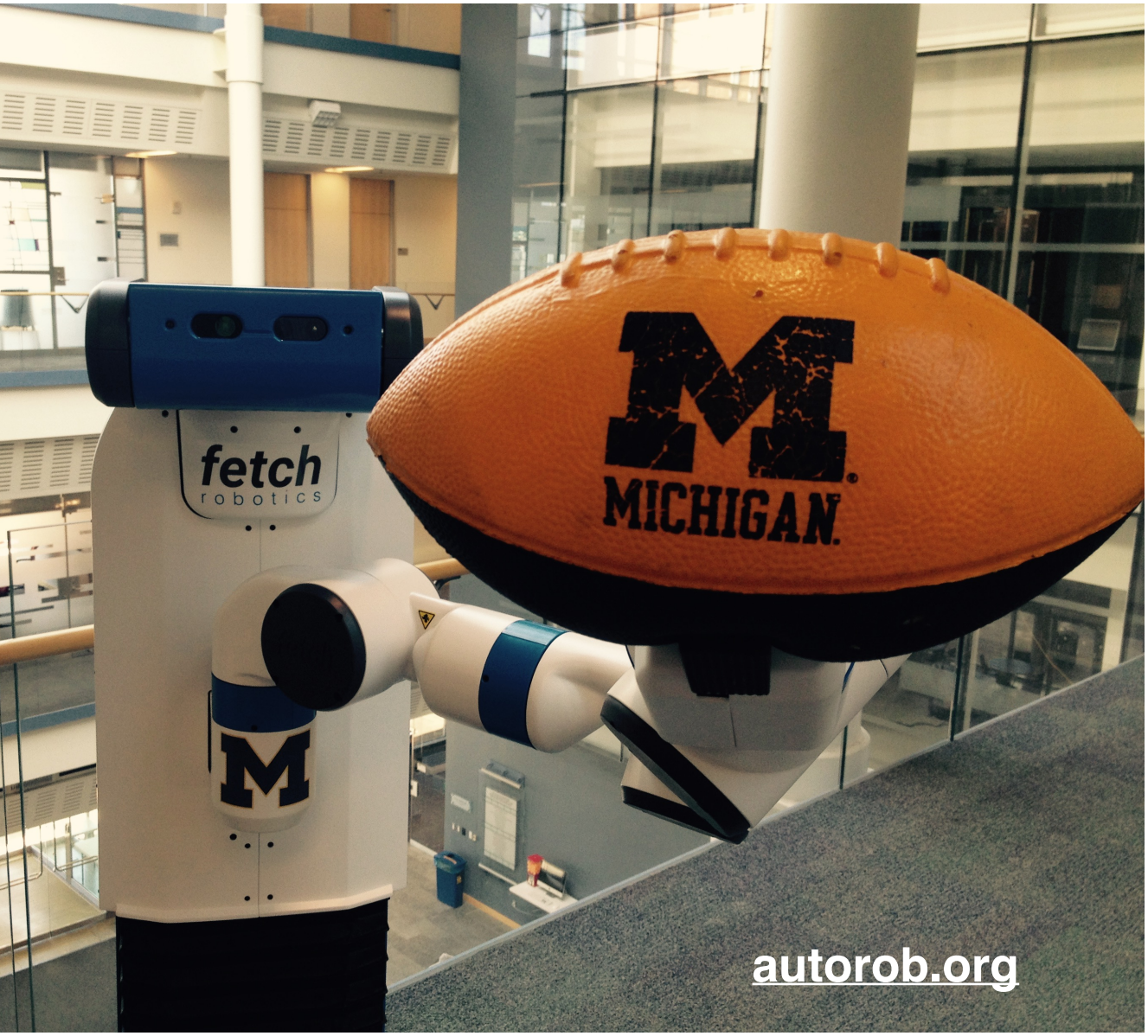


Initialization

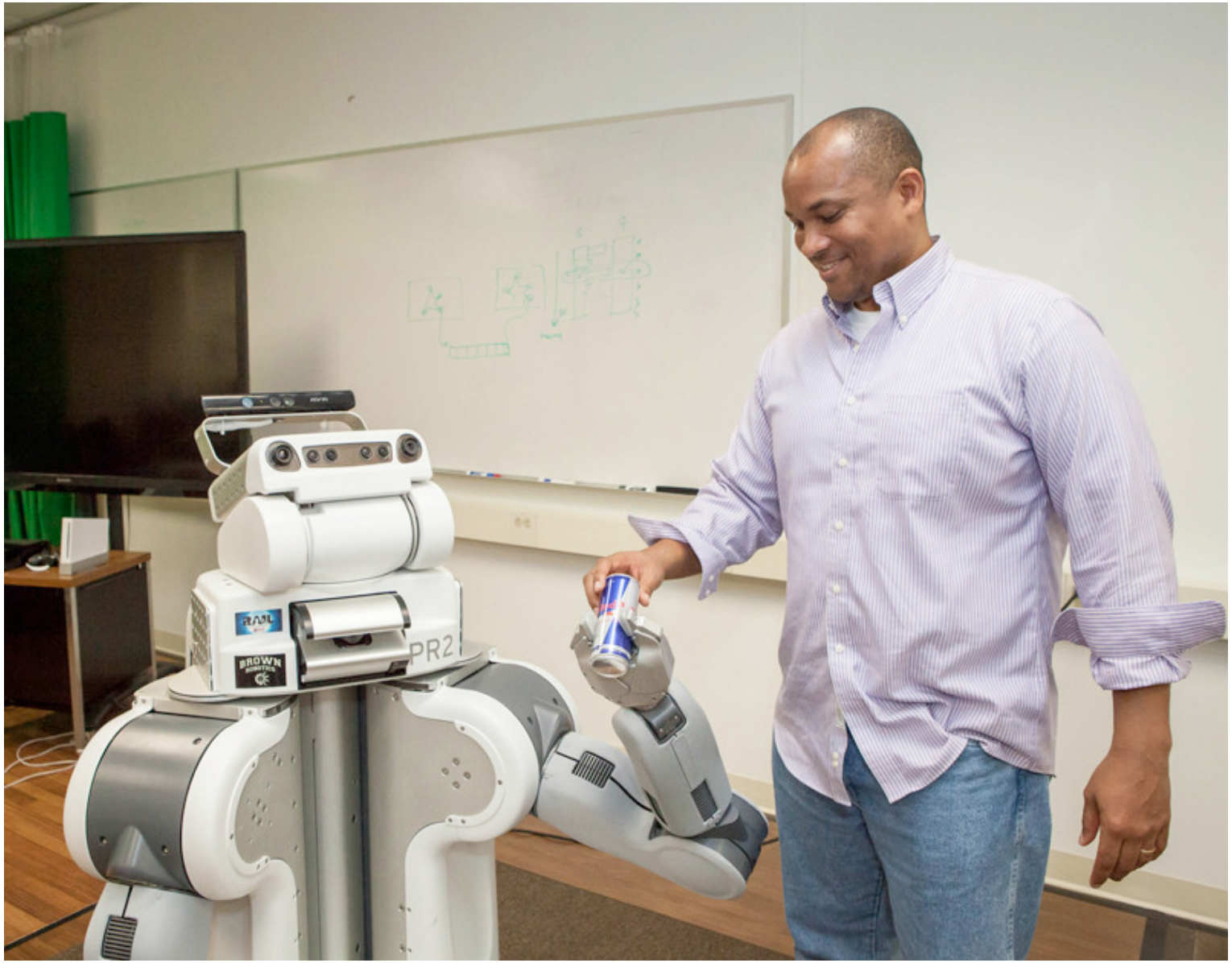
EECS 398
Intro. to Autonomous Robotics

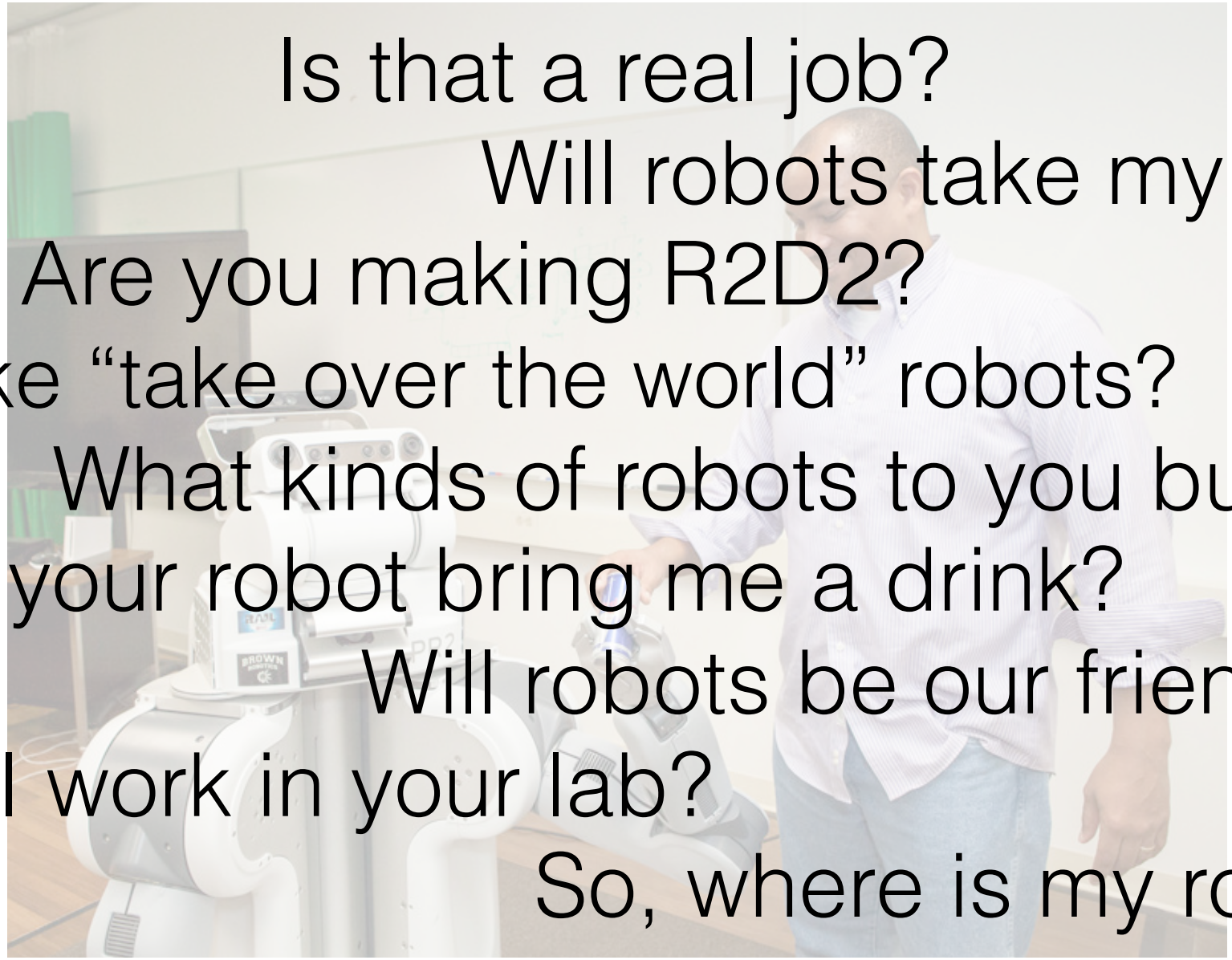
ME/EECS 567 ROB 501
Robot Modeling and Control

Fall 2018

Agenda

- So, where is my robot?
- Roadmap for autonomous robotics
- Course administrative overview
- Assignment 1 (Path Planning) assigned Monday
  - JavaScript/HTML5 and git covered this and next lecture
- Action items: what I need from you now


PR2



Is that a real job?

Will robots take my job?

Are you making R2D2?

Like “take over the world” robots?

What kinds of robots to you build?

Can your robot bring me a drink?

Will robots be our friends?

Can I work in your lab?

So, where is my robot?

So, where is my robot?

