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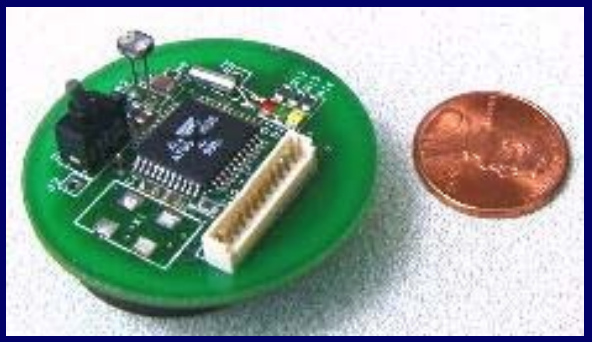
Multi-Agent Simulations for Assessing Massive Sensor Deployment

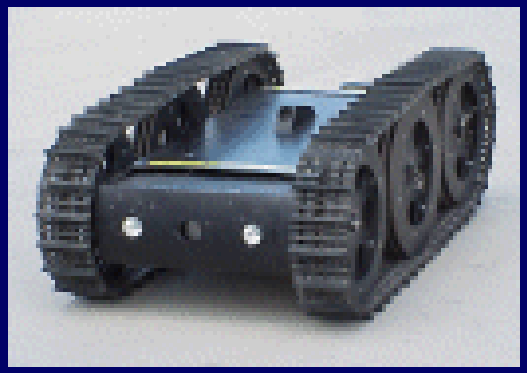
Captain Sean Hynes, USMC
sehynes@nps.edu

Dr. Neil Rowe
nrowe@nps.edu

Outline

- Problem Space
- Sensor Coverage
- Sensor Deployment

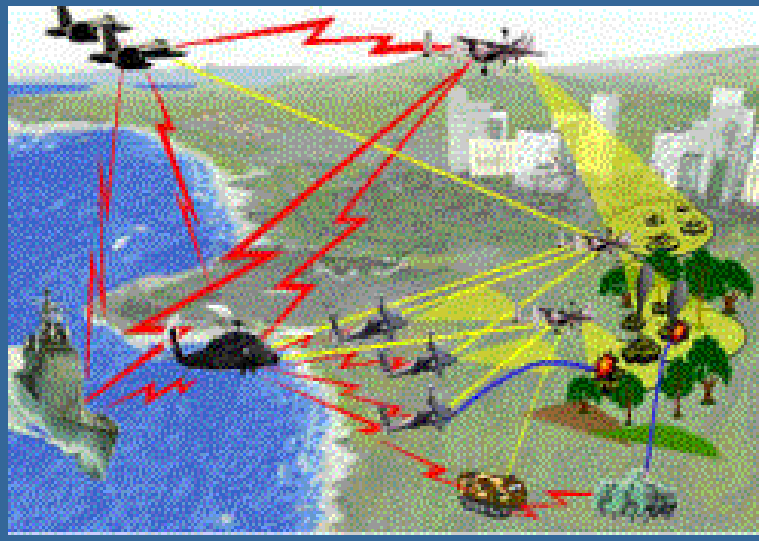




Small and Mobile

Problem Space

- Next-generation Web and network-centric warfare
- Counterintelligence
- Expeditionary sensor networks
- Coverage, minimal exposure, and cost
- Efficient deployment algorithms for autonomous sensor vehicles



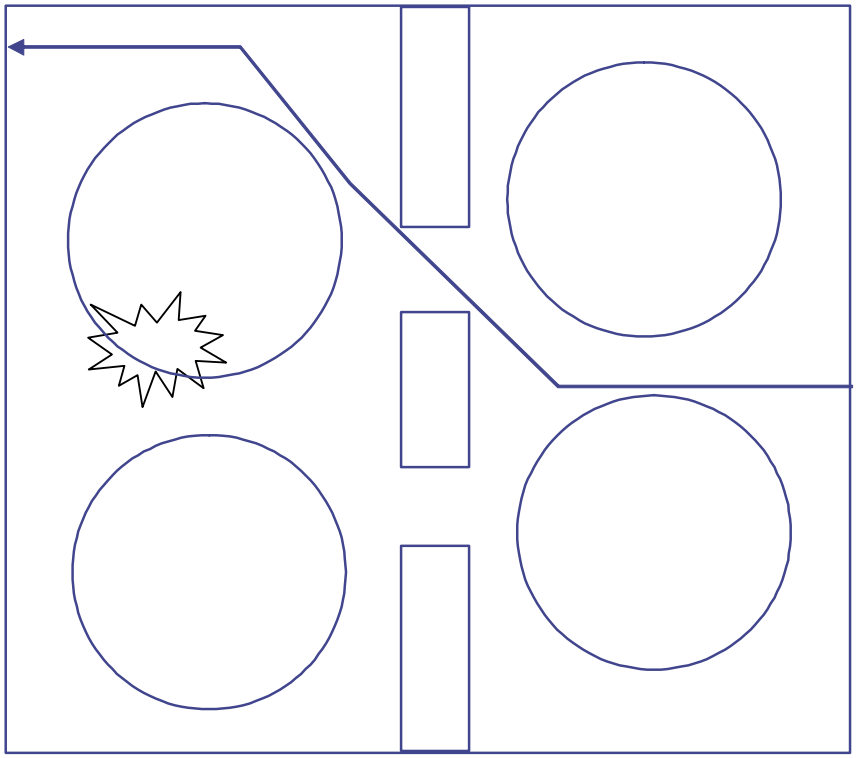
Research Project

- A sensor network simulation
- Coverage and deployment issues for mobile and non-mobile sensors
- An expeditionary sensor network multi-agent simulation designed and implemented
- Novel search, coverage, and deployment algorithms implemented, tested, and compared to known methods

