

Visibility-based probabilistic roadmaps for motion planning

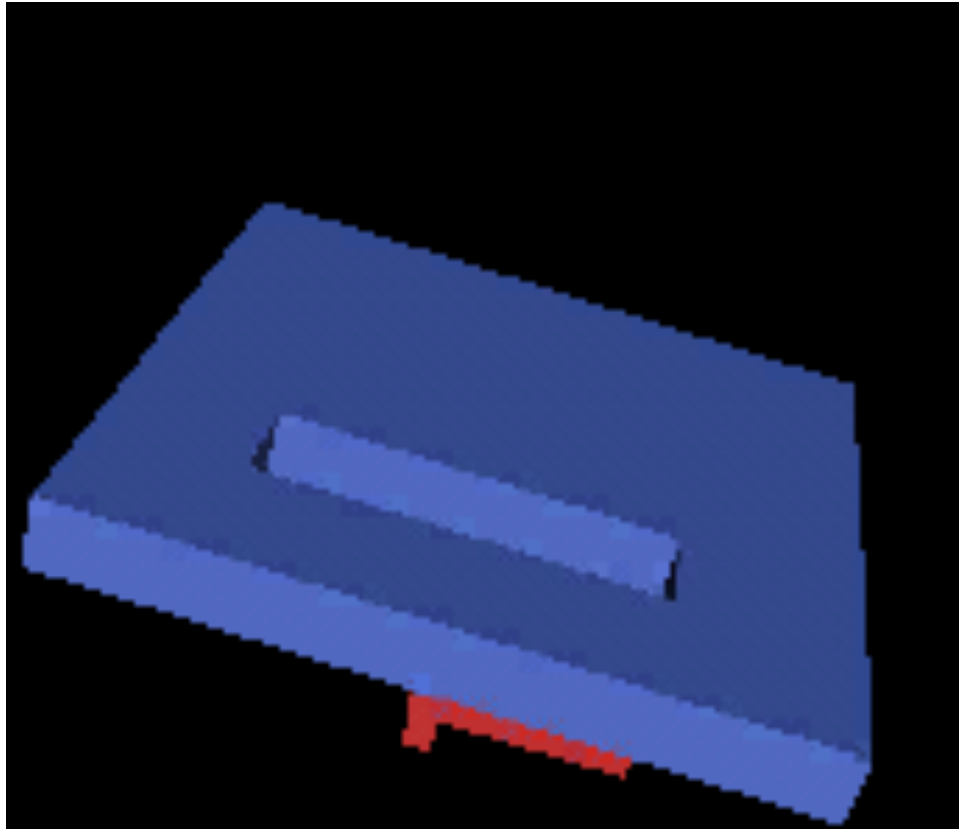
T.Simeon, J.-P. Laumond and C. Nissoux
Advanced Robotics, 2000

Presented by Stefanos Nikolaidis

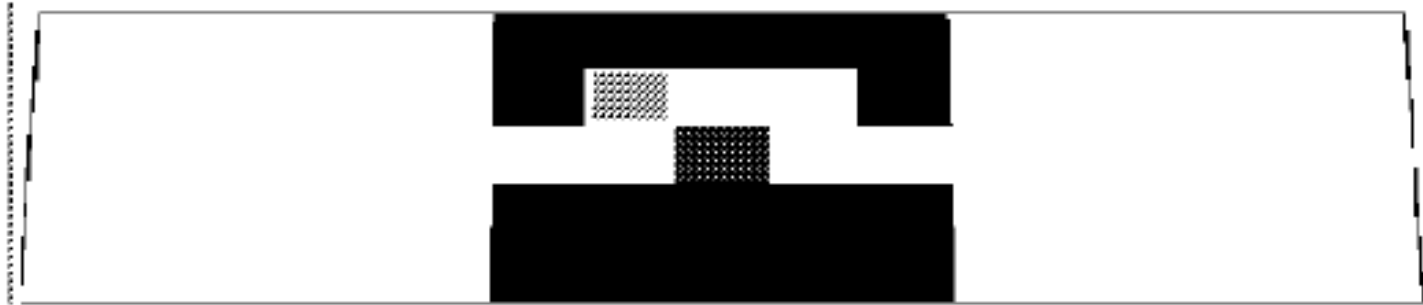
Problem

Improve performance of multi-query
sampling-based motion-planning algorithms

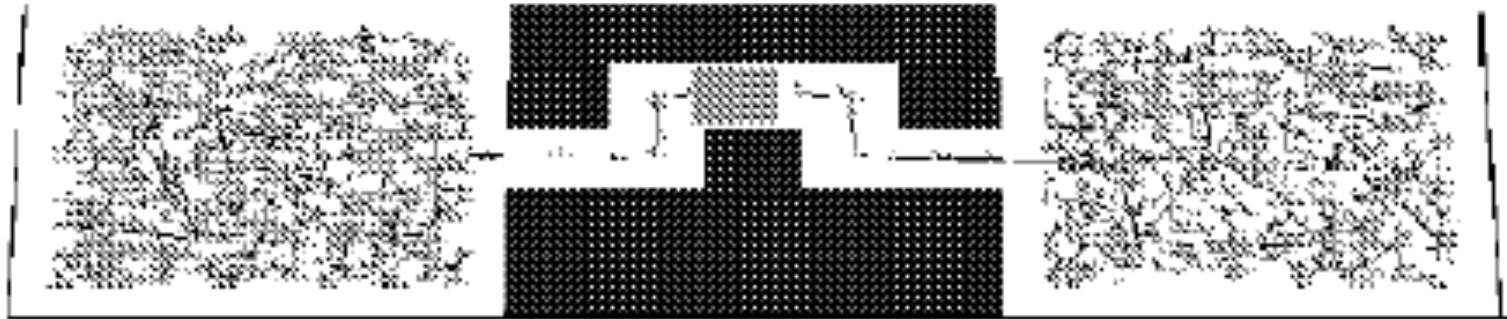
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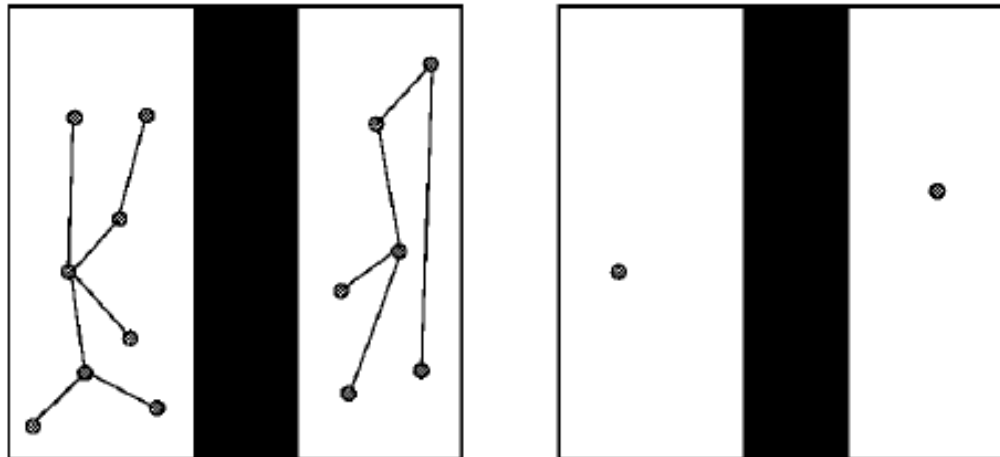


Previous Work

- Connection of subgraphs through reflection onto C-space obstacles [Hosch et al. 1994]
 - Precursor to PRM
- Basic-PRM [Kavraki et al. 1996]
 - Dense roadmaps required for connectivity
- OBPRM [N. Amato et al. 1998]
 - Greater density of nodes near the boundary of the free space
- Dilation of Free-Space [Hsu et al. 1998]
 - Requires complex geometric operations

Key Insight

Use notion of “visibility” to cover the free space, while keeping the size of the roadmap small

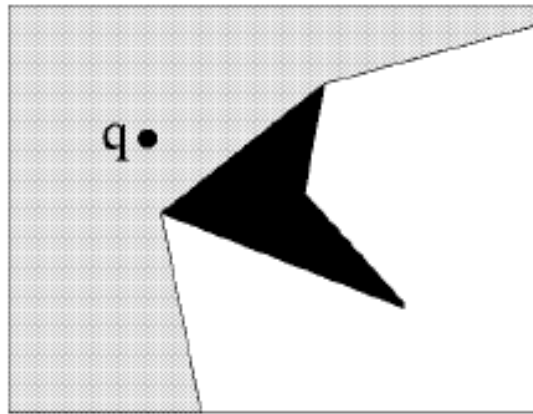


Definitions

$L(q, q')$: A feasible path between configurations q and q' , in the absence of any obstacle

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$$Vis_{\mathcal{L}}(q) = \{q' \in CS_{\text{free}} \text{ such that } \mathcal{L}(q, q') \subset CS_{\text{free}}\}$$



Configuration q : Guard of $Vis_{\mathcal{L}}(q)$

Algorithm Visib-PRM

$Guard \leftarrow \emptyset; Connection \leftarrow \emptyset; ntry \leftarrow 0$

While ($ntry < M$)

Select a random free configuration q

$g_{vis} \leftarrow \emptyset; G_{vis} \leftarrow \emptyset$

For all components G_i of $Guard$ **do**

$found \leftarrow FALSE$

For all nodes g of G_i **do**

If (q belongs to $Vis(g)$) **then**

$found \leftarrow TRUE$

If ($g_{vis} = \emptyset$) **then** $g_{vis} \leftarrow g; G_{vis} \leftarrow G_i$