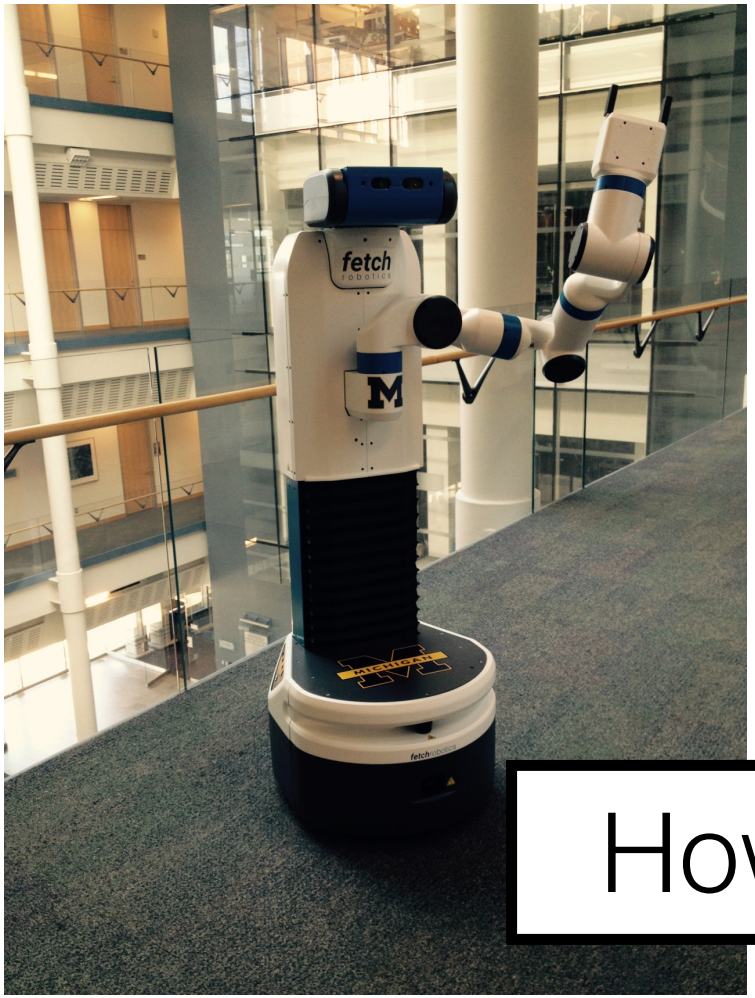

fetch
robotics
M
MICHIGAN

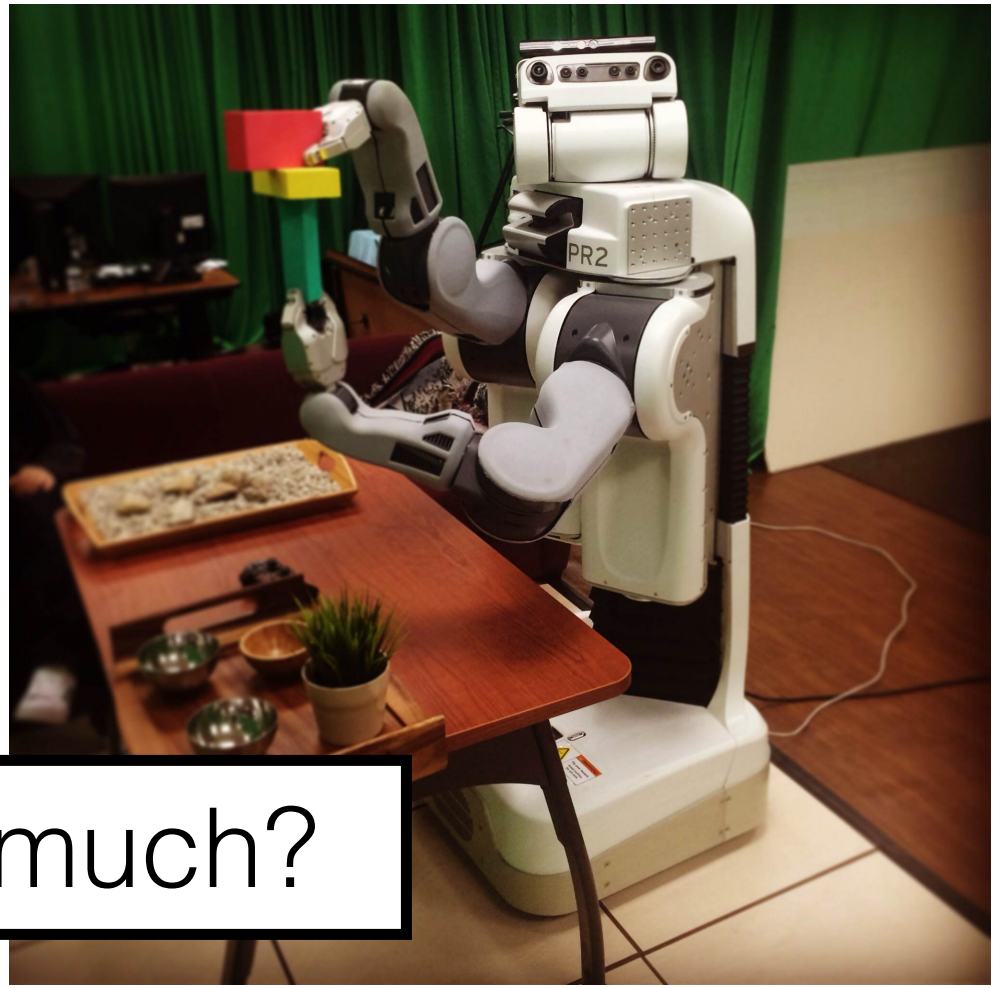

PR2

Mobile Manipulation Robots

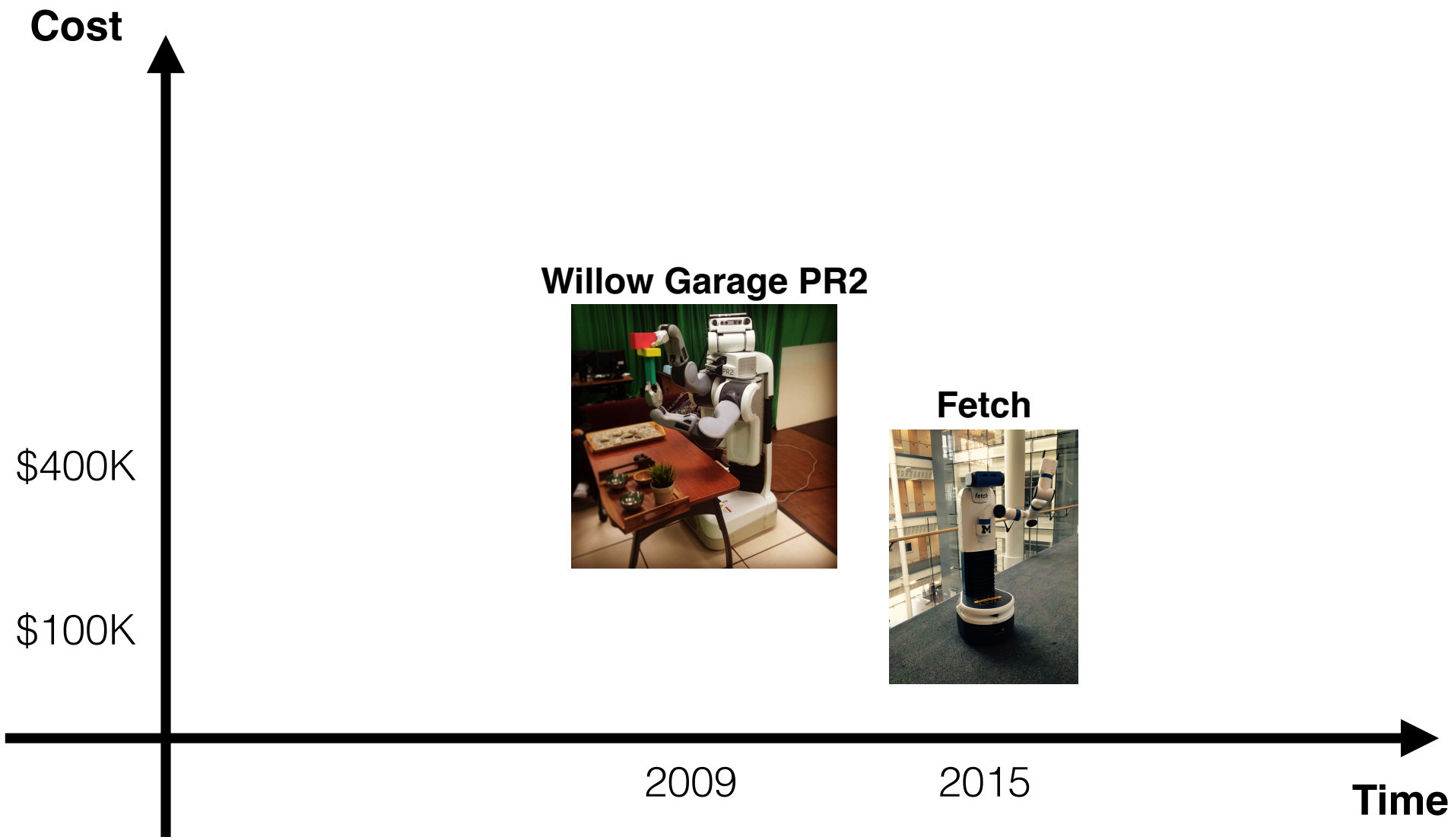

fetch

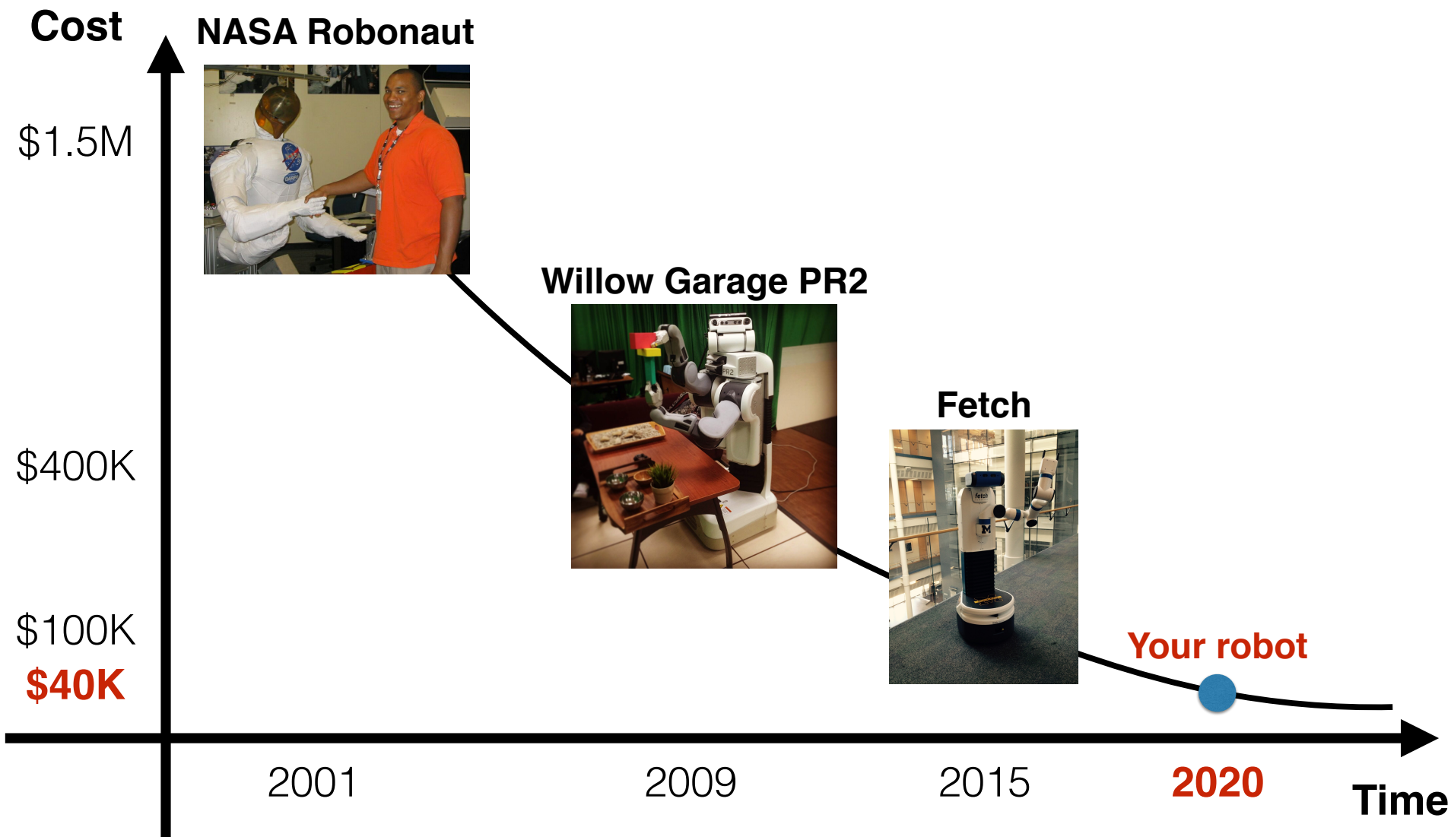

PR2

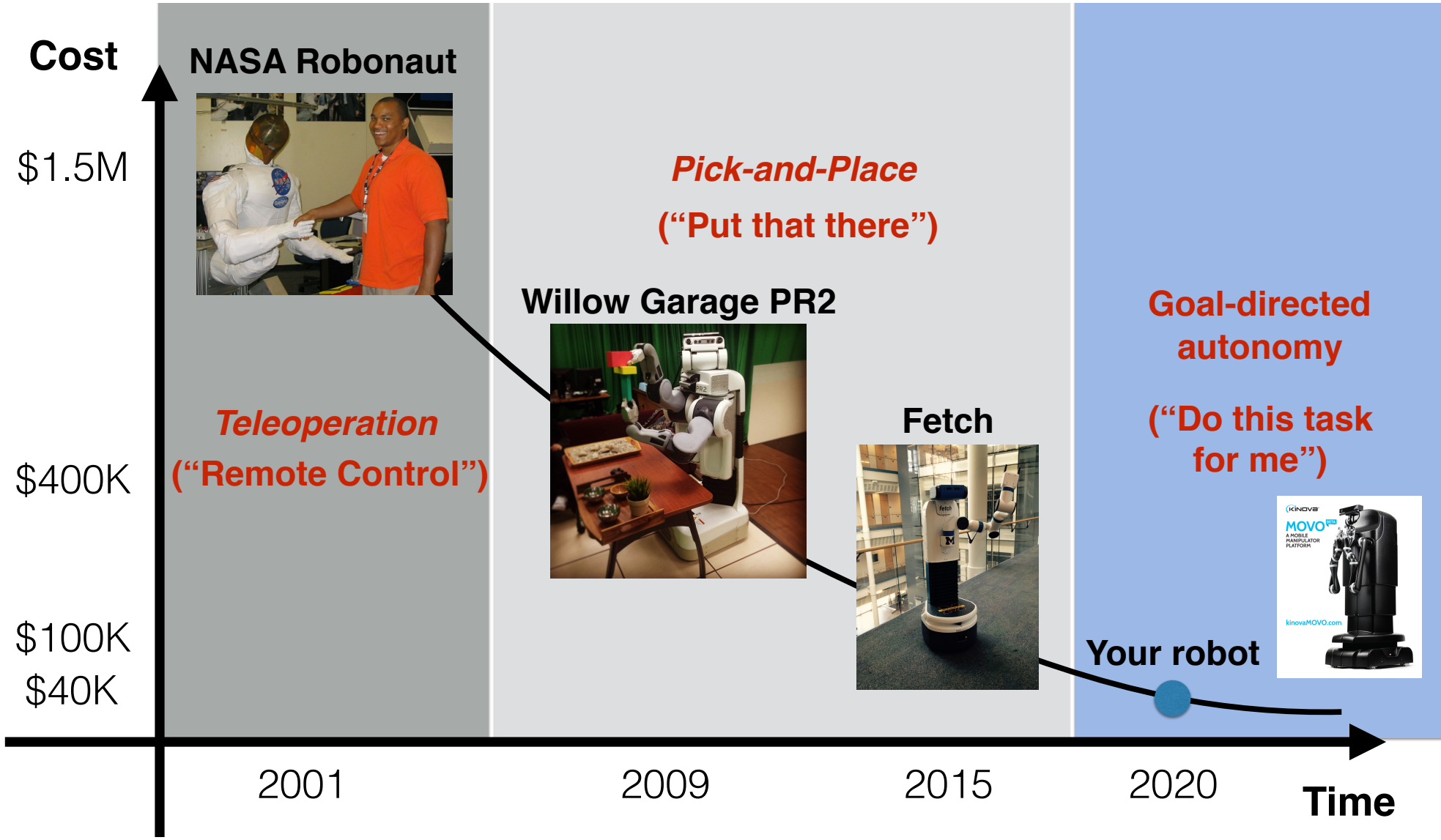




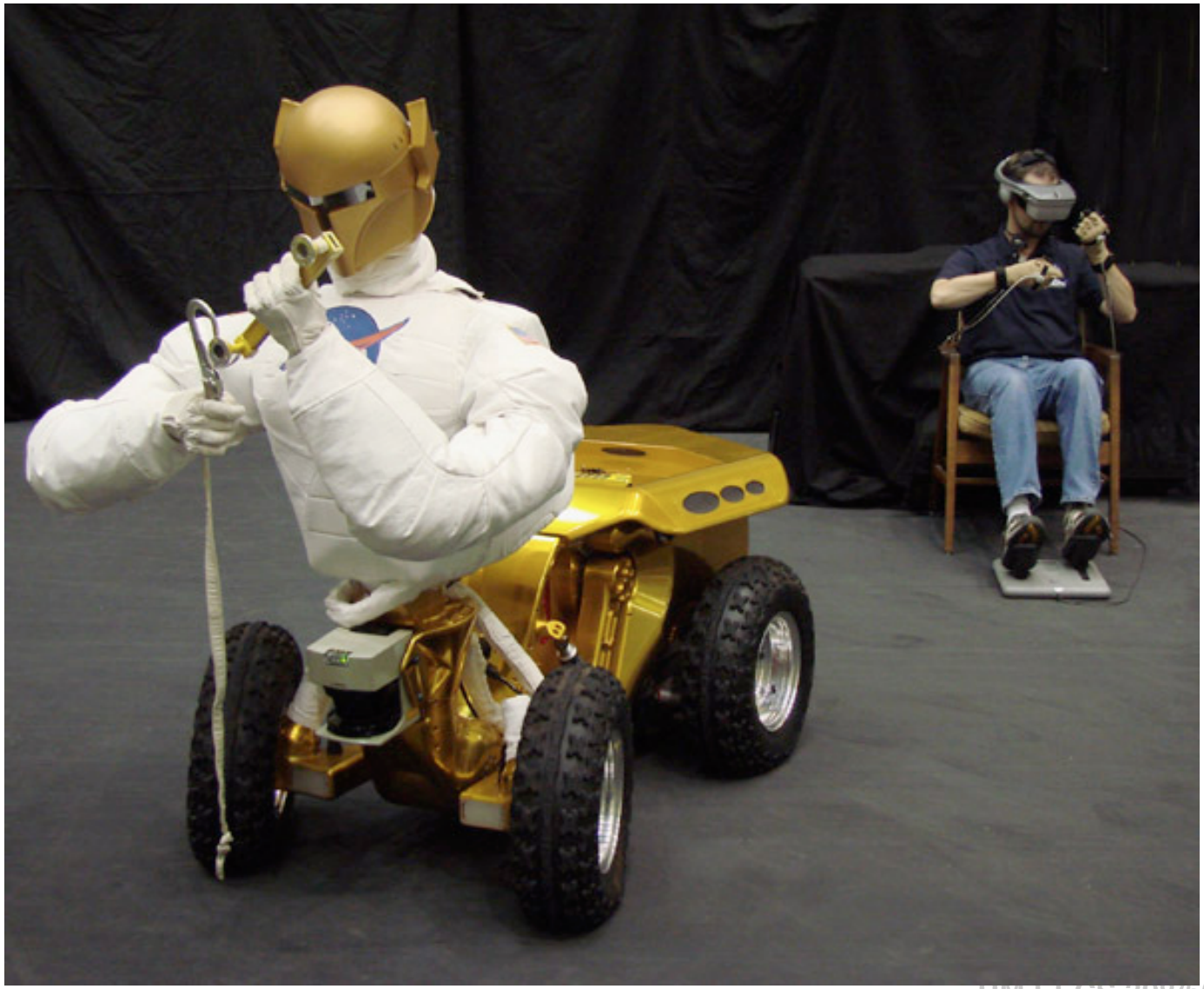
How much?


Cost
Willow Garage PR2
Fetch
$400K
$100K
2009
2015
Time

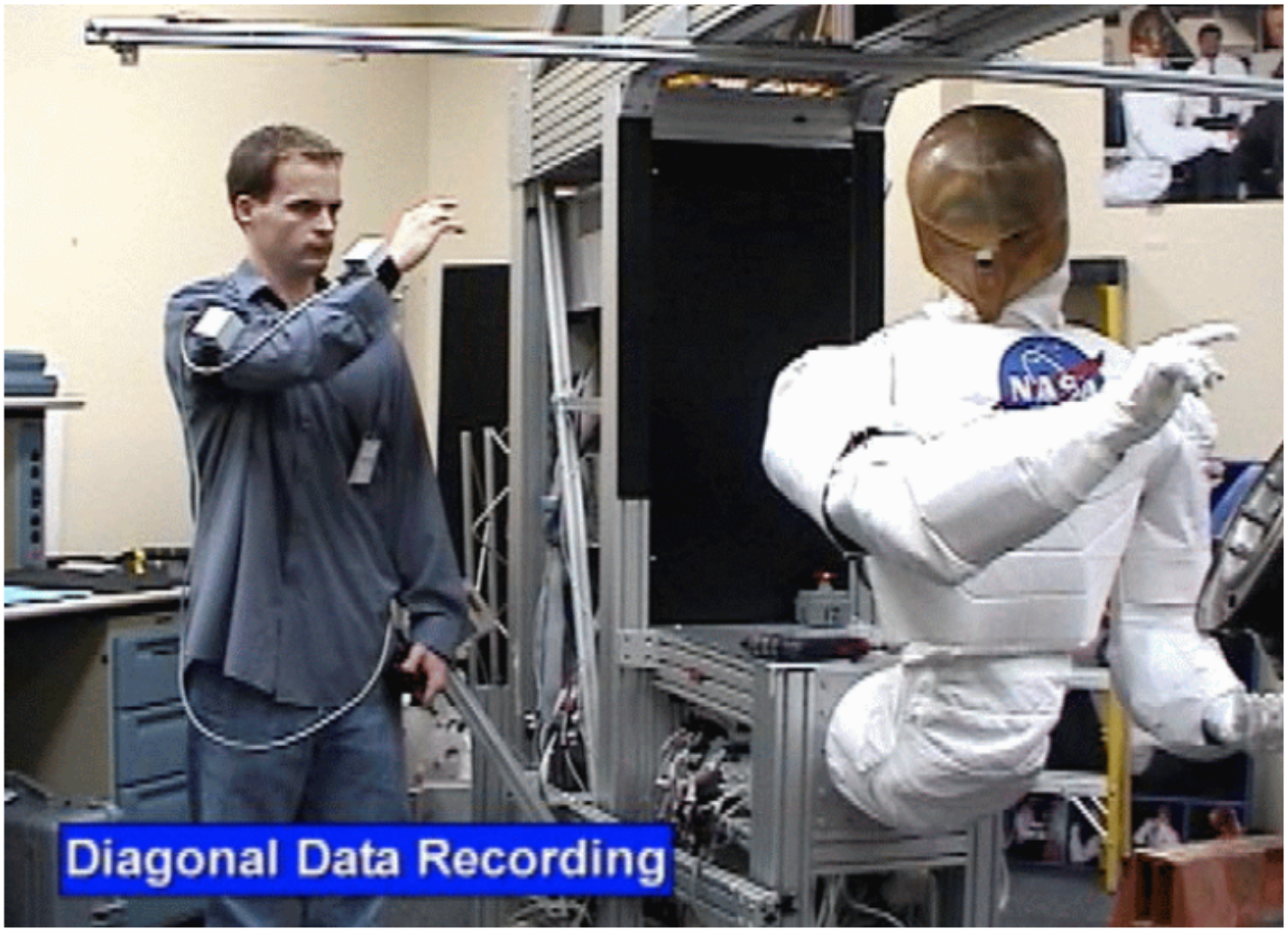

Cost
NASA Robonaut
$1.5M
Willow Garage PR2
$400K
Fetch
$100K
$40K
Your robot
2001
2009
2015
2020
Time


Cost
$1.5M
$400K
$100K
$40K
NASA Robonaut
Teleoperation
("Remote Control")
Pick-and-Place