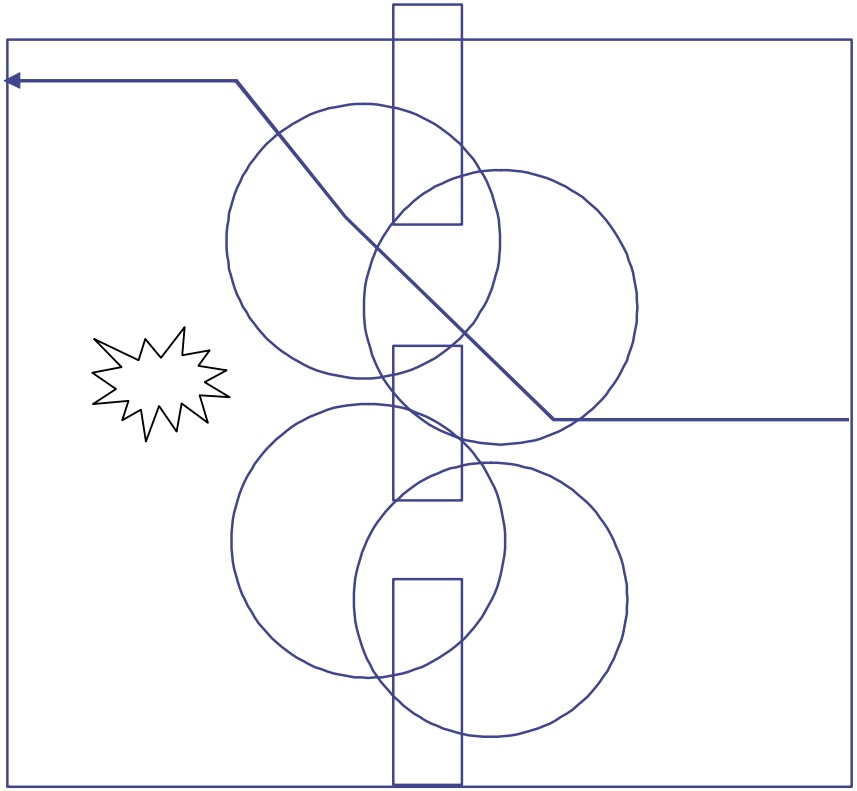
Coverage in Sensor Networks

- We address distribution of multiple homogeneous sensors for detecting targets.
- We assume a large enough number of sensors that a human operator cannot manage each.
- Much literature on search in operations research.
- Some literature on area coverage.
- Not much literature on traversal detection.

Which Deployment = Better Coverage?

