Introduction

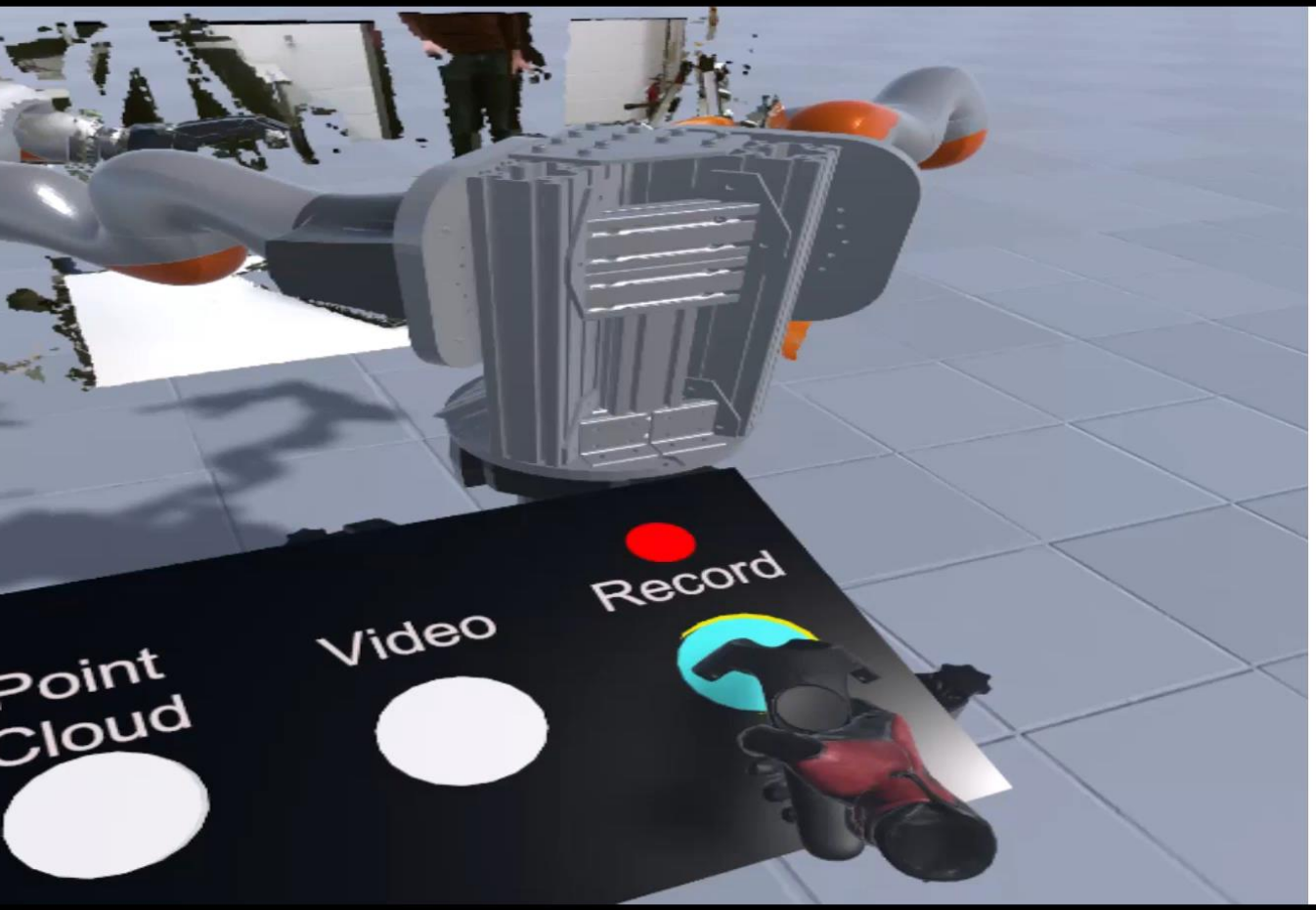
This lecture is being recorded

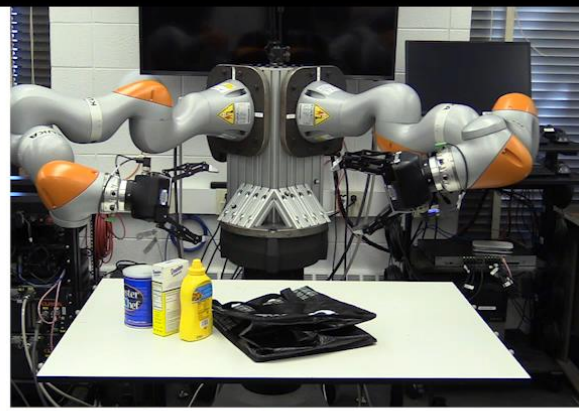
Hardware
(actuators, materials)

Robotics

Software
(algorithms)

What is holding us back?





