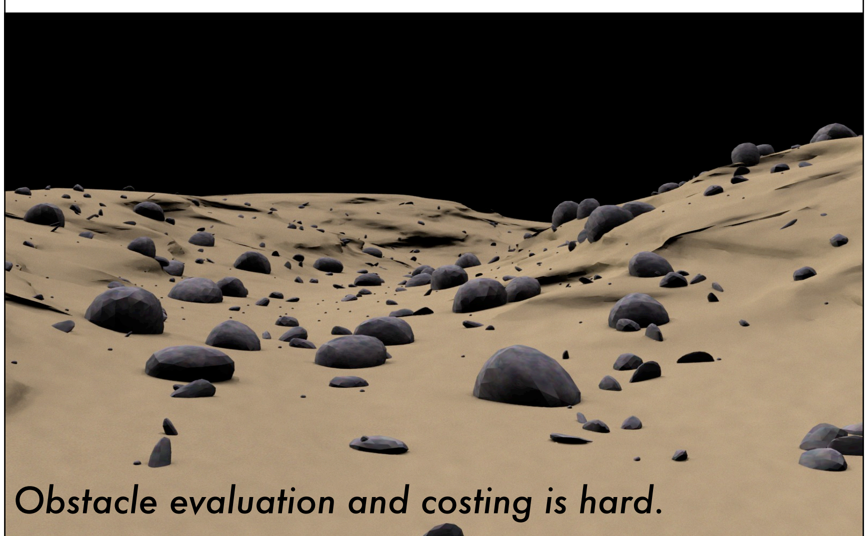
Obstacles and Cost

ME/CS 132b
Advanced Robotics: Navigation and Perception
4/07/2011



What are Obstacles?

Obstacles can generally be viewed as vehicle mobility hazards

- Tip-Over
- High-Centering
- Collision
- Traction Loss

Chassis interaction w/ environment

Obstacles and Cost Lecture Outline

- Configuration Space Obstacles
- Continuum Representations
- Applications
- Current and Active Research

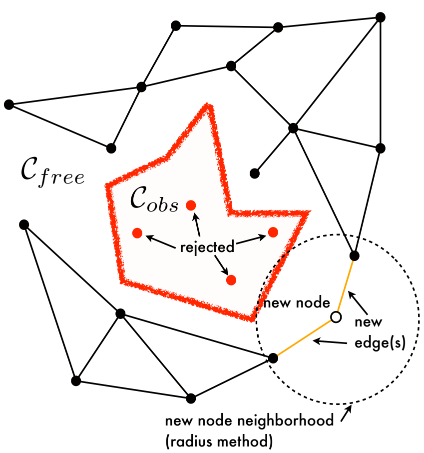
Covers topics in Chapters 4, 5, and 7 in S. LaValle's *Planning Algorithms*

Configuration Space Obstacles

Configuration Space Obstacles

The obstacle configuration space $\mathcal{C}_{obs}$ represents an inaccessible region of the robot configuration space

In sampling-based planners configurations or states in $\mathcal{C}_{obs}$ are rejected



Computing $\mathcal{C}_{obs}$

When

$$\mathcal{C} = \mathbb{R}^n$$
$$1 \leq n \leq 3$$

translation only

The obstacle region can be computed by convolution

$$X, Y \in \mathbf{R}^n$$

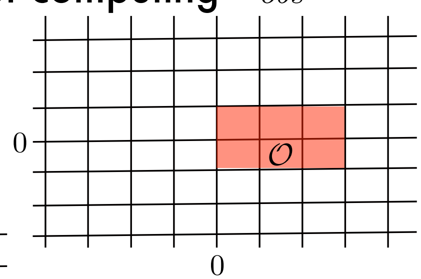
vector subtraction

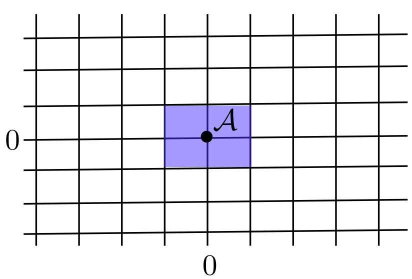
$$X \ominus Y = \{x - y \in \mathbb{R} | x \in X, y \in Y\}$$