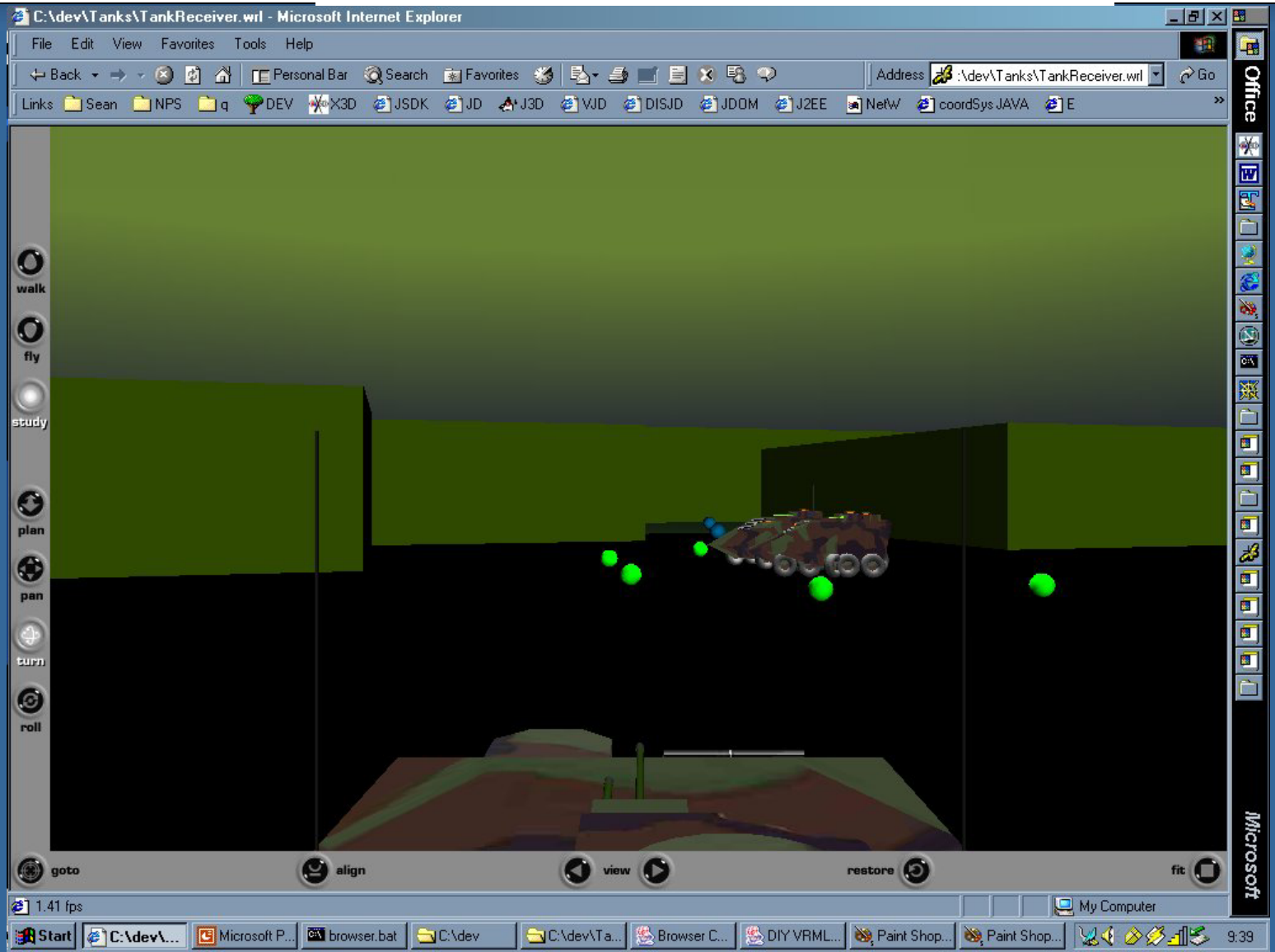


Area Coverage Deployment
(More Area Covered)



Barrier Coverage Deployment
(More Likely Traversal Detection)

Application Preview



Dimensions of sensor networks

- General sensor mechanism
  - Radial
  - Distance-directed
  - Line-of-sight
- Coverage type (sweep, area, traversal)
- Presence/absence of obstacles
- Mobility
- Localization

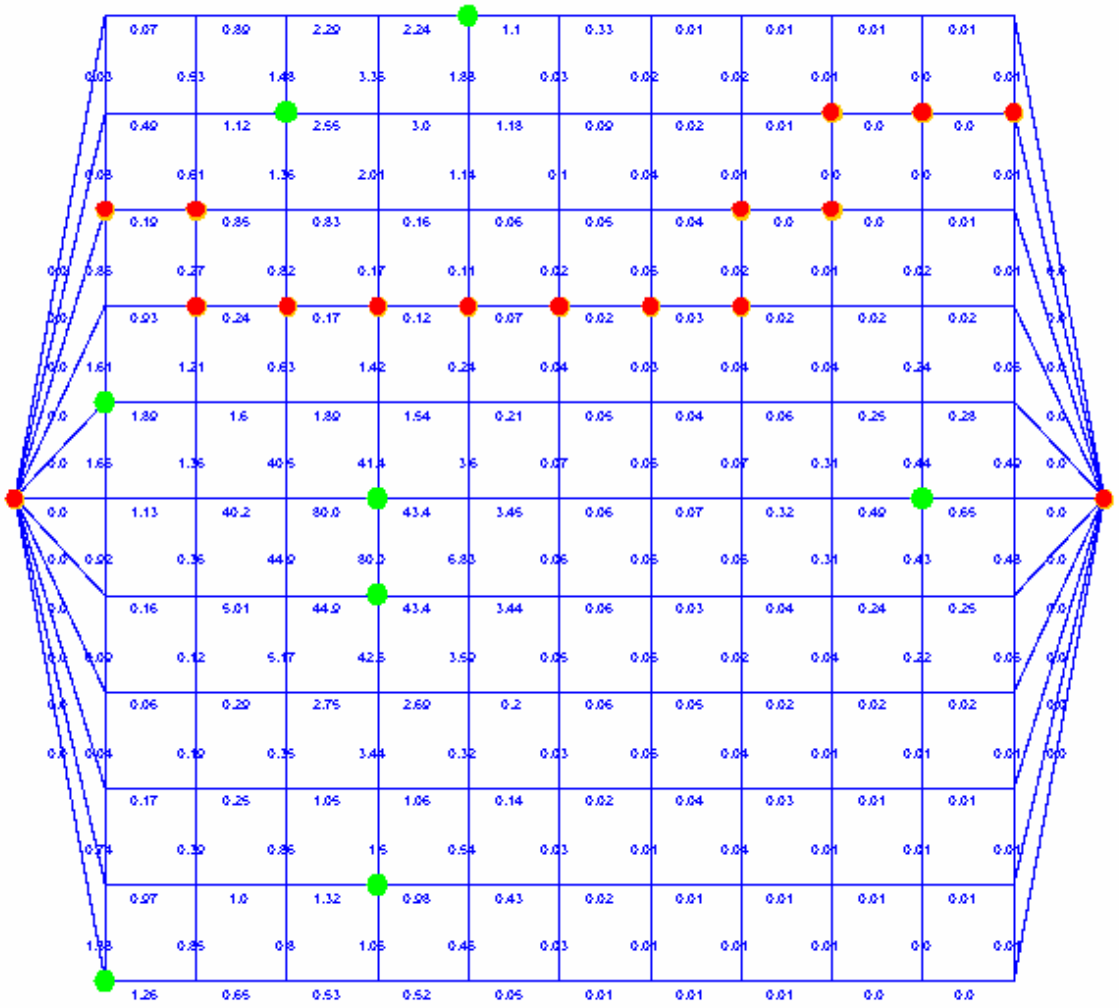
Deployment Algorithms: Constraints

- Should be efficient, de-centralized, fault-tolerant, and scaleable
- Communications
- Geographical Knowledge
- Localized Decisions