("Put that there")
Willow Garage PR2
Fetch
Goal-directed autonomy
("Do this task for me")
Your robot
2001
2009
2015
2020
Time

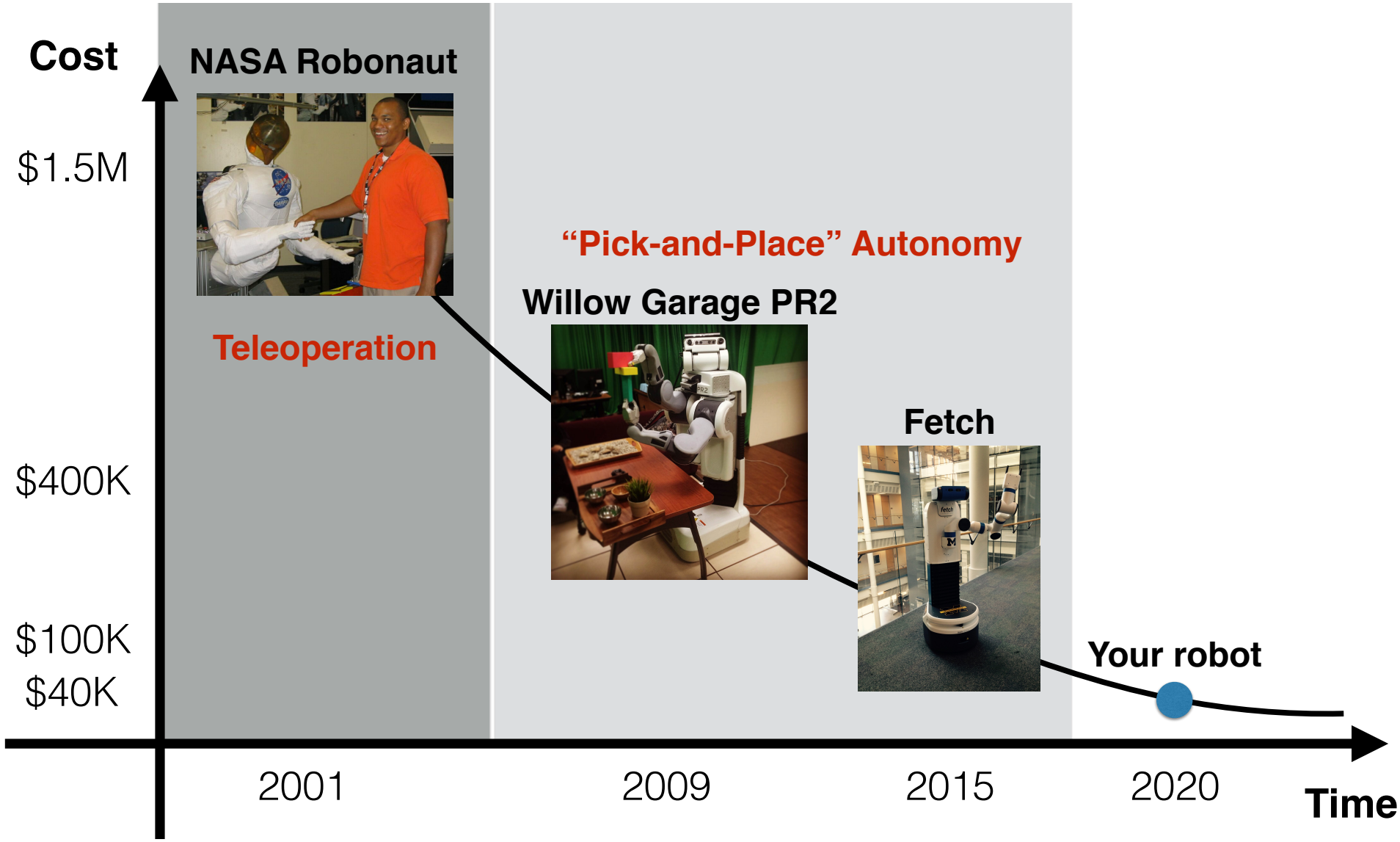
NASA Robonaut 2 on the International Space Station



Wearable wireless motion capture for robot teleoperation



[Miller, Jenkins, et al., 2004, “Motion Capture from Inertial Sensing for Untethered Humanoid Teleoperation”]


Cost
$1.5M
$400K
$100K
$40K
NASA Robonaut
Teleoperation
"Pick-and-Place" Autonomy
Willow Garage PR2
Fetch
Your robot
2001
2009
2015
2020
Time

Autonomous Robotics in 3 words

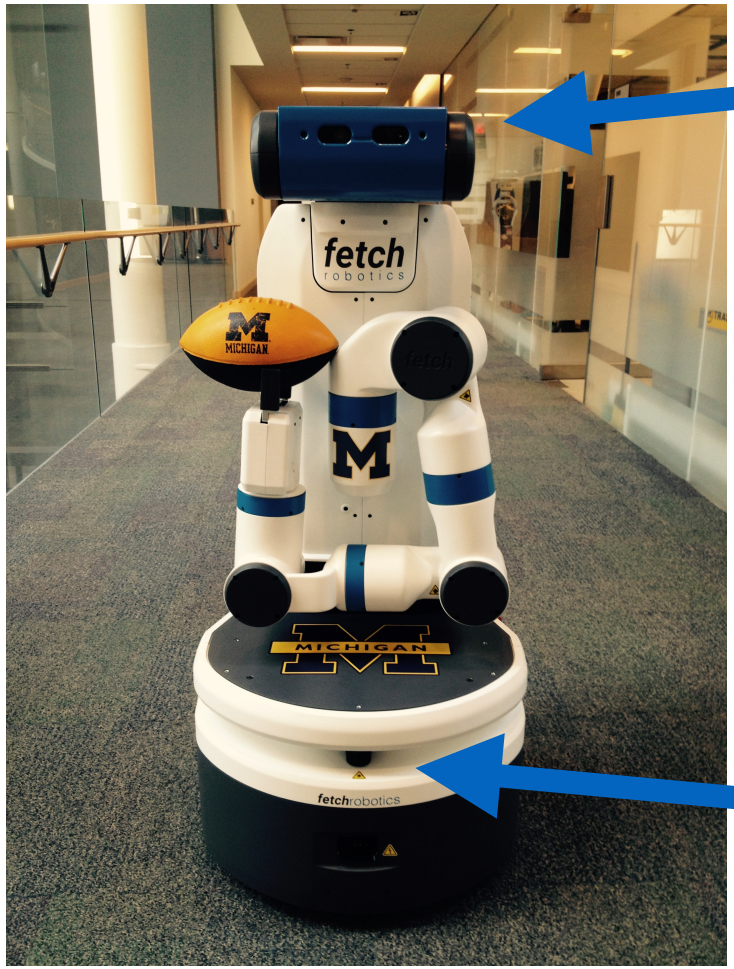
Sense.
Plan.
Act.

