Actuated Sensor Networks:

a 40-minute rant on convergence of vision, robotics, and sensor networks

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Women in Computer Science
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Three Primary Issues

- My research addresses three main issues
  - Acquisition: how to capture data from the world representative of human performance?
  - Learning: how can machine learning and data analysis be used to extract structure from performance data?
  - Control and Perception: how to utilize structures learned from performance for building autonomous robot controllers and perception mechanisms?

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Acquisition Big Picture

- Assisting and monitoring the elderly
- Rehabilitation
- Dynamic scene reconstruction
- Search and rescue
- Telepresence

(Mataric, USC)

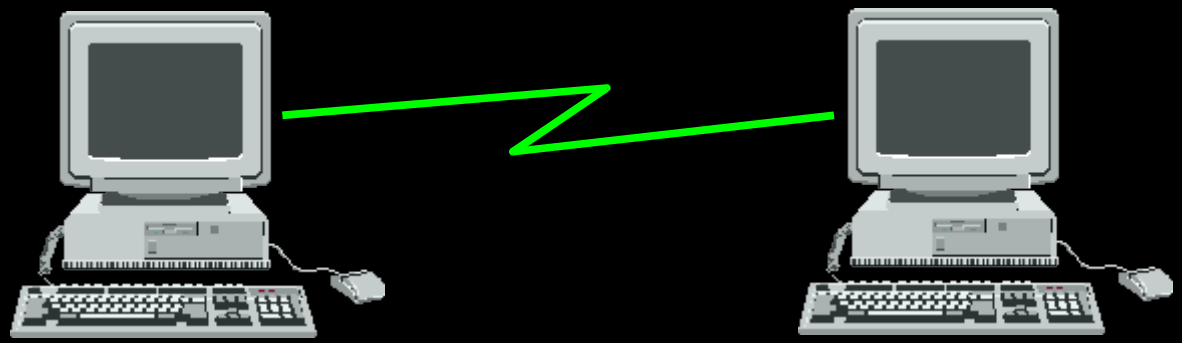
Kanade/CMU

Murphy/USF

iRobot

Components of an Actuated Sensor Net

- Network: distributed computation between a set of nodes with wireless ad-hoc communication



Components of an Actuated Sensor Net

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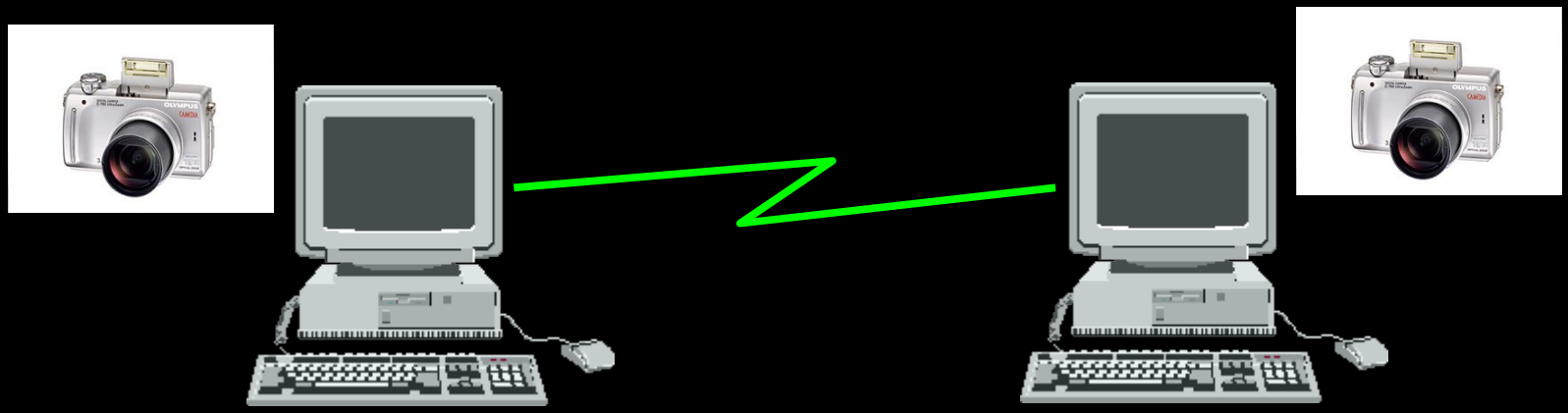
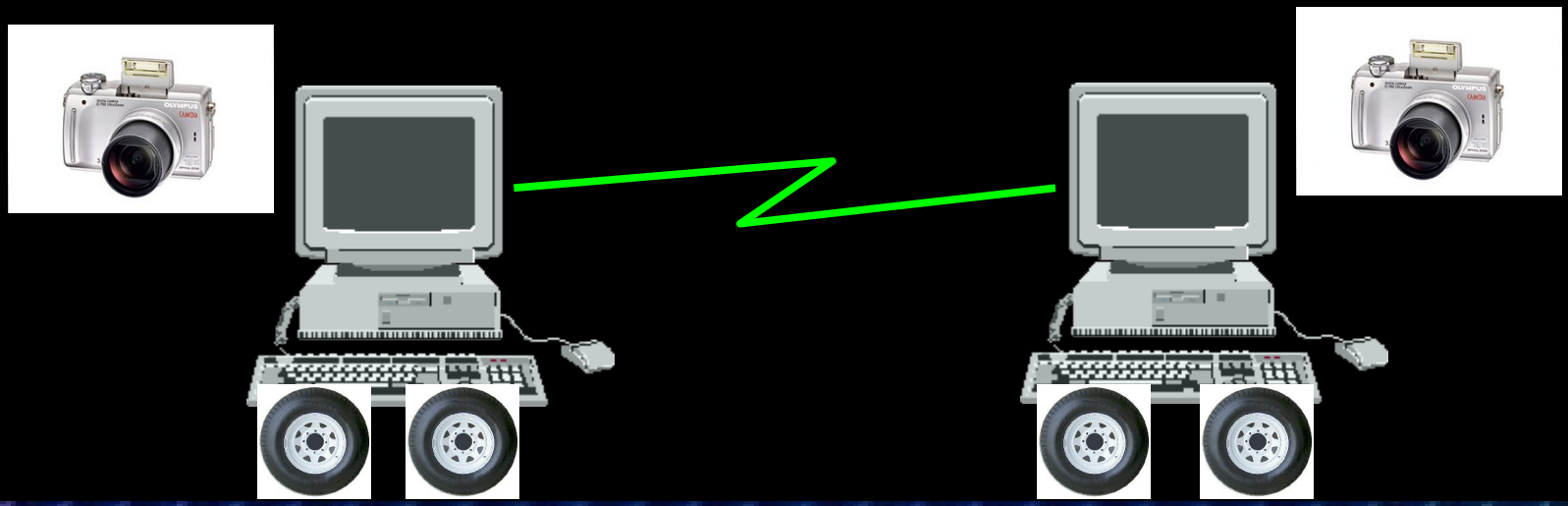
- Sensor: each node has sensing to collect information about the real-world



Components of an Actuated Sensor Net

- Network: distributed computation between a set of nodes with wireless ad-hoc communication
- Sensor: each node has sensing to collect information about the real-world
- Actuation: each node has the ability to move around and/or affect the environment