Gladiator

A grid for detecting traversal: calculate worst-case path

$$S(s,p) = \frac{\lambda}{[d(s,p)]^K}$$



Probability of detection = 87%

Placement Complexity

Consider

- N – # Sensor Nodes
- A – environment area
- D – length of grid square

Consider

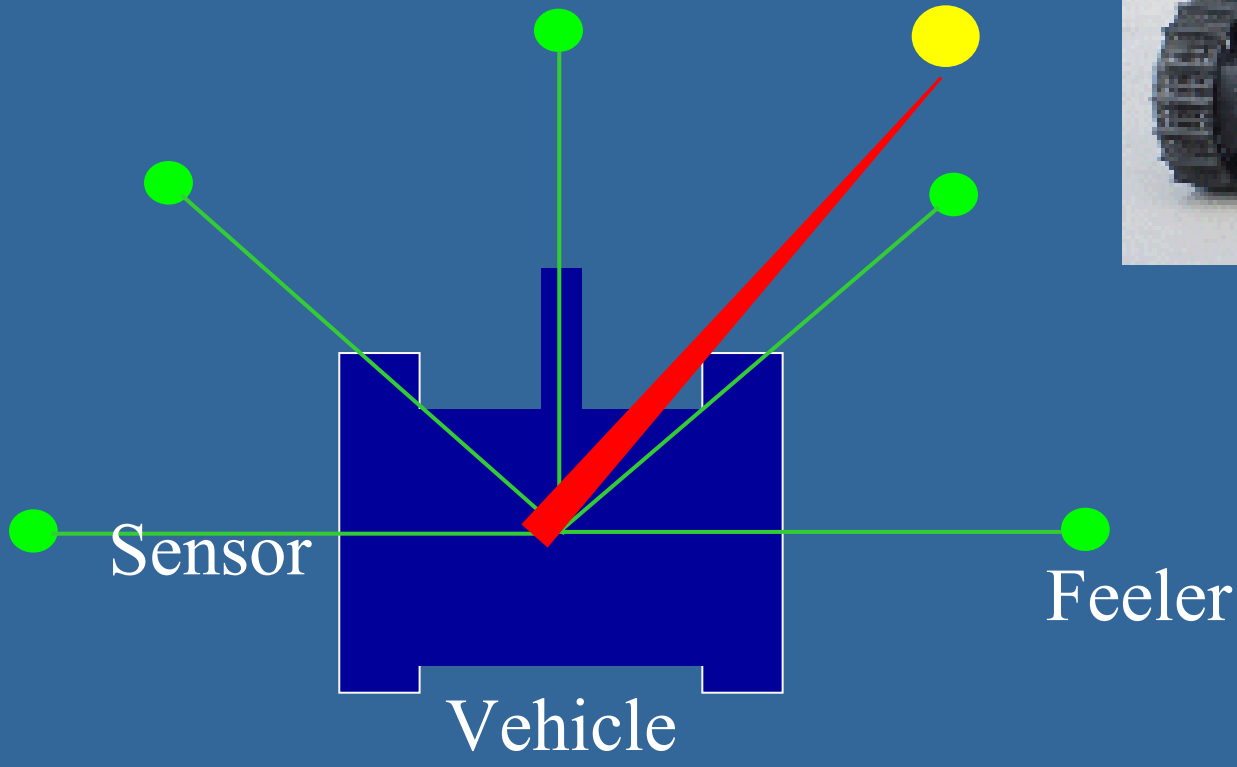
- N – 10
- A – 100 m^2
- D – 10m

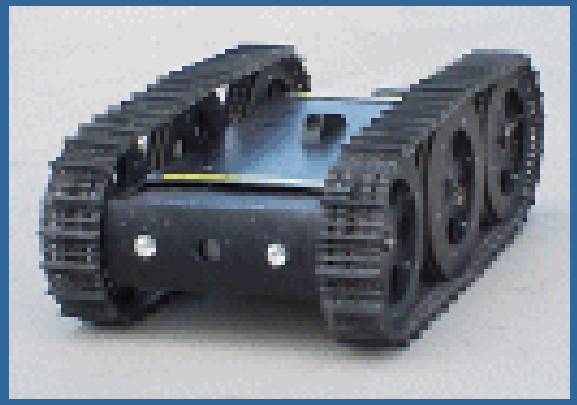
# of Configurations

$$C = (D * A)^N$$

$$C = (10 * 100)^{10} = (10)^{20}$$