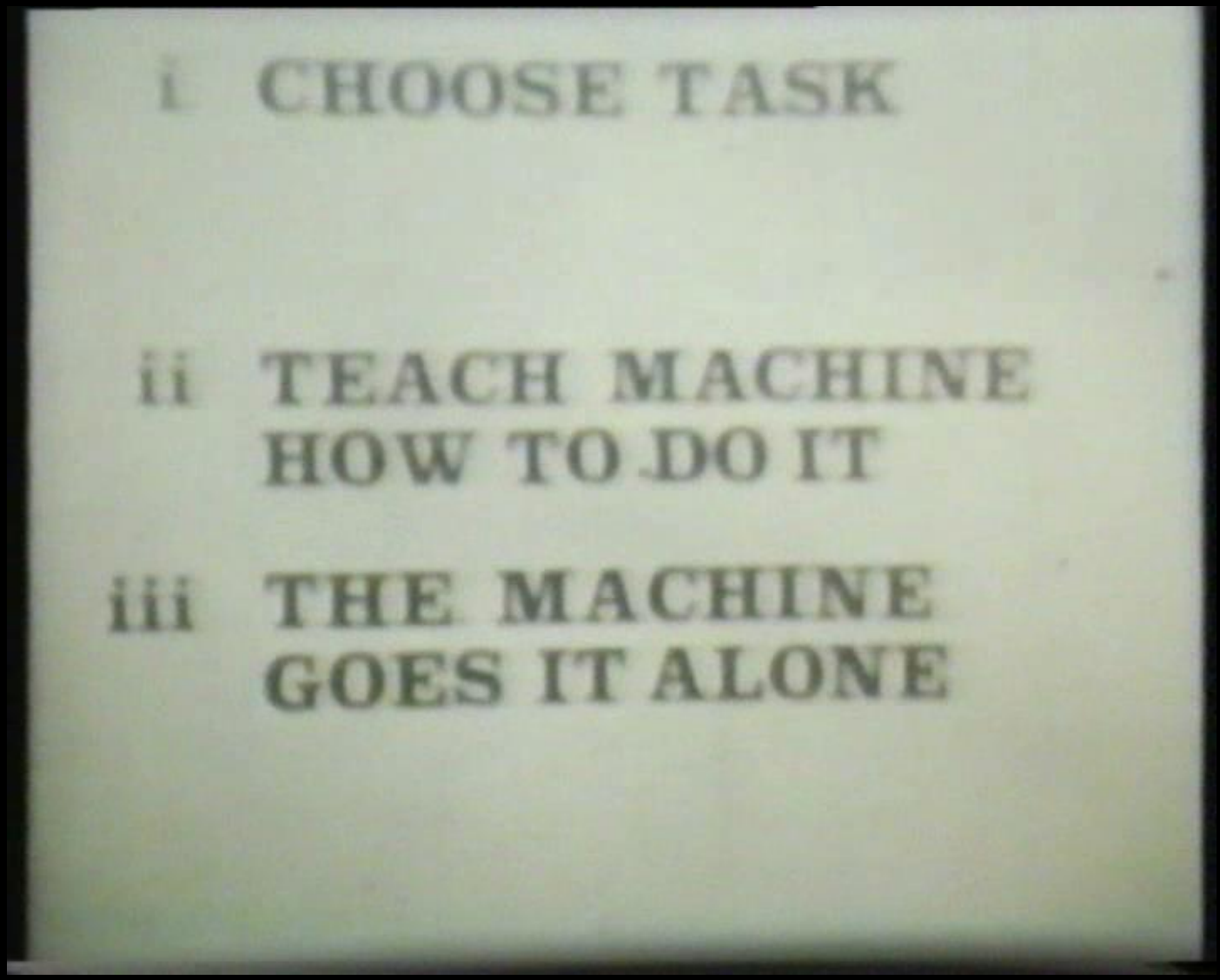
TO DO THIS AUTONOMOUSLY WE NEED BETTER ALGORITHMS

WHAT IS ALGORITHMIC ROBOTICS?

A Brief (and Incomplete) History of Algorithmic Robotics (in videos)

