Communication-assisted Localization and Navigation for Networked Robots


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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° 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