Mobile Sensor Model





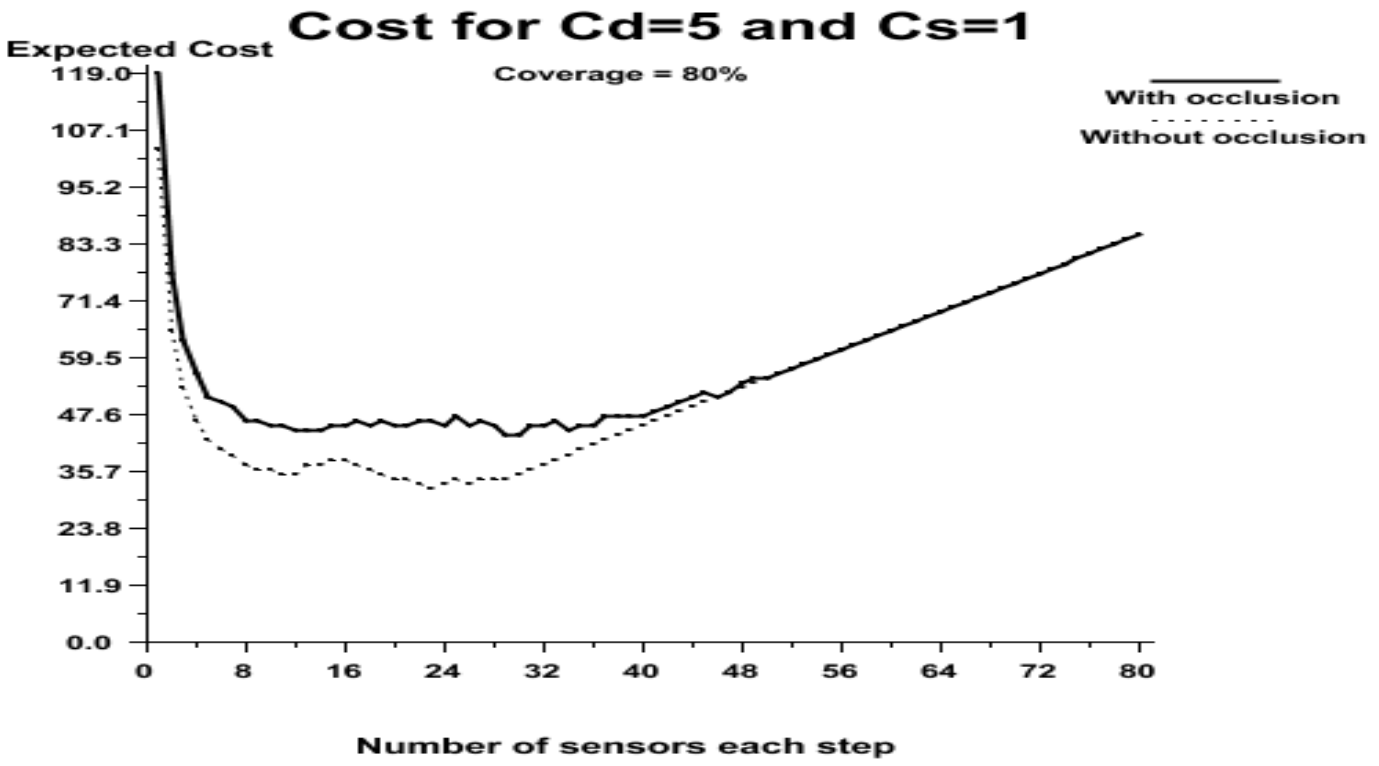
Deployment Algorithms: Methods

- Global or centralized
  - Best-first, greedy, genetic, simulated annealing, ….
- Local or autonomous
  - Potential forces, vector field, local direction, ….
  - Coevolution of evasion and detection with neural networks

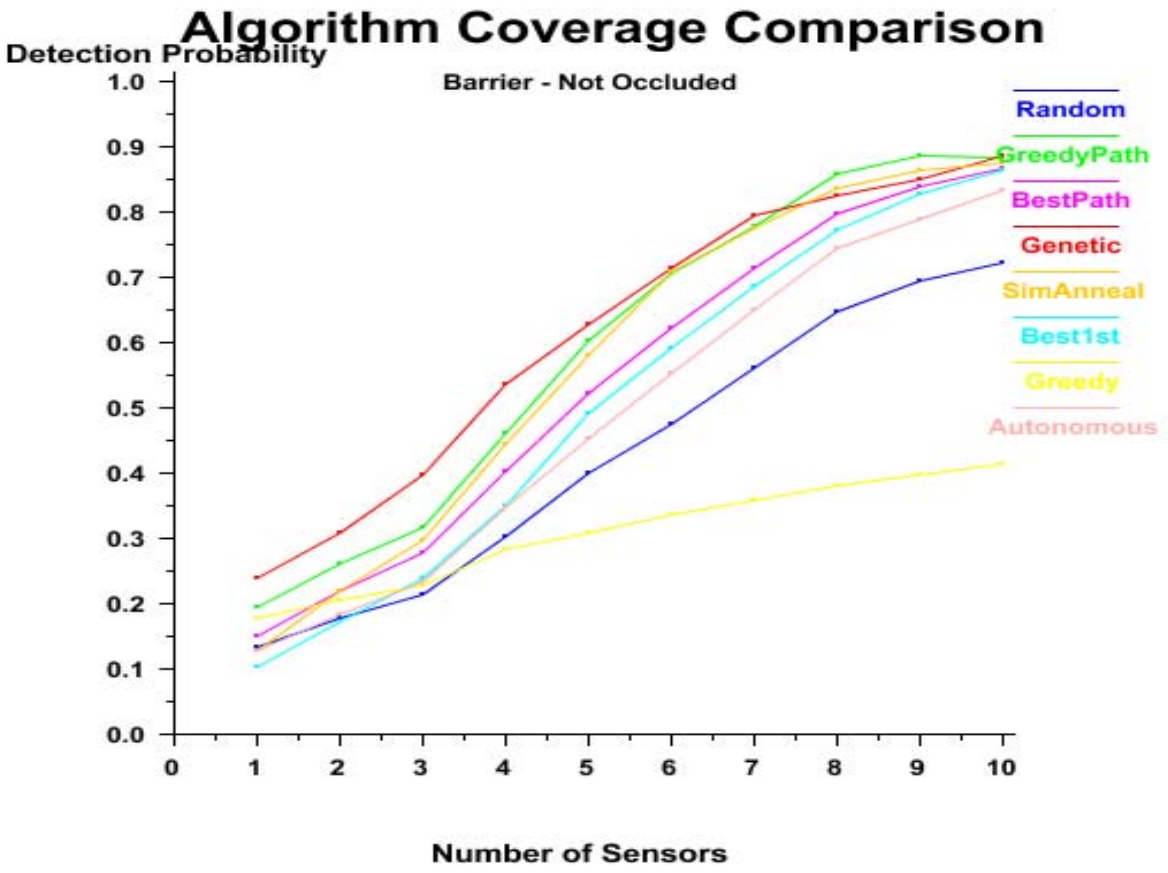
Average barrier coverage (%) with multistage random deployment

