Search Techniques in AI and Robotics

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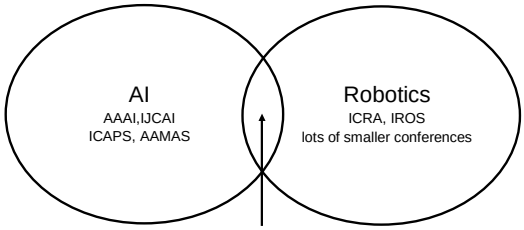
The symposium is supported by NSF!

Note: Some of the pictures in this talk have been taking from the WWW but the source is no longer known.

AI and Robotics



e.g. search

AI and Robotics

Planning and search (almost) started with robotics:

- Shakey [1966-1972] - STRIPS

AI and Robotics

Planning and search (almost) started with robotics:

- Shakey [1966-1972]: Box Pushing
- GPS: [1957]: Towers of Hanoi
- SHRDLU [1968-1970]: Blocksworld

Search in AI

Search Problems in AI

- States are given and discrete
- Off-line search
- One can concentrate on planning (execution follows)
- Real-time constraints do not exist
- Search space does not fit into memory

Search in Robotics

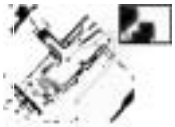
Search Problems in Robotics

- States are not given, continuous and often hard to characterize
- On-line search
- Planning and execution have to be interleaved
- Real-time constraints exist
- Search space might or might not fit into memory

20(!) megahertz RAD6000 processor

Speeding Up A* Search

How to search faster and faster is important:



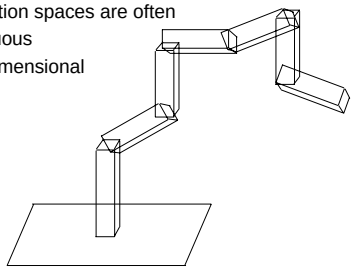
2d (x, y) planning
- 54,000 states
- Fast planning
- Slow execution

4d (x, y, Θ, v) planning
- More than 20,000,000 states
- Slow planning
- Fast execution

[from Maxim Likhachev]

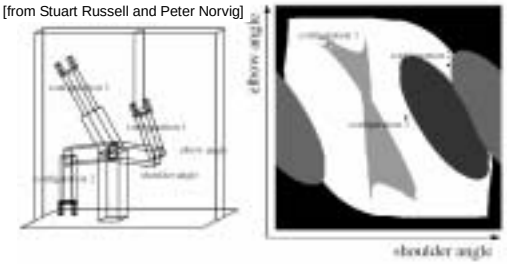
Work vs Configuration Space

- Configuration spaces are often
  - continuous
  - high-dimensional



Work vs Configuration Space

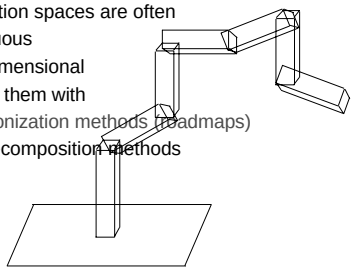
[from Stuart Russell and Peter Norvig]



work space configuration space

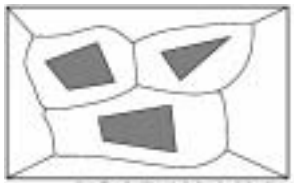
Work vs Configuration Space

- Configuration spaces are often
  - continuous
  - high-dimensional
- Discretize them with
  - Skeletonization methods (roadmaps)
  - Cell-decomposition methods



Discretizing Configuration Space

- Skeletonization methods



[from Stuart Russell and Peter Norvig – the figure has slight problems]
Voronoi graph

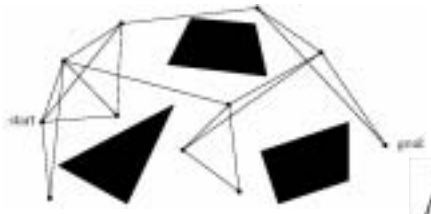
Discretizing Configuration Space

- Skeletonization methods

visibility graph

Discretizing Configuration Space

- Skeletonization methods:



roadmap using random points [Kavraki et al, 1994]
(there are also roadmaps using RRTs [LaValle, 1998])