Shakey, SRI, 1966-1972

Freddy, University of Edinburgh, 1973



Sensorless Parts Orienting, CMU, 1986

Navlab, CMU, 1986

Navlab, CMU, 1986-2002

DARPA Urban Challenge, 2007

Team CMU

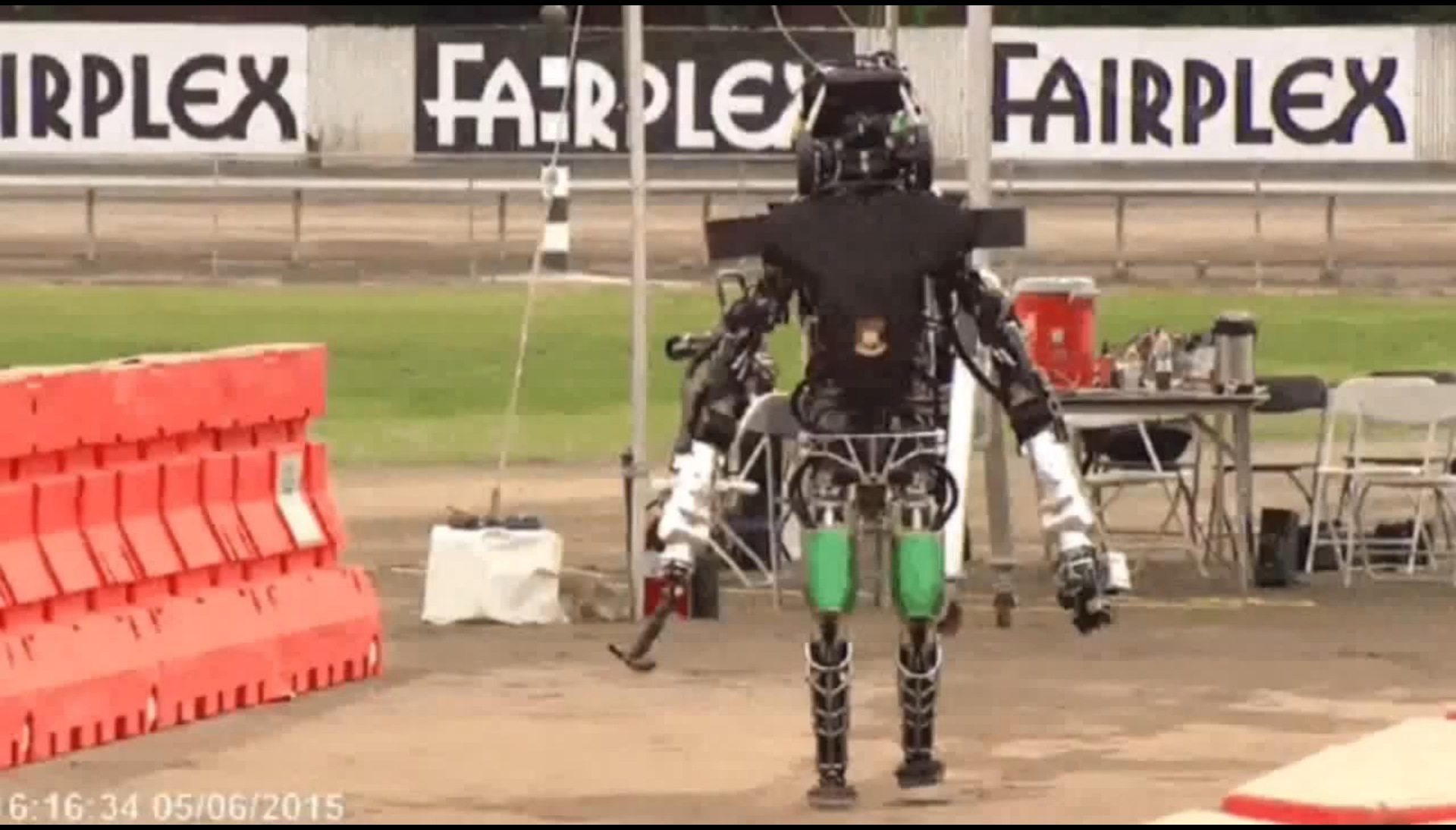
PR2 and ROS, Willow Garage, 2008-2013

KinectFusion, Microsoft Research, 2011

Kiva Robots, Amazon, 2014

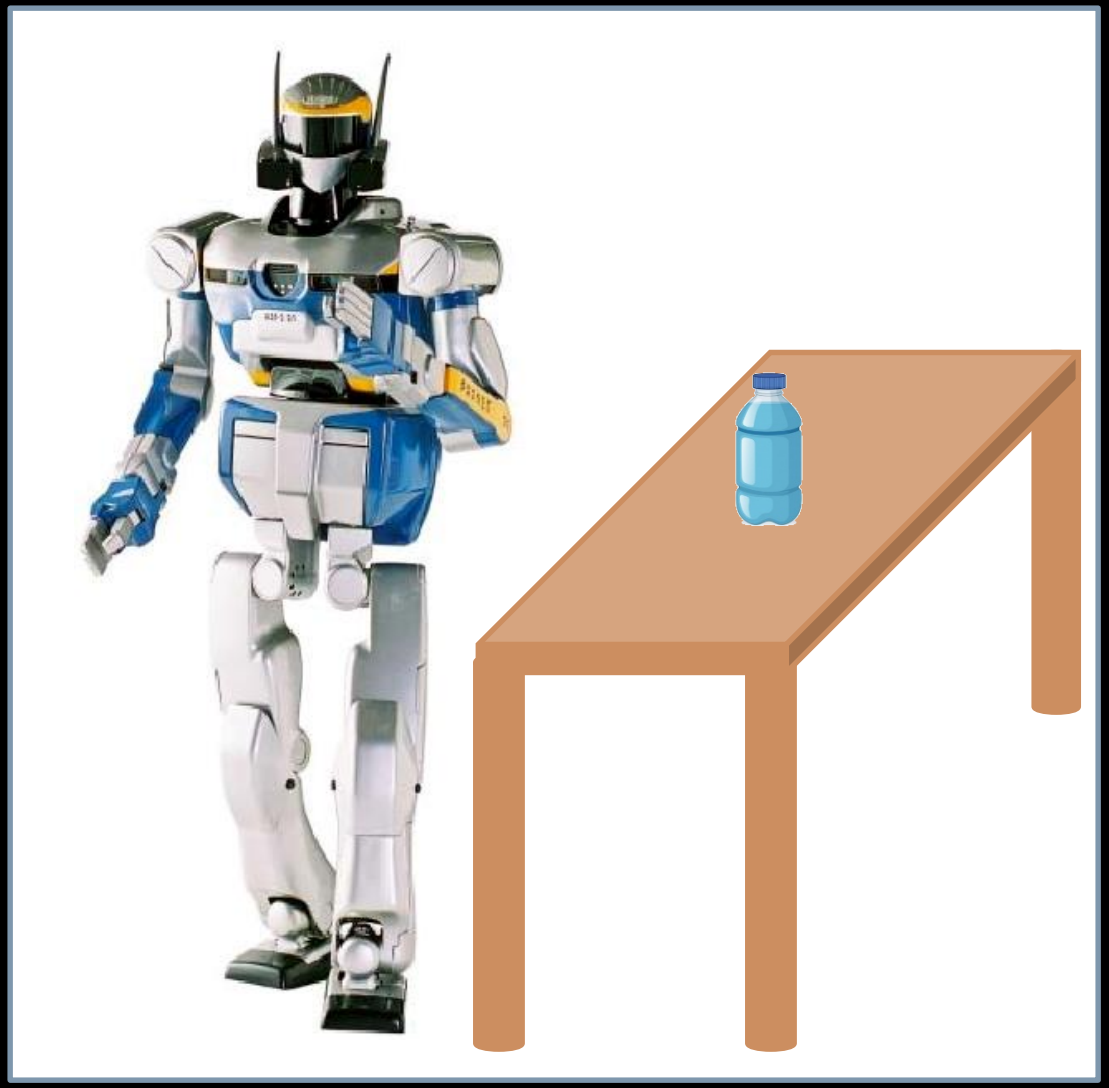
DARPA Robotics Challenge, 2015

DARPA Robotics Challenge, 2015



Still a long way to go…

