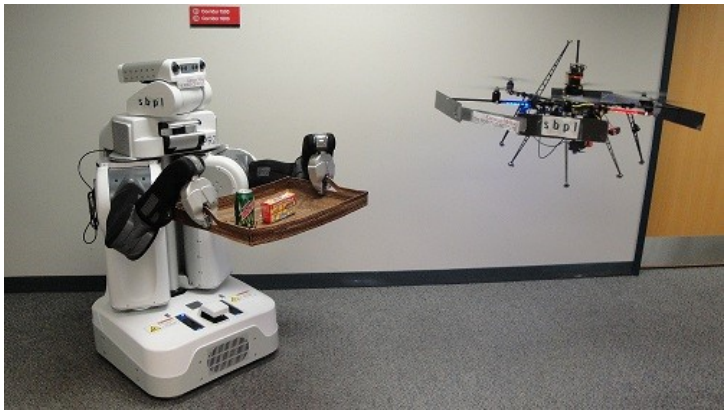
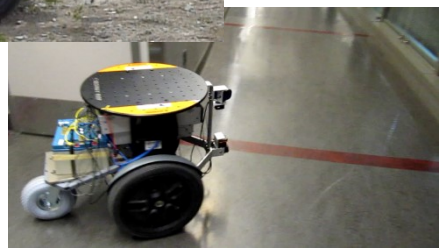
About Me

- My Research Interests:
  - Planning, Decision-making, Learning
  - Applications: planning for complex robotic systems including aerial and ground robots, manipulation platforms, small teams of heterogeneous robots

- More info: *http://www.cs.cmu.edu/~maxim*
- Search-based Planning Lab: *http://www.sbpl.net*







What is Planning?

- According to Wikipedia: *"Planning is the process of thinking about an organizing the activities required to achieve a desired goal."*

- *Given*
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*

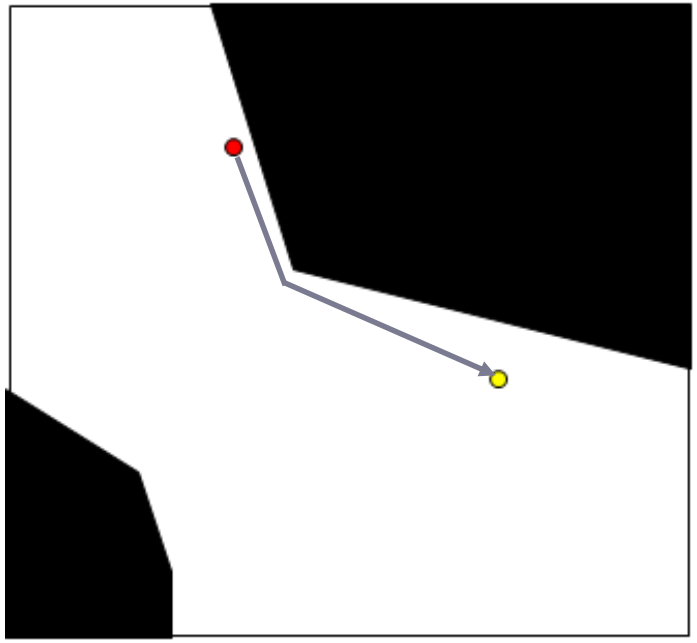
- *Compute a plan π that:*
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

Few Examples

- ***Given***
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*
- ***Compute a plan π that:***
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

2D path planning for omnidirectional robot:

What is M^a?
What is b_c^a?
What is b_c^w?
What is C?
What is G?