Sensor Networks

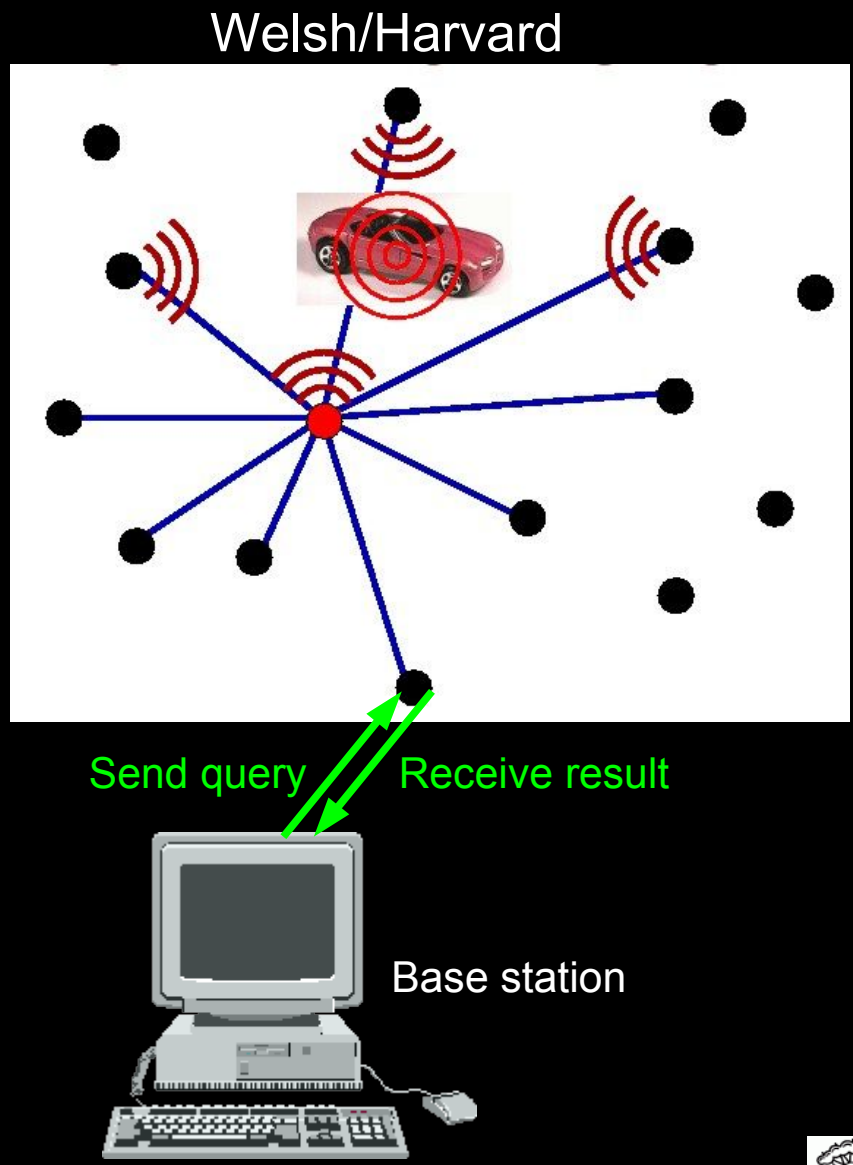
- Sensor node hardware
  - on-board computation
  - wireless communication
    - e.g., 802.11
    - antenna properties are crucial
  - sensing device
    - light, temperature, magnetometer
  - limited power source
    - 2 AA batteries for the mote
  - smaller is better

Motes/Crossbow

Mote/Intel Research

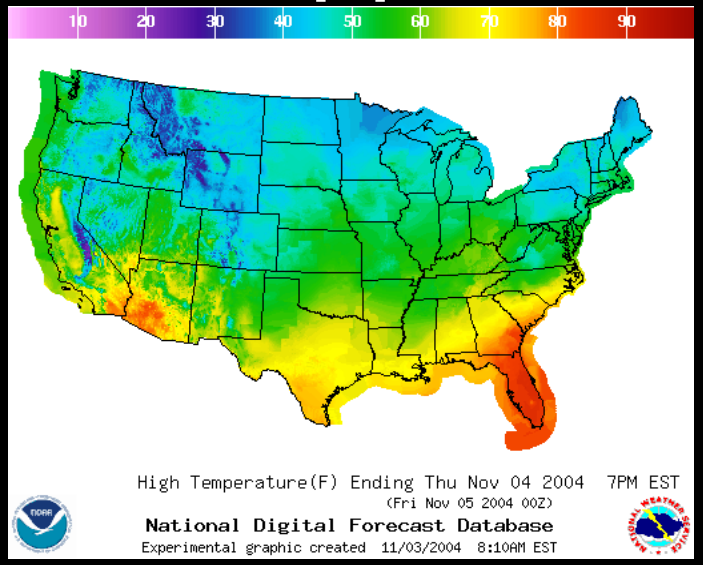
Sensor Networks

- Setup
  - query placed from a base station to entry node
  - query routed to each node
  - each node answers query using sensor data
  - routing parents agglomerate answers of children
  - entry node provides agglomerated answer to base station

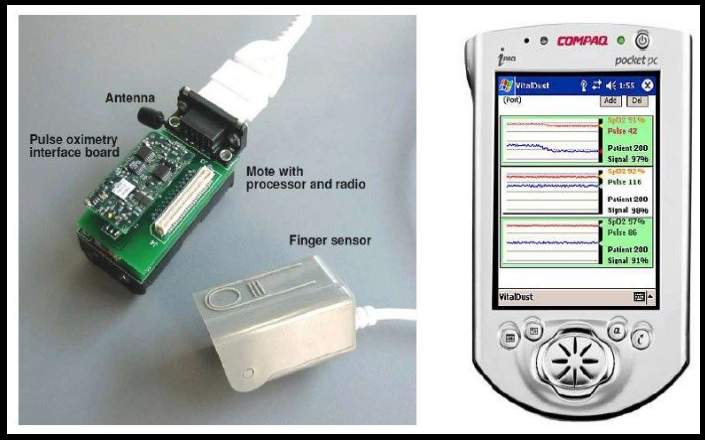


Sensor Networks: Applications

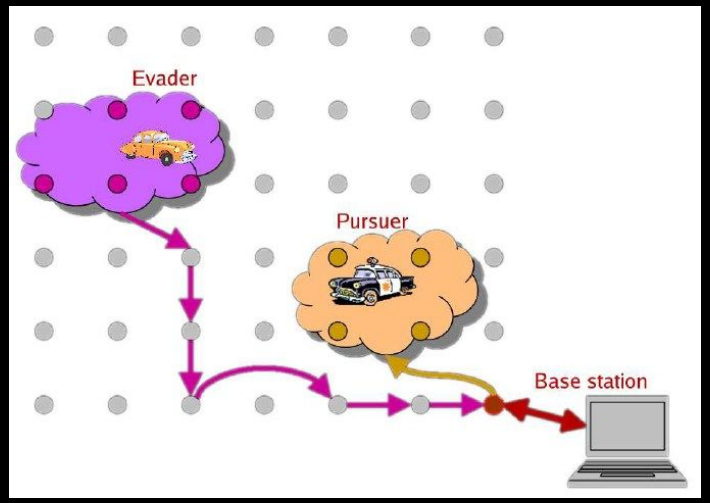
- Weather
  - temperature
  - hurricanes
- Ecology
  - light exposure
  - habitats
- Object tracking
- Monitoring
  - medical



National Weather Service



CENS/UCLA



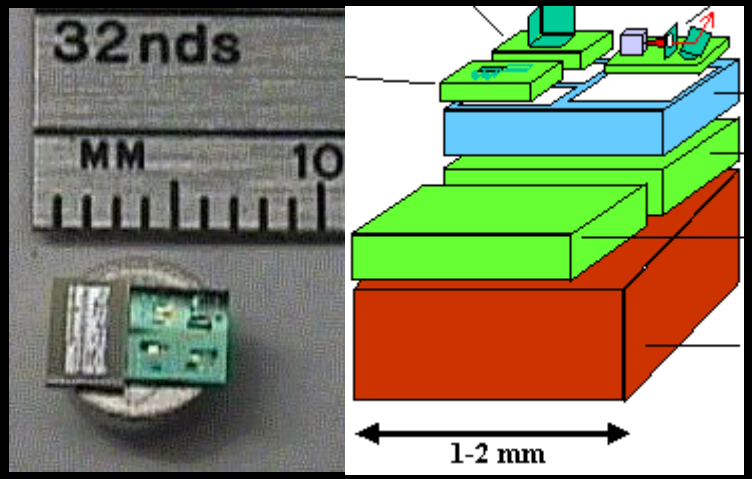
Welsh/Harvard

Sensor Networks Issues

- data management
- efficient usage of resources w.r.t. power consumption
- routing
- coordination

- localization
- heterogeneity
- limited sensing

Mica/Mainwaring et al.



