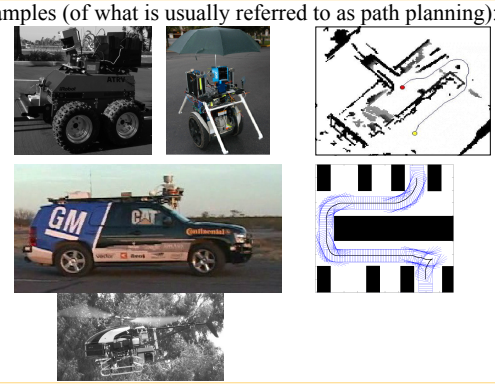
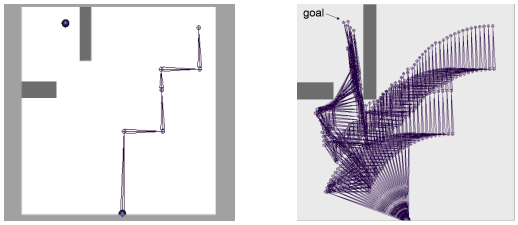
Motion/Path Planning

Examples (of what is usually referred to as path planning):



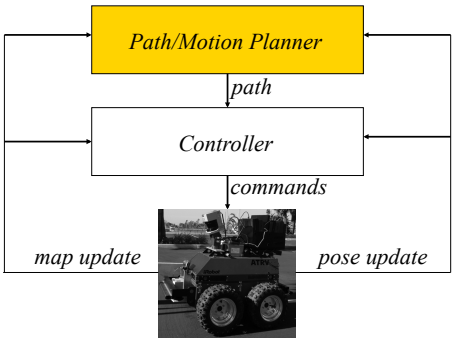
Motion/Path Planning

Examples (of what is usually referred to as motion planning):



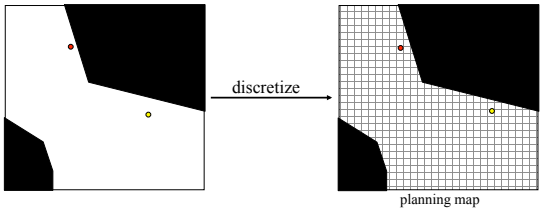
Planned motion for a 6DOF robot arm

Motion/Path Planning



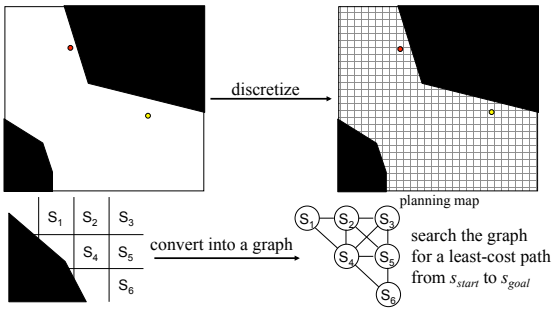
Planning via Cell Decomposition

- Approximate Cell Decomposition:
  - overlay uniform grid over the C-space (discretize)



Planning via Cell Decomposition

- Approximate Cell Decomposition:
  - construct a graph and search it for a least-cost path



Planning via Cell Decomposition

- Approximate Cell Decomposition:
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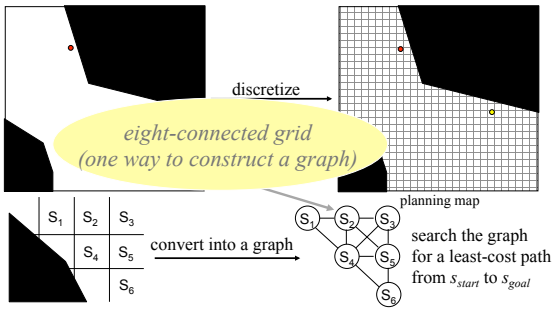


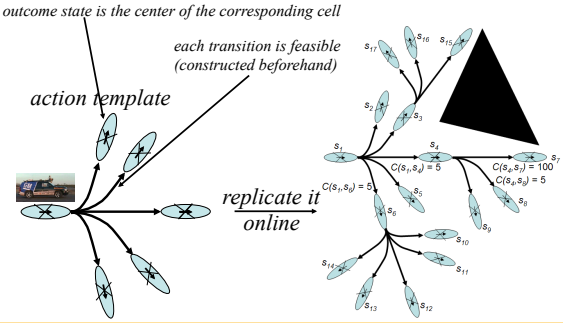
Planning via Cell Decomposition

- Graph construction:
  - lattice graph

outcome state is the center of the corresponding cell

each transition is feasible (constructed beforehand)

