Communication-assisted Localization and Navigation for Networked Robots

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Outline

- Introduction
- Navigating with a Sensor Network
  - Robot-assisted Localization
  - Communication-assisted Path computation
  - Communication-assisted Robot Navigation
- Experiments
- Conclusions
- References

Introduction

- Sensor networks are well-suited for tasks in extreme environments
  - The environment don't have any computation and communication infrastructure.
  - The environment model and the task specifications are uncertain and dynamic.

Introduction

- A Robot can be thought of as a mobile node in the sensor networks.
- Robots can help doing different tasks:
  - Sensor nodes localization
  - Using navigation information to pass through the sensor networks

Introduction

- Problem definition
  - A sensor network is dispersed over a large geographical area.
  - The robot, which is equipped with a GPS receiver, is used to initially localize the nodes.
  - A flying robot is tasked to travel along a path across this area to reach multiple goal locations.
  - The sensor network computes the path or externally embed a path into the network.

Navigating with a Sensor Network

- Robot-assisted Localization
- Communication-assisted Path computation
- Communication-assisted Robot Navigation

Robot-assisted Localization

- The nodes in the sensor network need location information in order to support path computation.
- However, it is impractical for each sensor node to have GPS capability (for reasons of cost and power consumption).

Robot-assisted Localization

- The flying robot sweeps across the area and broadcasts GPS coordinates which contain its position $p_i = (x_i; y_i)$.
- The sensors receive the message with signal strength s_i.
- The sensors incrementally process all broadcasts they receive to refine their estimated location.

Robot-assisted Localization

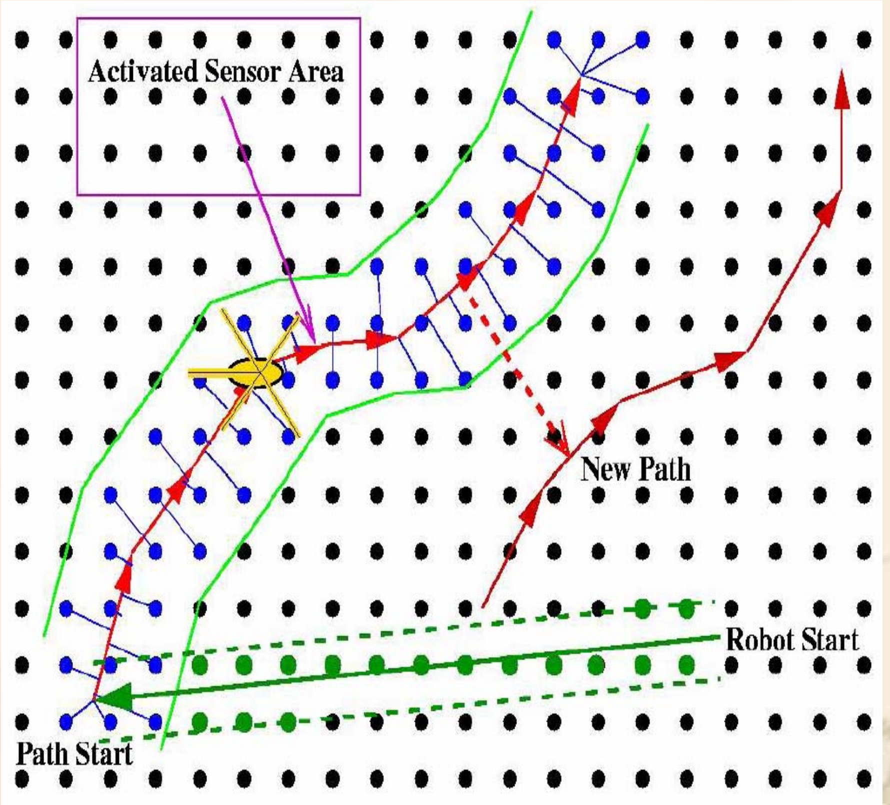
- Location estimate algorithms
  - strongest
  - mean
  - wmean
  - median
  - constraint
    - Assuming the sensor position lie within the rectangular region Q
    - $Q(k+1) = Q(k) \cap [x(k)-d, x(k)+d] \times [y(k)-d, y(k)+d]$

Communication-assisted Path computation

- Two main categories
  - The sensor network can monitor the environment and constructed a map incrementally and adaptively as an artificial potential field.[1]
  - Path Routing
    - Enables us to “embed” one or more paths adaptively in the sensor network.