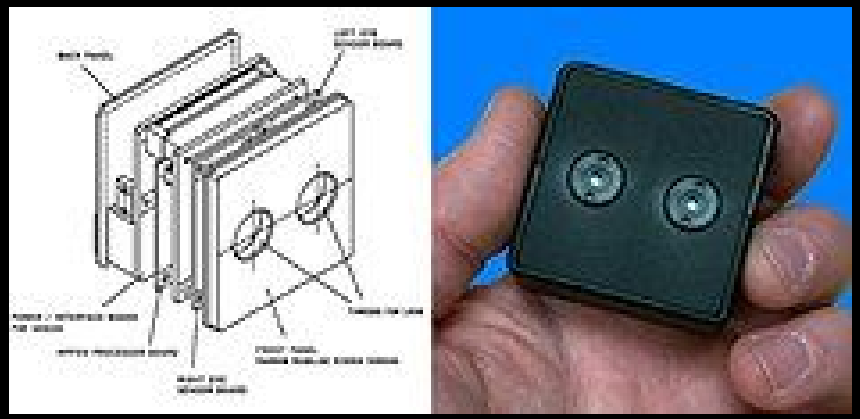
Smart Dust/UCB

Sensor Limitations

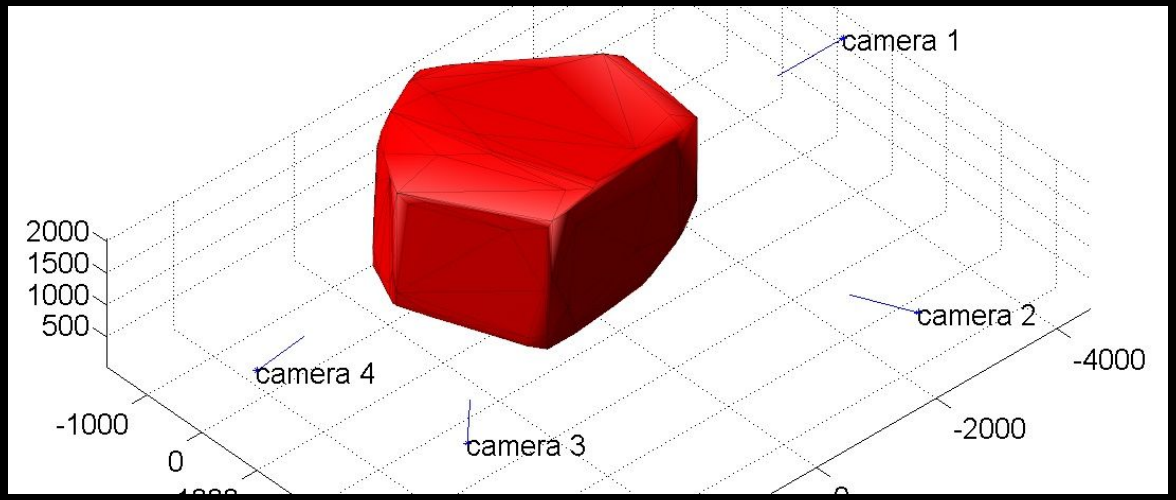
- Applications are limited due to simple sensors
  - Limited sensing networks
- Trade-off better sensing for greater size and power
  - use better sensor modes and techniques
    - cameras and computer vision
  - ease restrictions on sensor size and power consumption

Multi-view Sensor Networks

- Hardware platforms
  - smart cameras
- Calibration
- Given multiple viewpoints, what can we infer?



Taubin/Brown



Loper and Jenkins

Mocap Lab (CIT 1st floor)

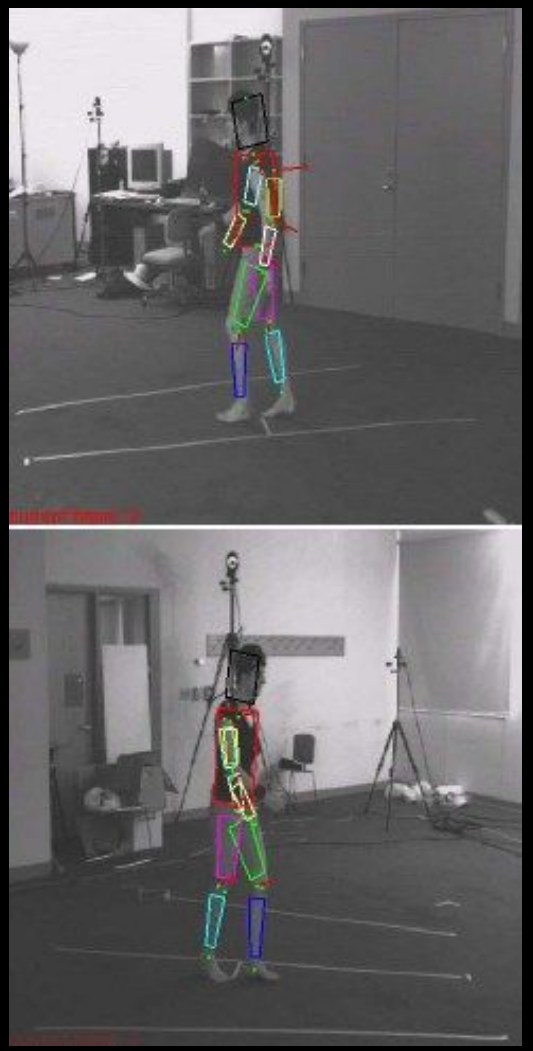
Multi-view Computer Vision

- Applications
  - markerless motion capture
  - kinematic model estimation
  - object reconstruction
  - user-interfaces
  - biomechanics analysis

Multi-view Computer Vision

- Traditional motion capture requires instrumentation and structure
- Markerless motion capture aims to not require subject instrumentation