Let’s play “Make the Robot Pick up the Bottle”!



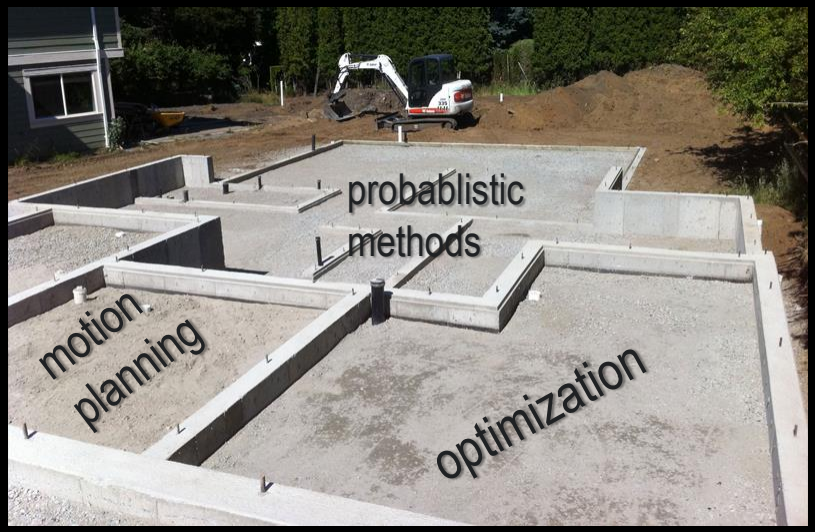
BREAK

I'm interested in robotics; what should I learn?

- Robotics is a rapidly-changing field
  - New methods develop quickly
  - Old methods become obsolete quickly
- How can you keep up with the changes?
  - Don't *only* learn the latest/greatest new method
  - Do develop a strong understanding of robotics fundamentals
    - You will be able to understand new methods much better/faster
    - You will see what's common to many methods
    - Improvements and limitations of new methods will be more obvious

Why should I take this course?

- The Goal: Build a **foundation** for more advanced robotics courses/concepts



- Emphasize breadth over depth
  - Will cover many areas
  - Opportunities to go deeper beyond the course
  - Can make an informed decision about what to study next

What is algorithmic robotics?