Else /* q is a connection node */

Add q to $Connection$

Create edges (q, g) and (q, g_{vis})

Merge components G_{vis} and G_i ;

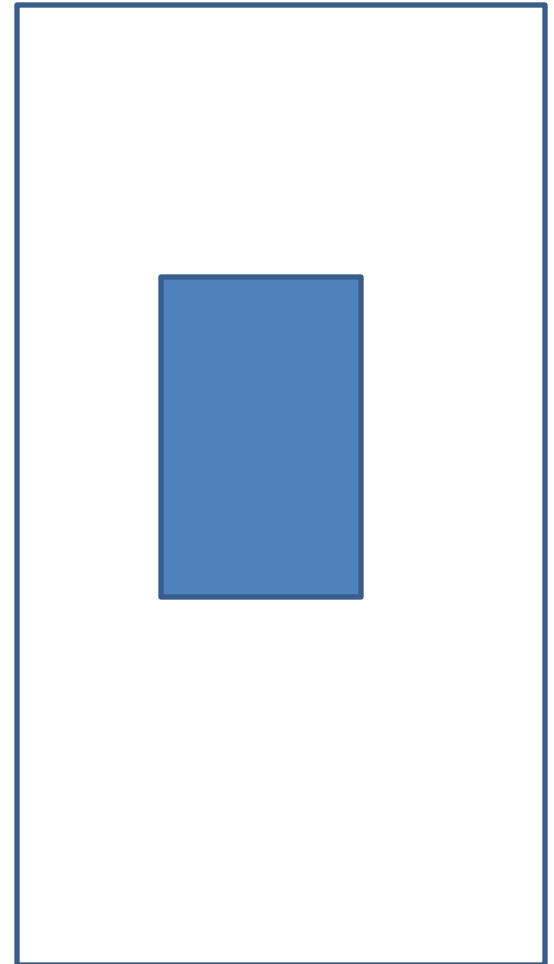
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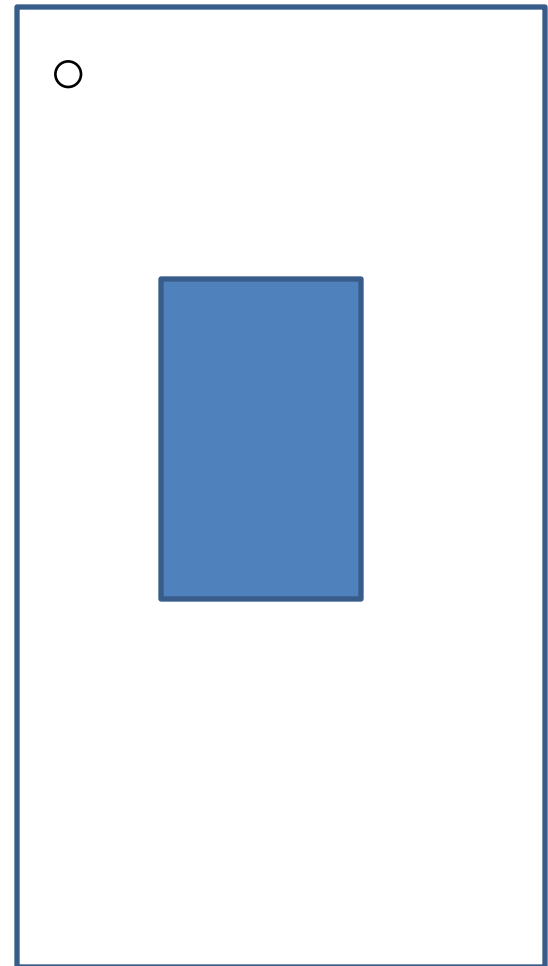
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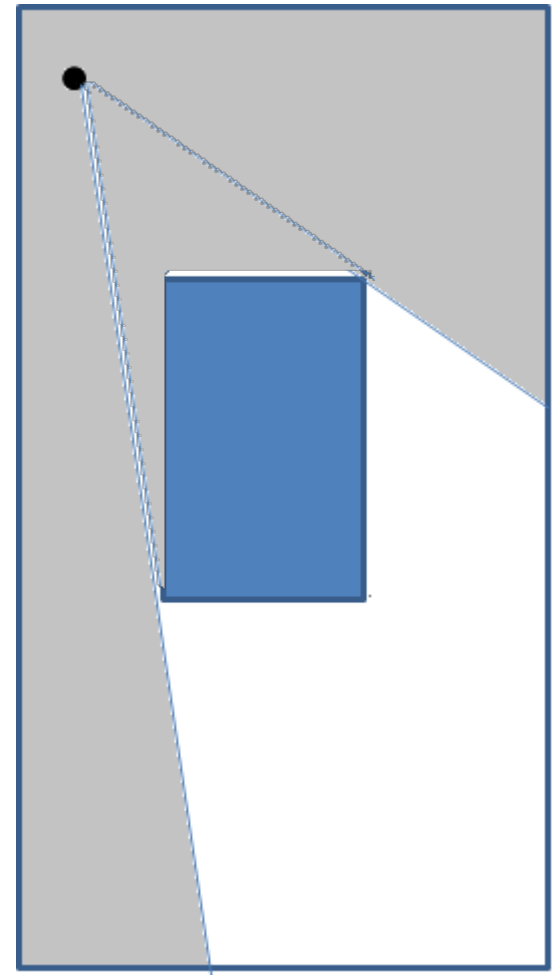
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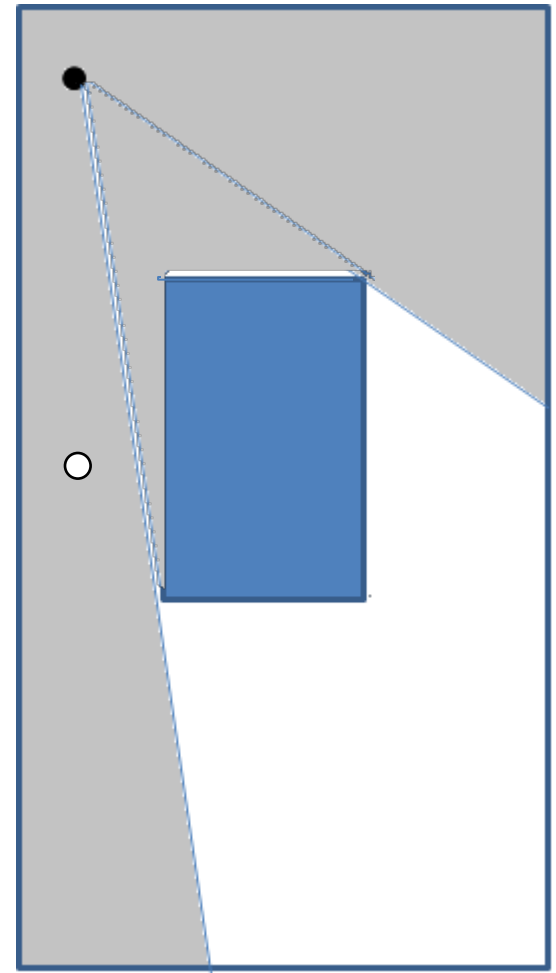
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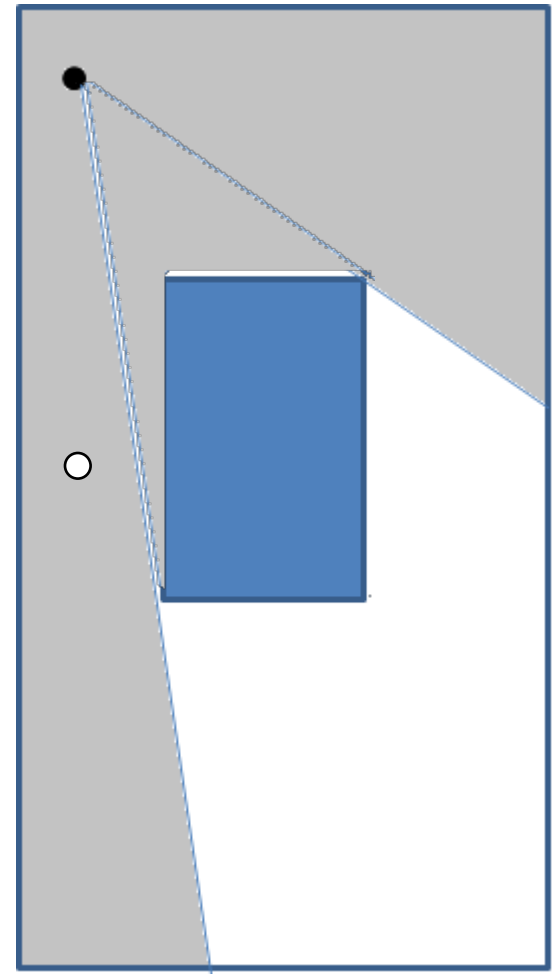