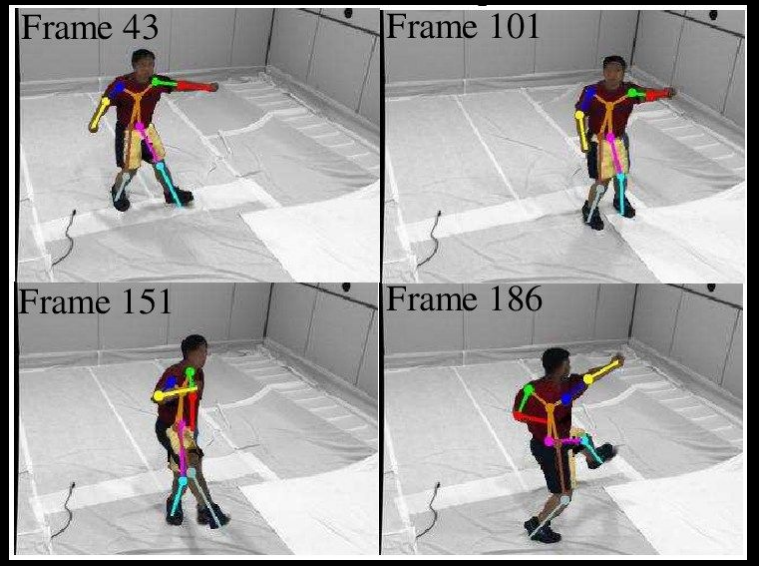
nba.com



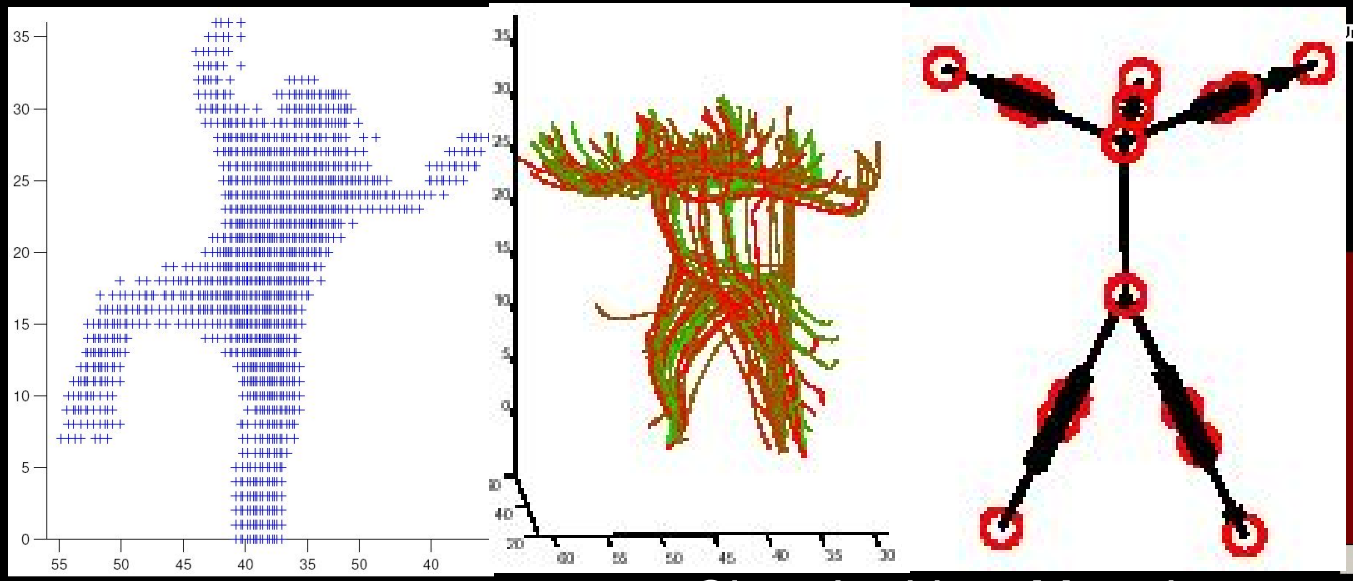
Black/Brown

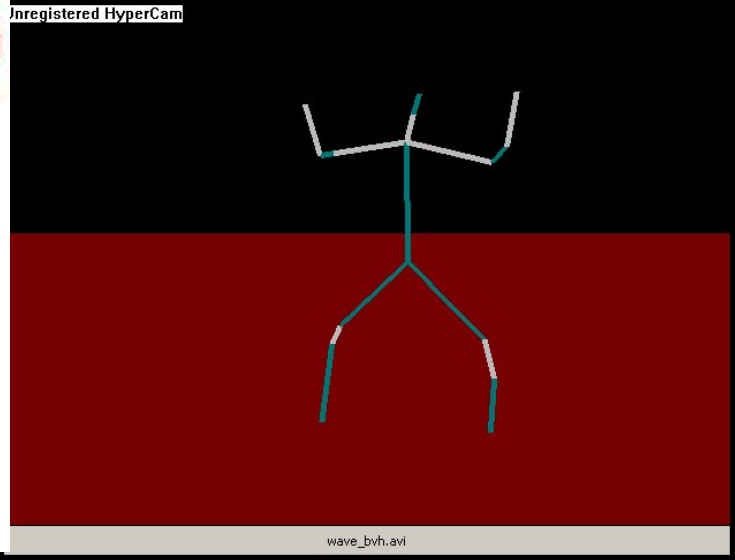
Multi-view Computer Vision

- Standard markerless mocap assumes a specific kinematic model and/or topology
- New approaches estimate kinematic models and motion