Number of sensors	2	10	15	20
Coverage %, no obstacles	4	41	64	85
Coverage %, with obstacles	6	25	39	55

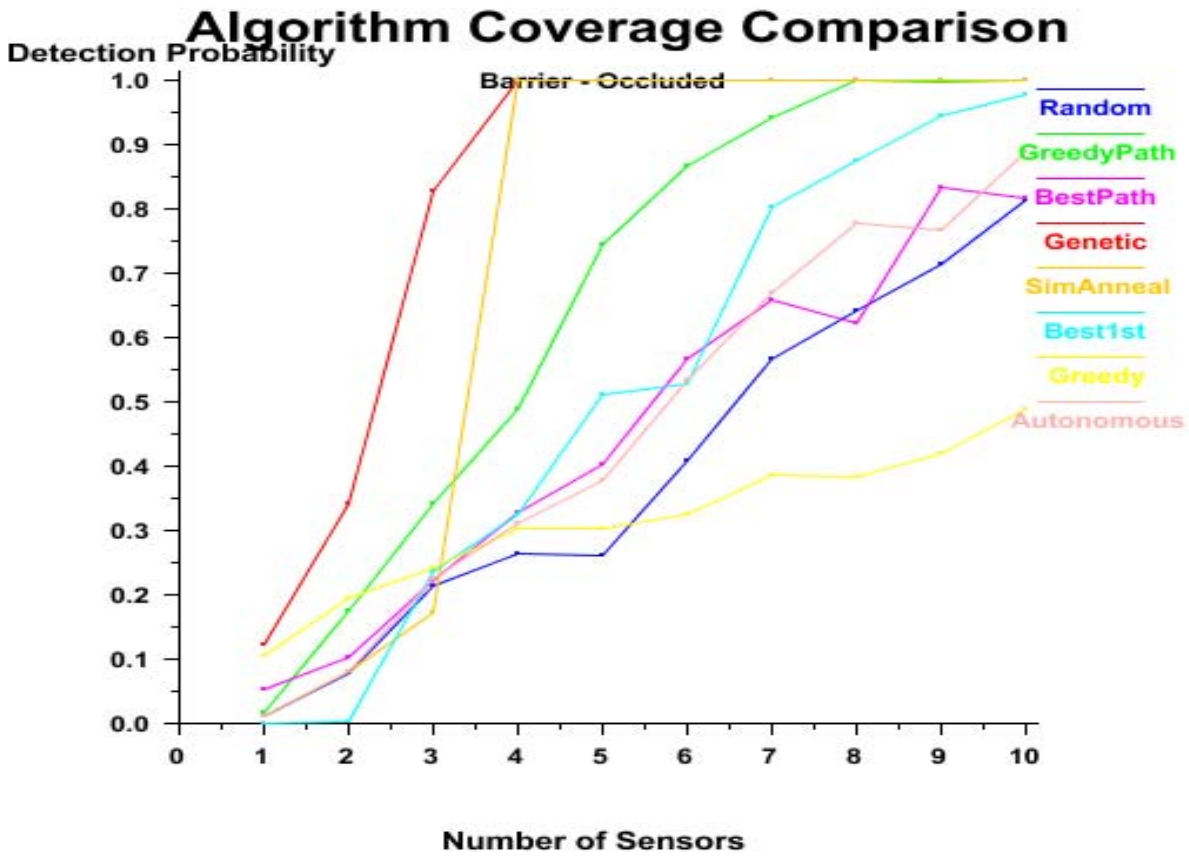
Cost of achieving 80% coverage with multistep deployment of sensors



