CS354

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Representing Space

- Two issues to consider today:
  - How to efficiently and conveniently encode a map of the robot's environment?
  - How to parameterize the configuration of the robot?
- Both questions need to be addressed in order to plan.

Grid Based Maps

- Easy to work with, not space efficient
- Naive 2d grid representation of a 10m $\times$ 10m room at 1cm accuracy:
  - $1000 \times 1000 = 1,000,000$ cells
- Quadtree is a more space efficient alternative...

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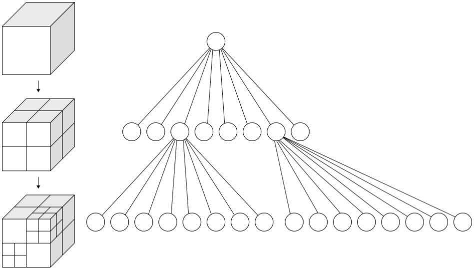
- Octree is the 3d generalization



Topological Maps

Example

Configuration Spaces

- "A configuration $\mathbf{q} \in \mathcal{C}$ of the robot $\mathcal{A}$ is a specification of the state of $\mathcal{A}$ with respect to a fixed frame F_w" (Dudek and Jenkin)
- Turtlebot configuration: $\mathbf{q} = [x, y, \Theta]$.

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- A **C-Obstacle** $\mathcal{C}B_i$ is defined as:
  - $\mathcal{C}B_i = \{\mathbf{q} \in \mathcal{C} \mid \mathcal{A}(\mathbf{q}) \cap \mathcal{B}_i \neq \emptyset\}$
    - $\mathcal{B}_i$ is the space occupied by obstacle i.
    - $\mathcal{A}(\mathbf{q})$ is the space occupied by the robot in configuration $\mathbf{q}$.

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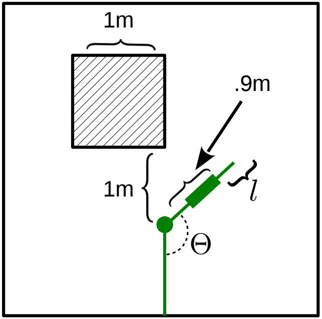
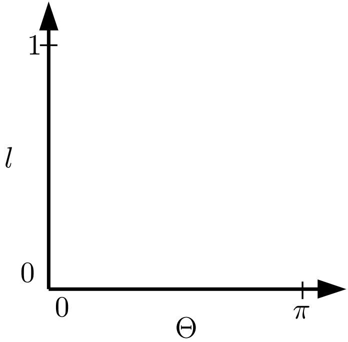
- $\mathcal{C}_{free} = \{\mathbf{q} \in \mathcal{C} \mid \mathcal{A}(\mathbf{q}) \cap (\cup_i \mathcal{B}_i) = \emptyset\}$
- $\mathcal{C}_{obs} = \overline{\mathcal{C}_{free}}$

Exercise

Draw $\mathcal{C}_{free}$ for this robot:





- Robot arm with a single rotational joint and a single prismatic joint
  - l - prismatic joint extension in meters
  - Θ - angle of rotational joint ($\Theta \approx \pi/4$ in the image)

Planning

- "A free path in C-space is a continuous curve exclusively in $\mathcal{C}_{free}$ that connects two configurations $\mathbf{q}_{start}$ and $\mathbf{q}_{goal}$."
- Paths may be
  - free: obstacles are not touched.
  - semi-free: obstacles may be touched.
- The goal of planning is to find a path.

Additional Topics

- Holonomic vs. Non-holonomic constraints
  - Holonomic constraints restrict the allowed configurations.
  - Non-Holonomic constraints put limits on the paths between configurations.
- Point robot assumption and object dilation
  - Simplifies the problem of finding $\mathcal{C}_{free}$