicle entering sensitive area, track using magnetics, pursue and capture by UGV.

Components
- 10x10 array of robust wireless, self-localizing sensors over 400 m² area
- Low cost, robust ‘mote’ device: magnetometer, microcontroller, radio network, ultrasonic transceiver
- Evader: human controlled Rover
- Pursuer: autonomous rover with mote, embedded PC, GPS

Operation
- Nodes inter-range (Ultrasonic) and self localize from few anchors, correct for earth mag, go into low-power ‘sentry’ state
- Detect entry and track evader
  » Local mag signal processing determines event and announces to neighbors
  » Neighborhood aggregates and estimates position
  » Network routes estimate from leader to tracker (multihop)
- Pursuer enters and navigates to intercede
  » Motes detect and estimate multiple events
  » Route to mobile Pursuer node
  » Disambiguates events to form map
  » Closed inner-loop navigation control
  » Closed information-driven pursuit control
  » Capture when within one meter
NEST PEG Architecture

- **Node Services**
  - Event-driven, power-aware operating system (TinyOS)
  - Sensing, data processing (EWMA threshold detector), RF packet comm
  - Ultrasonic ranging
  - Power control
  - Interactive configuration

- **Neighborhood Services**
  - Local Connectivity
  - Tuple-based information sharing
  - Distributed center-of-mass estimation (mag events)
  - Distributed shortest sum of distance to anchors localization

- **Network Services**
  - Distributed robust tree-build and broadcast
    » RSSI-based, density aware, low-collision
  - Multihop routing
  - Mobile-to-mobile landmark-based routing
  - In situ network programming

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Technical Innovations & Performance

- Complex self-organized embedded network system
- Modular event-driven SW to provide concurrent high-capability within limited resources
- Application-driven network stack
- Robust mobile-to-mobile routing based on RF and density aware tree formation via landmarks.
- Adaptive neighborhood service for information sharing.
- Hierarchical info-driven closed loop control
  - Many simple nodes detect, localize and route events
  - Few powerful nodes disambiguate, map, navigate with feedback loop rate proportional to quality of event and position info.
- US/RF TofF distributed localization of sensor array
- Fraction of captures (~1)
- Time to detect & Time to capture (~ min)
- Pursuit path stretch from optimal.
- Rate of successfully delivered event detections
- Network capacity consumed per event notification (eqv. Max notification rate).
- Localization accuracy
  - Time to achieve certain faction of nodes within certain tolerance of position.
- Tolerance to link and node loss rate.
- Pursuer degradation wrt position noise and estimate delay.
- Toward final demo with multiple P&E, 1,000 node, more realistic scenario, deep performance analysis
The Larger Agenda

• Change the practice of environmental sciences, civil engineering, … (omniscope)
• Enable built environments that observe and respond to what is going on within them.
• Fundamental enhancement to manufacturing processes
• Enable information technology throughout the 3rd world

• Rethink the many levels of networked system design with a focus on constrained resources, uncertainty, and robustness despite noise and failure
Monitoring Space

Building Comfort, Smart Alarms

Great Duck Island

Vineyards BC

Sentries, UVA, OSU

Ecophysiology of Redwoods

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Monitoring Things

Earthquake Response, Glaser et al.

Wind Response Of Golden Gate Bridge

UCLA Factor Bldg 72 channels

Intel Research

Condition-Based Maintenance
Interactions of Space and Things

ElderCare

Sensor Augmented Fire Response

Clinical Management

Manufacturing

Asset Management

Shooter Localization - Vanderbilt, BBN

Soil Sampling
Mapping & Crop Scouting

Field Preparation
Planning

Agriculture
Solutions

Water Management

Fertilizer Application

Harvesting

Crop Protection

Planning

Cultivation

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Bullet proof defends sound with several tiny microphones (CPP)

f(x,y)
Example uses

• Env. Monitoring, Conservation biology, ...
  – *Precision agriculture, land conservation, ...*
  – *built environment comfort & efficiency ...*
  – *alarms, security, surveillance, treaty verification ...*

• Civil Engineering: structures response
  – *condition-based maintenance*
  – *disaster management*
  – *urban terrain mapping & monitoring*

• Interactive Environments
  – context aware computing, non-verbal communication
  – handicap assistance
    » *home/elder care*
    » *asset tracking*

• Integrated robotics
Resolving The Systems Challenge

Monitoring & Managing Spaces and Things

Applications

Data mgmt

Service

Network

System

Architecture

Technology

MEMS sensing

Comm

Proc

Store

uRobots actuate

Power

1/ Miniature, low-power connections to the physical world
A Day of Sensor Network Research at UCB  

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- Jan Rabaey: Ultra-low power and ultra-low cost wireless sensor nodes - an integrated perspective
- Eric Brewer: Sensor Networks in Developing Region
- Todd Dawson: Redwoods go wireless
- Michael Gastpar: Information Theory and Large Sensor Network
- Joe Hellerstein: Sensornet Tasking in the Large: Querying, Inference and Beyond
- David Culler: Distributed System Design from a Sensor Net Perspective
- Michael Jordan: Sensor networks as pattern recognition machines
- Ed Arens: Price-responsive electricity management in buildings
- Paul Wright: Industrial and Social Applications of Wireless Sensor Nets
- Greg Fenves: Monitoring the Golden Gate Bridge
- Kris Pister: Smart Dust and Micro Robots
- Pravin Varaya: Sensor Networks for Traffic Monitoring
- Jim Demmel: Mathematics of Modeling MEMS sensors
- Alice Agogino: Lighting and Medical Personalization
- Steve Glaser: Downhole sensor arrays and Firebugs
- Deirdre Mulligan: Do Sensor Networks fit with Fair Information Practices
- Pam Samuelson: Towards a Legal Framework for Sensor Networks
- Kannan Ramachandran: Distributed signal processing for sensor networks: challenges and opportunities
- Shankar Sastry: Conceptual Issues in Scaling Sensor Networks
- Michael Franklin: Sensor Net implications for Database Systems and Vice Versa
• Introduction and Overview
• Presentations on Important Developments
• Participant Demos and Posters
• Technical Working Groups (over lunch)
• Panel: Nurturing the Wireless Embedded Networking Industry
• Panel: Facilitating the TinyOS Open Source Community
• Report outs from the Working Groups
• Future Plans
2004 the year of the mote?

- Emergence of a viable IEEE std radio / mac
- Open source community pulls together
- Components ‘built to suit’ - or even integrated
- Numerous companies jumping in or forming with business plans (05-06)

- Bunch of strong PhDs

- New projects spin out
Agenda

• [http://www.cs.berkeley.edu/~bmliller/NEST_agenda.html](http://www.cs.berkeley.edu/~bmliller/NEST_agenda.html)