Autonomous Robotics in 3 words

Sense. **Perceive** a model of the current world state.

Plan. **Search** over actions towards a goal state.

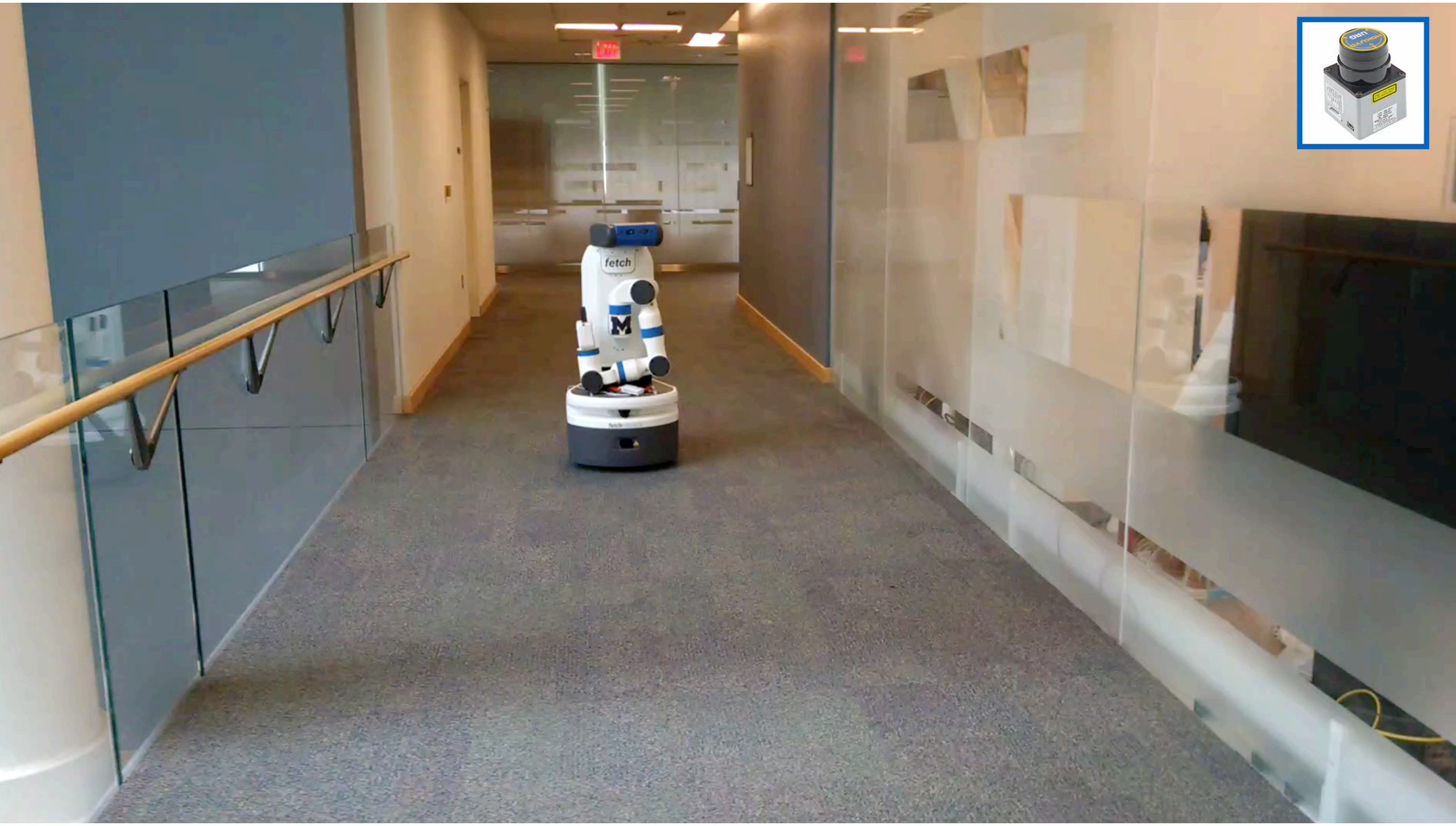
Act. **Execute** actions through forces at robot's motors



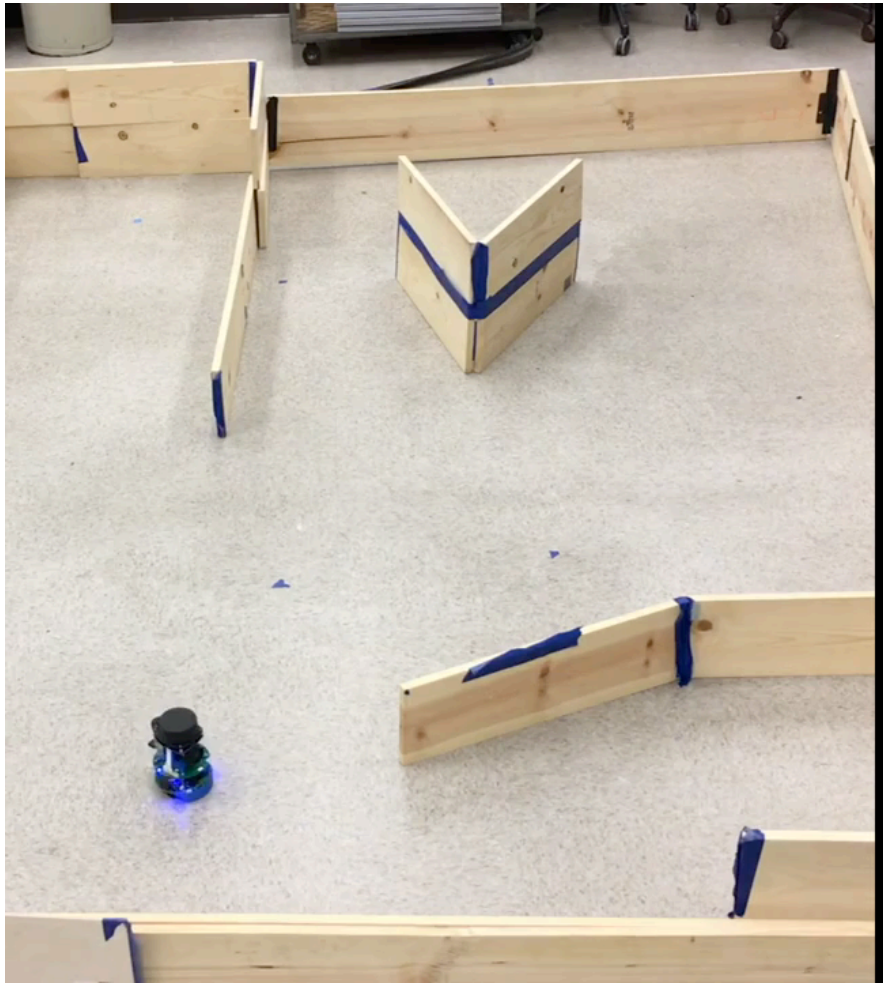
Color+Depth Camera

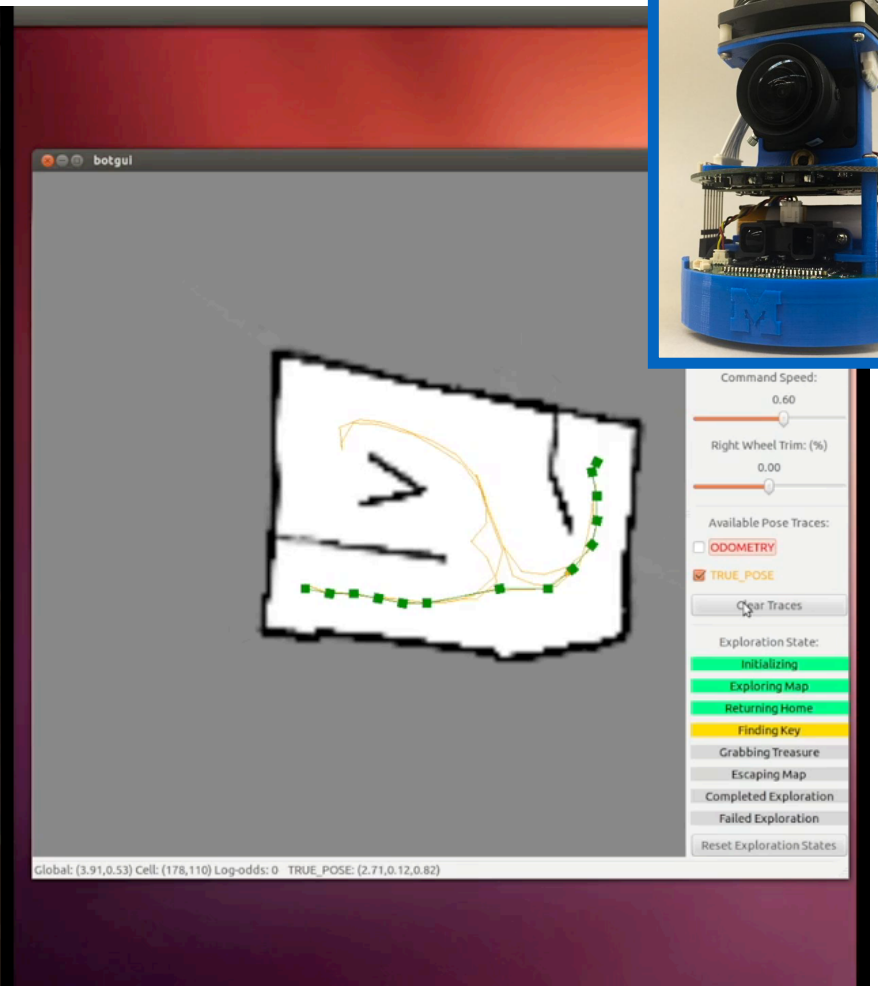
Laser Rangefinder


fetch
robotics
MICHIGAN
MICHIGAN
fetchrobotics


fetch

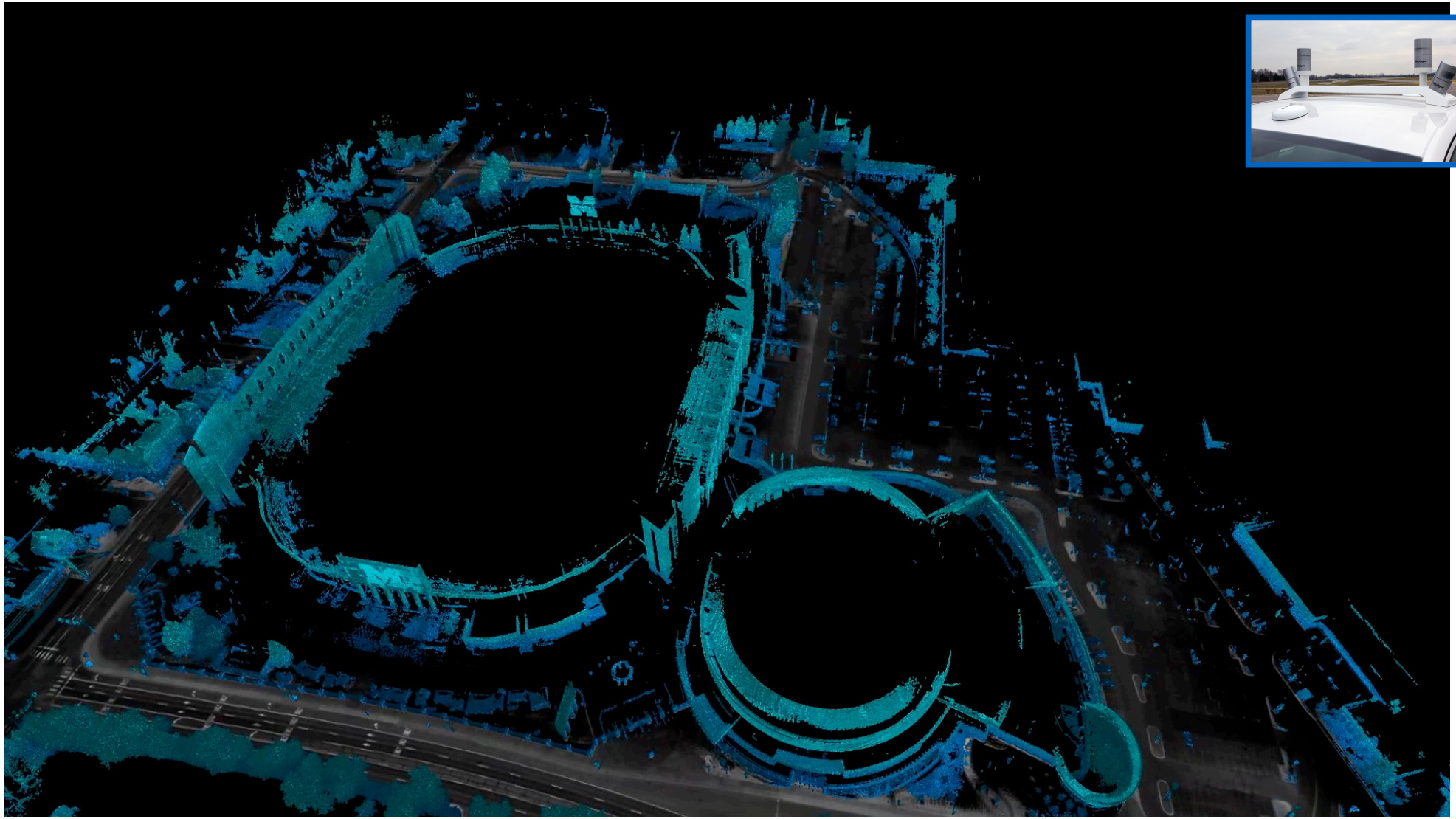
ROB 550 BotLab / EECS 467 Escape Challenge 2016-17