- The goal is to make robots sense, plan, and act intelligently
- To do this we draw ideas from:
  - Artificial Intelligence
  - Motion Planning
  - Optimization
  - Perception
  - Estimation and Mapping
  - Machine learning
  - Human-robot interaction
  - ….
- Impossible to cover everything in one course!

What will be covered?

- Artificial Intelligence (some in this course, more in EECS 492/592)
- Motion Planning (some in this course, more in ROB 520)
- Optimization (some in this course, more in IOE 611)
- Perception (some point clouds in this course, vision in EECS 442/504/542, ROB 535: Self Driving Cars, ROB 330)
- Estimation and Mapping (some estimation in this course, mapping and more in EECS 467, ROB 530, ROB 330)
- Kinematics/Dynamics (a little in this course, more in ROB 320, ME 567)
- Machine Learning (a little in this course, take EECS 445, ROB 498)

Prerequisites and Enrollment

- Prerequisites: EECS 280, MATH 215
- Recommended: EECS 281, Linear algebra (MATH 214/MATH 217/ROB 101)

Practical Issues

- GSI: Abhinav Kumar
  - Office hours: Mon 10am-12pm and Thurs 2pm-4pm

- See course website for most current information:

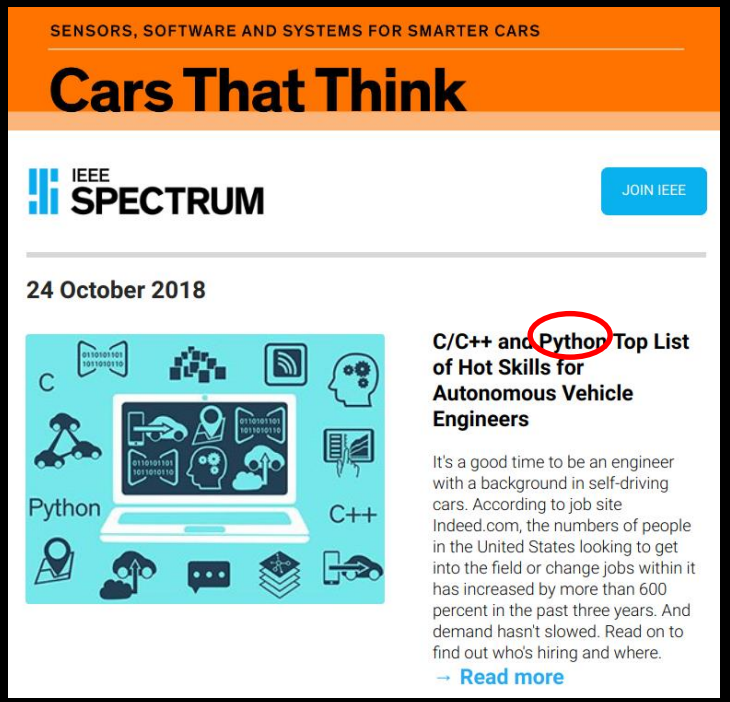
  http://berenson.robotics.umich.edu/courses/fall2023iar/index.html

  (Link to this site is on my homepage)

- Office hours with me are after class: MW 4:30-5:00

Programming expectations

- We will use Python for programming assignments
- This is a language you WANT to know
  - Relatively easy to learn and use
  - A very common language for robotics algorithms (when you don't need real-time performance)
  - Allows you to use many common robotics, optimization, and math libraries
- There will be a Python tutorial offered by our GSI
  - You don't need to be an expert!
  - Many tutorials online
- Can I use Matlab instead?
  - No


SENSORS, SOFTWARE AND SYSTEMS FOR SMARTER CARS

Cars That Think

IEEE SPECTRUM

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24 October 2018

C/C++ and Python Top List of Hot Skills for Autonomous Vehicle Engineers

It's a good time to be an engineer with a background in self-driving cars. According to job site Indeed.com, the numbers of people in the United States looking to get into the field or change jobs within it has increased by more than 600 percent in the past three years. And demand hasn't slowed. Read on to find out who's hiring and where.