Communication-assisted Path computation

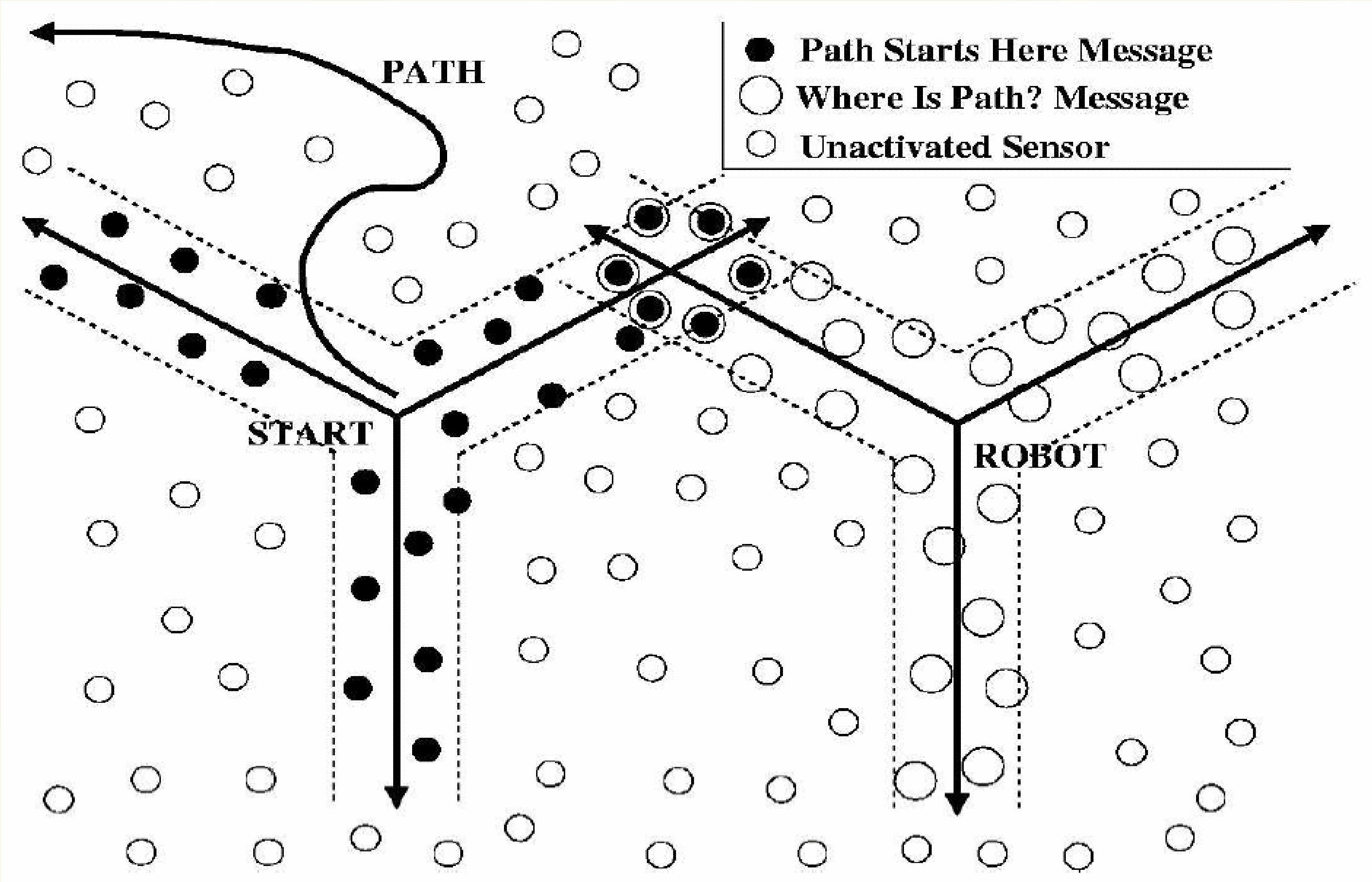
- Propagate Path message
  - The **Path** message is routed in the general direction of the start location of the path.
- Route the message along the path, activating the sensors on the path.