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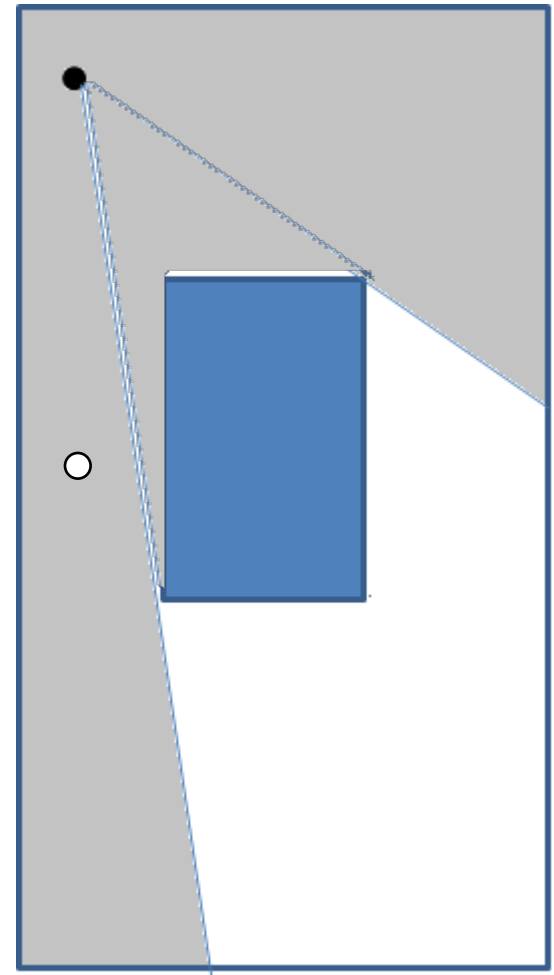
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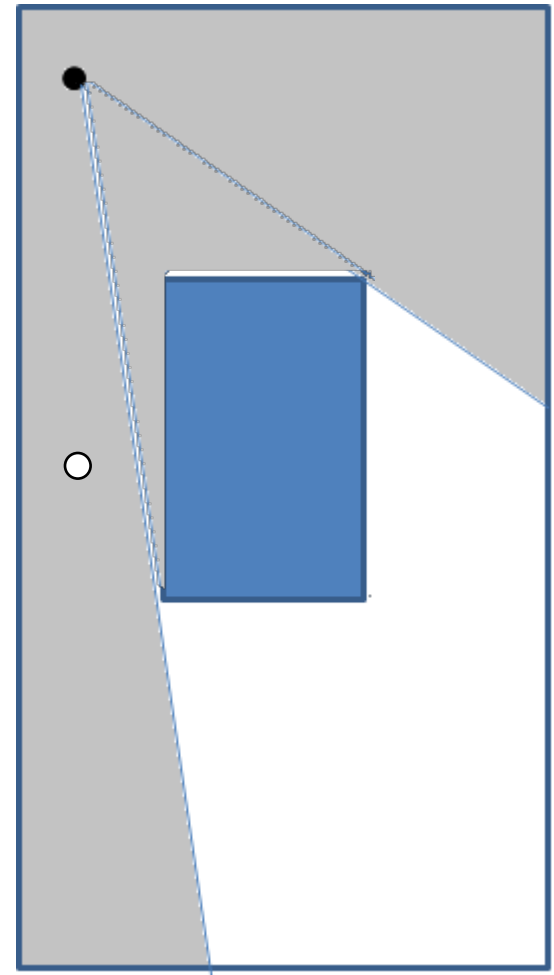
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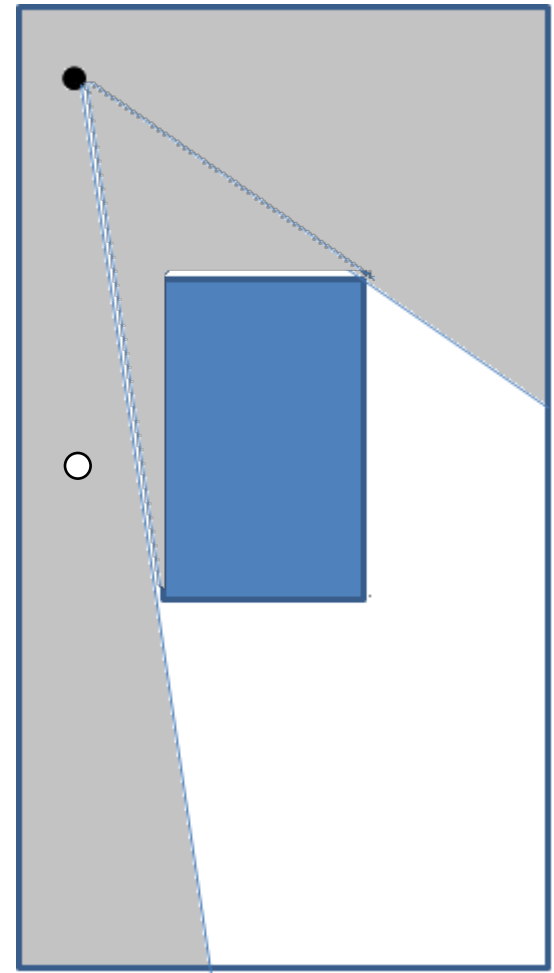
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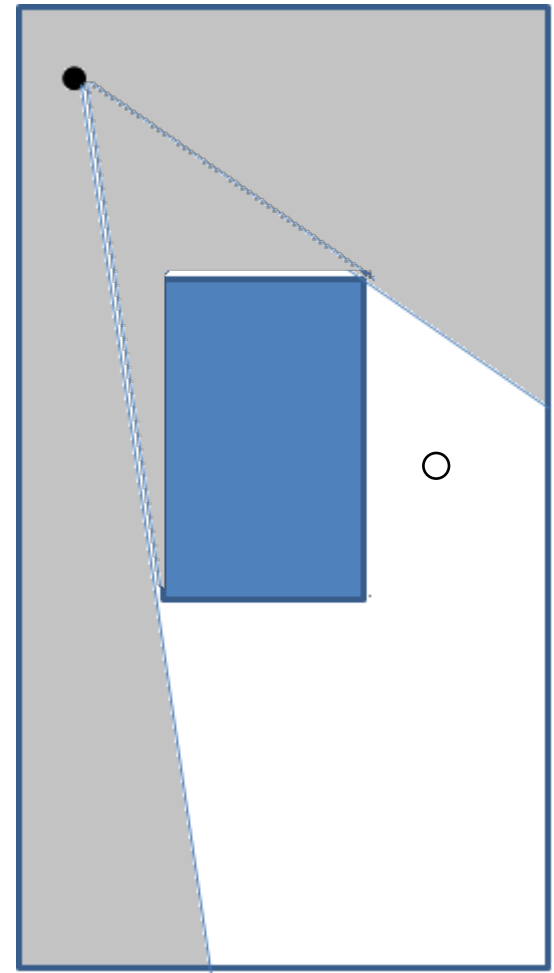
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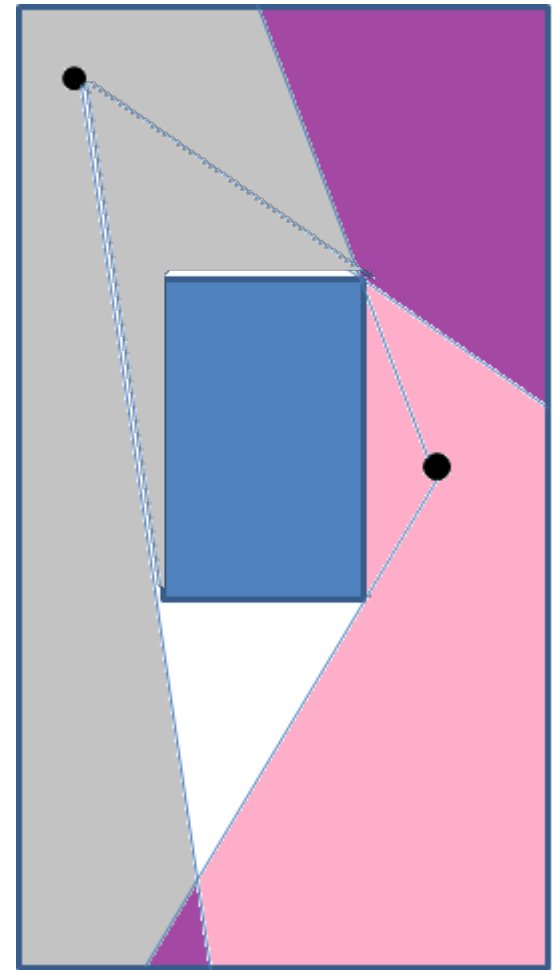
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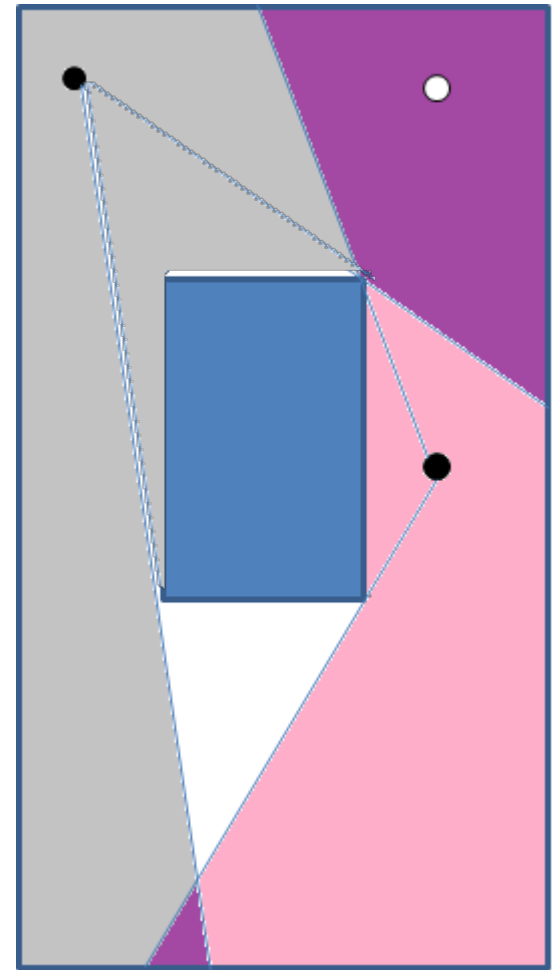