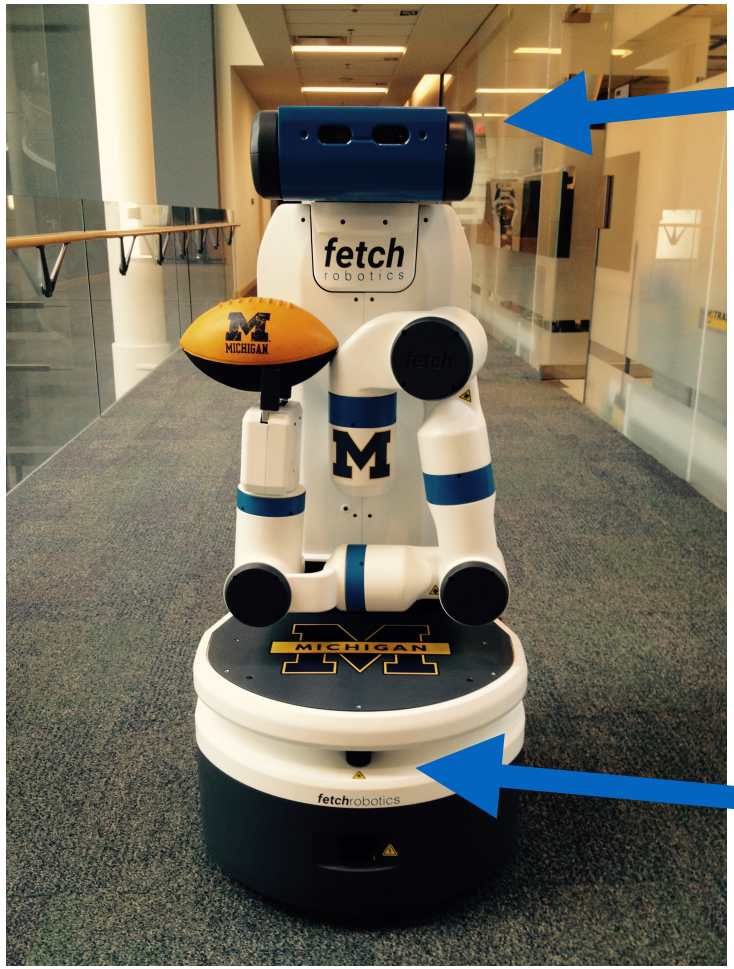


Jasmine Liu et al.

Michigan Next Generation Vehicle (Olson, Eustice, et al.)

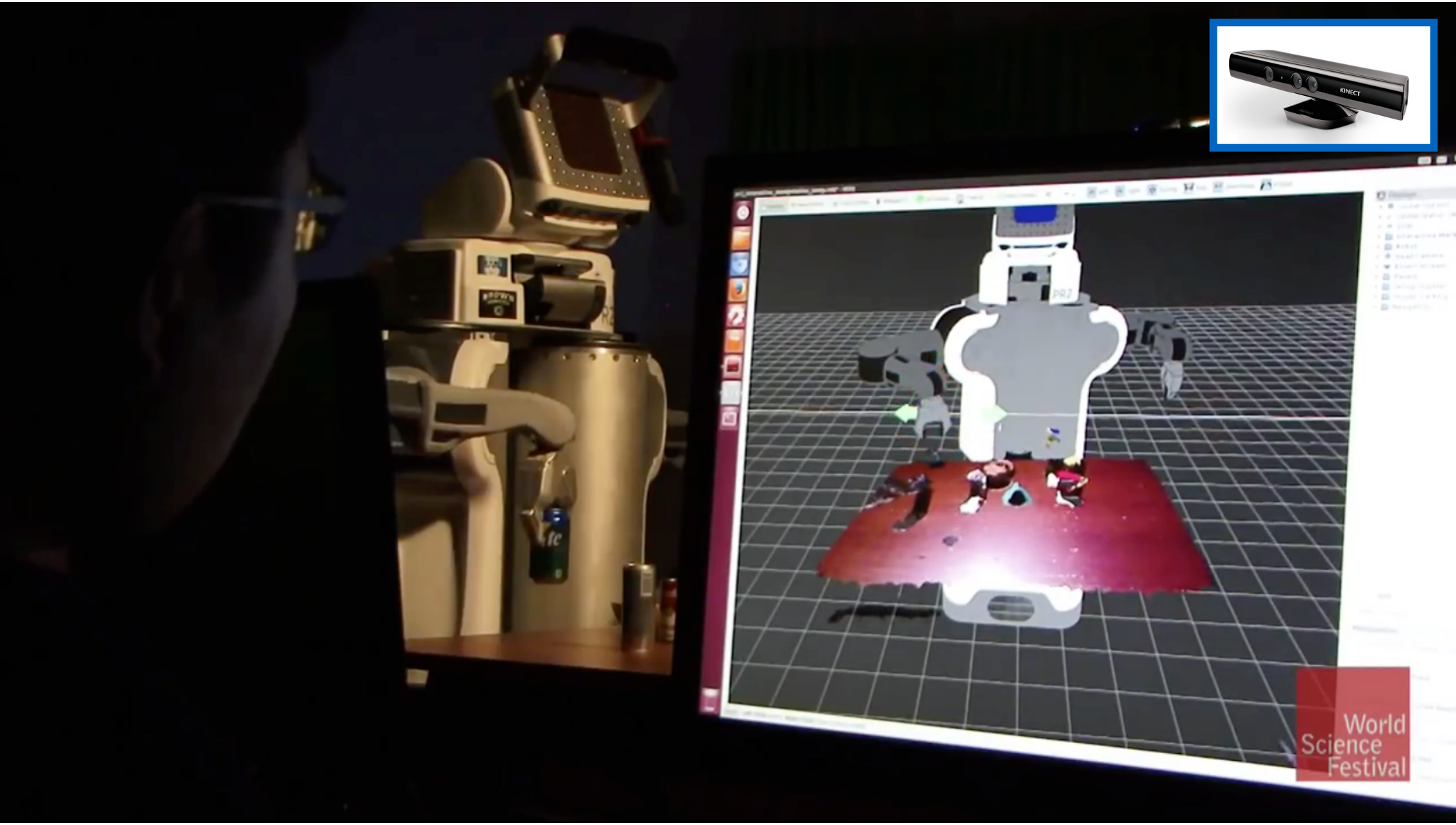


Michigan Next Generation Vehicle (Olson et al.)