Communication-assisted Robot Navigation

- 1.Telling the robot where the path starts.
  - The sensor which near the start point of the path send out three messages.
  - The messages contain the location of the start point, and a heading direction which set 120^{o} apart.
  - The Robot also send search message in the same manner.
  - These two messages will meet in some place, and the sensor at the crossing can send location information of the start point back to the robot.
- 2.Guide the robot along the path.

Communication-assisted Robot Navigation

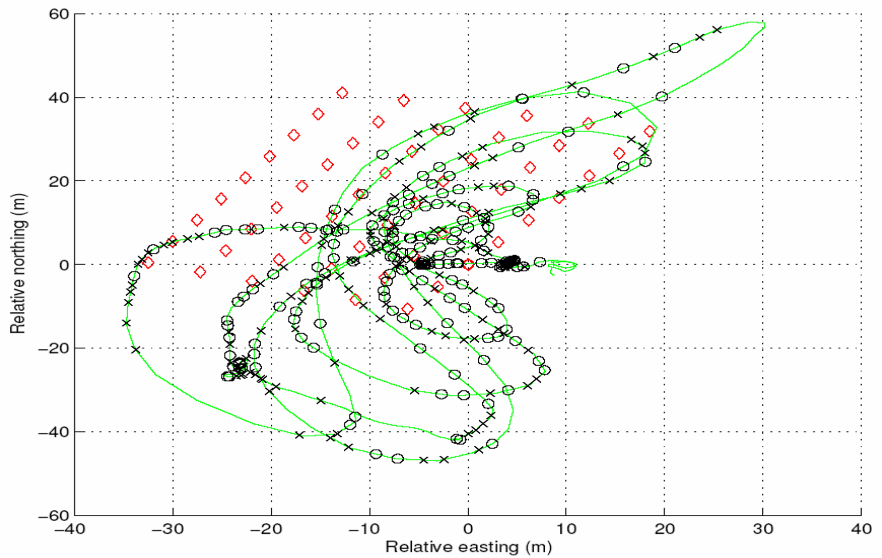


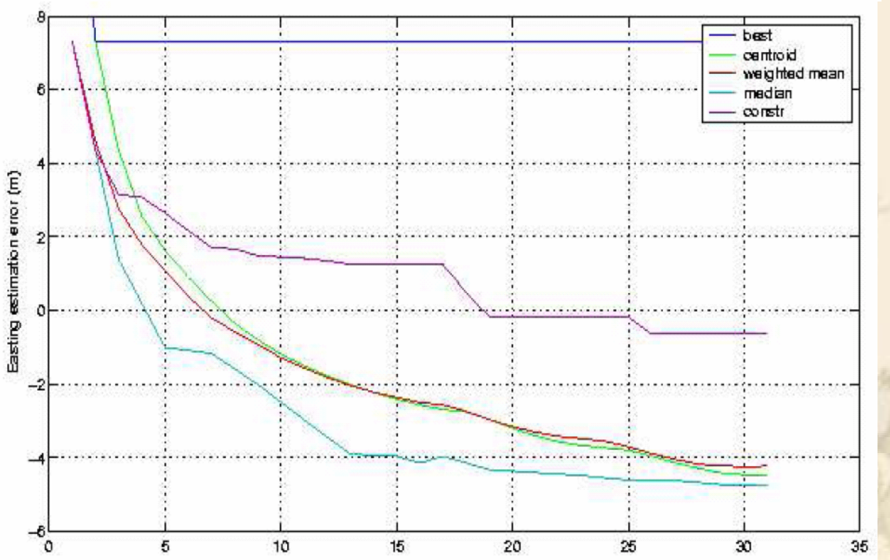
Experiments

- Mica Motes
- Robot
  - CSIRO helicopter
  - Equip with 800MHz P3 cpu, 1Hz differential GPS receiver, mote.
- Flying robot simulator