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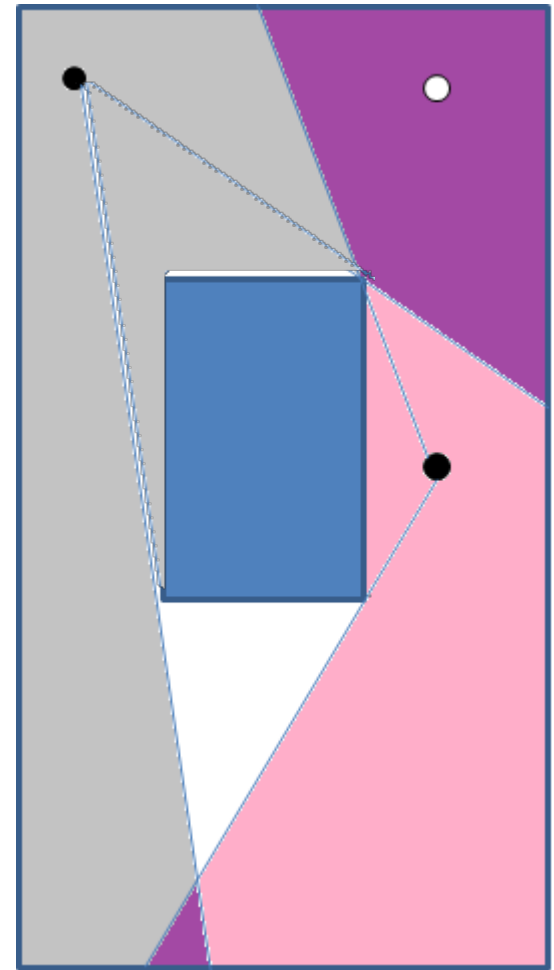
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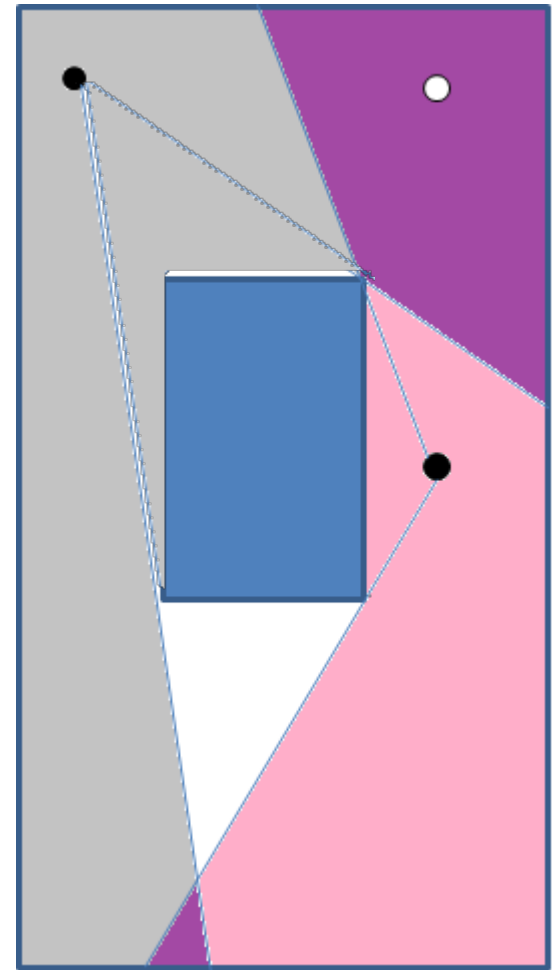
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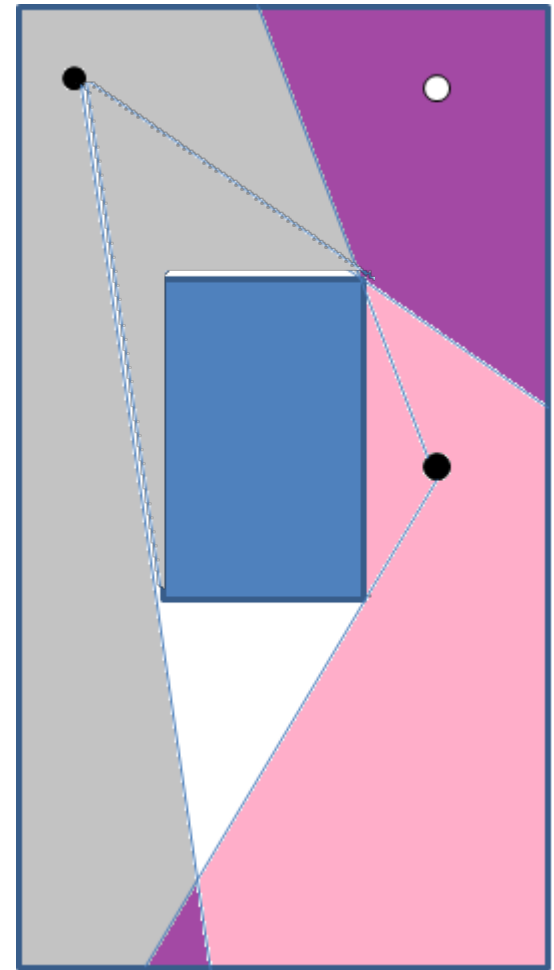
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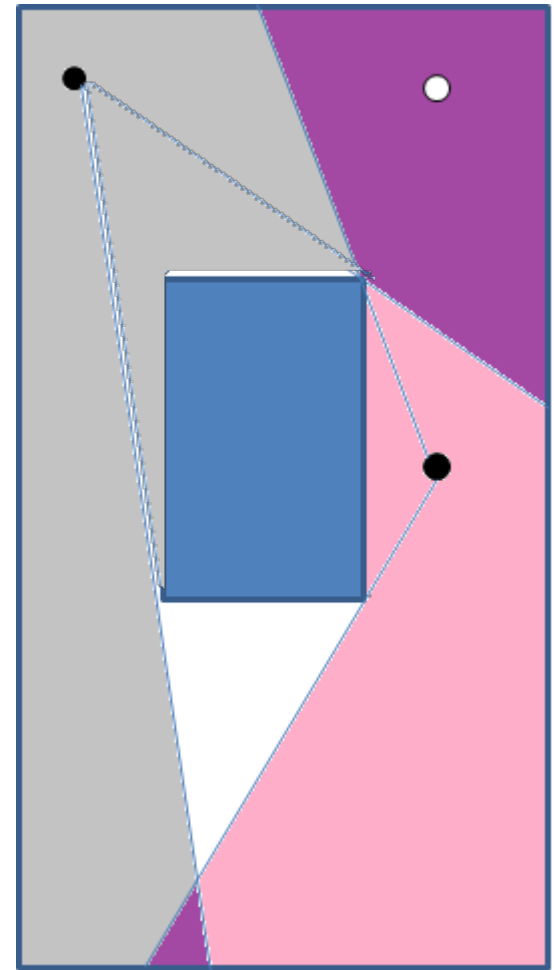
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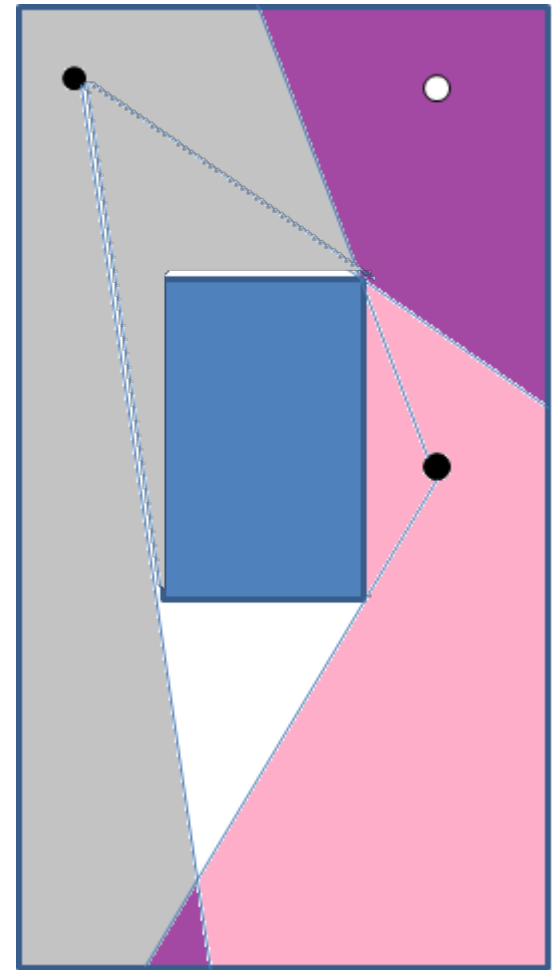