Cheung/CMU

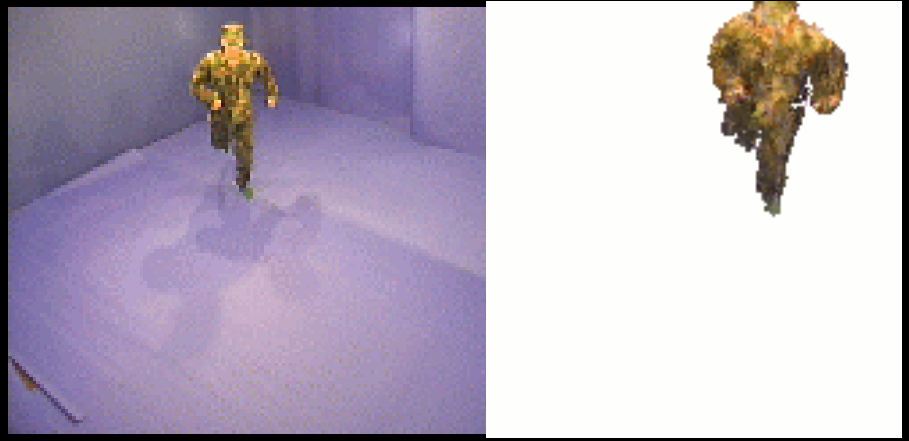




Chu, Jenkins, Mataric

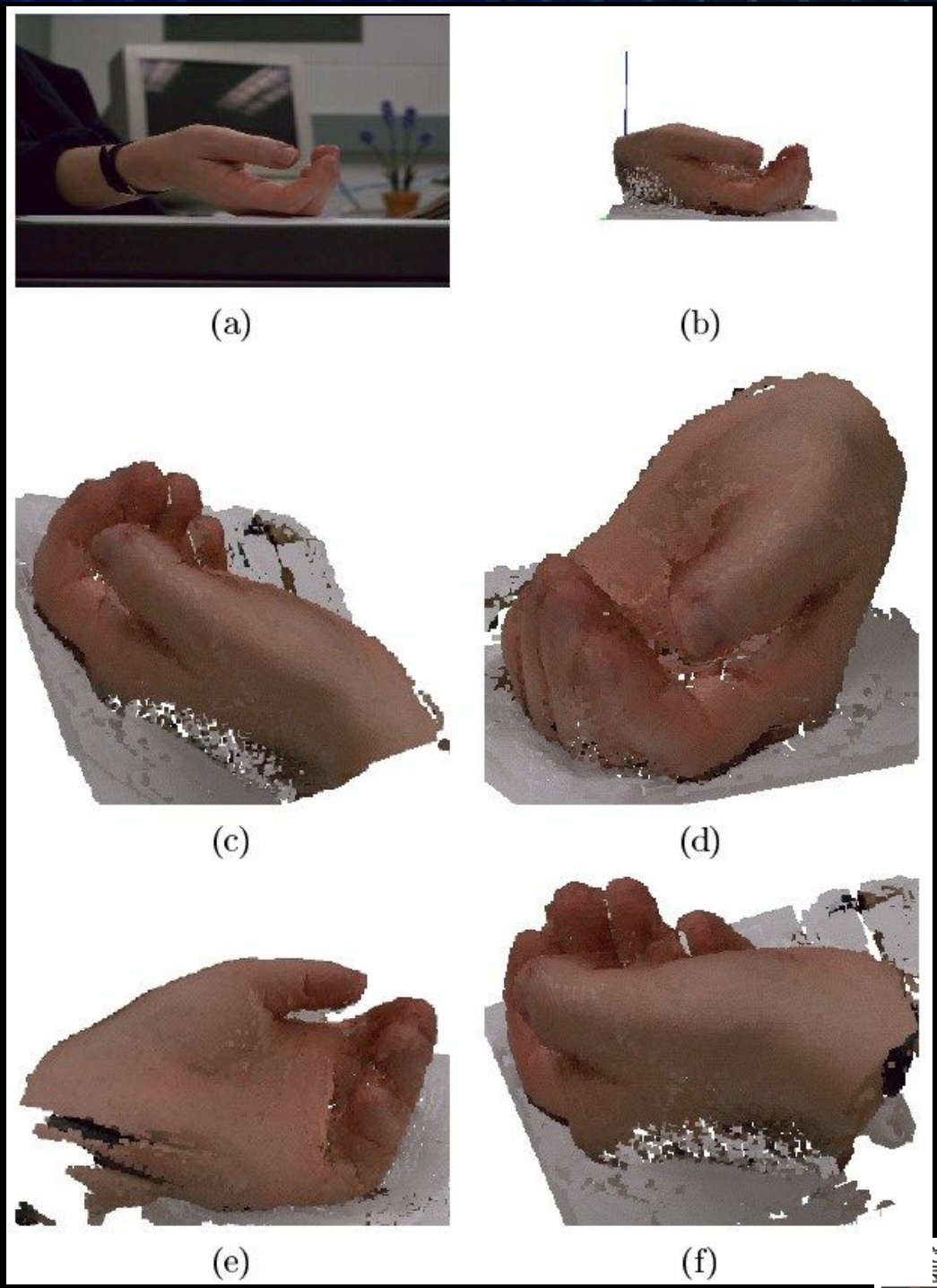
Multi-view Computer Vision

- Reconstruct color and geometry
- Computational issues prevent real-time speed

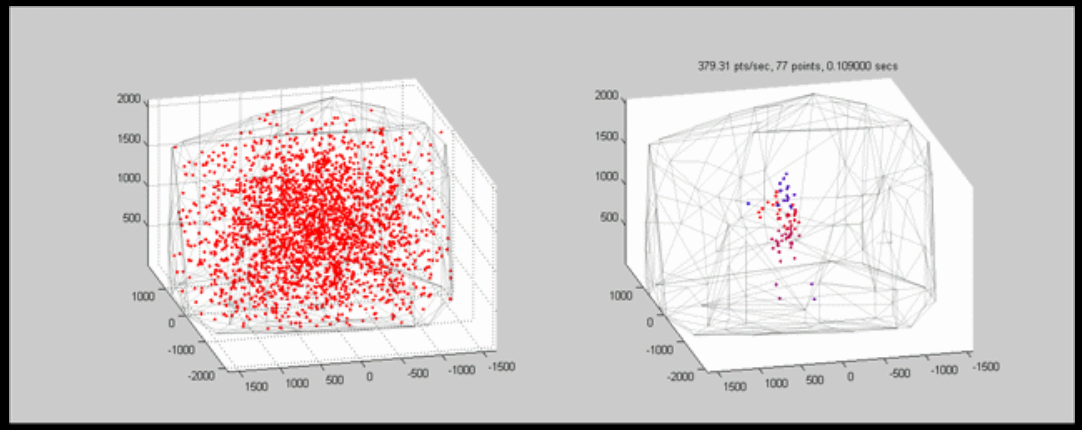


Prock,Dyer/Wisconsin

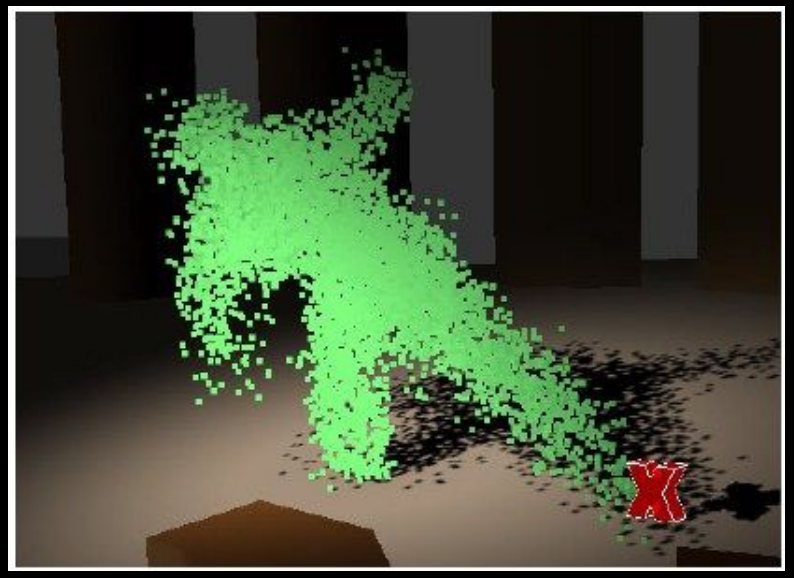
Voxel coloring/
Kutulakos,Seitz



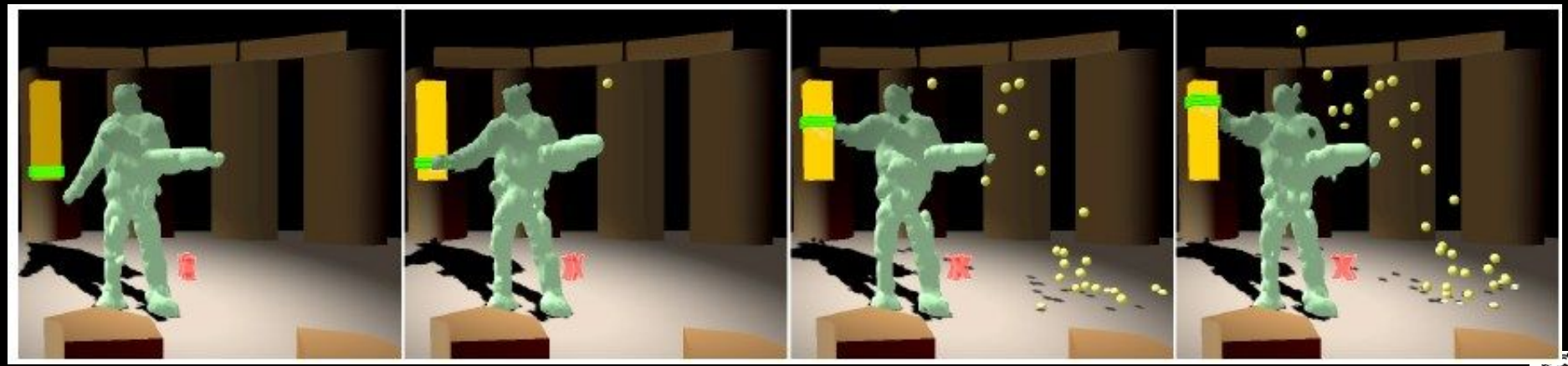
Multi-view Computer Vision: dynamic tracking and user interfaces



Loper and Jenkins



Hasenfratz et al.



Multi-view Computer Vision

- One application: biomechanics
  - analyze the performance of athletes
  - infer important variables
  - provide suggestions for improving performance

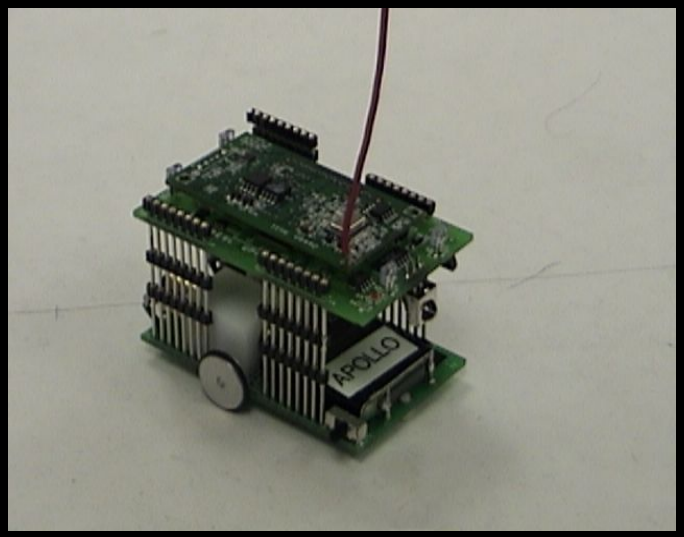
Issues

- Vision does not leverage the upcoming explosion of new sensors being developed
- Calibration is vision is hard
  - but localization for robots is feasible
- Choosing better views through automated deployment
-
- Address these issues through robotics research