Experiments

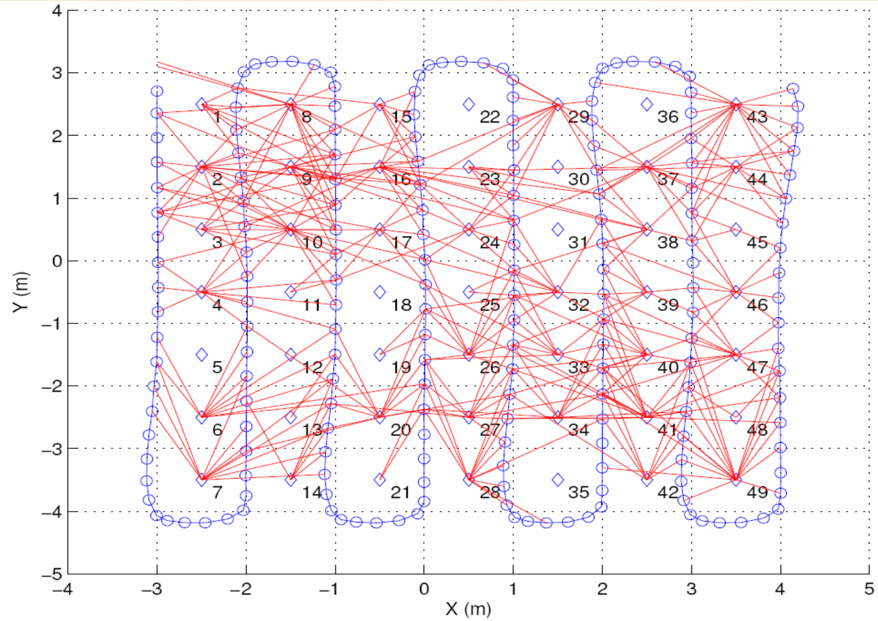
- Localization results
  - The constraint method was arguably the best performer.

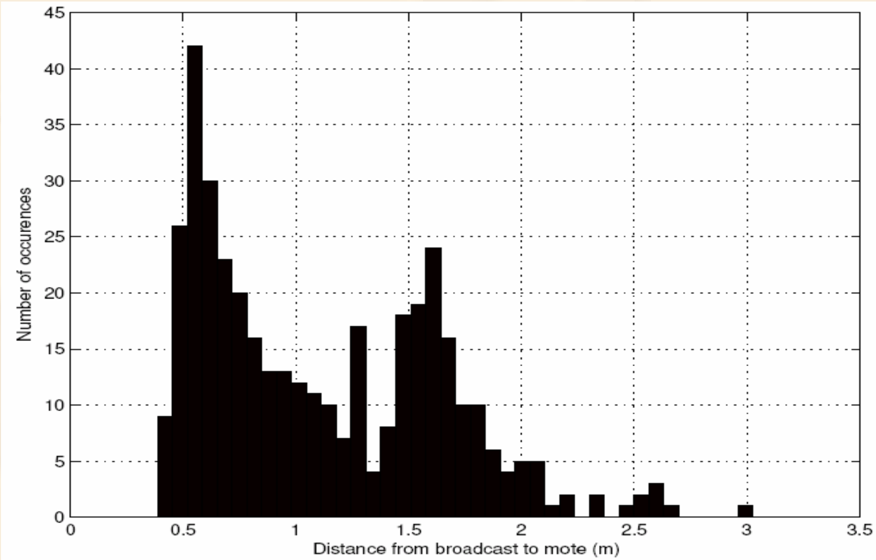




Experiments

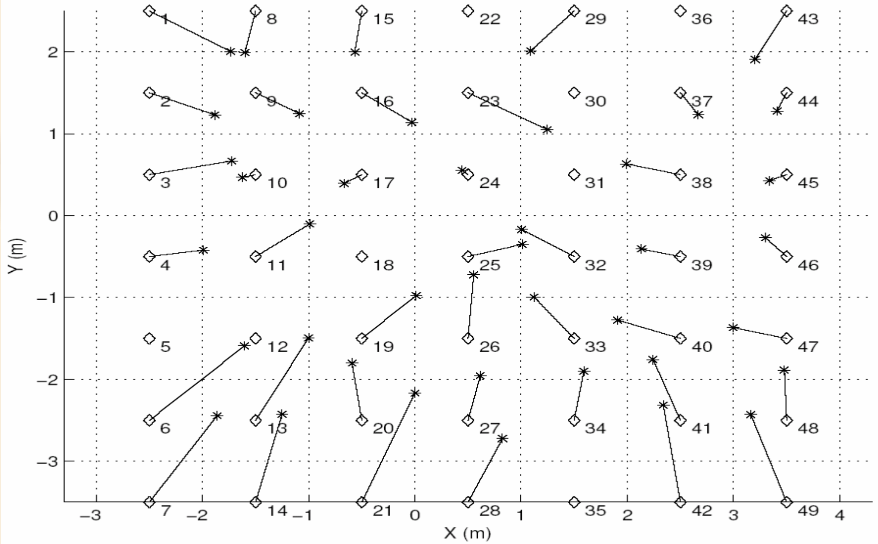
- Using flying robot simulator
  - Following a Serpentine path
  - Once per second the robot obtain its current coordinate