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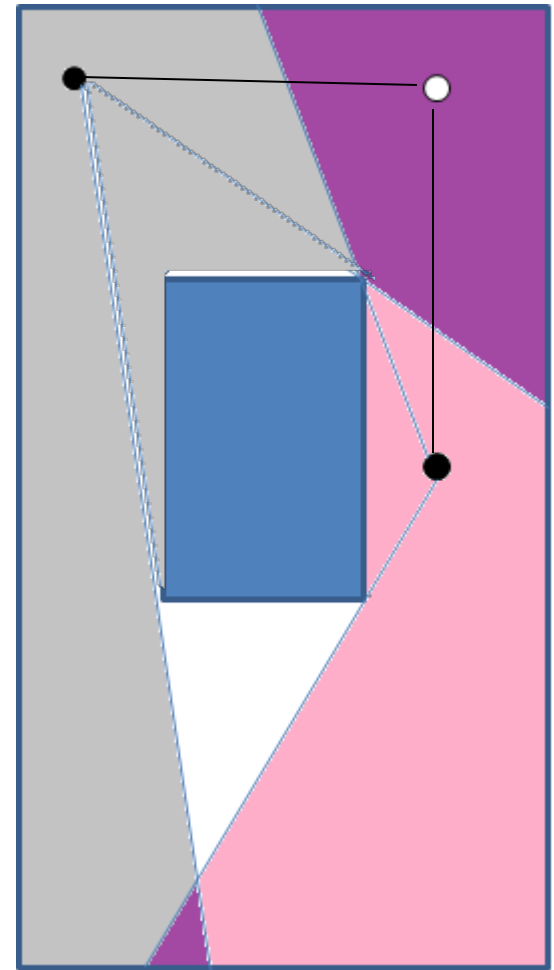
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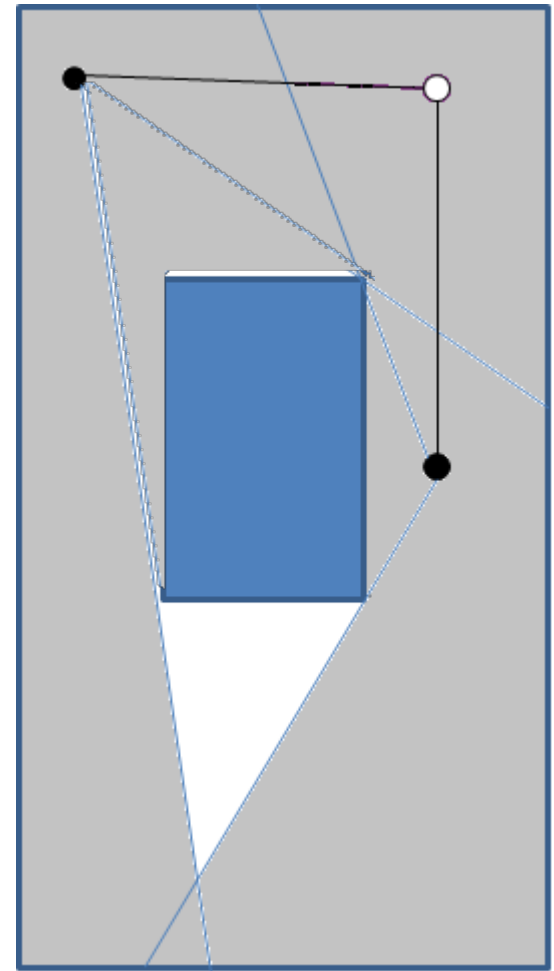
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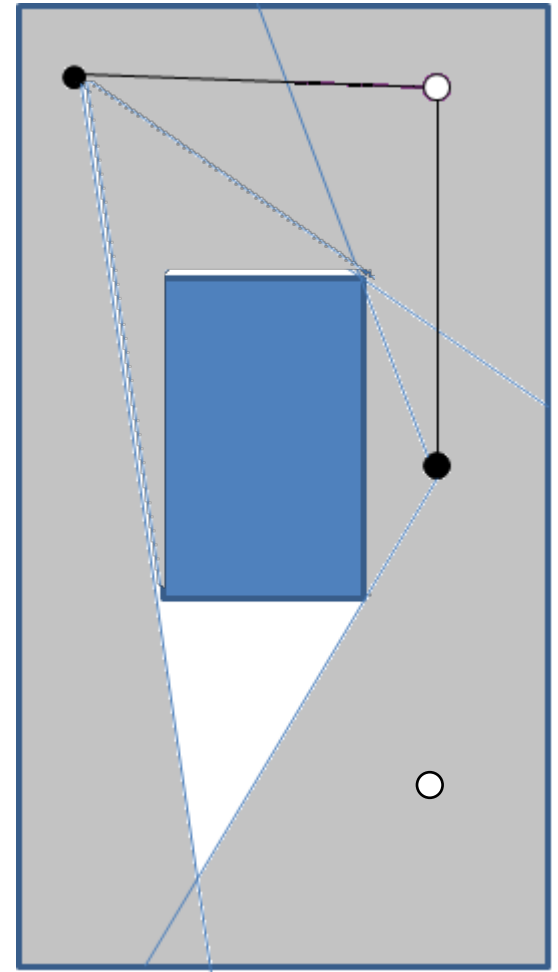
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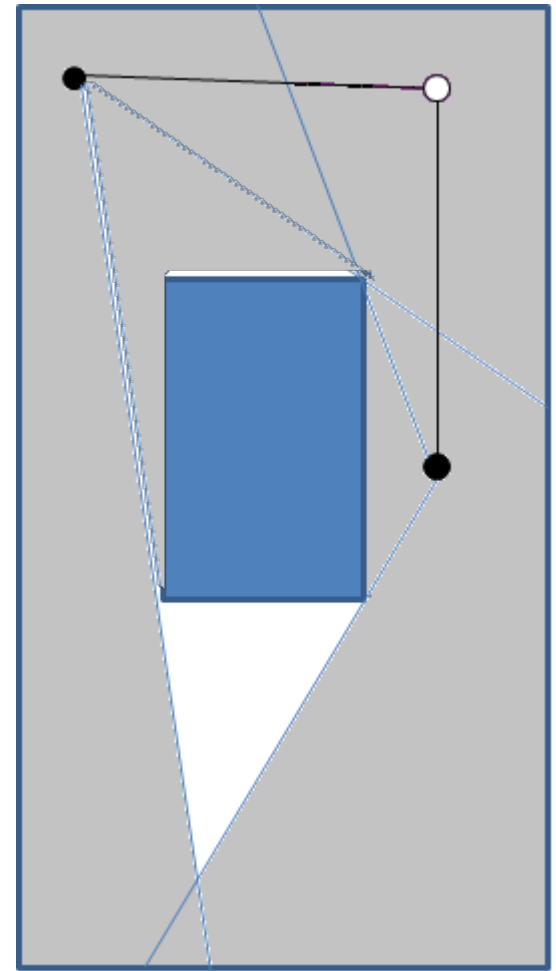
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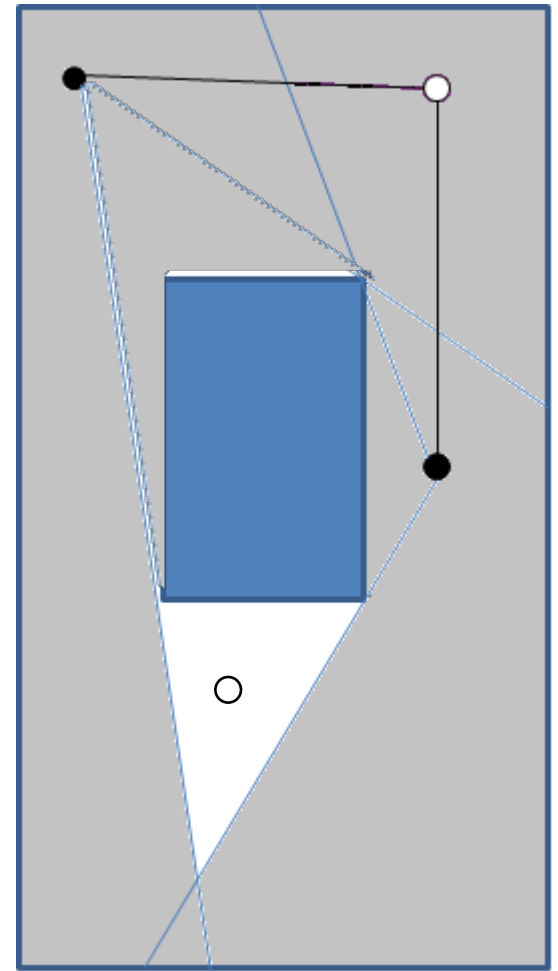
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 Add $\{q\}$ to $Guard$; $ntry \leftarrow 0$