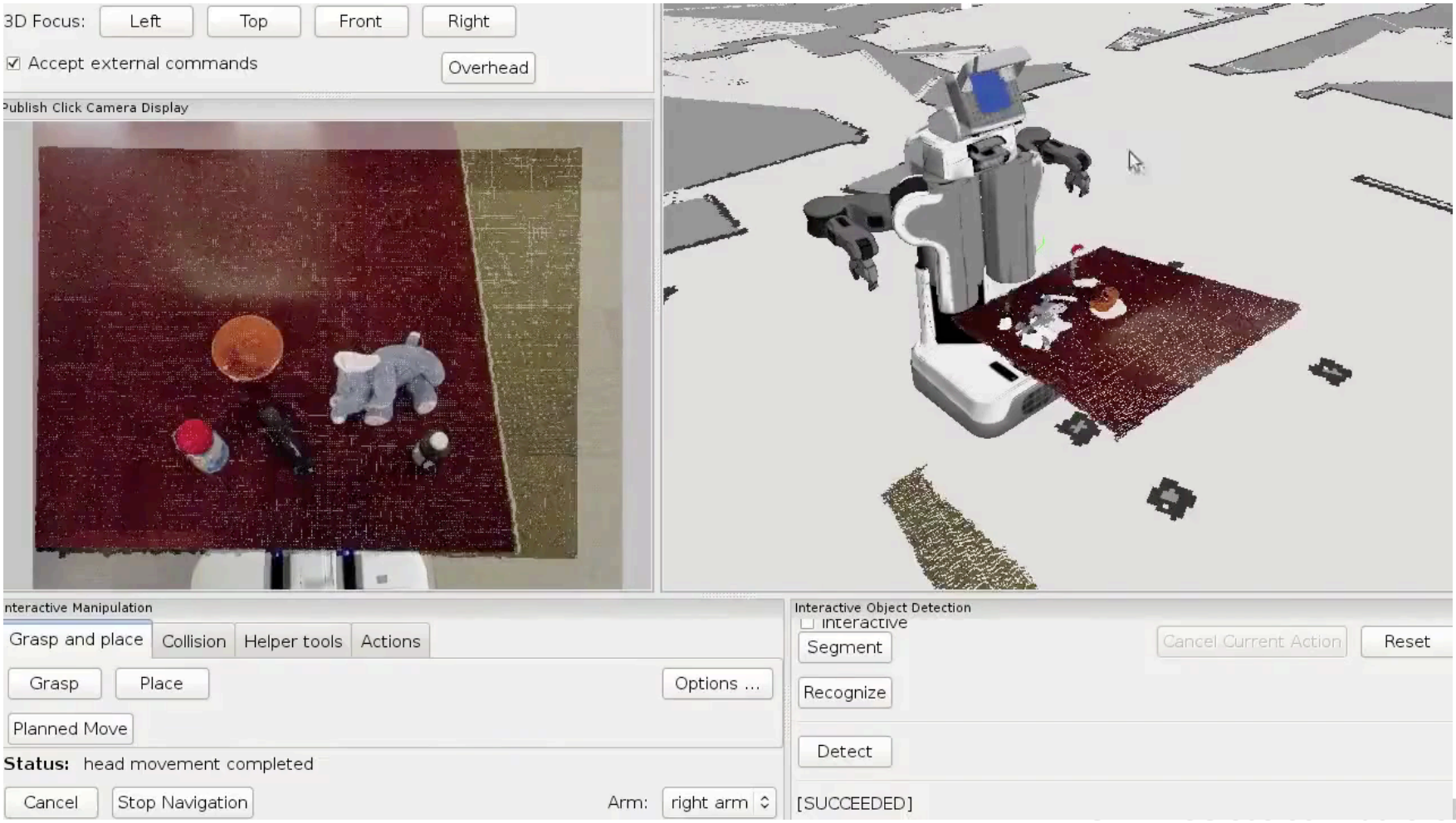
Color+Depth Camera

Laser Rangefinder


KINECT
World
Science
Festival

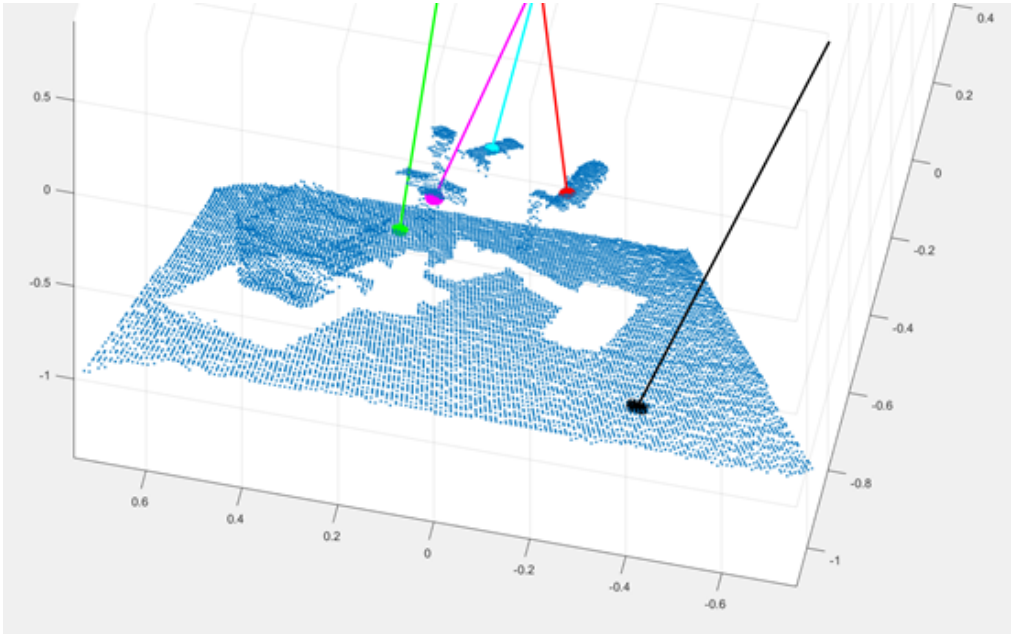
Object Manipulation

Willow Garage



b.github.io

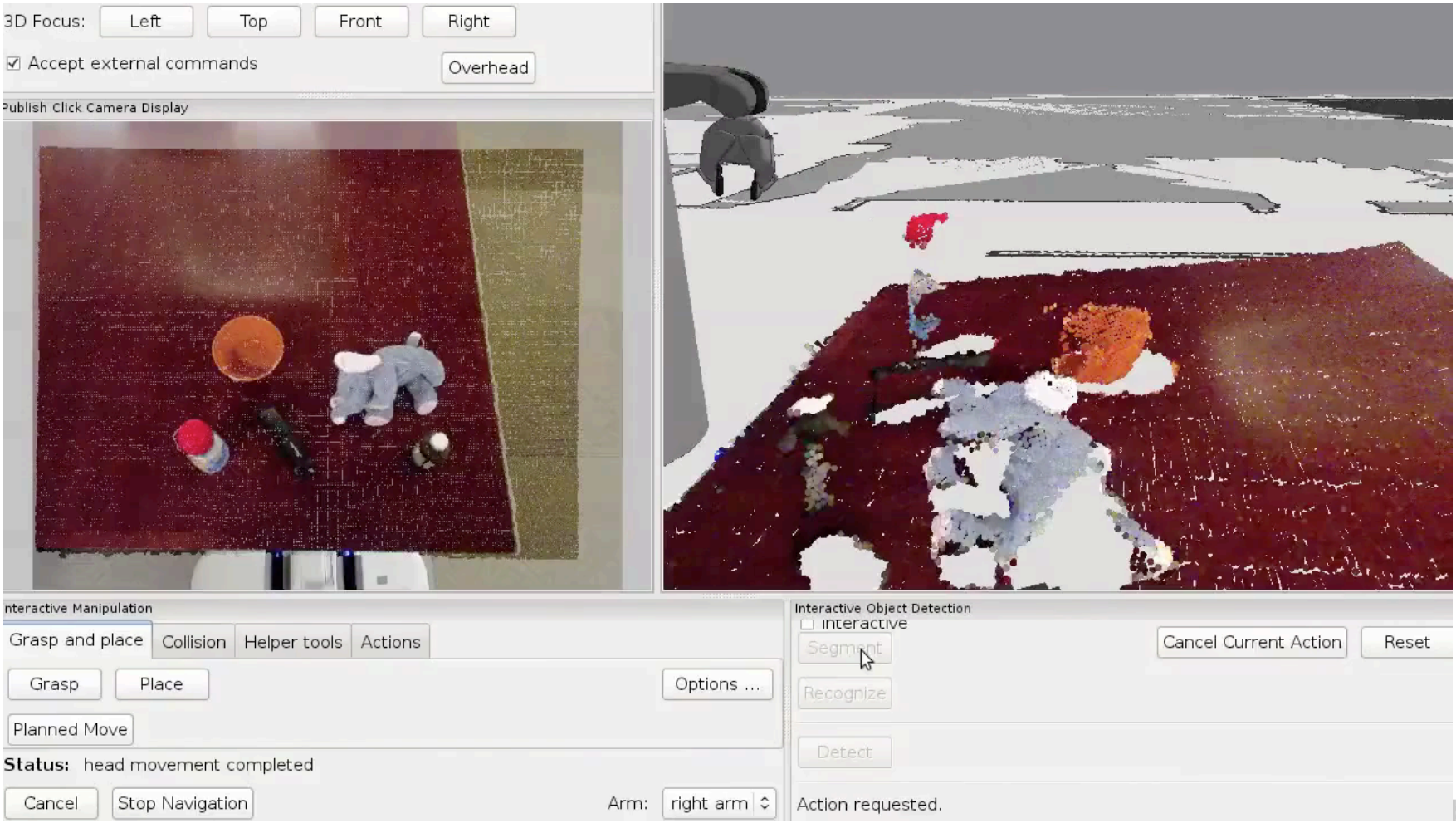
Point Cloud Processing (briefly)



- For every point:
  - compute nearest neighbors
  - compute principal components in neighborhood `eig(cov(nbhd(:,1:3))`
  - surface normal is eigenvector for smallest eigenvalue
- Cluster points based on direction similarity of normal

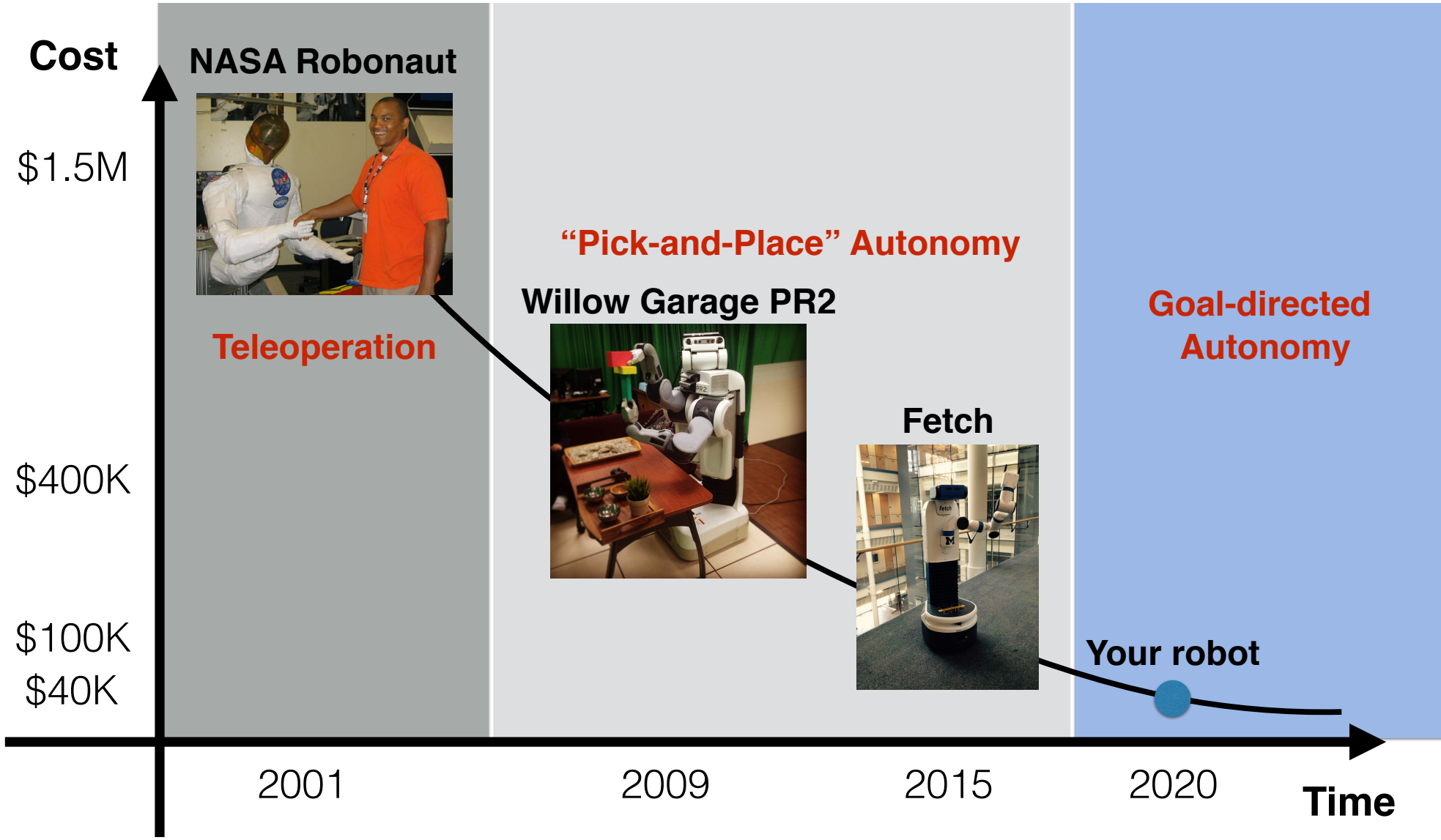
Object Manipulation

Willow Garage



b.github.io


[Sui, Jenkins, et al. IROS 2017]
GO BLUE
M
BUBBLE 1000
BAKING SET
RACLETTE GRILLING PAN
What's in Your Sample?


Cost
NASA Robonaut
$1.5M
Teleoperation
"Pick-and-Place" Autonomy
Willow Garage PR2
Goal-directed Autonomy
Fetch
$400K
$100K
$40K
Your robot
2001
2009
2015
2020
Time

Goal-directed Manipulation

Initial Scene → Goal Scene

"put small objects in bin"


“put small objects in bin”
Crest
PRO-HEALTH
Pringles
Kellogg's
GREEK
[Sui, Xiang, Jenkins, Desingh, IJRR 2017]

Semantic Robot Programming

[Zeng, Jenkins, et al. ICRA 2018]

Enable natural user programming of robots
by demonstration of intended goal scenes

Goals shown in upper left corners

8x

Agenda

- So, where is my robot?
- Roadmap for autonomous robotics
- **Course administrative overview**
- Assignment 1 (Path Planning) assigned today
  - JavaScript/HTML5 and git covered this and next lecture

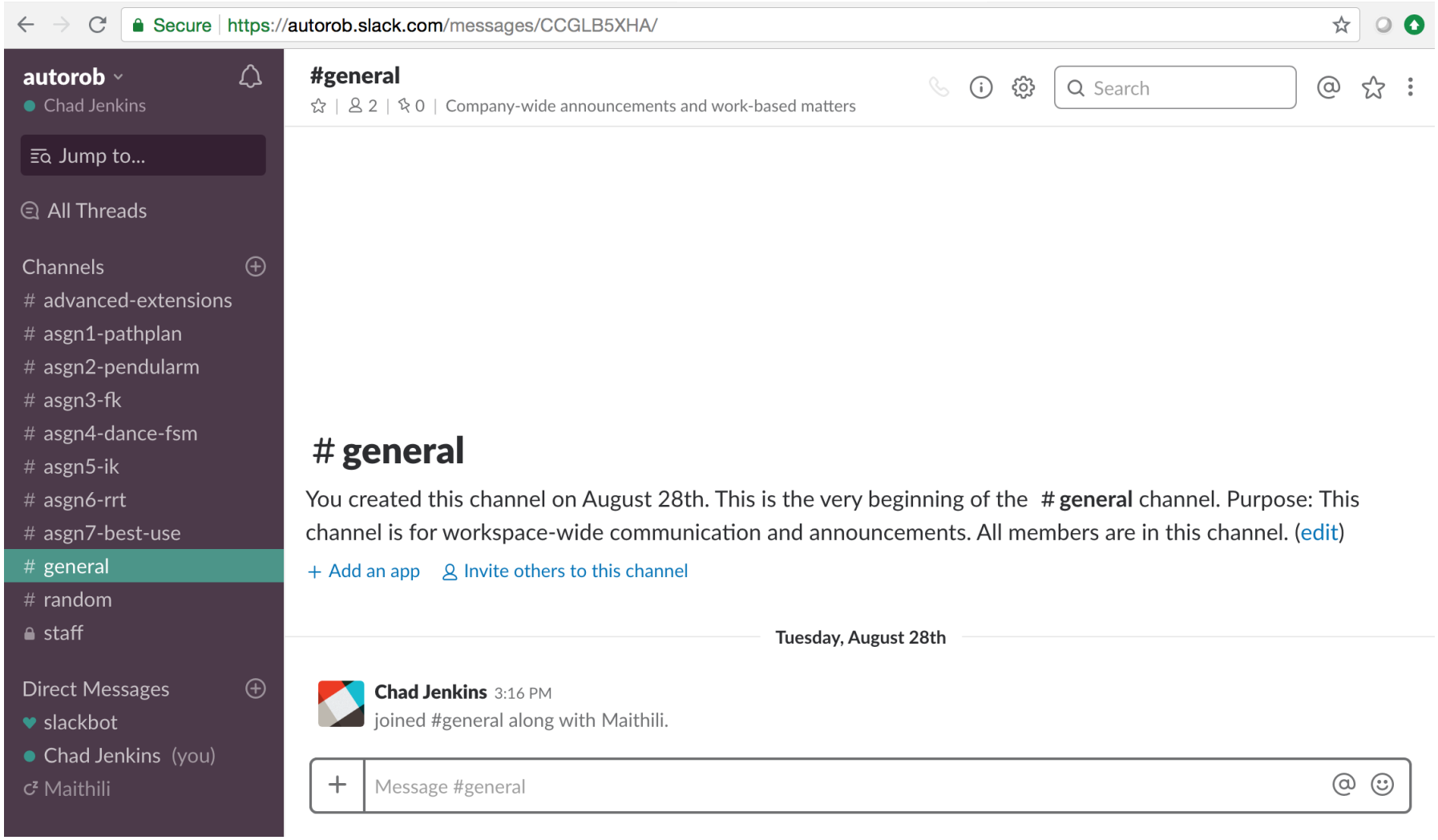
Course Staff

- Instructor: Chad Jenkins (ocj)
  - Office hours (Beyster 3644)
    - Monday 3-5pm, Tuesday 1-3pm
- GSI: Maithili Varang Patel (maithili)
  - Office hours (Beyster 1637 A)
    - Monday 3-5pm, Tuesday 1-3pm (tentative)