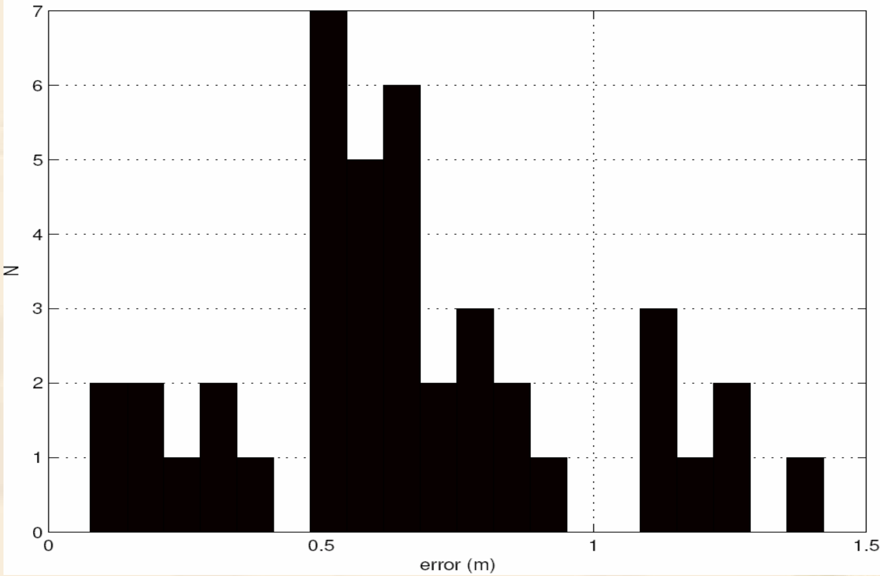




Experiments

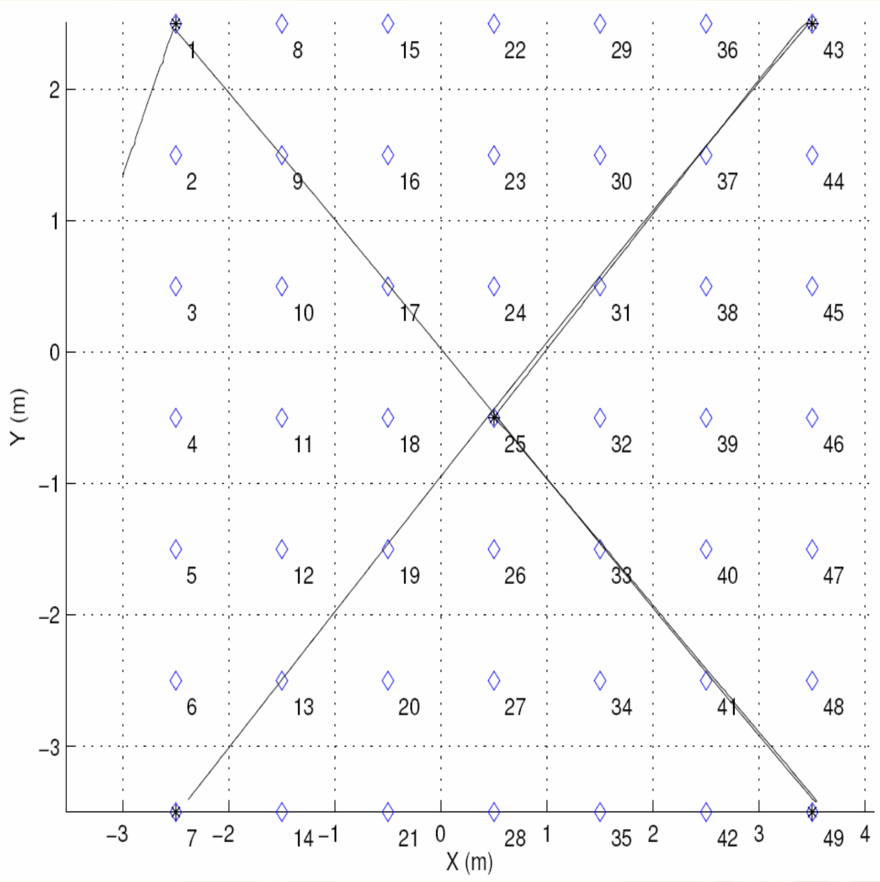
- Localization performance using centroid method