Else $ntry \leftarrow ntry + 1$

End



Algorithm Visib-PRM

$Guard \leftarrow \emptyset; Connection \leftarrow \emptyset; ntry \leftarrow 0$

While ($ntry < M$)

Select a random free configuration q

$g_{vis} \leftarrow \emptyset; G_{vis} \leftarrow \emptyset$

For all components G_i of $Guard$ **do**

$found \leftarrow FALSE$

For all nodes g of G_i **do**

If (q belongs to $Vis(g)$) **then**

$found \leftarrow TRUE$

If ($g_{vis} = \emptyset$) **then** $g_{vis} \leftarrow g; G_{vis} \leftarrow G_i$

Else /* q is a connection node */

Add q to $Connection$

Create edges (q, g) and (q, g_{vis})

Merge components G_{vis} and G_i ;

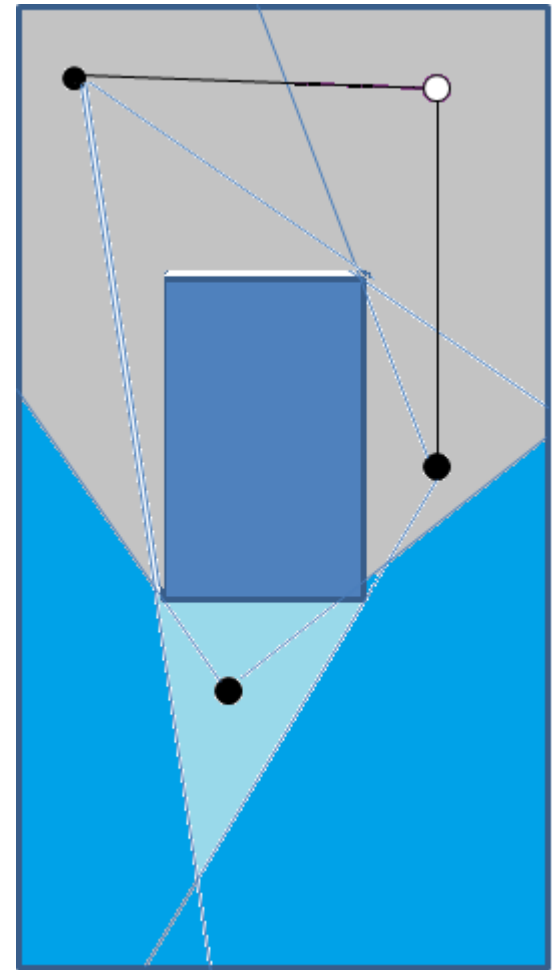
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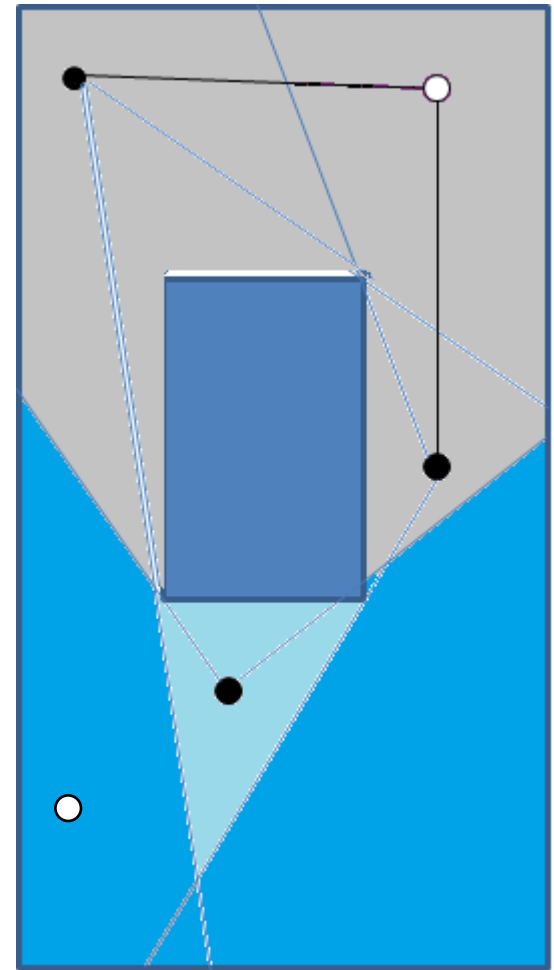
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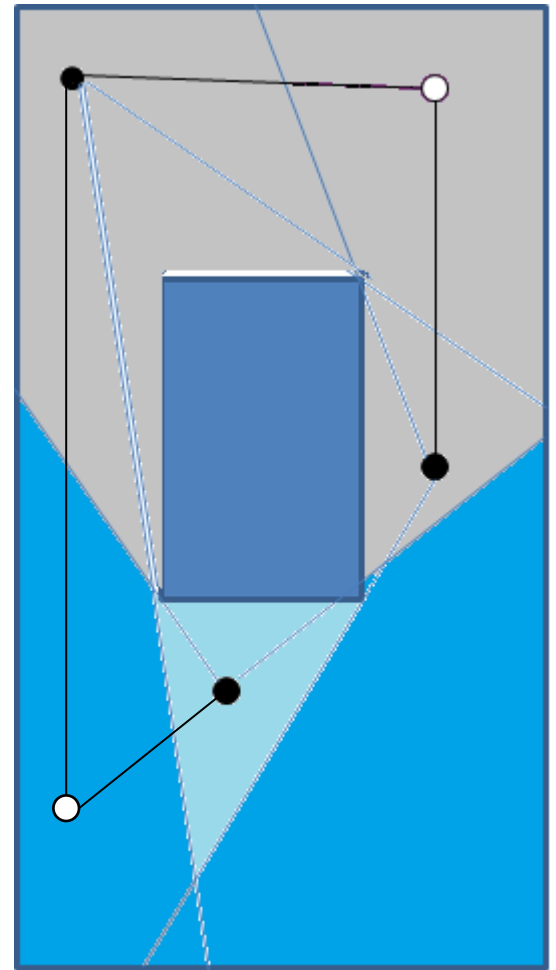
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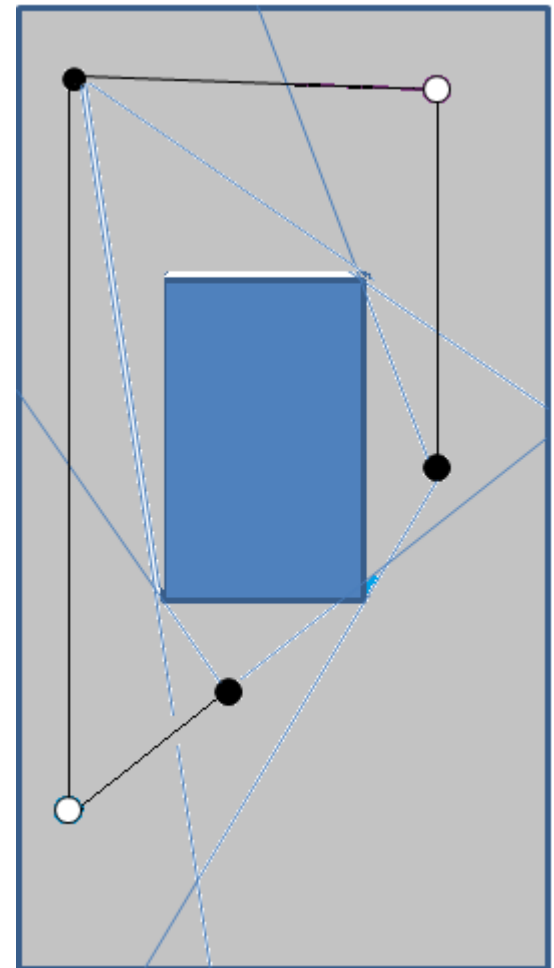
until $found = TRUE$

