Motion Planning for Finding Evasive Targets in a Cluttered Environment

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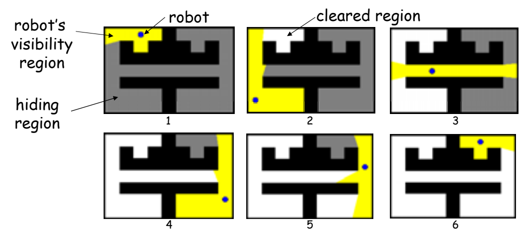
Map Building

Example



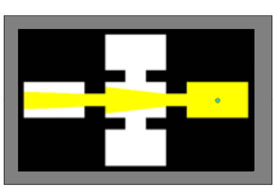
Problem

- A target is hiding in an environment cluttered with obstacles
- A robot or multiple robots with vision sensor must find the target
- Compute a motion strategy with minimal number of robot(s)

Assumptions

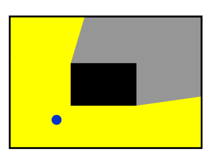
- Target is unpredictable and can move arbitrarily fast
- Environment is polygonal
- Both the target and robots are modeled as points
- A robot finds the target when the straight line joining them intersects no obstacles (omni-directional vision)

Animated Target-Finding Strategy

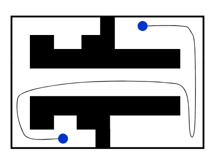


Does a solution always exist for a single robot?

No !

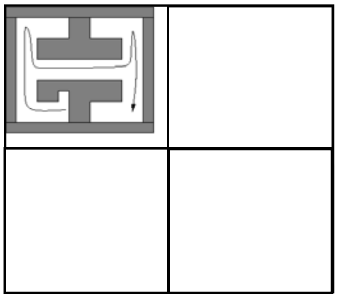


Easy to test:
"Hole" in the workspace



Hard to test:
No "hole" in the workspace

Effect of Geometry on the Number of Robots



Two robots are needed

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Effect of Number n of Edges

Minimal number of robots **N = Θ(log n)**

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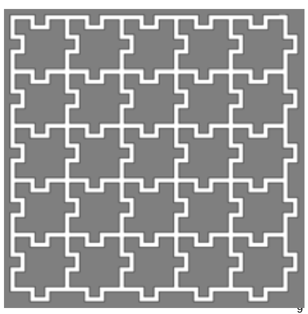
Effect of Number h of Holes

$N=\Theta(\sqrt{h})$



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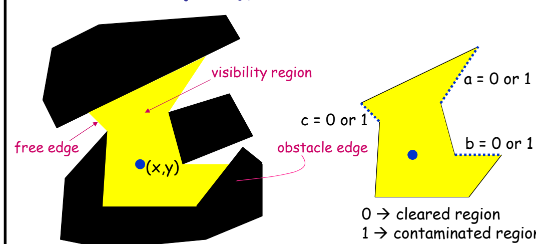
Information State



- Example of an information state = (x,y,a=1,b=1,c=0)
- An **initial state** is of the form (x,y,a=1,b=1,...,u=1)
- A **goal state** is any state of the form (x,y,a=0,b=0,..., u=0)

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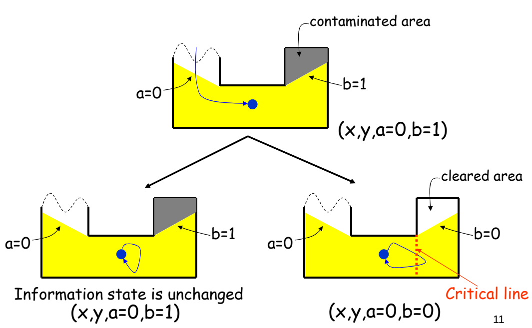
Critical Line



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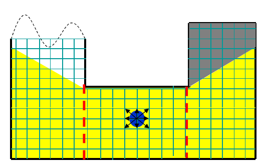
Grid-Based Discretization



- Ignores critical lines → Visits many "equivalent" states
- Many information states per grid point
- Potentially very inefficient