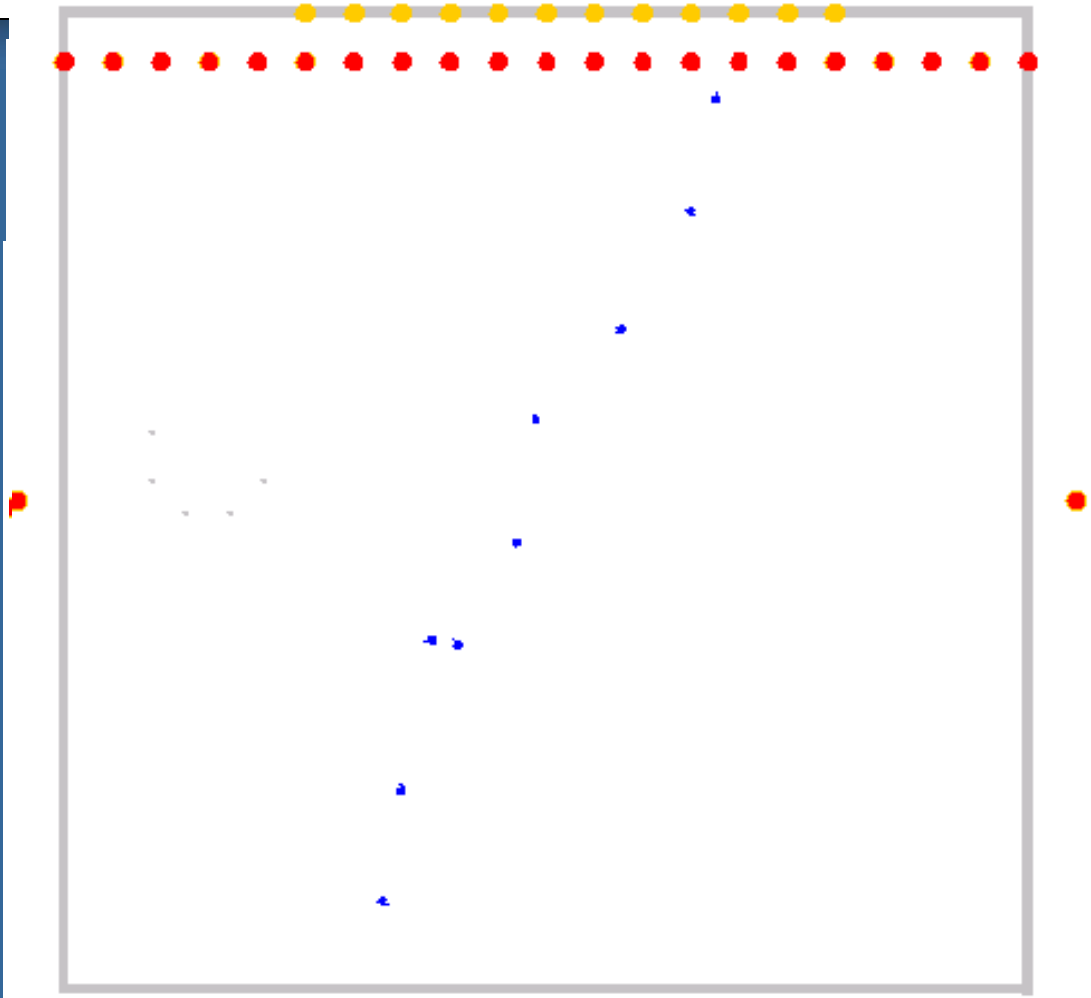
Algorithm comparison, no obstacles



Algorithm comparison, with obstacles

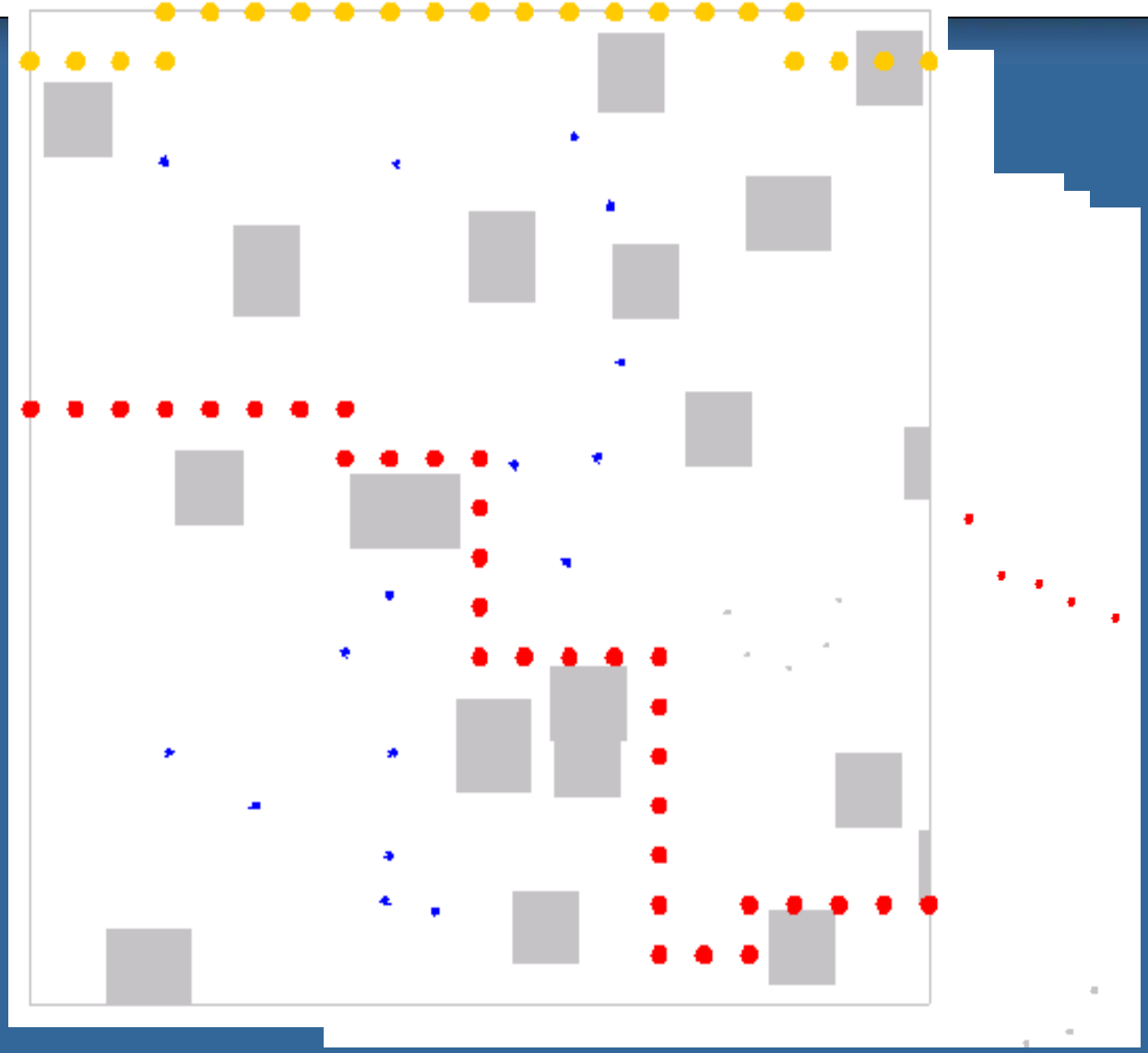


Some Pics



Free Detection Probability = 1-Exposure = 0.3432
Obstructed Detection Probability = 1-Exposure = 0.9949