If ($g_{vis} = \emptyset$) **then** /* q is a guard node */

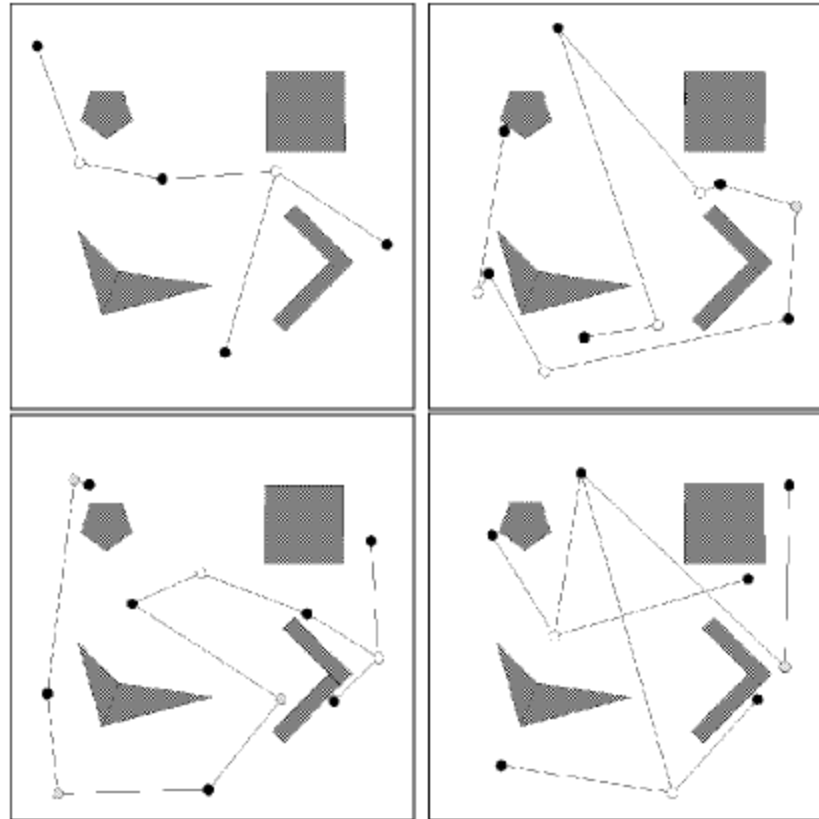
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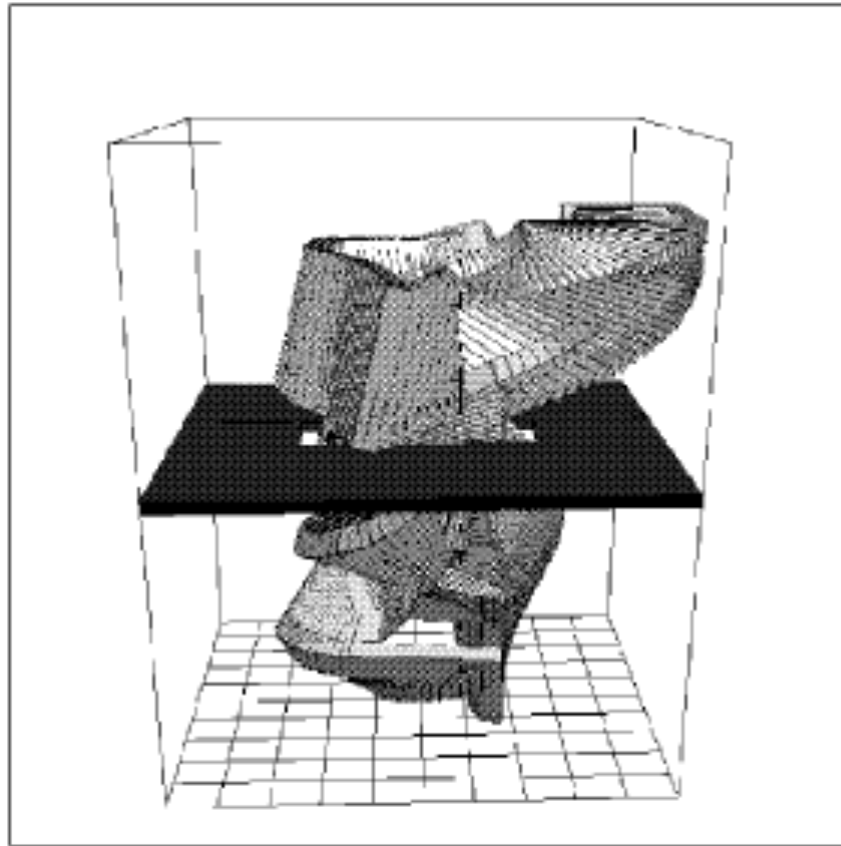
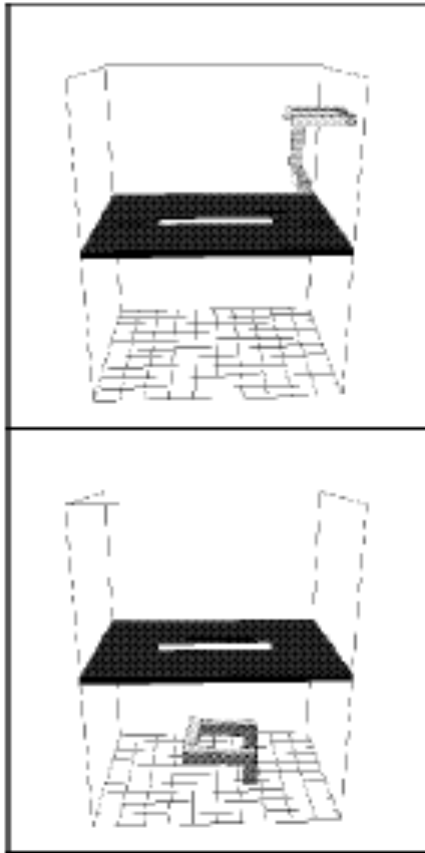
End



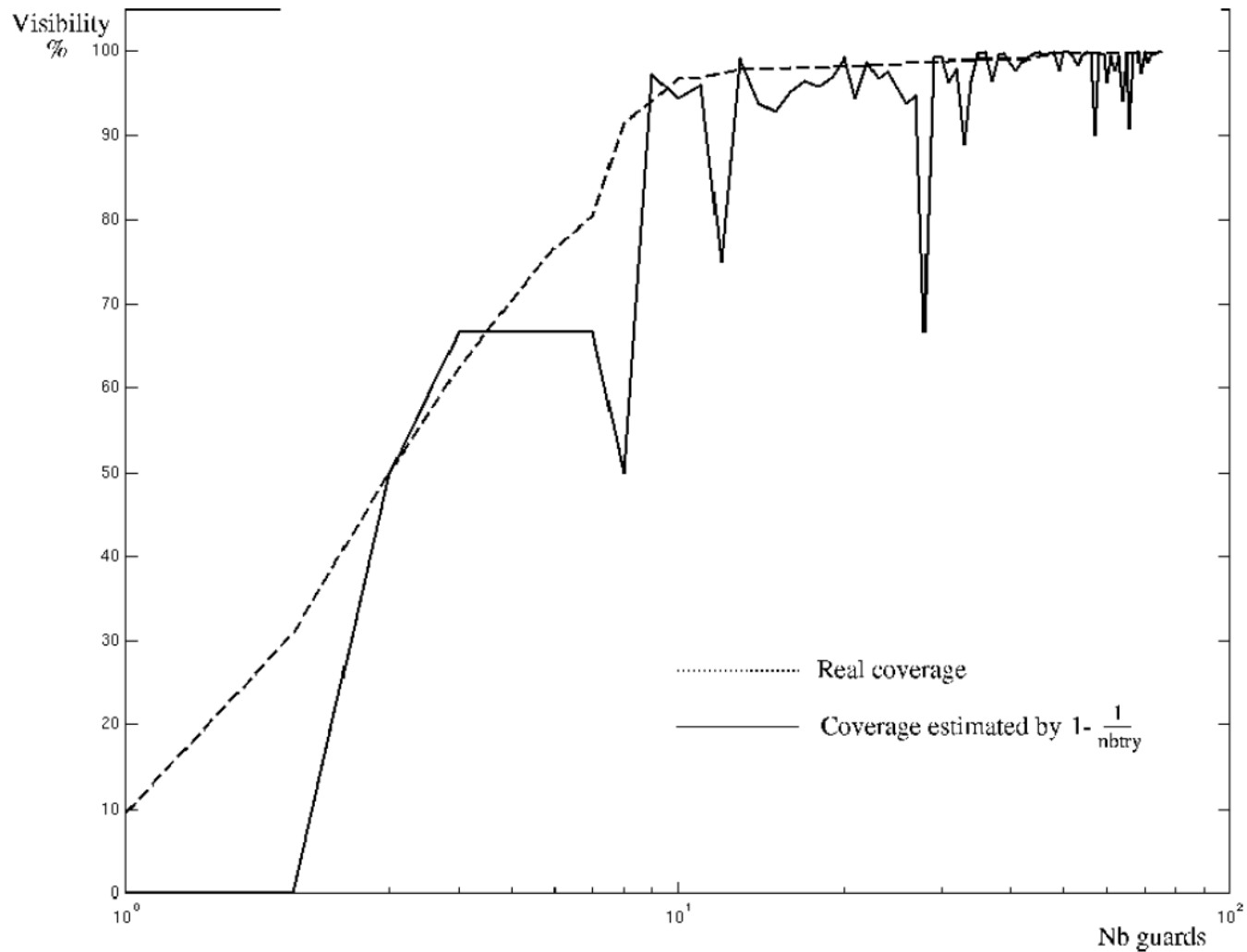
Results



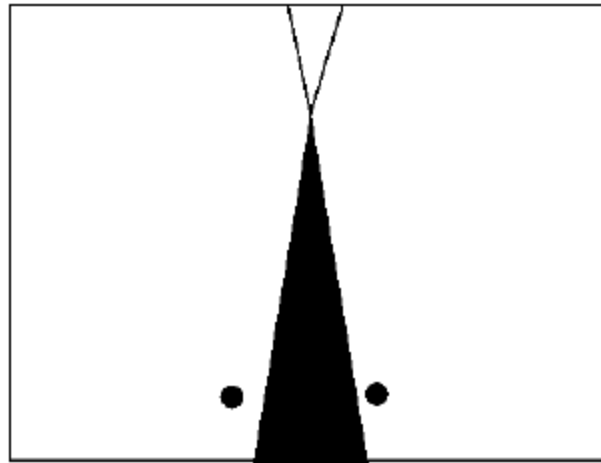
Results



Termination Criterion



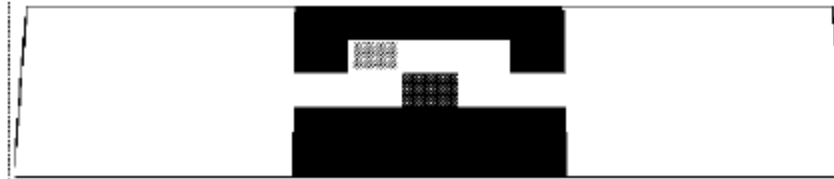
Pathologic Case



Comparison to Basic-PRM

- More expensive to generate nodes
- Cheaper to connect each node to the roadmap

Comparison to Basic-PRM



$\frac{1}{\epsilon}$	Basic-PRM		Visib-PRM		<i>gain</i> $\frac{l_b}{l_v}$
	$l_b (*1000)$	<i>#nodes</i>	$l_v (*1000)$	<i>#nodes</i>	
12	18	250	4	13	4.5
25	142	635	8	13	17
50	2.000	2.900	30	13	66
100	31.000	11.700	145	13	213