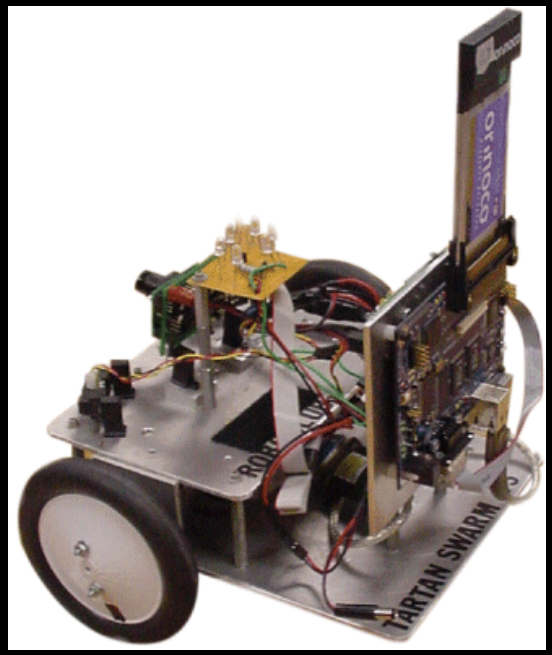
Robots as Sensor Nodes

- Robots with
  - wireless communications
  - a variety of sensors

Thrun/Stanford



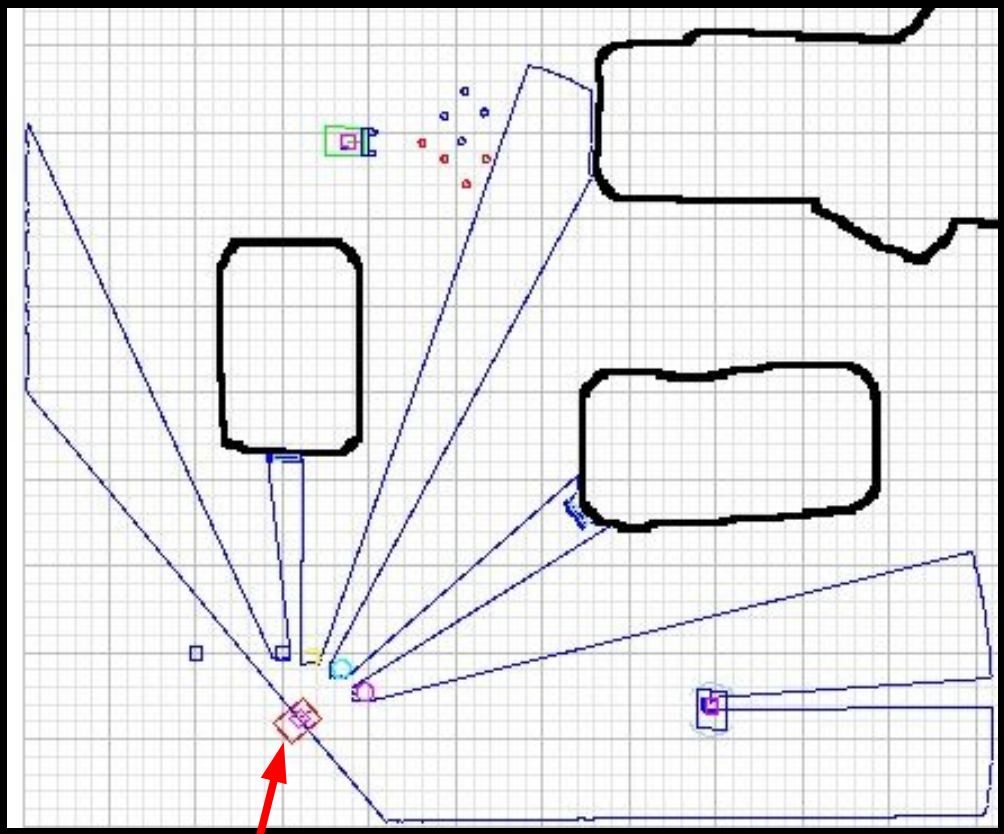
RoboMote/USC



Nourbakhsh/CMU

Laser Ranging

- Ranging provides depth from device to object
- Emit laser and measure time of flight by phase shift
- Provide depth scan by rotating mirror reflecting laser

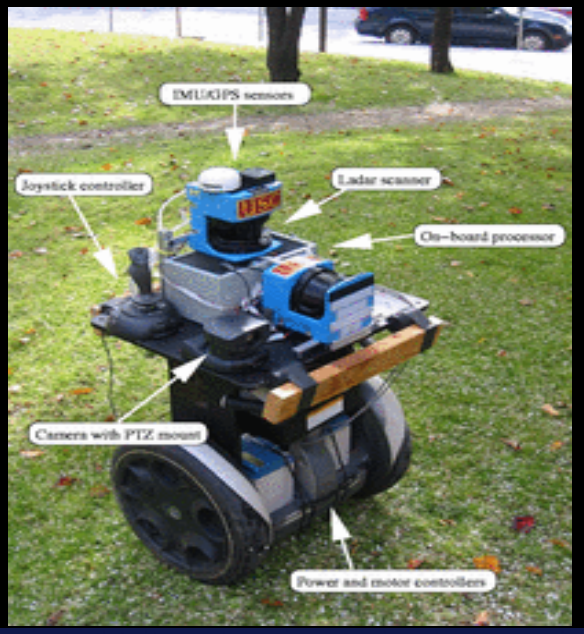


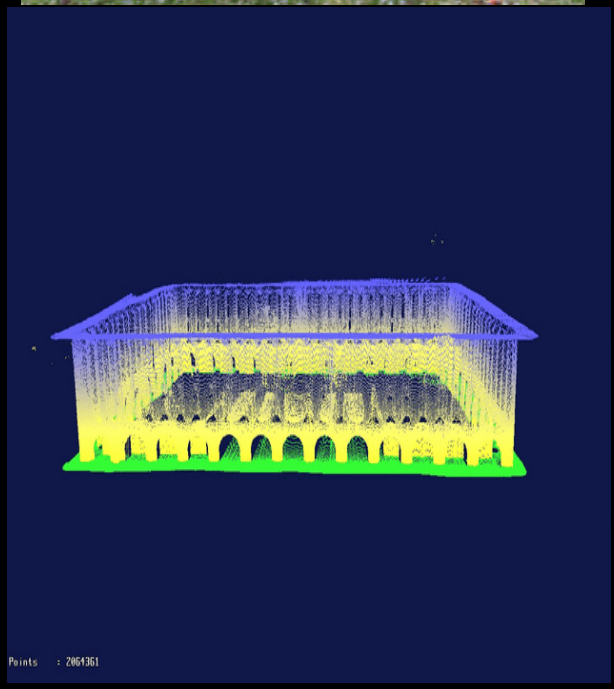
SICK Laser

Pioneer/ActivMedia

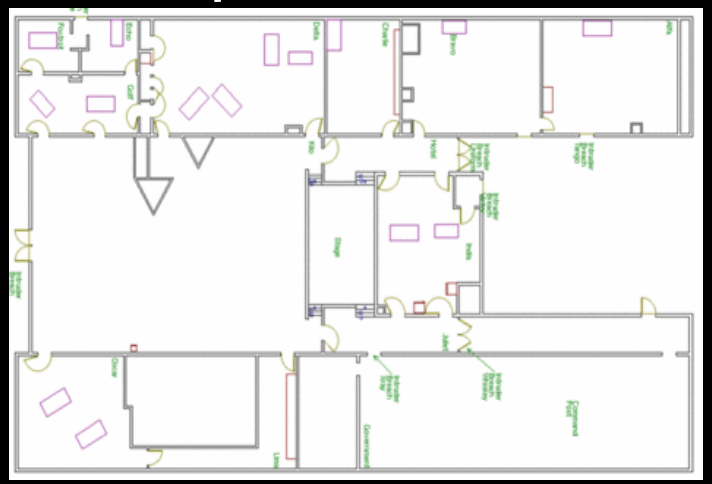
Localization and Mapping

- Localization: estimation of where the robot is in an unknown space?
  - Monte Carlo localization
- Mapping: inferring occupancy of objects in an unknown space?
  - categorizing types of space



