Target Tracking with Binary Proximity Sensors

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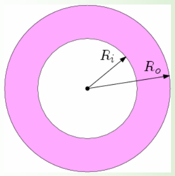
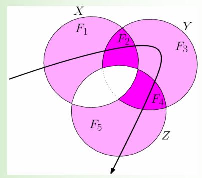
Fundamental localization limits : One target scenario

(joint work with N. Shrivastava, Prof. S. Suri, UC Santa Barbara)



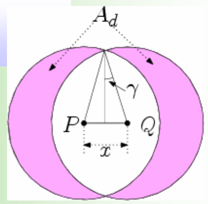
Simple binary detection model
- detect objects within some radius
- only yes/no detection, no range info

Practical imperfections
- detection errors
- misses and false positives
- variations among sensors

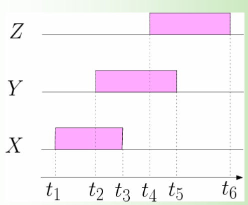


Localization patches

How well can we localize with a network of sensors
- Each sensor can localize to within detection range
- Better localization by aggregating sensor data
- Intuition: more sensors → better localization
- Does larger detection radii improve localization?

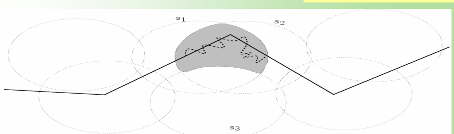


Fundamental limits with geometric methods
- Probability that P & Q be distinguished
- For random deployment density ρ
- Localization accuracy $\propto \frac{1}{\rho R}$

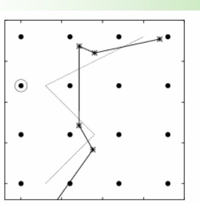


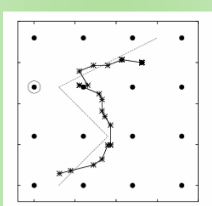
Sensor Outputs

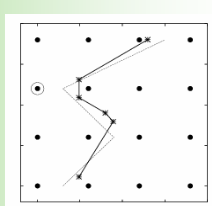
Binary network for tracking
- Tracking → localization over time
- Binary sensors give sampled trajectory
- "Low-pass" version of actual path
- Simple geometric approach
  - motivated by Occam's Razor
  - works well for smooth paths
- Does NOT work well with detection errors
- Combination of geometric and particle-filtering



Experiment with acoustic motes
- uses a tone-detection circuit for detection
- Extremely noisy and unreliable
- One sensor failed completely!
- Geometric approach not optimal
- Needs to be combined with particle filtering
  - works even with extreme imperfections

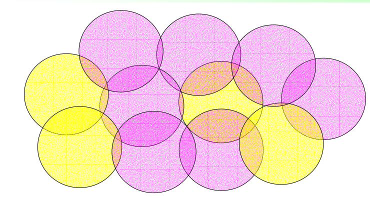






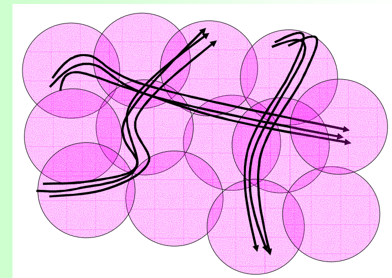
Tracking multiple targets with binary sensors

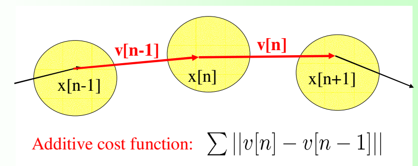
(joint work with R. Kumar, Prof. S. Suri, UC Santa Barbara, R. Cagley, Toyon Research)



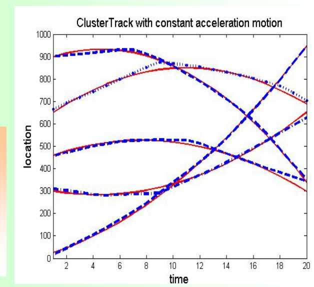
Snapshot based inference
- significant ambiguity about not only the target locations, but also the number of targets
- greedy algorithm for minimal description in one dimension

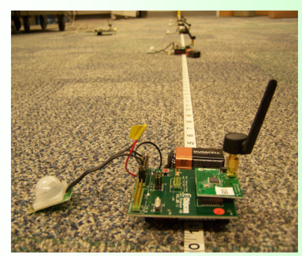
Tracking across snapshots : Particle-filter algorithm
- Exploit the temporal correlations across snapshots : pick a cost function that penalizes variation in velocity
- To identify and track multiple targets, look for clusters of particles



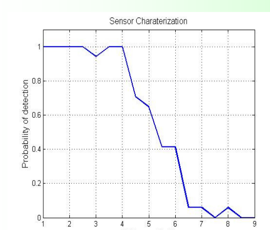


Simulation results
- works really well if the targets separate out occasionally enough
- may generate some spurious trajectories, depending on the extent of overlap of the true paths





Experiment with Passive Infrared Sensors
- each sensor transmits to base station when it changes state
- data gets time-stamped at the PC
- for ground truth: targets are provided separate sensor nodes equipped with localization engines



Tracking performance
Respectable performance even though one sensor completely missed a target