Comparison to Basic-PRM

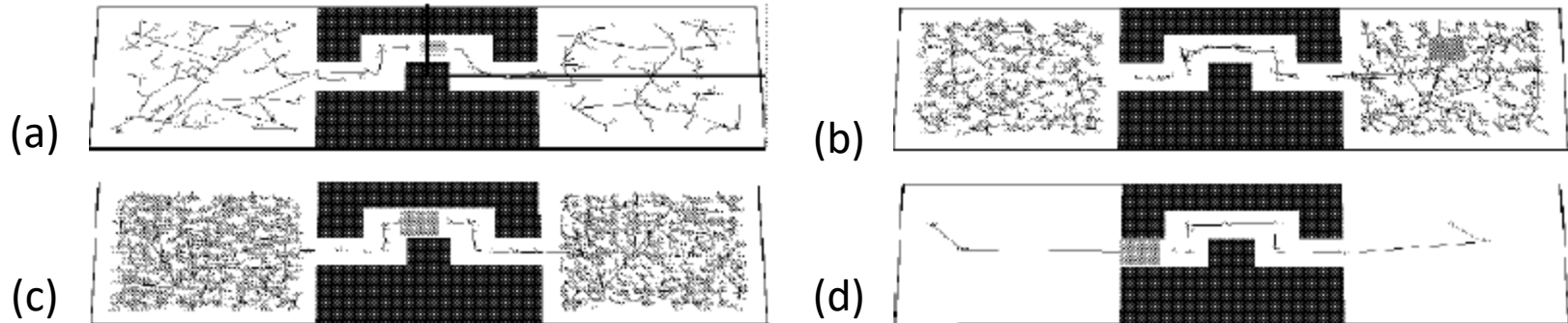
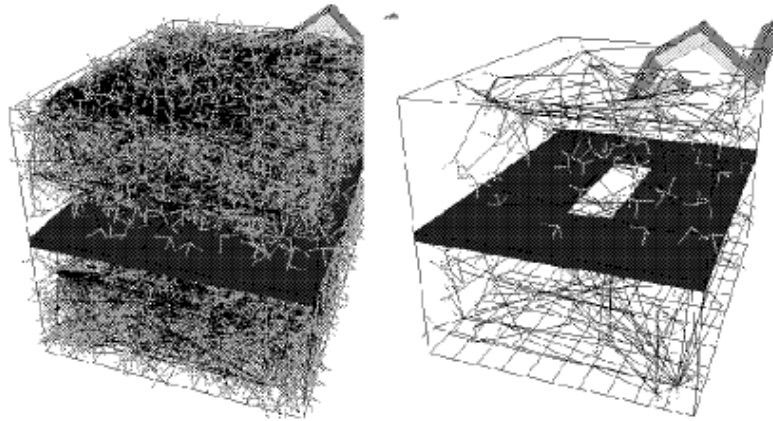


Figure 10. Roadmaps produced by Basic-PRM for (a) $1/\varepsilon = 12$, (b) $1/\varepsilon = 25$ and $1/\varepsilon = 50$, and by (d) Visib-PRM for any value of ε .

Comparison to Basic-PRM



PRM	Basic	Visibility
Roadmap size	4723	103
CS_{free} coverage	99.9%	99.7%
Random confs	14169	14369
Free confs	4723	4753
Local method #calls	700610	57622
Col. checker #calls	8.725985	1.121790
CPU time	3367 sec	281 sec

Experiments

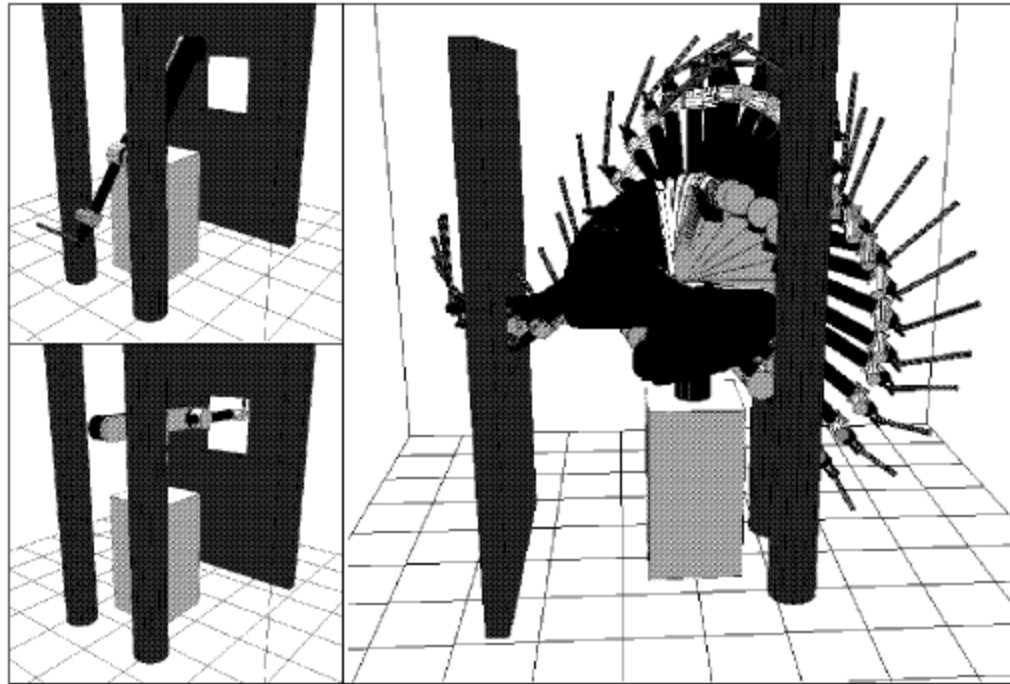


Table 1.

Mechanical system	d.o.f.	Local method	Roadmap's size	CPU time (s)
<u>Robot arm</u>	6	linear	26	370
Mobile manipulator	9	linear/ReedsShepp	75	55
Rolling bridge	4	Manhattan	25	2
Articulated hand	25	linear	70	90

Experiments

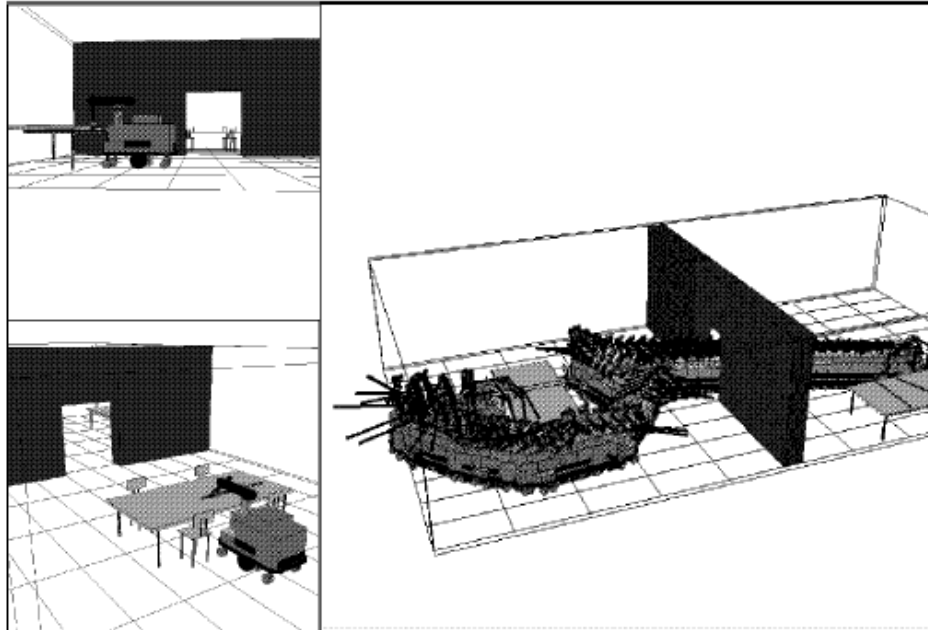


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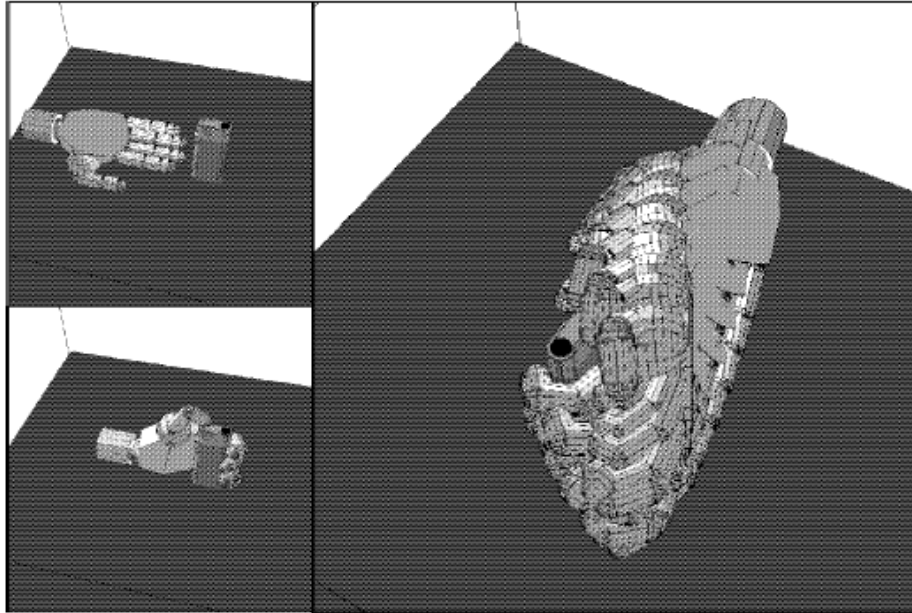


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Work After

- Compact Representations of Roadmap Graphs [Shaharabani et al. 2013]
- Rapidly-exploring Random Trees [LaValle and Kuffner 2001]
- Incremental Sampling-based Algorithms for Optimal Motion Planning [Karaman and Frazzoli 2010]
- LQR-Trees [Tedrake et al. 2010]