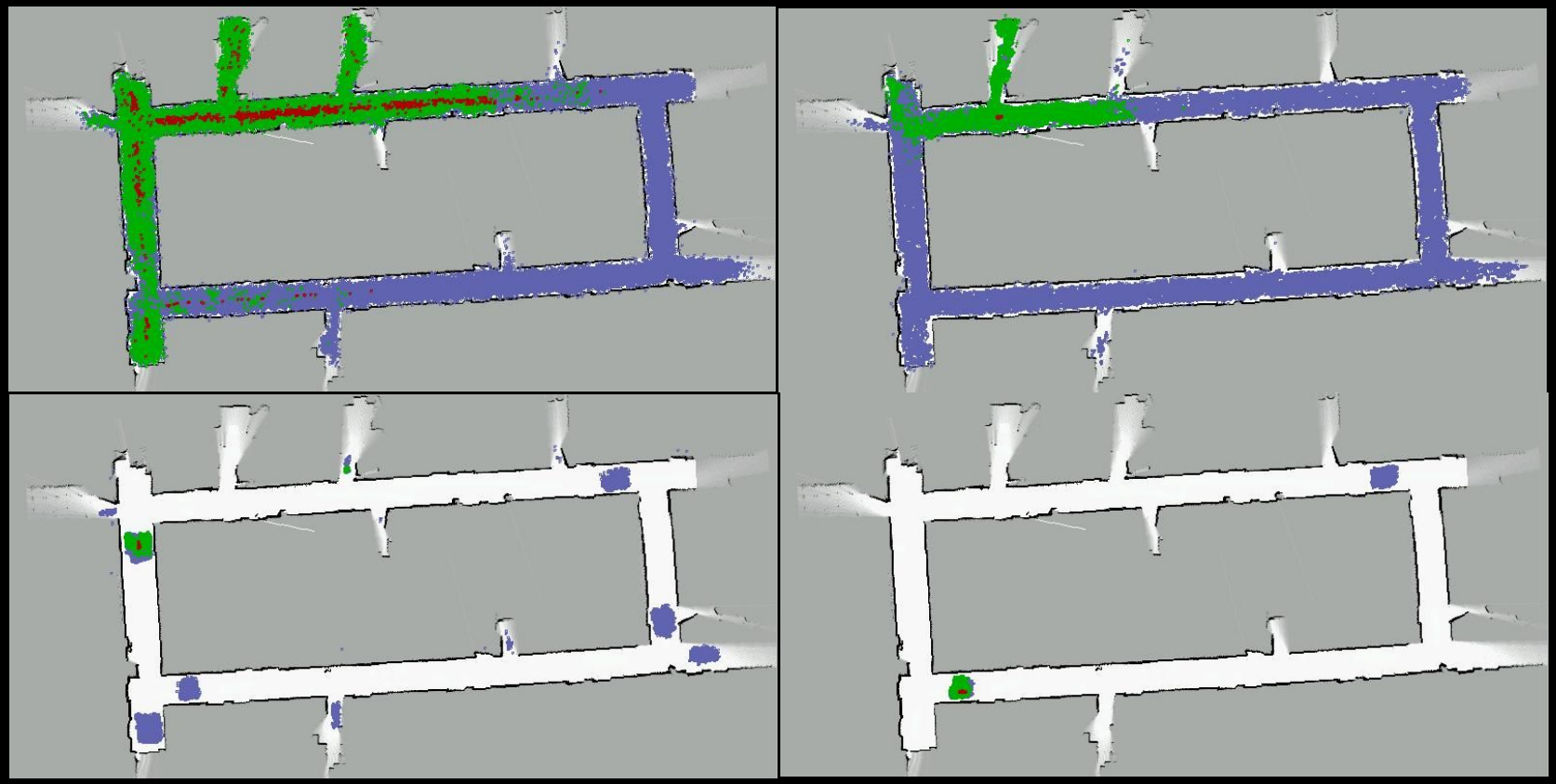


Howard/USC



Robot localization

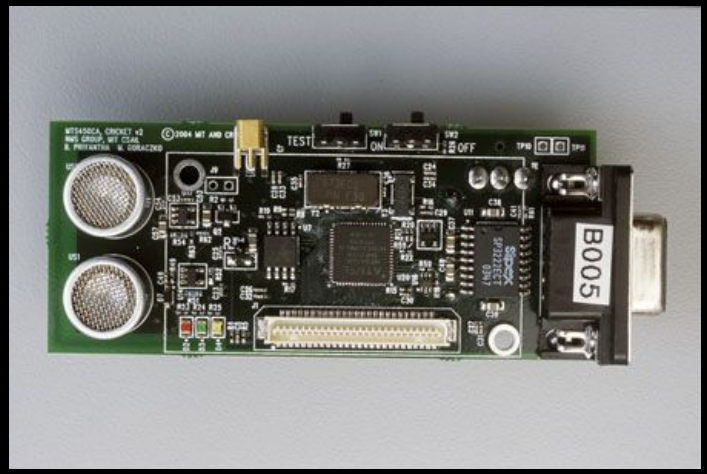
- Laser, odometry, wi-fi

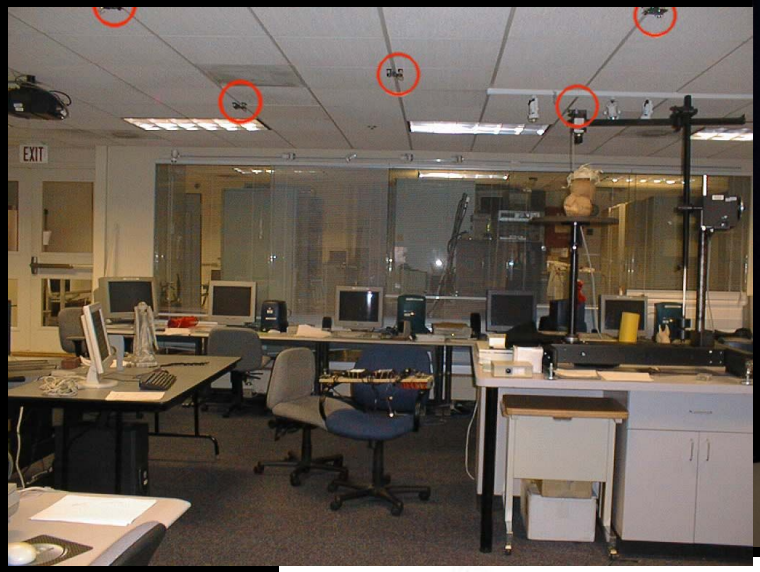


Howard/USC

Cricket Localization (MIT)