→ Read more

Math expectations

- Linear algebra is important
  - We will cover important concepts briefly
  - E.g. dot products, cross products, matrix operations, etc.,
- Be comfortable with math notation
  - An example:

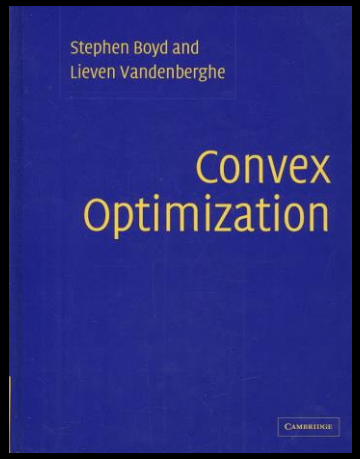
$$X_{obs} = \left(\bigcup_{i=1}^{m} X_{obs}^{i}\right) \bigcup \left(\bigcup_{ij,\ i \neq j} X_{obs}^{ij}\right)$$

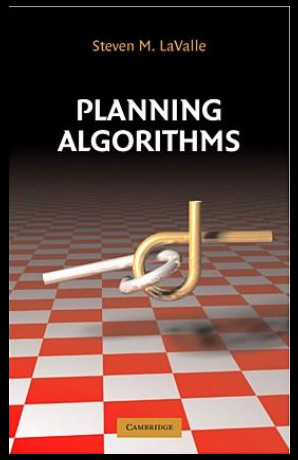
$$X_{obs}^{ij} = \{(s_1, \ldots, s_m) \in X \mid \mathcal{A}^i(\tau_i(s_i)) \cap \mathcal{A}^j(\tau_j(s_j)) \neq \emptyset\}$$

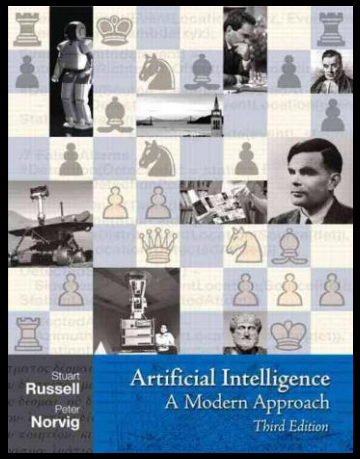
$$\mathcal{C}_{obs}^{p} = \{(q^a, q^p) \in \mathcal{C} \mid \text{int}(\mathcal{P}(q^p)) \cap \mathcal{O} \neq \emptyset\}$$

Readings

- We will read selected chapters from three books:
  - Stephen Boyd and Lieven Vandenberghe. Convex optimization. Cambridge university press, 2004. Free online!
  - Steven M. LaValle, *Planning Algorithms* , Cambridge University Press, 2006. Free online!
  - Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach* **(Third edition)** , Cambridge University Press, 2004. Need to buy/rent.