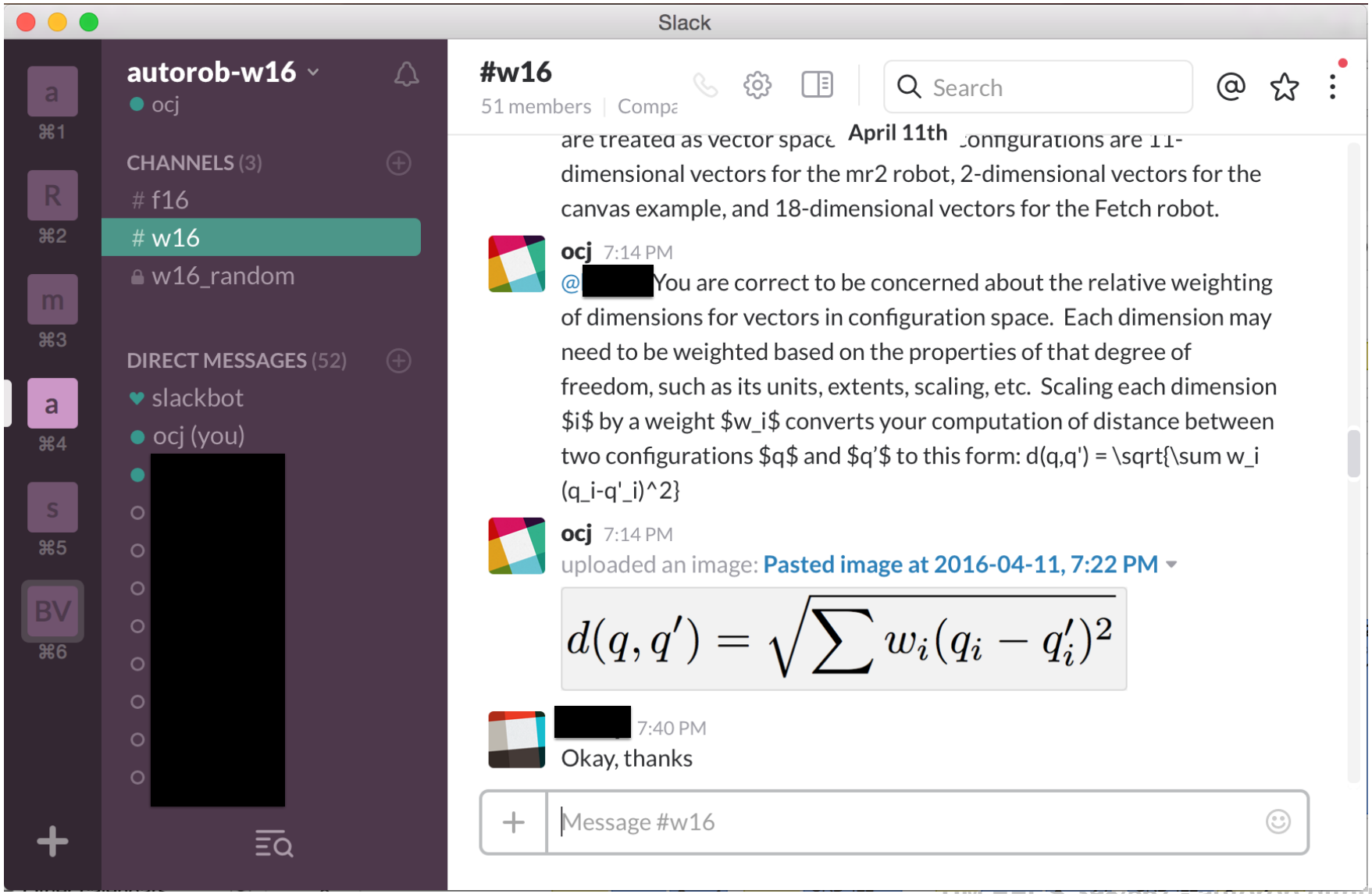
Administrivia

- Meeting time/place
  - MW 1:30-2:40pm MMT, EECS 1500
- Website
  - http://autorob.github.io/
- Discussion channel
  - https://autorob.slack.com/

Slack
via web



Slack OS X app

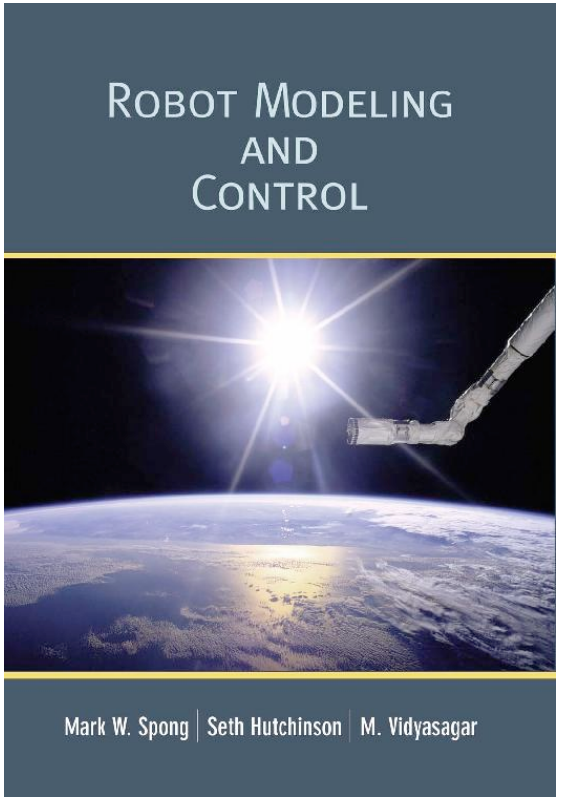


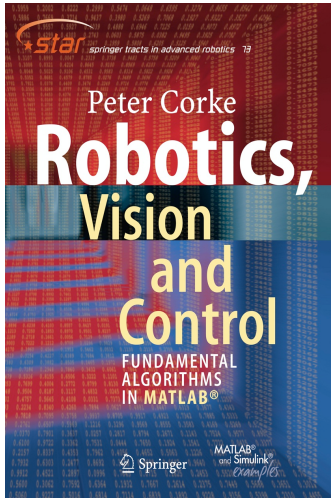
Course Structure

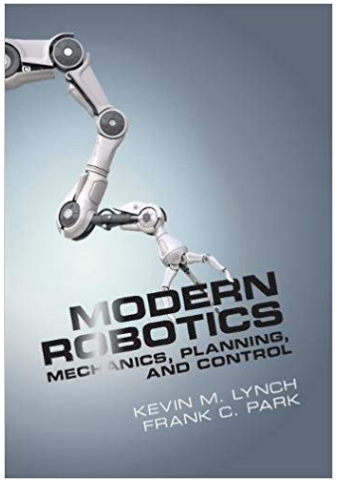
- Autonomous robot modeling and control
  - Objective: Give you the computational skills (and code) to model and control any mobile manipulator
- Project-focused class
  - 7 individual projects: from single joint control up to articulated motion planning
- Computing-friendly introduction to robotics: projects in JavaScript

Course Textbook

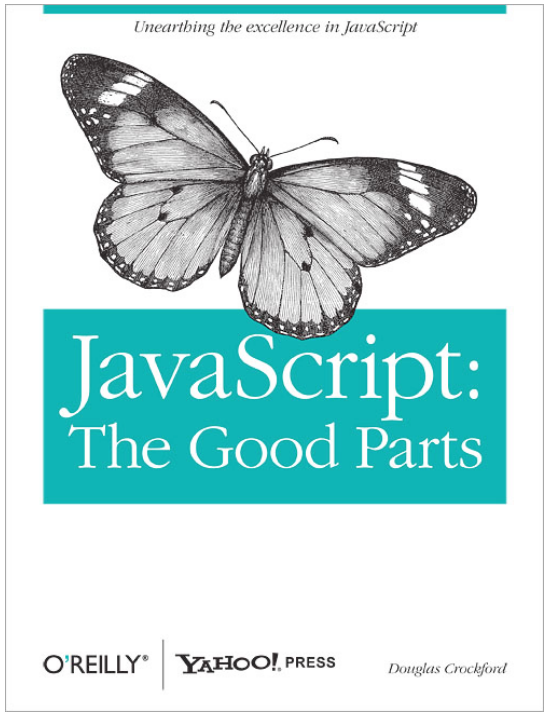
- Robot Modeling and Control (Spong, Hutchinson, Vidyasagar)
- Alternative: Robotics, Vision, and Control (Corke)
- Suggested but unsupported: Modern Robotics (Lynch and Park)
- In-depth coverage of concepts and math contained in textbooks
- Additional handouts and links will appear on the course website

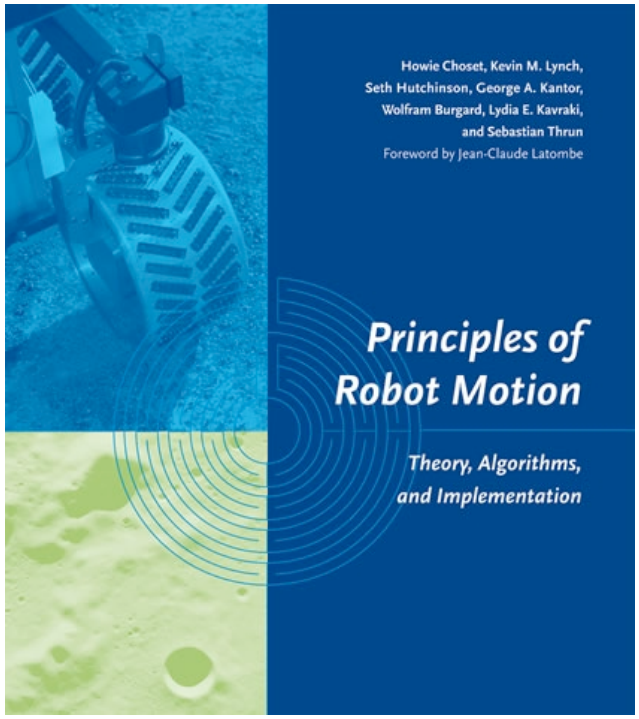






Optional reading





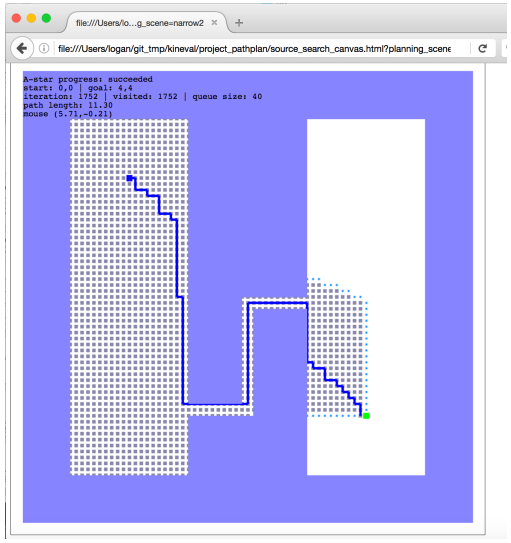
Projects

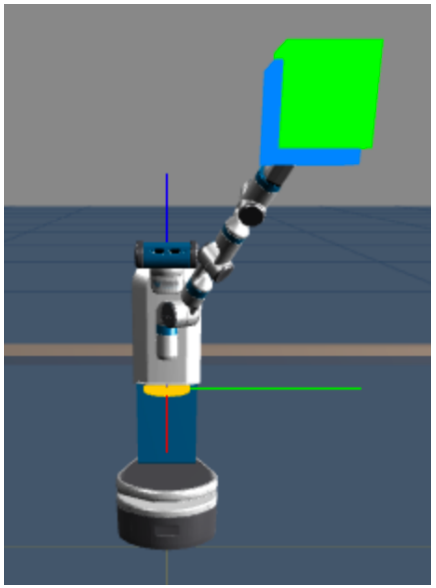
- Projects implemented in JavaScript/HTML5 using KinEval stencil
  - Projects submitted and tracked through git (gitlab|github|bitbucket)
  - Instructor (ohseejay|ocj) needs admin access
- 7 projects
  - 6 Programming, 1 Written/Oral
- Grading: projects are broken down into features that are “checked”
  - points are earned through successful implementation of features

Projects

- **Path Planning** A-star search in 2D world
- **Pendularm** physical simulation and PID control of 1 DoF robot
- **Forward Kinematics** convert robot configuration to 3D space
- **Dance Contest** control of robot joints to do a dance
- **Inverse Kinematics** control gripper of a robot to reach a point in 3D
- **Motion Planning** collision-free planning over robot configurations
- **Best Use of Robotics** what will you do with all of this power?

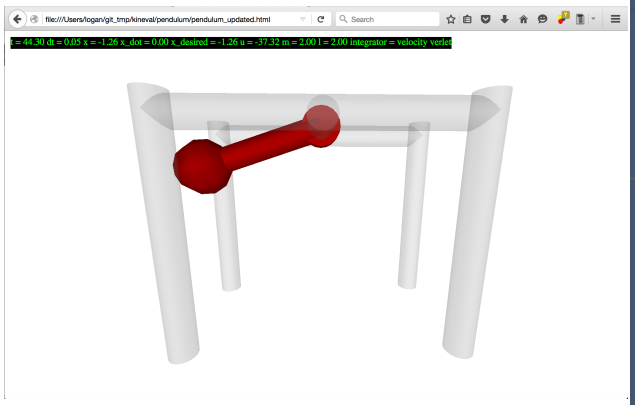
- **Path Planning**

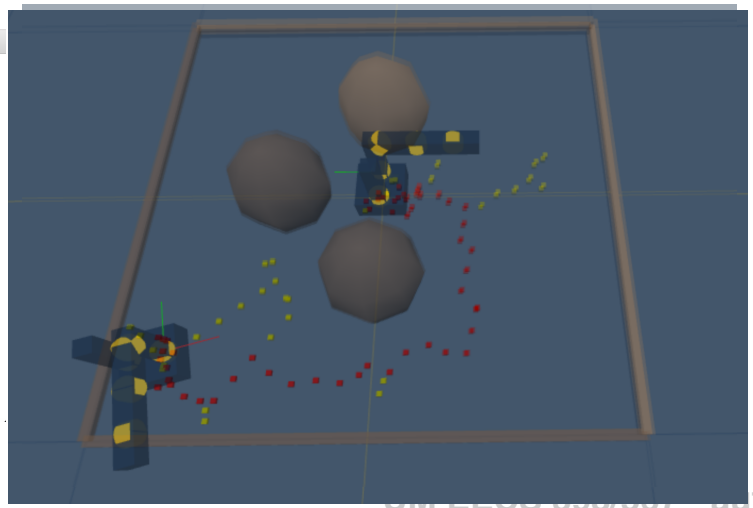




- **FK/IK**

- **Pendularm**

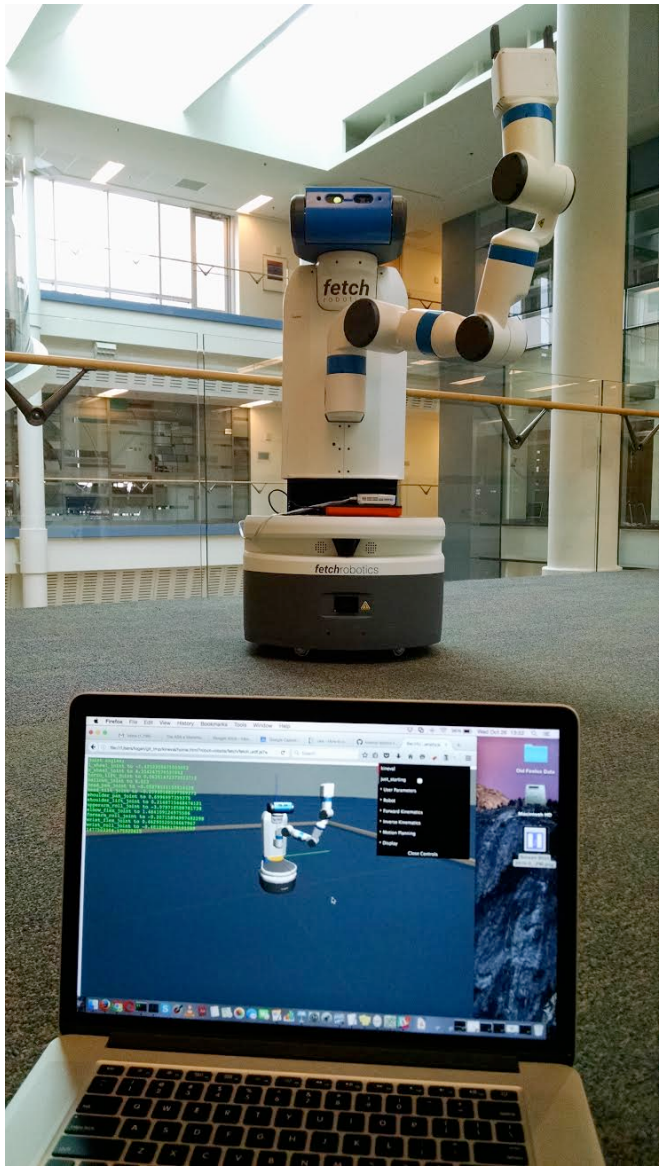




- **RRT**

Will you work with a real robot?