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  - high-dimensional
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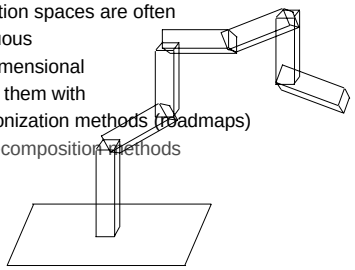
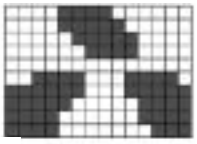


Discretizing Configuration Space

- Cell decomposition methods:

[from Stuart Russell and Peter Norvig]

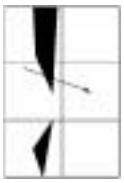
vertical strips



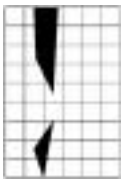
grid

Discretizing Configuration Space

- Non-uniform cell decomposition



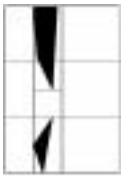
coarse-grained discretization
might not be able to find a path

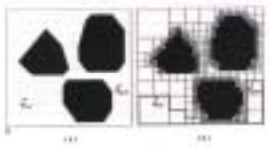


fine-grained discretization
Is very inefficient

Discretizing Configuration Space

- Non-uniform cell decomposition

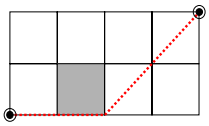




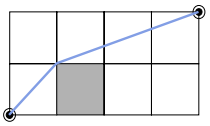
non-uniform discretization
avoids these problems

Discretizing Configuration Space

- Any-angle planning methods



grid path



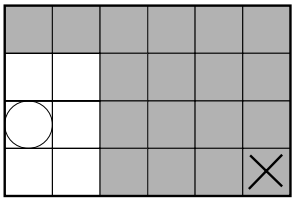
any-angle path

Planning and Execution

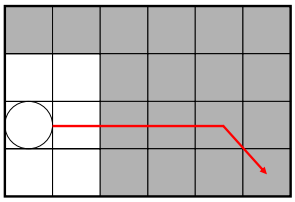
- Incomplete information (knowledge of the robot changes)
  - About the location of the robot (localization)
  - About the configuration space (mapping)
  - About teammates and competitors
- Dynamically changing terrain (terrain changes)
- Uncertainty about actuation and sensing



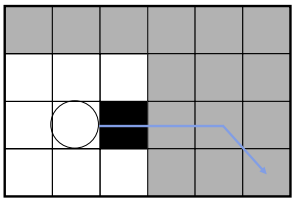
Planning and Execution



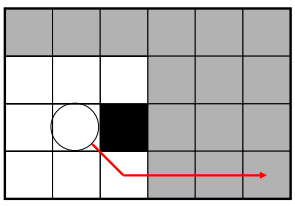

Planning and Execution



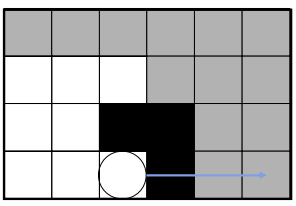

Planning and Execution



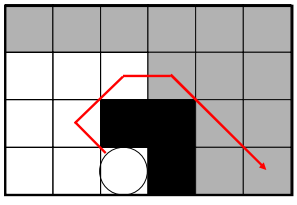

Planning and Execution




Planning and Execution




Planning and Execution



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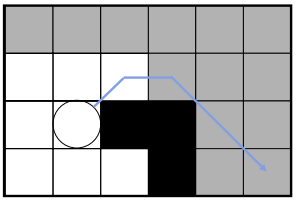
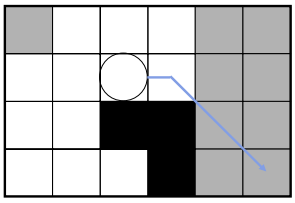
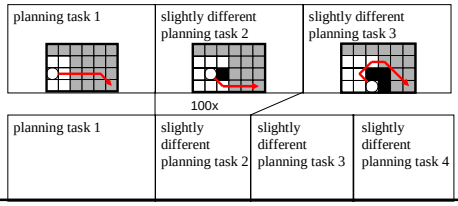


Planning and Execution



Planning and Execution

- Incremental heuristic search speeds up A* searches for a sequence of similar search problems by exploiting experience with earlier search problems in the sequence. It finds shortest paths.



Artificial Intelligence

These problems are not specific to robotics.
They occur whenever one interfaces to the world!

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icaps International Planning Competition

1998
2000
2002
2004
2006