Syllabus

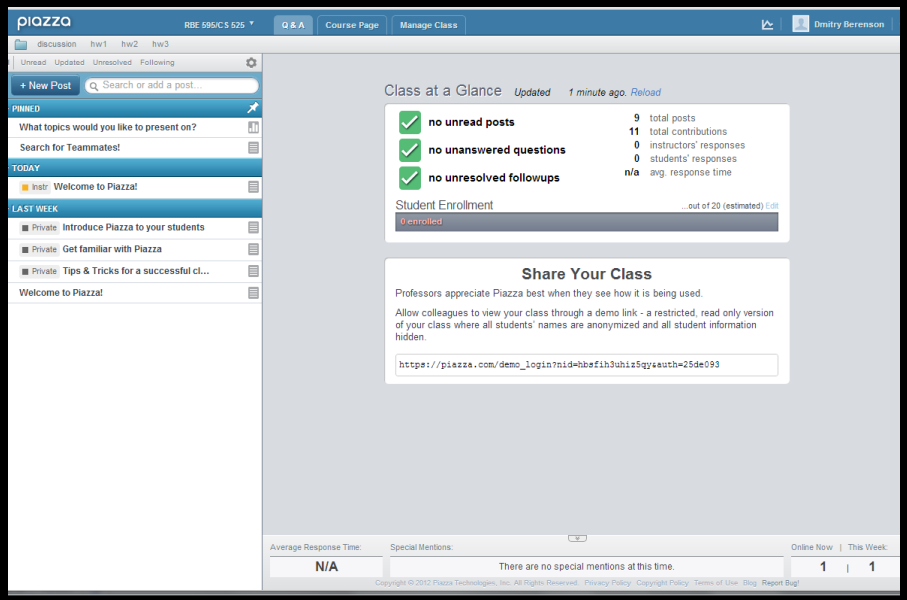
- No exams!
- Quizzes (online through canvas)
  - Approximately 1 per week (maybe more, maybe less)
  - Should review previous lecture's reading/notes before quiz
  - Lowest quiz grade is dropped
- Homeworks
  - Individual (no groups)
  - Learn to implement algorithms
- Final Project
  - Expand on one of the homeworks
  - Write a report

Grading

- Homeworks 50%
- Quizzes 15% (drop lowest)
- Final Project 35%

Piazza

- We will use **piazza.com** for all class communication (question/answer about homeworks, paper discussion, etc.)



Schedule

- Latest schedule is on course website:

Intro to Alg Robotics Course 2021 : Schedule

8/30/2021	Introduction		Boyd Linear Algebra Book: Chapters 1.1-1.4; 3.1-3.2; 5.1-5.3; 6.1-6.4; 10.1; 11		Make sure you can access the course on Piazza
9/1/2021	Linear Algebra		LaValle Chapter 3.2		
9/6/2021	LABOR DAY				
9/8/2021	Transformations		Convex Optimization Book: Chapters 1; 2.1-2.3; 2.5; 3.1-3.2.5		Homework 1 Out
9/13/2021	Convexity and Optimization		Convex Optimization Book: Chapters 9.1-9.1.1; 9.2; 9.3-9.3.1; 9.5-9.5.2; 9.5.4	Subgradients (except Section 4)	Numerical Differentiation (up to Complex-variable Methods)
9/15/2021	Unconstrained Optimization		Convex Optimization Book: Chapters 5.1-5.1.5; 5.2-5.2.3; 5.5; 11.1-11.3)		
9/20/2021	Constrained Optimization		Graphs in computer science	AI book Ch. 4.1-4.2	
9/22/2021					
9/27/2021					
9/29/2021					
10/4/2021					
10/6/2021					
10/11/2021					
10/13/2021					
10/18/2021	FALL BREAK				
10/20/2021					
10/25/2021					
10/27/2021					
11/1/2021					
11/3/2021					
11/8/2021					
11/10/2021					

What can you expect to get from this course?

- An understanding of the fundamentals behind many algorithmic robotics methods
- Programming experience
- Hands-on experience working with optimization, motion planning, and estimation
- Opportunities to go beyond the class

Homework

- Make sure you can access Piazza through the Canvas site
- Read Boyd Linear Algebra book (https://web.stanford.edu/~boyd/vmls/)
  - Chapter 1.1-1.4
  - Chapter 3.1-3.2
  - Chapter 5.1-5.3
  - Chapter 6.1-6.4
  - Chapter 10.1
  - Chapter 11
  - Chapter 13.1

Waitlisted Students

- Course size is limited by the capacity of the room
  - I can't change this
- Keep coming to class to see if spots open
- We will admit people in order of the waitlist (this is done automatically)

- I can add you to Canvas if you want to keep up with the lecture recordings
  - I will send out a form for you to do this
- Please don't email me asking for permission to enroll