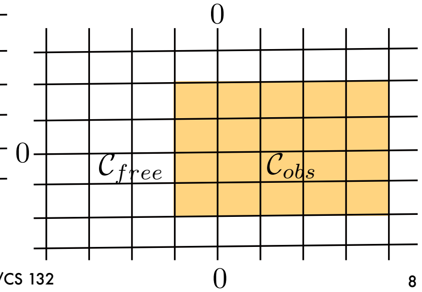
$$\mathcal{C}_{obs} = \mathcal{O} \ominus \mathcal{A}(0)$$

An example of computing $\mathcal{C}_{obs}$

$$\mathcal{A} = ([-1, 1], [-1, 1])$$
$$\mathcal{O} = ([0, 3], [0, 2])$$
$$\mathcal{C}_{obs} = ([-1, 4], [-1, 3])$$

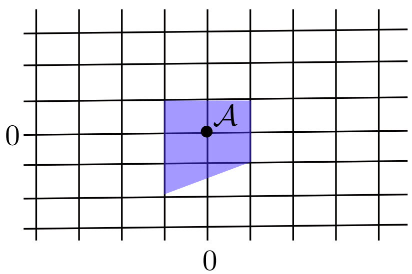


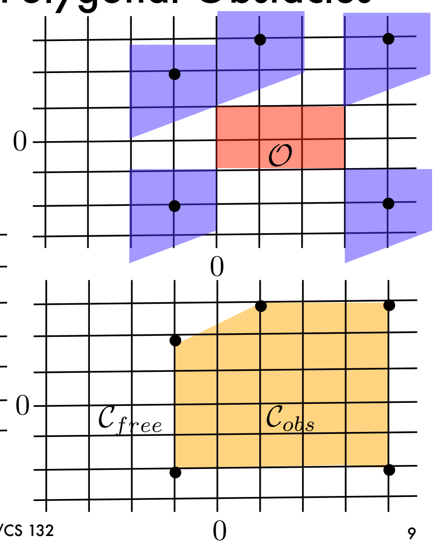




Star Algorithm for Polygonal Obstacles

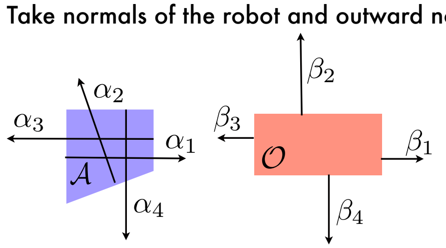
compute a convex polygon by translating the robot about the edge of the obstacle

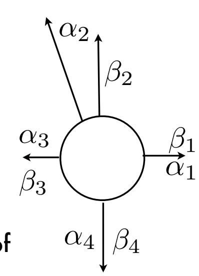




$\mathcal{C}_{obs}$ Edges

Take normals of the robot and outward normals of the robot

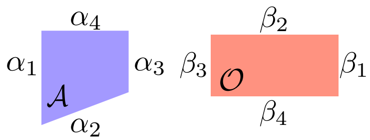


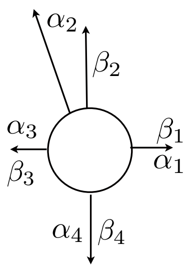


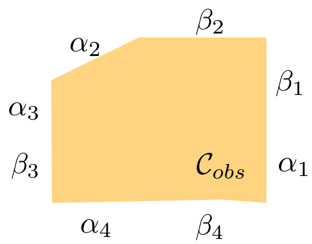
ordering on $\mathbb{S}^1$ determines order of edges in $\mathcal{C}_{obs}$

$\mathcal{C}_{obs}$ Edges

Is this consistent?