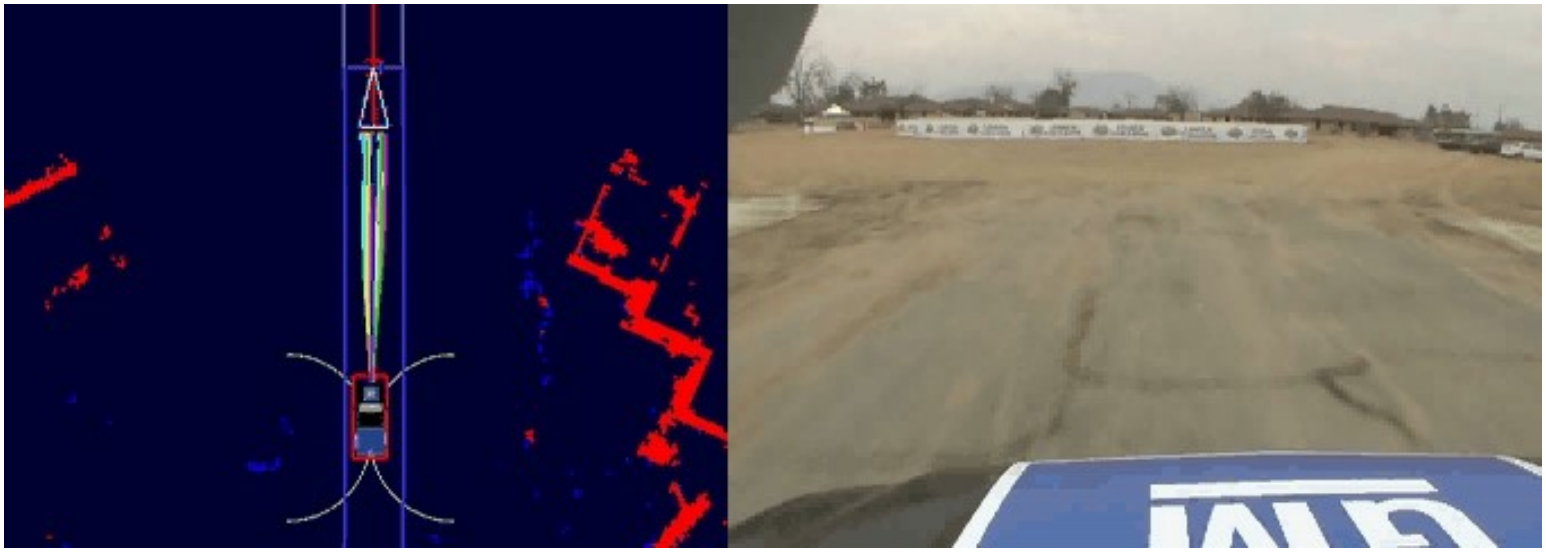


Few Examples

- ***Given***
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*
- ***Compute a plan π that:***
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

4D (x,y,heading,velocity) path planning for autonomous navigation:

What is M^a?
What is b_c^a?
What is b_c^w?
What is C?
What is G?



part of efforts by Tartanracing team from CMU for the Urban Challenge 2007 race

Few Examples

- ***Given***
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*
- ***Compute a plan π that:***
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

5D (x,y,z,heading,time) path planning for autonomous flight among people :

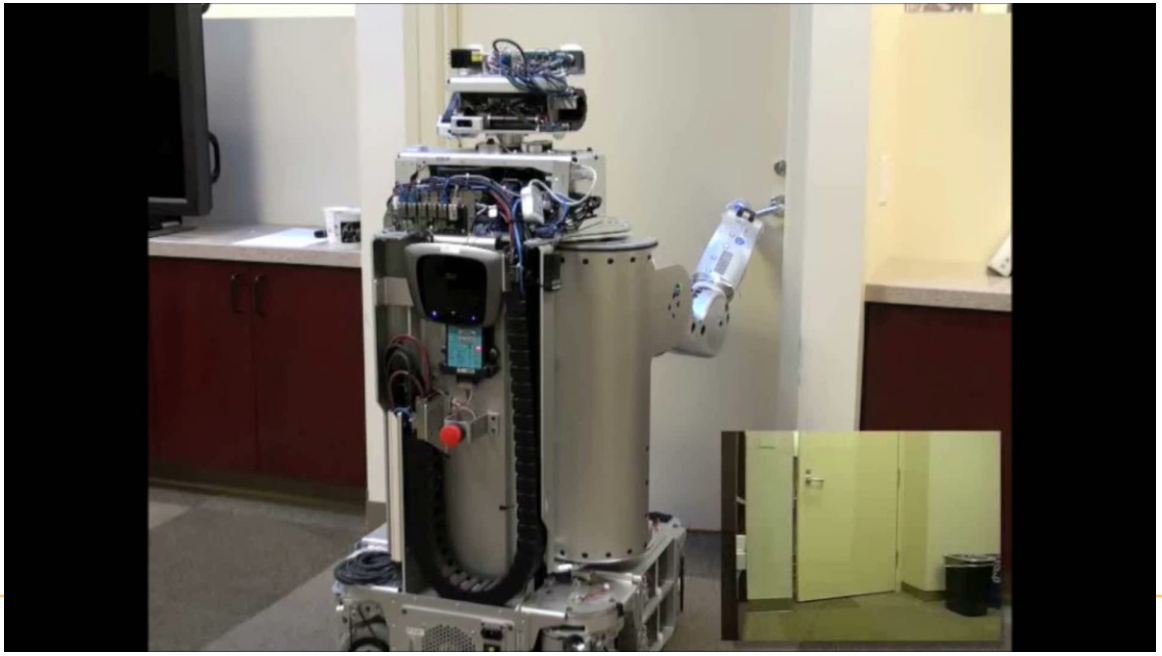
What is M^a?
What is b_c^a?
What is b_c^w?
What is C?
What is G?