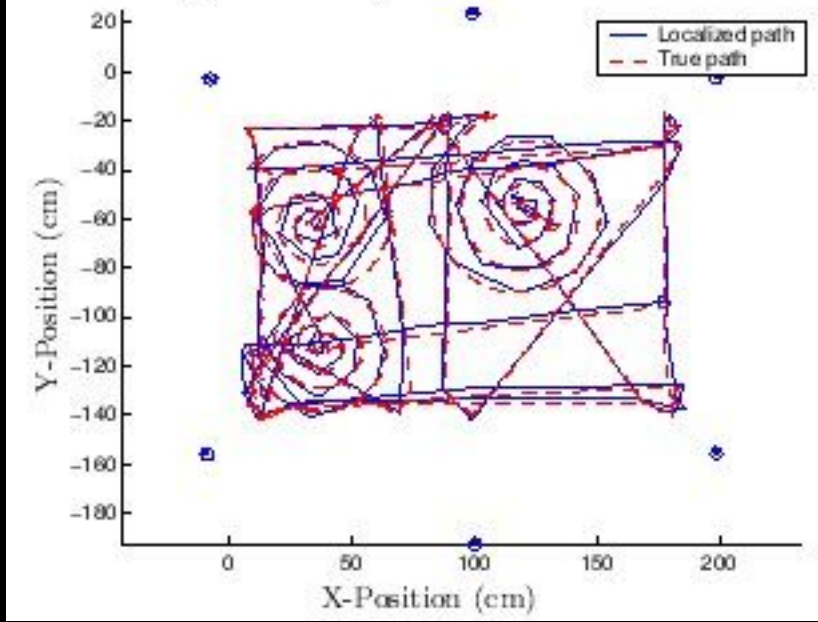
- RF with ultrasound





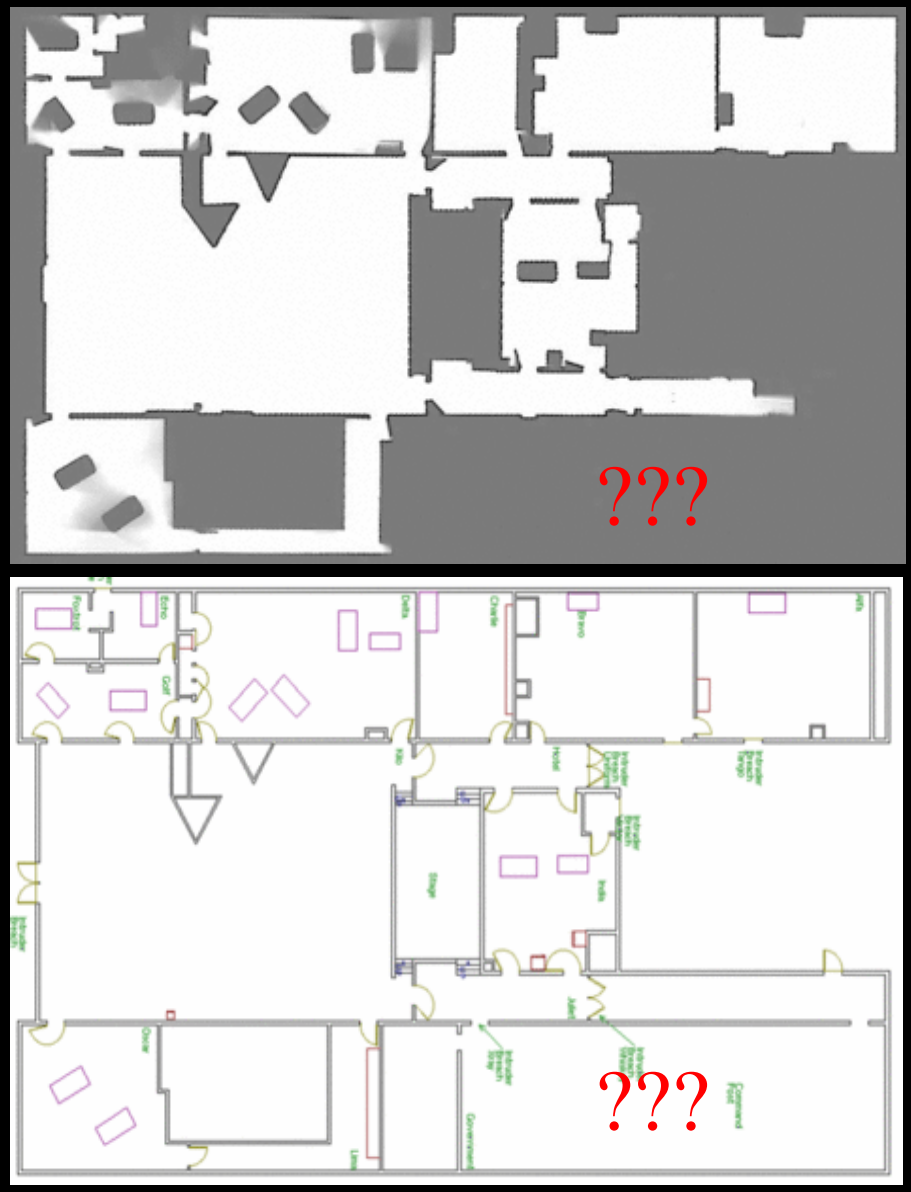
(c) Experimental setup

(a) Localized path of mobile node



Deployment

- How to explore an unknown space to achieve coverage?
- Utilize robot teams



Howard/USC

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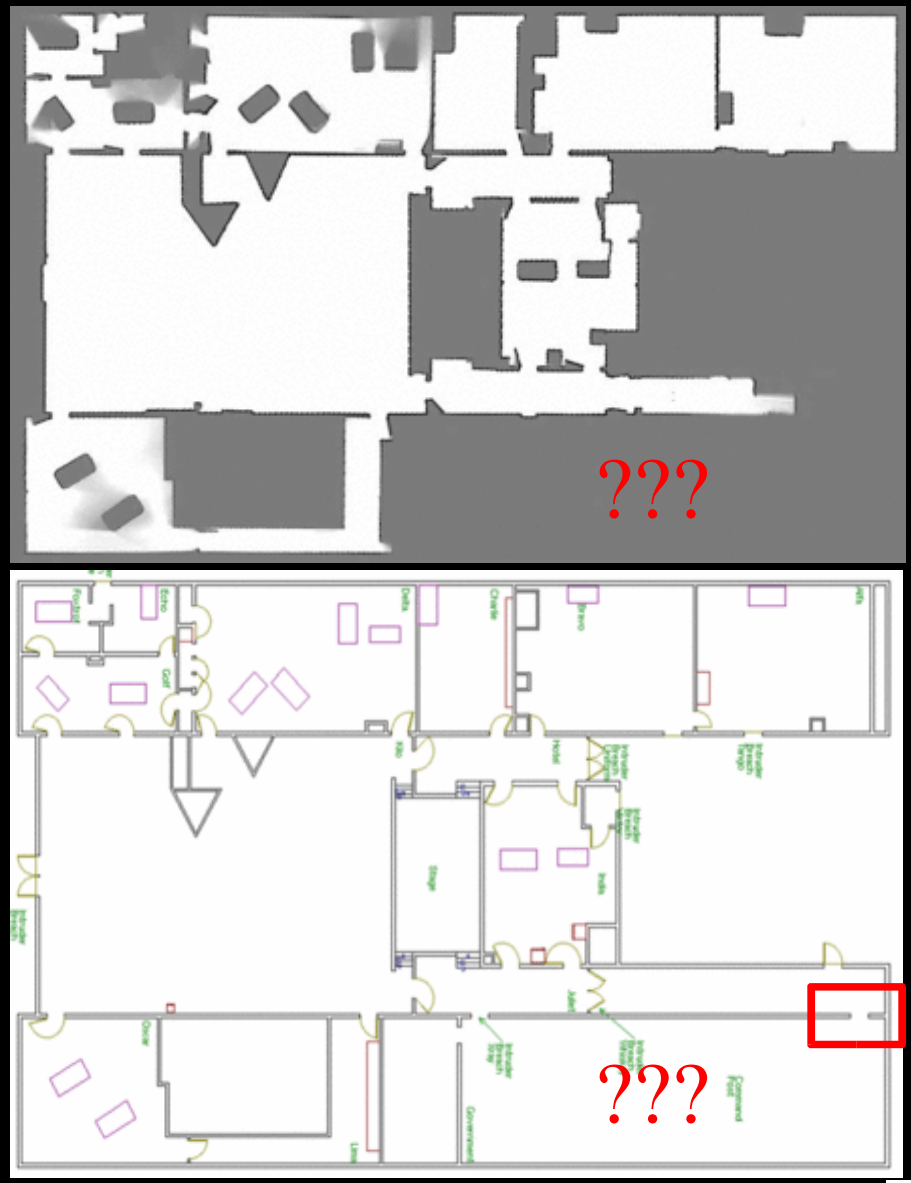
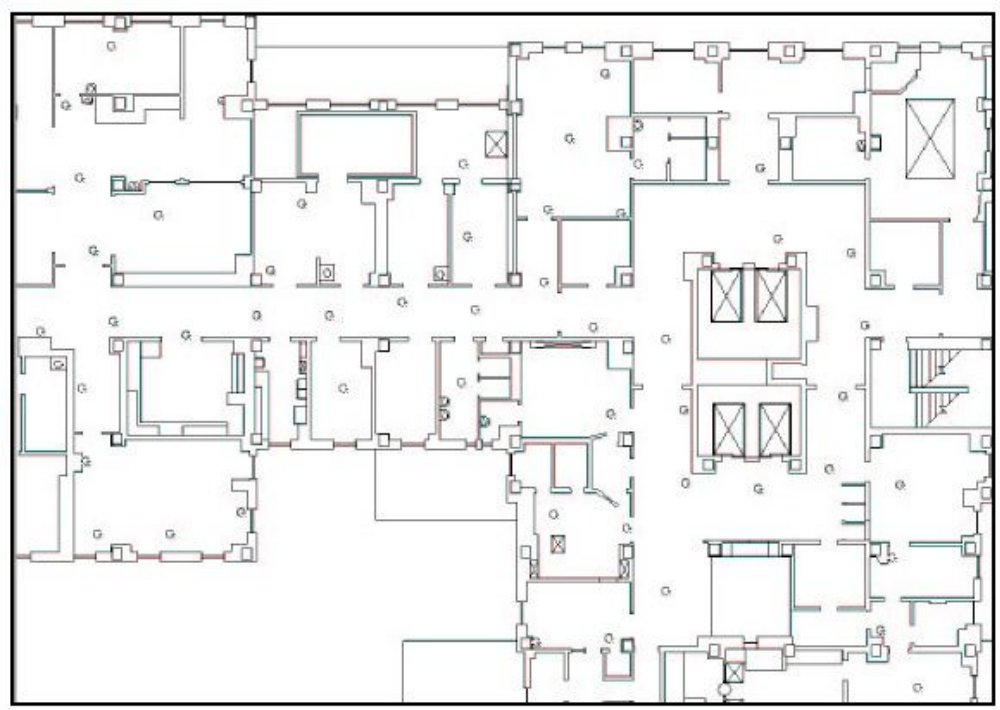


Howard/USC

Potential Fields for Deployment

- Treat robot team as a cloud of gas
- Robot repel from each other into new space but maintain contact



Howard/USC

Multi-modal Sensing

- Lasers are
  - bulky, expensive, and contain less information
  - accurate and have meaning
- Cameras are
  - difficult to interpret and calibrate
    - color blob tracking is the most prominent approach
  - cheap, ubiquitous, and relatively inexpensive
- Combine these modalities
  - no restrictions on including sensor modalities
  - use localization for calibration, vision for interpretation

Opportunities for Collaboration

- Human-computer interfaces
  - video games and increasing accessibility
  - neural prosthesis project
- Machine learning
  - increasing input size for multidimensional scaling
- Humanoid robotics/animation
  - building predictive control modules
  - use predictive models for monocular MCMC tracking
- RoboCup
- Robotics meetings Tuesdays at 5pm (CIT 443)

Conclusion

- Combine sensor nets, robots, and computer vision
- Merge real and virtual worlds
- Infer about and act in the real world

(Mataric, USC)

Kanade/CMU

Murphy/USF

iRobot