An Incremental Self-Deployment Algorithm For Mobile Sensor Networks

Presented by Yifan Tang

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About this Paper

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The Problem

- How to perform deployment in an unknown environment
  - How to maximize the network coverage
    - In this paper: the blanket coverage
  - How to determine the location of each node
    - In this paper: how to maintain the line-of-sight relationships among the nodes/robots, i.e. that each node can be seen by at least one other node (the visibility constraint)

The Algorithm Overview(1)

- Key assumptions
  - Homogeneous nodes
  - Static environment
  - Model-free
  - Full communication
  - Localization

The Algorithm Overview(2)

- Four phases
  - Initialization
    - Nodes are assigned one of three states: waiting, active or deployed
  - Selection
    - To form a common map and to select the deployment location for the next node
  - Assignment
    - Assign nodes to their goal points: waiting→active
  - Execution
    - Deploy nodes to their goal points: active→deployed

The Selection Phase(1)

- Occupancy grid
  - Sensor data from the deployed nodes are combined to form an occupancy grid
  - Three states: free, occupied or unknown
  - Visibility constraint is satisfied by selecting goals that lie on the free grids
- Configuration grid
  - Three states: free, occupied or unknown
  - Grid growing: A cell is free(or occupied) if all the occupancy grids cells within d (d>=node's radius) are free (or occupied)
- Reachability grid
  - Two states: reachable or unreachable
  - Flooding-fill algorithm

The Selection Phase(2)

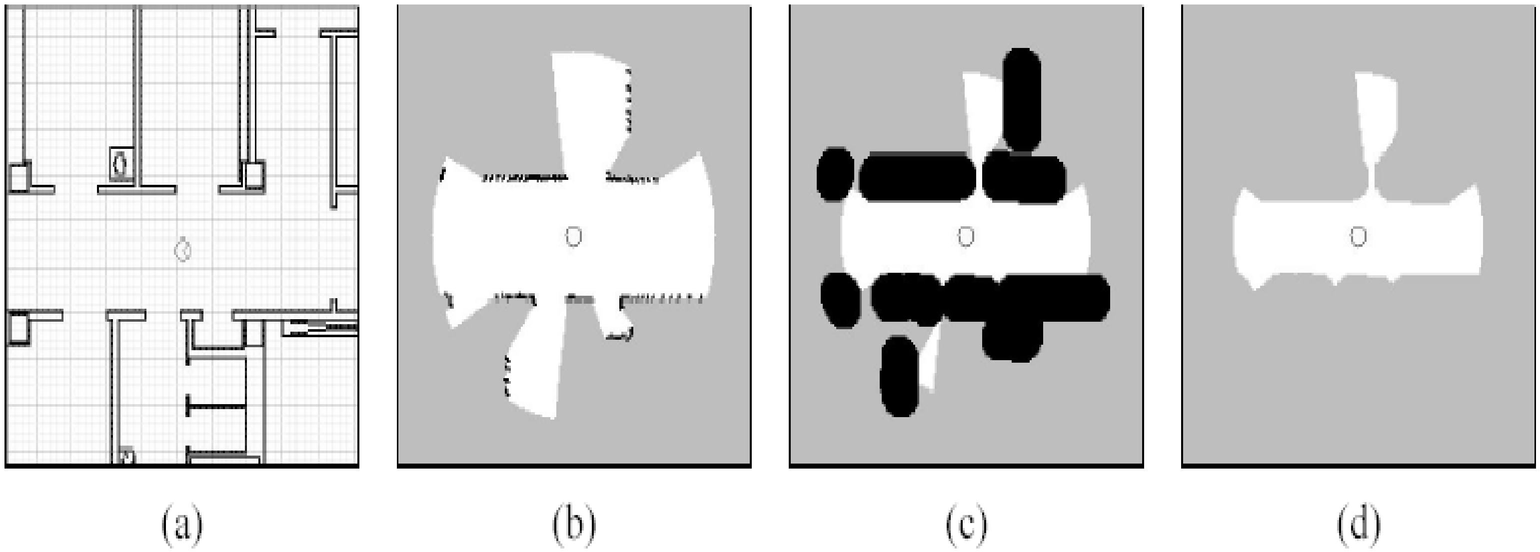
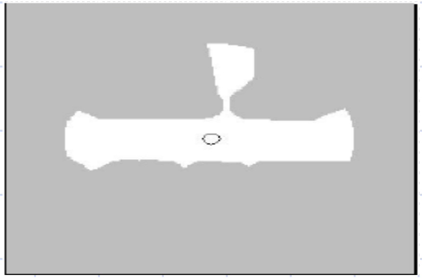


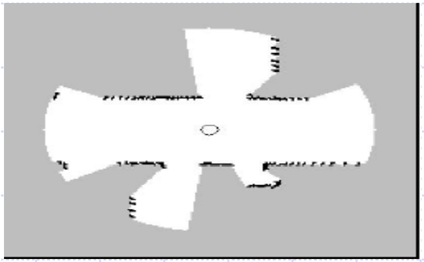
Figure 1. (a) A fragment of the simulated environment containing a single node. (b) Occupancy grid: black cells are occupied, white cells are free, gray cells are unknown. (c) Configuration grid: black cells are occupied, white cells are free, gray cells are unknown. (d) Reachability grid: white cells are reachable, gray cells are unreachable.