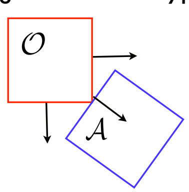


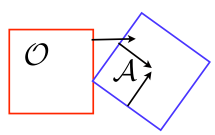




$\mathcal{C}_{obs}$ Edges

Can compose a convex polygon from half-planes based on evaluating two different types of intersections





Type EV
Obstacle touches edge of robot
Contributes n edges

Type VE
Robot touches edge of obstacle
Contributes m edges

n: number of edges in $\mathcal{A}$
m: number of edges in $\mathcal{O}$

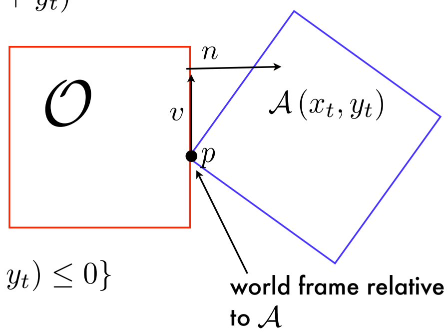
$\mathcal{C}_{obs}$ Edges

Use the edge and the point of intersection to compute the half-plane H

$$p\left(x_t, y_t\right) = \left(p_x + x_t, p_y + y_t\right)$$

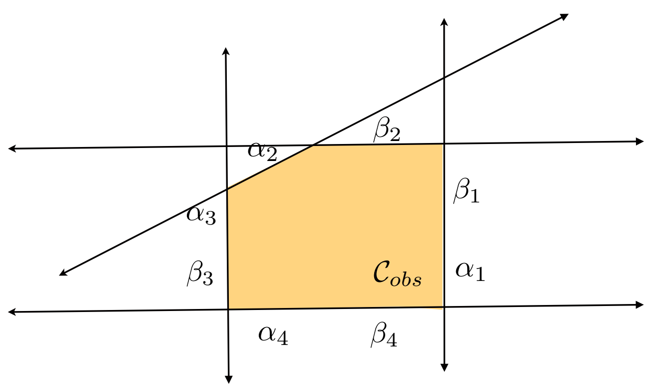
$$n \cdot v = 0$$

$$f\left(x_t, y_t\right) = n \cdot v\left(x_t, y_t\right)$$



$$H = \left\{\left(x_t, y_t\right) \in \mathcal{C} \middle| f\left(x_t, y_t\right) \leq 0\right\}$$

$\mathcal{C}_{obs}$ Edges



Edges determined by concatenating half-planes

Time-Varying Obstacles

Configuration space obstacles need not be fixed in time

Requires a search space that is aware of the expected time at a particular state

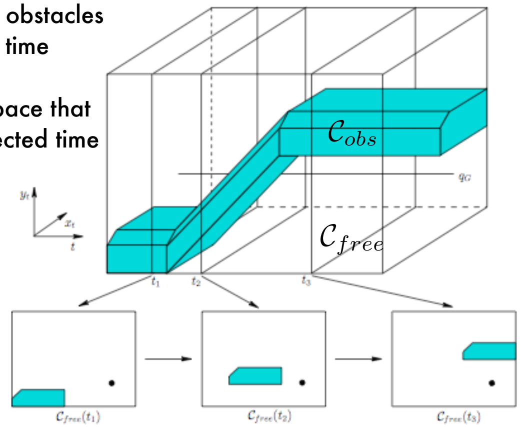


Image from Figure 7.1 in [LaValle 06a]