Few Examples

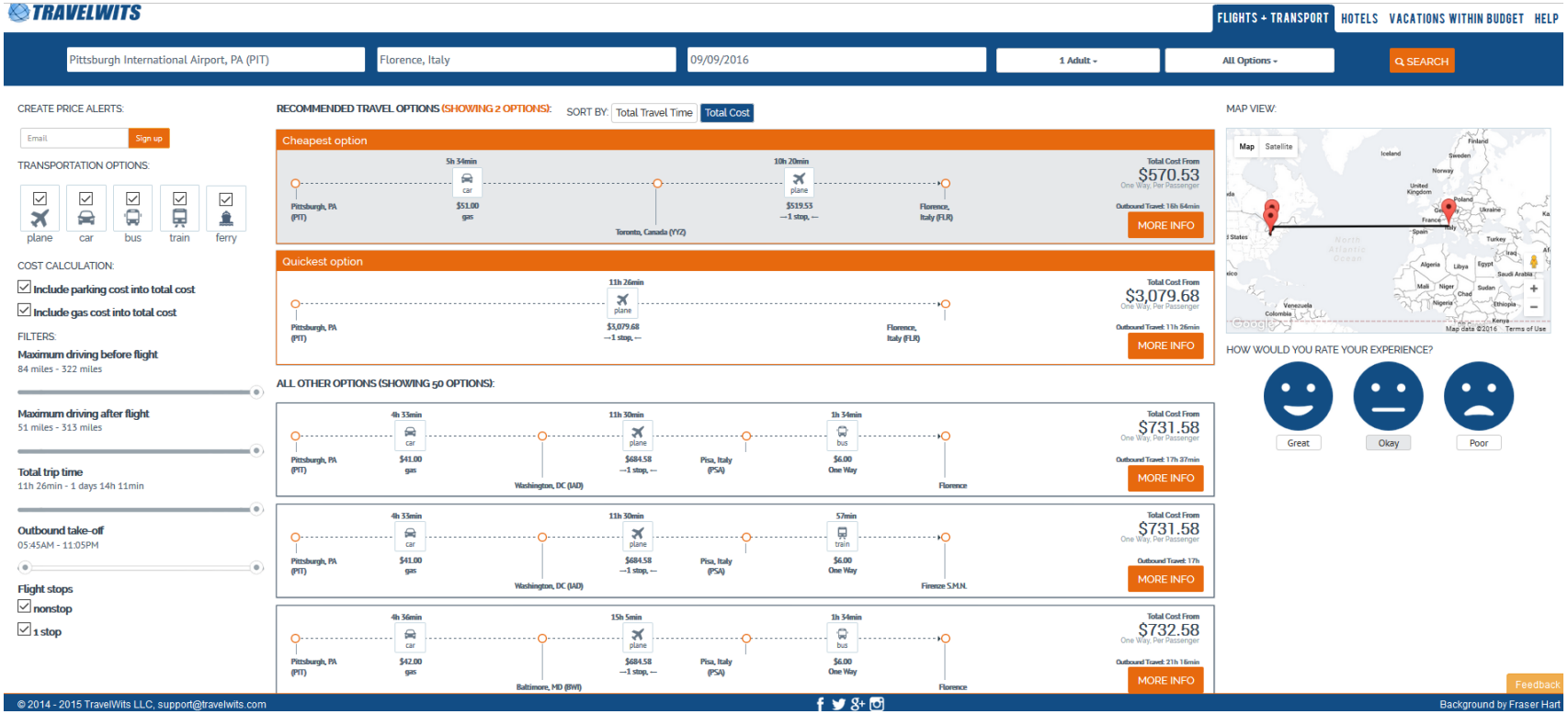
- ***Given***
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*
- ***Compute a plan π that:***
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

Motion planning for a mobile manipulator PR2 opening a door:

What is M^a?
What is b_c^a?
What is b_c^w?
What is C?
What is G?