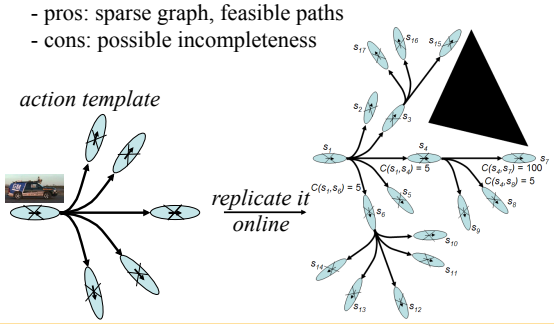
action template



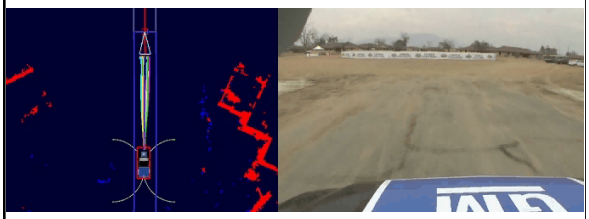
Planning via Cell Decomposition

- Graph construction:
  - lattice graph
  - pros: sparse graph, feasible paths
  - cons: possible incompleteness

action template



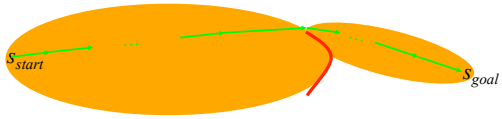
Example



*Urban Challenge Race, CMU team, planning with Anytime D**

Effect of the Heuristic Function

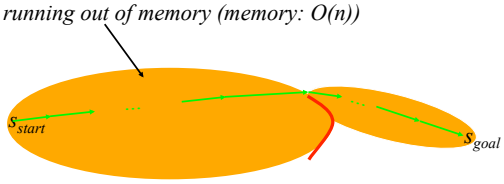
- A* Search: expands states in the order of $f = g+h$ values



Effect of the Heuristic Function

- A* Search: expands states in the order of $f = g+h$ values

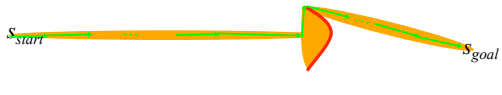
for large problems this results in A quickly running out of memory (memory: O(n))*



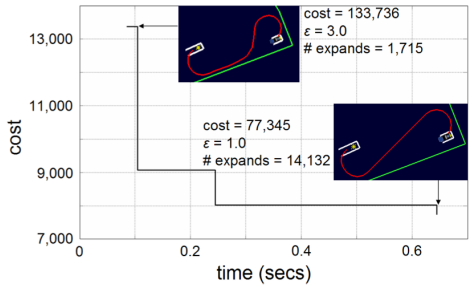
Effect of the Heuristic Function

- Weighted A* Search: expands states in the order of $f = g+\varepsilon h$ values, $\varepsilon > 1$ = bias towards states that are closer to goal

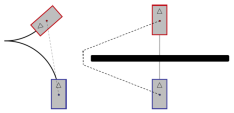
solution is always ε-suboptimal: cost(solution) ≤ ε·cost(optimal solution)

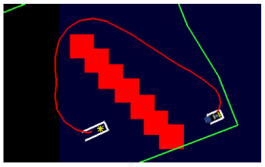


Anytime Aspects



Heuristics



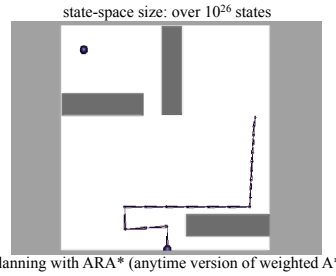


heuristic	states expanded	time (secs)
h	2,019	0.06
h_{2D}	26,108	1.30
h_{fsh}	124,794	3.49

Heuristic Function

- Weighted A* Search: expands states in the order of $f = g+\varepsilon h$ values, $\varepsilon > 1$ = bias towards states that are closer to goal

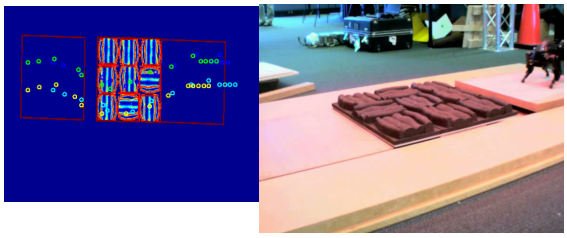
20DOF simulated robotic arm
state-space size: over 10^{26} states



planning with ARA* (anytime version of weighted A*)

Effect of the Heuristic Function

- planning in 8D (<x,y> for each foothold)
- heuristic is Euclidean distance from the center of the body to the goal location
- cost of edges based on kinematic stability of the robot and quality of footholds



planning with R* (randomized version of weighted A*)

joint work with Subhrajit Bhattacharya, Jon Bohren, Sachin Chitta, Daniel D. Lee, Aleksandr Kushleyev, Paul Vernaza

Incremental version of A* (D*/D* Lite)

- Robot needs to re-plan whenever
  - new information arrives (partially-known environments or/and dynamic environments)
  - robot deviates off its path

ATRV navigating initially-unknown environment

planning map and path