Continuous Representations

Continuous Cost Representations

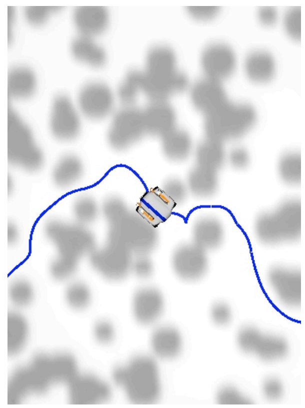
Obstacles are not always binary

Associated cost values with proximity to hazards

- Terrain Features
- Tip-Over
- Loss of Traction

Important in off-road environments

Cost functional used in trajectory planning



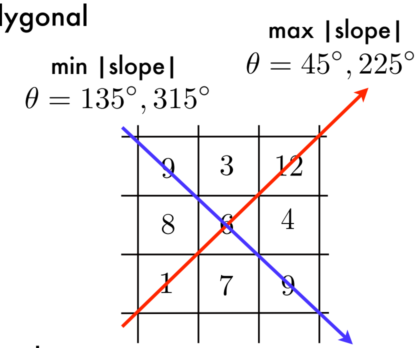
Continuous Cost Representations

Obstacles are not always polygonal

- Sample trajectory cost
- Approximate shape

Orientation dependent cost functions

- Vehicle dependent
- Sample in 3D and store worst case in extra dimension to get back to 2D



elevation map

Applications

Autonomous Navigation

Autonomous Navigation

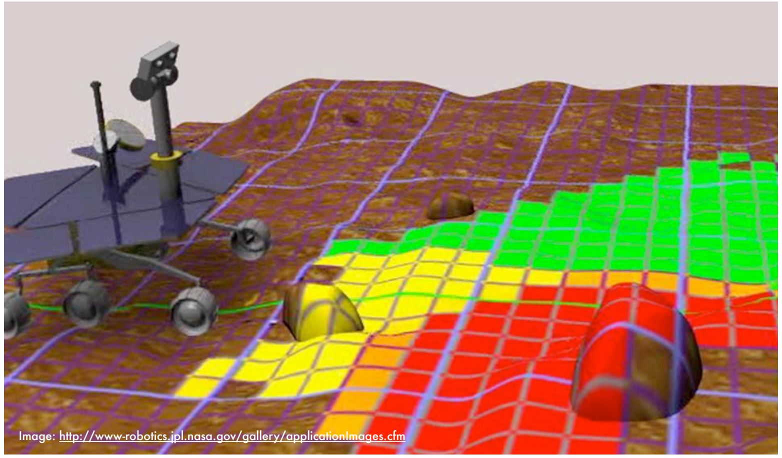


Image: http://www-robotics.jpl.nasa.gov/gallery/applicationImages.cfm

Research Topics

Learning Cost from Demonstration

Learning Cost from Demonstration

[Silver10a] demonstrates learning the mapping between terrain features and mobility cost by training the system with expert paths

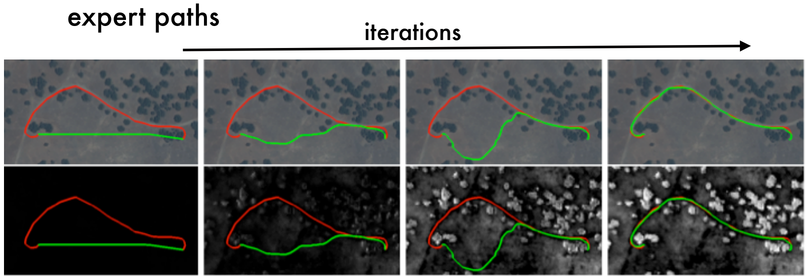


Image from Figure 5 in [Silver 10a]

expert path

path planned

Summary

Obstacle representation and costing is often the medium between planning and perception

Methods exist for explicitly computing configuration spaces for polygonal robots and obstacles

Binary (obstacle/free) representations of space disallow configuration or state in those regions

Continuous representations of obstacle associate risk with configuration or state space that is weighted with mobility costs

Next Lecture (4/12)

Search Algorithms I

- Breadth First Search
- Depth First Search
- Dijkstra
- A*

Document/Image References

[Silver 10a] D. Silver, D. Bagnell, and A. Stentz, "Learning from Demonstration for Autonomous Navigation in Complex Unstructured Terrain," International Journal of Robotics Research, Vol. 29, No. 12, October, 2010, pp. 1565 - 1592.

[LaValle 06a] S. LaValle, "Planning Algorithms". Cambridge: Cambridge University Press. ISBN 0521862051.