Few Examples



Planning a travel from Pittsburgh, PA to Florence, Italy:

What is M^a?
What is $b_c{}^a$?
What is $b_c{}^w$?
What is C?
What is G?

Example of Planning under Uncertainty

- ***Given***
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*
- ***Compute a plan π that:***
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

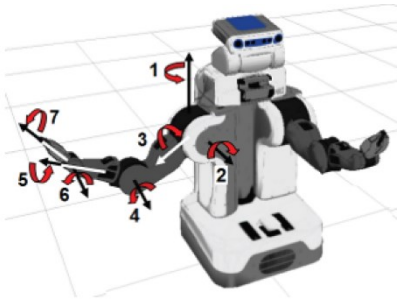
Planning for navigation under uncertainty in traversability:

What is M^a?
What is b_c^a?
What is b_c^w?
What is C?
What is G?

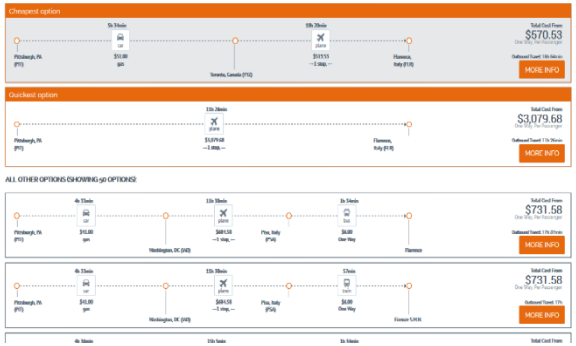
Continuous vs. Discrete vs. Hybrid Model

- ***Given***
  - *model (states and actions) of the agent(s) $M^a = <S^a, A^a>$*
  - *a model of the world M^w*
  - *belief b_c^a of the agent about its current state*
  - *belief b_c^w of the agent about the current state of the world*
  - *belief of the agent over the cost function C of its actions*
  - *desired set of states for agent and world G*
- ***Compute a plan π that:***
  - *maps one or more belief tuples $<b^a, b^w>$ onto actions a in A^a*
  - *reaches one of the desired states in G*