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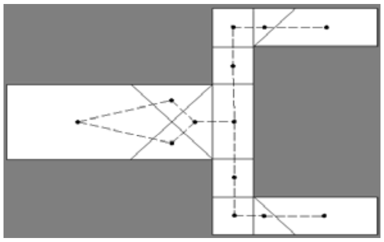
Discretization into Conservative Cells



In each conservative cell, the "topology" of the visibility region remains constant, i.e., the robot keeps seeing the same obstacle edges

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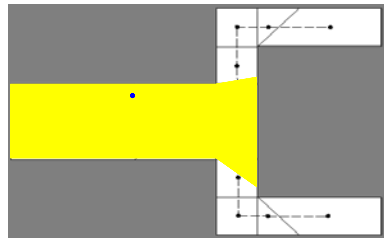
Discretization into Conservative Cells



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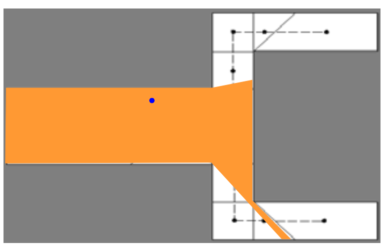
Discretization into Conservative Cells



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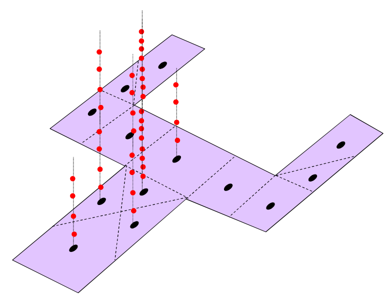

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Search Graph

- {Nodes} = {Conservative Cells} x {Information States}
- Node (**c**,**i**) is connected to (c',**i'**) iff:
  - Cells **c** and **c'** share an edge (i.e., are adjacent)
  - Moving from **c**, with state **i**, into **c'** yields state **i'**
- Initial node (**c**,**i**) is such that:
  - **c** is the cell where the robot is initially located
  - **i** = (1, 1, …, 1)
- Goal node is any node where the information state is (0, 0, …, 0)
- Size is exponential in the number of edges

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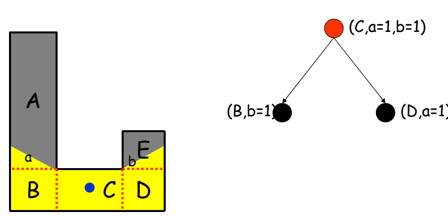
Example



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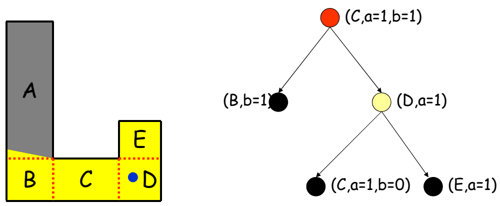
Example



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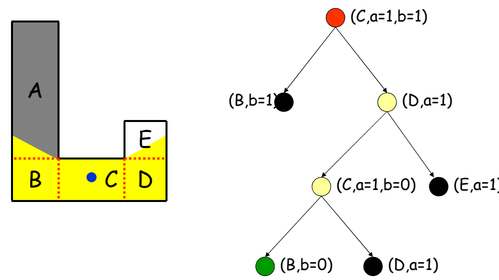
Example



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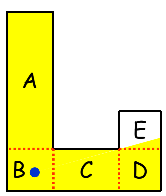
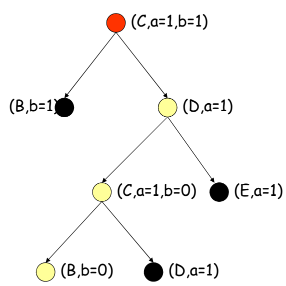
Example





Much smaller search tree than
with grid-based discretization !