Free Avg Detection Probability = 1-Exposure = 0.0751
Obstructed Avg Detection Probability = 1-Exposure = 0.0824

Some Pics



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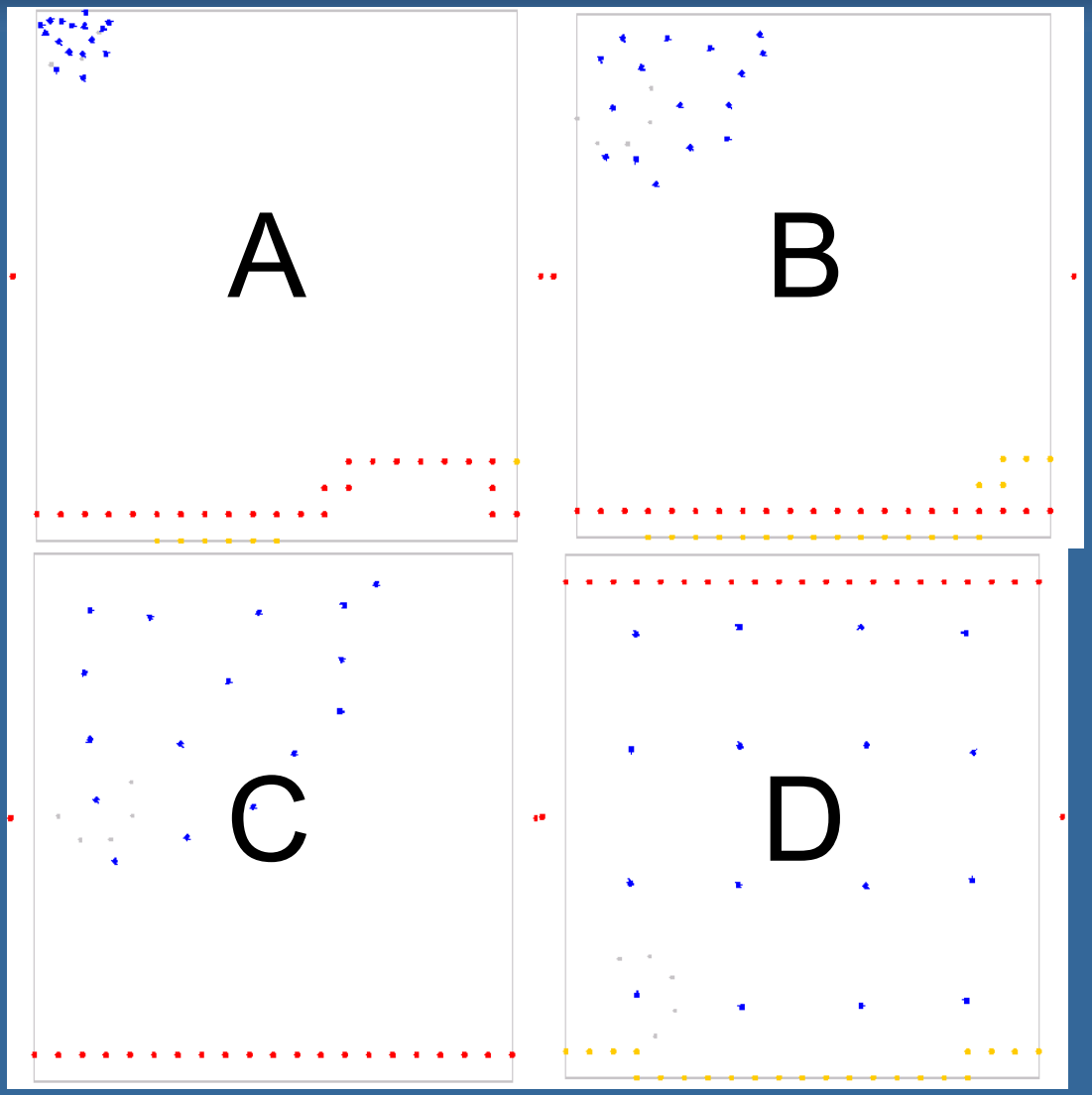

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