continuous

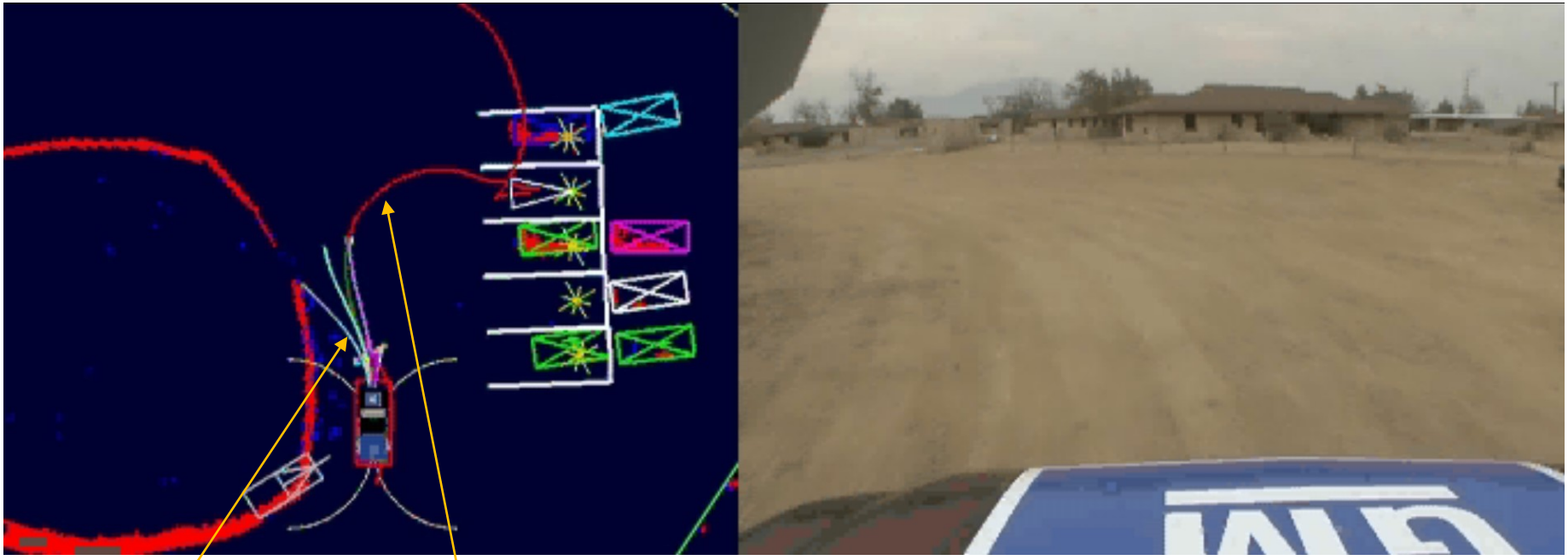


discrete



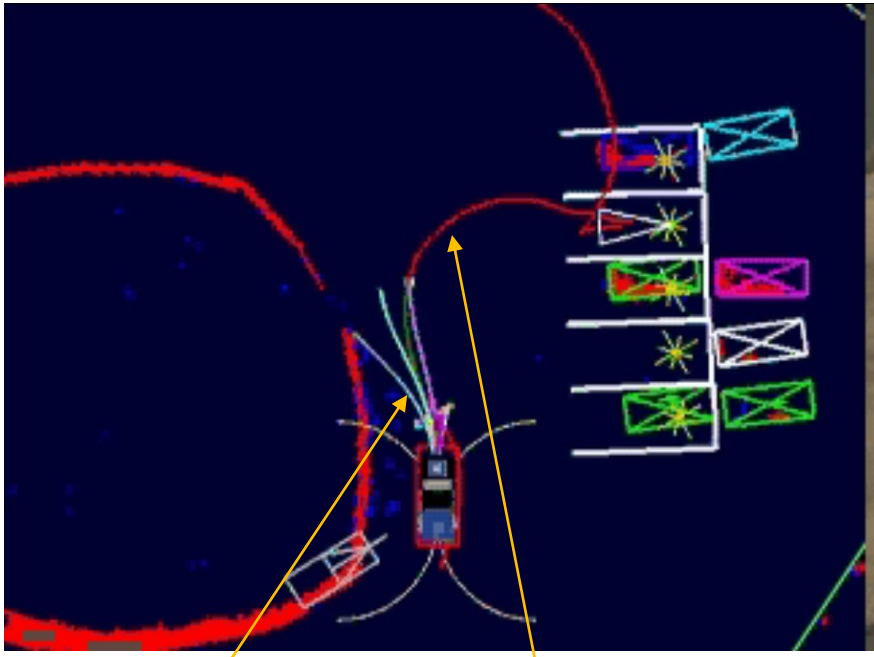
hybrid

Global vs. Local Planning



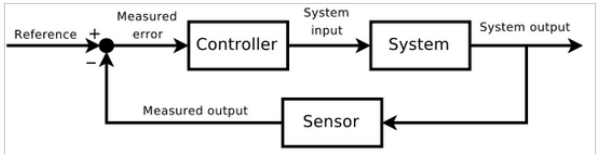
local planning *global planning*

Planning vs. Control

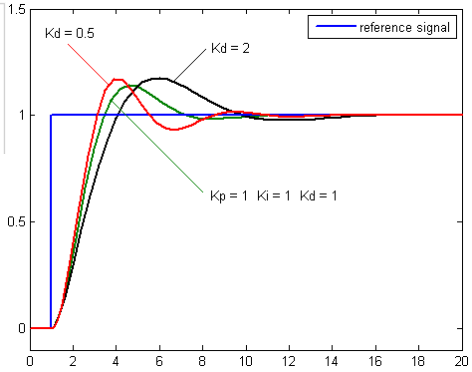


local planning

global planning



controller



Images from wikipedia

Some of the topics covered in class

- Methods for constructing models
- Methods for efficient planning on these models
- Interleaving planning and execution
- Improving planning via learning