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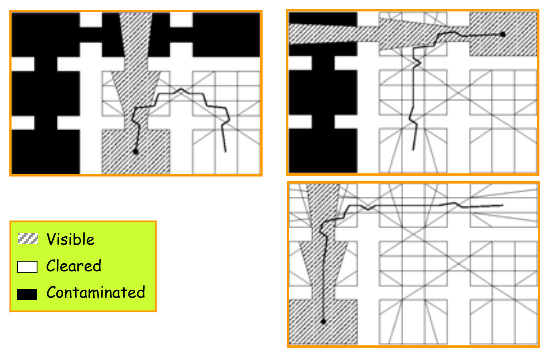
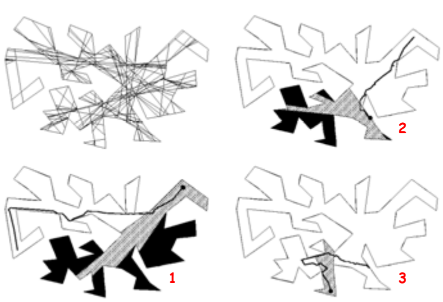
Example of Target-Finding Strategy



More Complex Example



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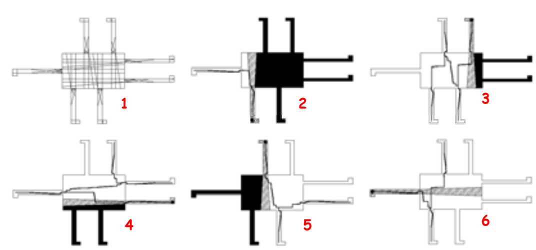
Example with Recontaminations



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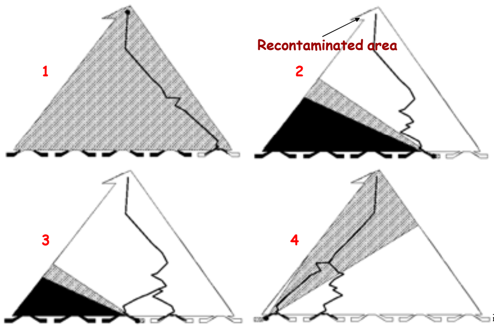
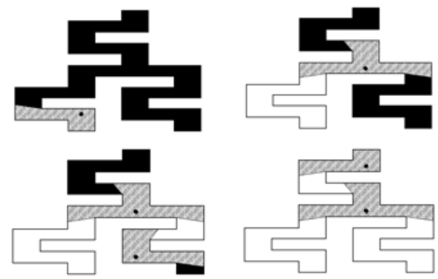
Example with Linear Number of Recontaminations

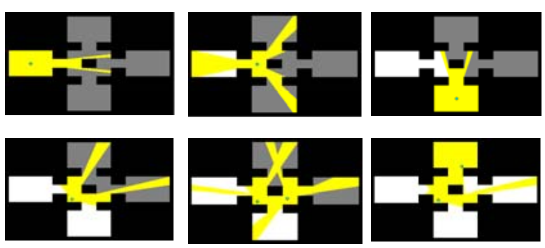


Example with Two Robots

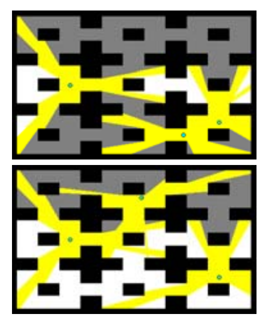
(Greedy algorithm)



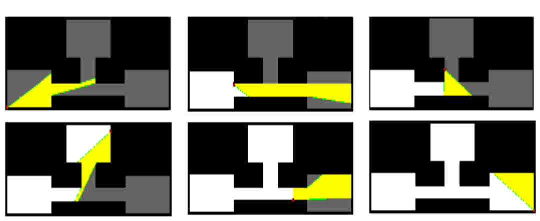
Example with Two Robots



Example with Three Robots



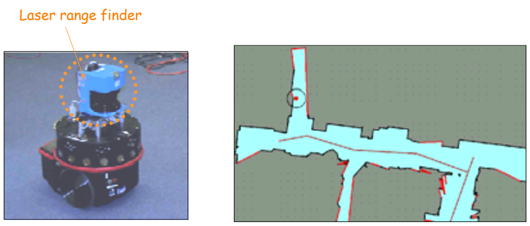
Robot with Cone of Vision



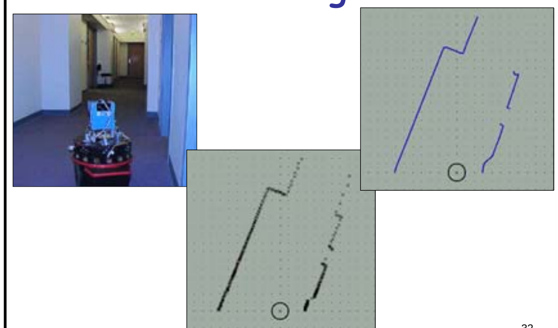
Other Topics

- Dimensioned targets and robots, three-dimensional environments
- Non-guaranteed strategies
- Concurrent model construction and target finding
- Planning the escape strategy of the target