The Selection Phase(3)

- The heuristics



  - Stochastic policies
    - P1: randomly select a location in reachable space
    - P2: randomly select a location on the reachable/unreachable boundary



  - Deterministic policies
    - P3: select the reachable space location that maximizes the coverage (cover the greatest area of unknown space in the occupancy grid)
    - P4: select the reachable/unreachable boundary location that maximize the coverage

The Assignment Phase(1)

- Construct a graph
  - Vertex: Network node
  - Edge: reachability between two nodes
  - Length of the edge: distance between the nodes
  - The goal is represented by a dummy vertex

- Find the shortest path from a waiting node to the goal

- Mark every node on the shortest path as active, and assign each node the goal of reaching the position currently occupied by the next node along the path

The Assignment Phase(2)

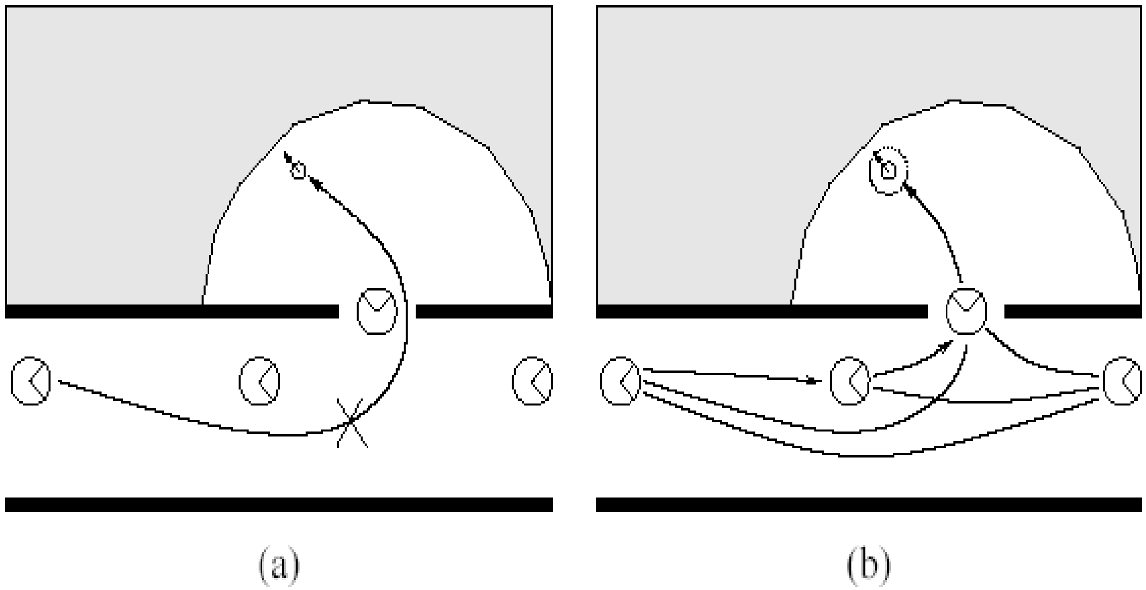


Figure 2. (a) A typical obstruction problem, with a waiting node unable to reach its deployment location. The gray area indicates the region of space that is not yet covered by the network. (b) The obstruction is resolved by re-assigning the deployment location to another node.

The Execution Phase

- Active nodes are deployed to their goal location using sequential execution
- Only one node in motion at any given time, hence no possibility for interference between nodes
- Disadvantage: slow
- Might consider concurrent execution

The Metrics

- Network coverage
  - Coverage=number of free cells in the occupancy grid*area covered by each cell
  - The coverage factor: the average area covered by each node
- Time
  - Computation time:
    - The selection phase and the assignment phase
  - Execution time:
    - The execution phase

The Result

- The coverage factors for policies P3 and P4 are between 70% and 85% of the value of a model-based greedy algorithm
- P3 and P4 provide almost identical coverage, while P3 is much more time intensive, hence should use P4 in preference to P3
- The algorithm scales as a polynomial function of the number of deployed nodes, and is in the worst case of order n^2

The Strength and the Weakness

- Strength
  - No model needed
  - Can be used for unknown environment
  - Can produce coverage results close to a greedy model-based algorithm
- Weakness
  - Rely on an idealized localization system
  - Incremental rather than adaptive algorithm: no adaptation possible by changing signal strength of the communication network

The Contribution of this Paper

- Maps are built entirely from live, not stored, sensory data
- Not only concerned with sensor range, the deployment algorithm must satisfy an additional constraint: the line-of-sight visibility
- Controlled deployment rather than random diffusion
- Extensive series of simulation experiments to validate the algorithm and illuminate its empirical properties

Thank you!

- Questions?