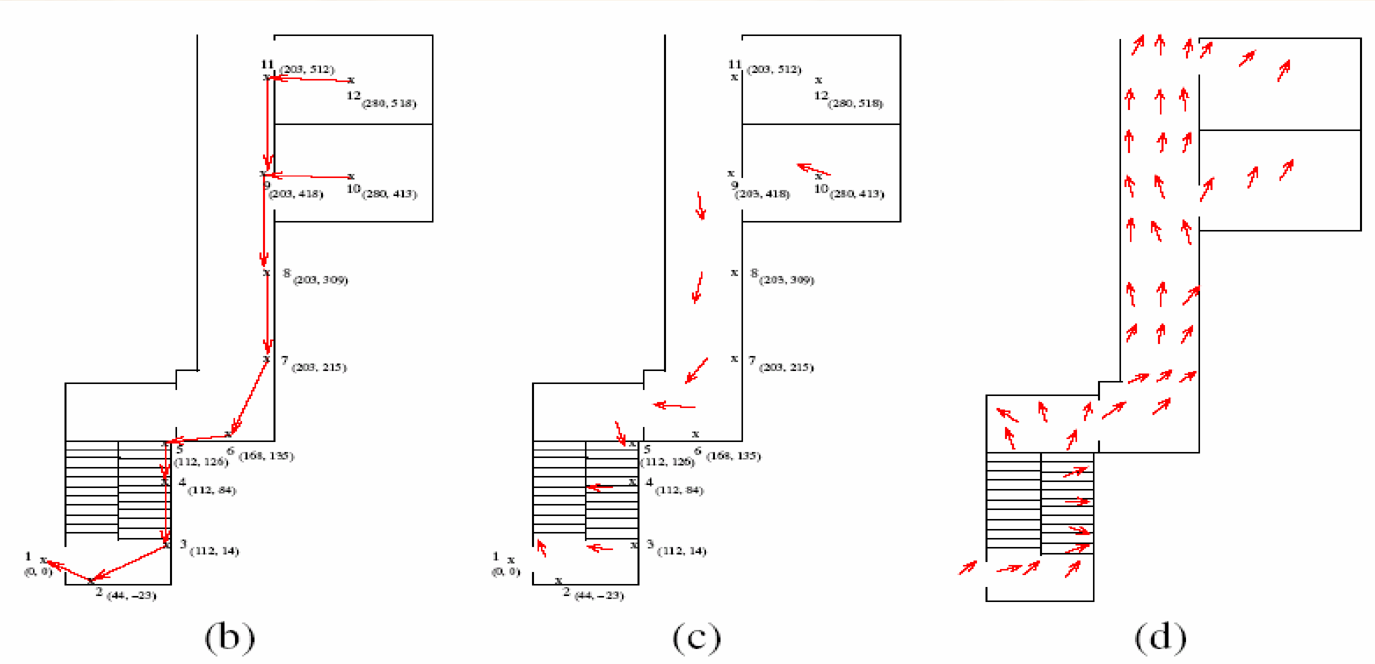
Experiments

- Navigation results
  - The robot queue for path waypoints
  - It build up a list of waypoints as it followed the path.



Experiments

- Extension to guiding humans
  - Sensory Flashlight
    - When the user points the flashlight in a right direction, a silent vibrating alarm activates and the LED lights.



Conclusions

- The authors proposed localization and navigation method in sensor networks.
- They have implemented the navigation protocols on a network of 54 Mote sensors in a large-scale outdoor setting, and tested aspects of helicopter and sensor network interaction.

References

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