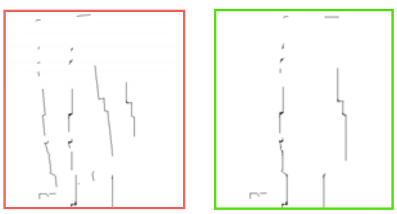
Map Building



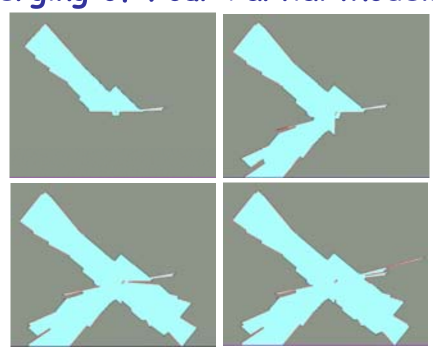
Sensing



Alignment of Contours



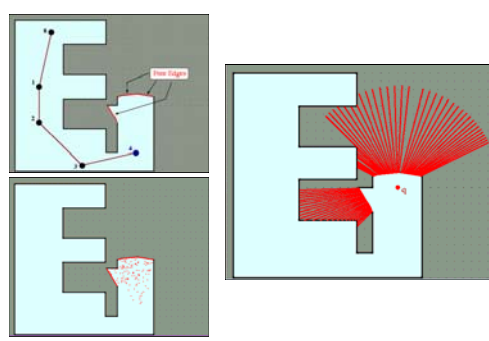
Merging of Four Partial Models



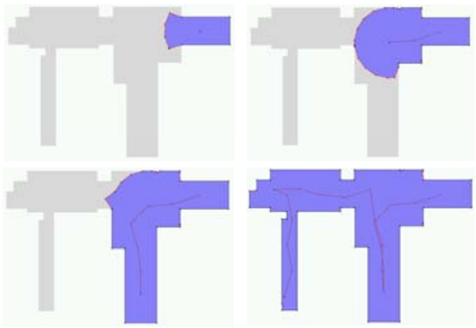
Dealing with Uncertainty

1. Simultaneous Localization and Mapping (SLAM)
2. Next-Best View (NBV) Planning

Next-Best View Planning



NBV Example 1



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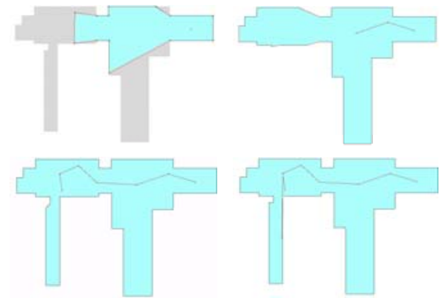
NBV Example 2



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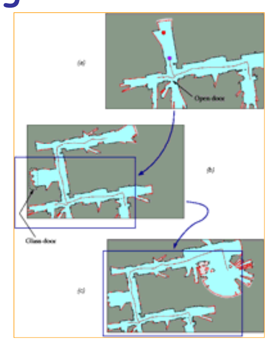
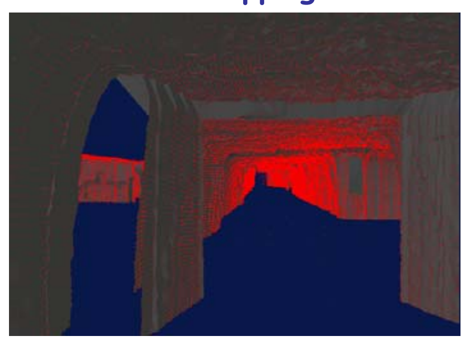
Map Building with NBV



3D Mapping



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