Yes, at least once using rosbridge/ROS



Grading Summary

EECS 398: Introduction to Autonomous Robotics

- 7 projects (12 points each)
- 5 quizzes (4 points each)

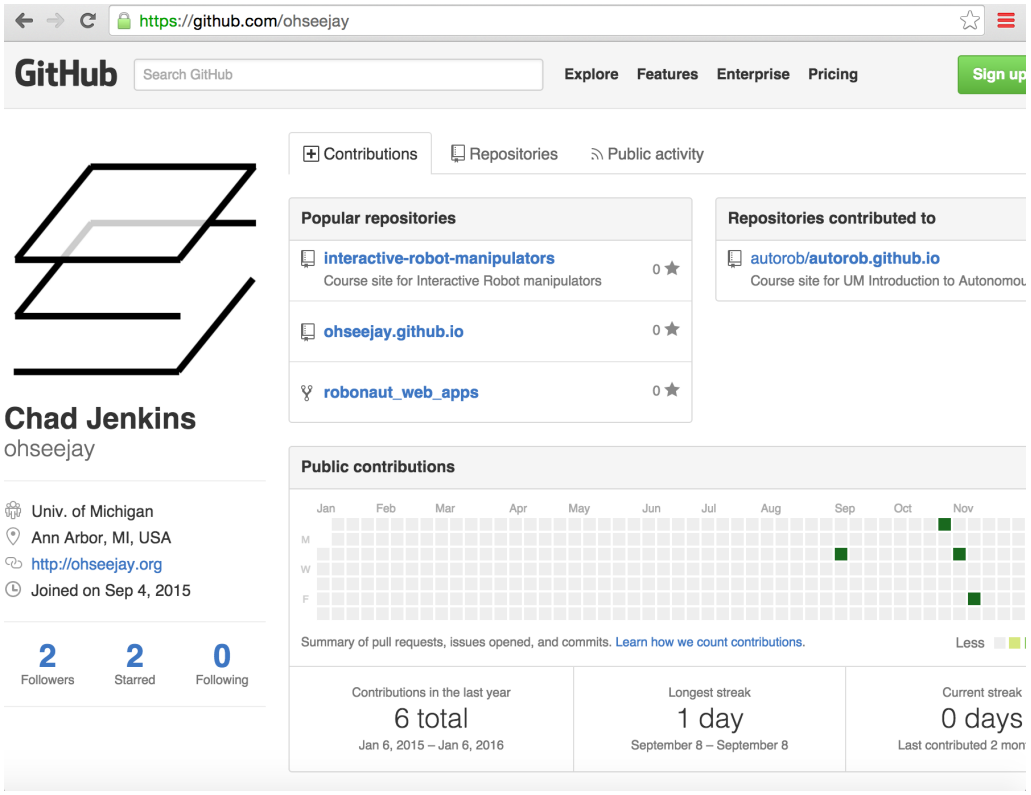
A: 93+ points
B: 83+ points
C: 73+ points

ME/EECS 567 ROB 510: Robot Kinematics and Dynamics

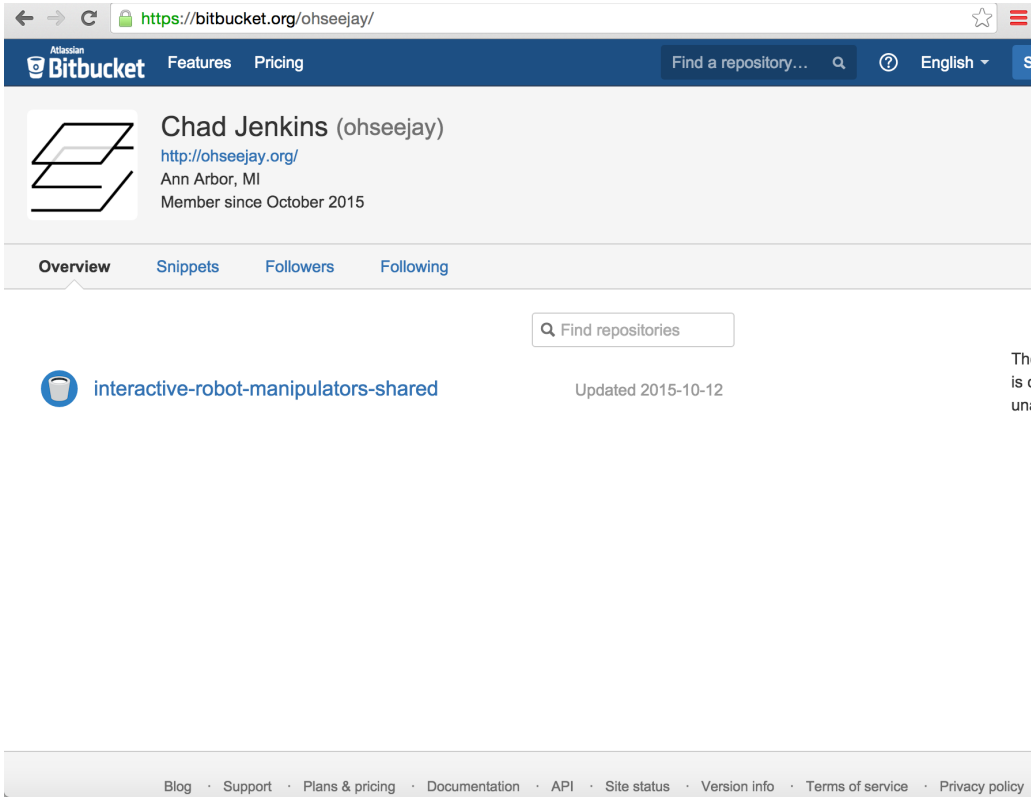
- 7 projects (18 points each)
- 5 quizzes (4 points each)
- Advanced features (4 points)

A: 135+ points
B: 120+ points
C: 105+ points

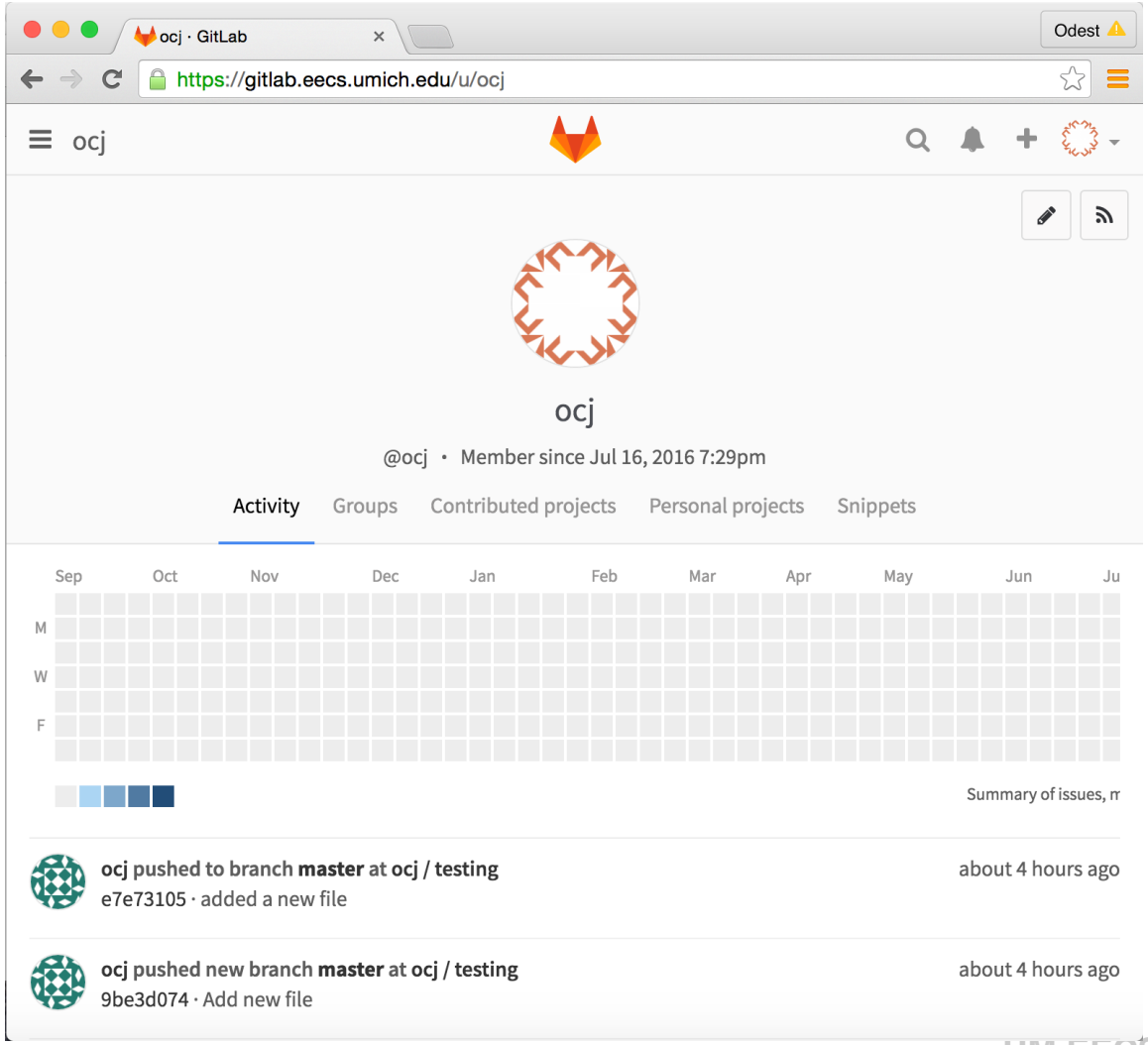
github.com/ohseejay



bitbucket.org/ohseejay



gitlab.eecs.umich.edu/ocj



Collaboration Policy

- All work submitted must be your own
  - All code submitted must comply with Michigan Honor License
- No code can be communicated, including verbally
  - Explicit use of external sources must be clearly cited
  - Repositories must be **private** for proper compliance
- Free flow of discussion and ideas is encouraged

Michigan Honor License

- 3-Clause BSD License + Michigan Honor Code + proper citation
- Assert the compliance of your code with the MHL
  - Append your name to the end of LICENSE in your repository
- Submitted code will not be graded without asserting LICENSE

Late Policy

- Projects submitted after deadline may not be graded (zero credit)
- If a late submission is allowed, it can receive at most
  - 80% credit if pushed within 2 weeks of the deadline
  - 60% credit if pushed within 4 weeks of the deadline
  - 50% credit if pushed anytime before final grading

Regrading policy

- Projects features are graded with:
  - “CHECK” (sufficiently completed)
  - “DUE” (insufficiently completed)
  - “PENDING” (not due yet)
- A project feature can be regraded for partial credit for at most
  - 80% credit if pushed within 2 weeks of the last returned grading
  - 60% credit if pushed anytime before final grading

sdnt / repository name Private

Unwatch 2 | Star 0 | Fork 0

Code | Issues 0 | Pull requests 0 | Projects 0 | Wiki | Insights

Projects for EECS398 Intro to Autonomous Robotics at the University of Michigan

71 commits | 7 branches | 0 releases | 3 contributors

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

sdnt Updated motion planning to disallow rotations about x-z axis — Latest commit `b14c770b` Jan 10

js	Fall 2016 release	a year ago
kineval	Disallow rotations about x-z axis. Fixed return val. Can now trace path	8 months ago
project_pathplan	2d rrt-connect complete using drawHighlightedPath. Had to change give…	8 months ago
project_pendularm	pendulum seems complete	11 months ago
robots	Fall 2016 release	a year ago
tutorial_heapsort	Added heap increase key function to heap.js to help with A* algorithm	10 months ago
tutorial_js	Playing with Javascript samples	a year ago
worlds	Deleted all source_*.js files and added honor.txt	10 months ago
.gitignore	Implemented and tested matrix multiply and matrix transpose	9 months ago
README.md	Fall 2016 release	a year ago
grading.txt	added grading for Final grading	9 months ago
home.html	Fall 2016 release	a year ago

Branch: master ▾ repository name / grading.txt

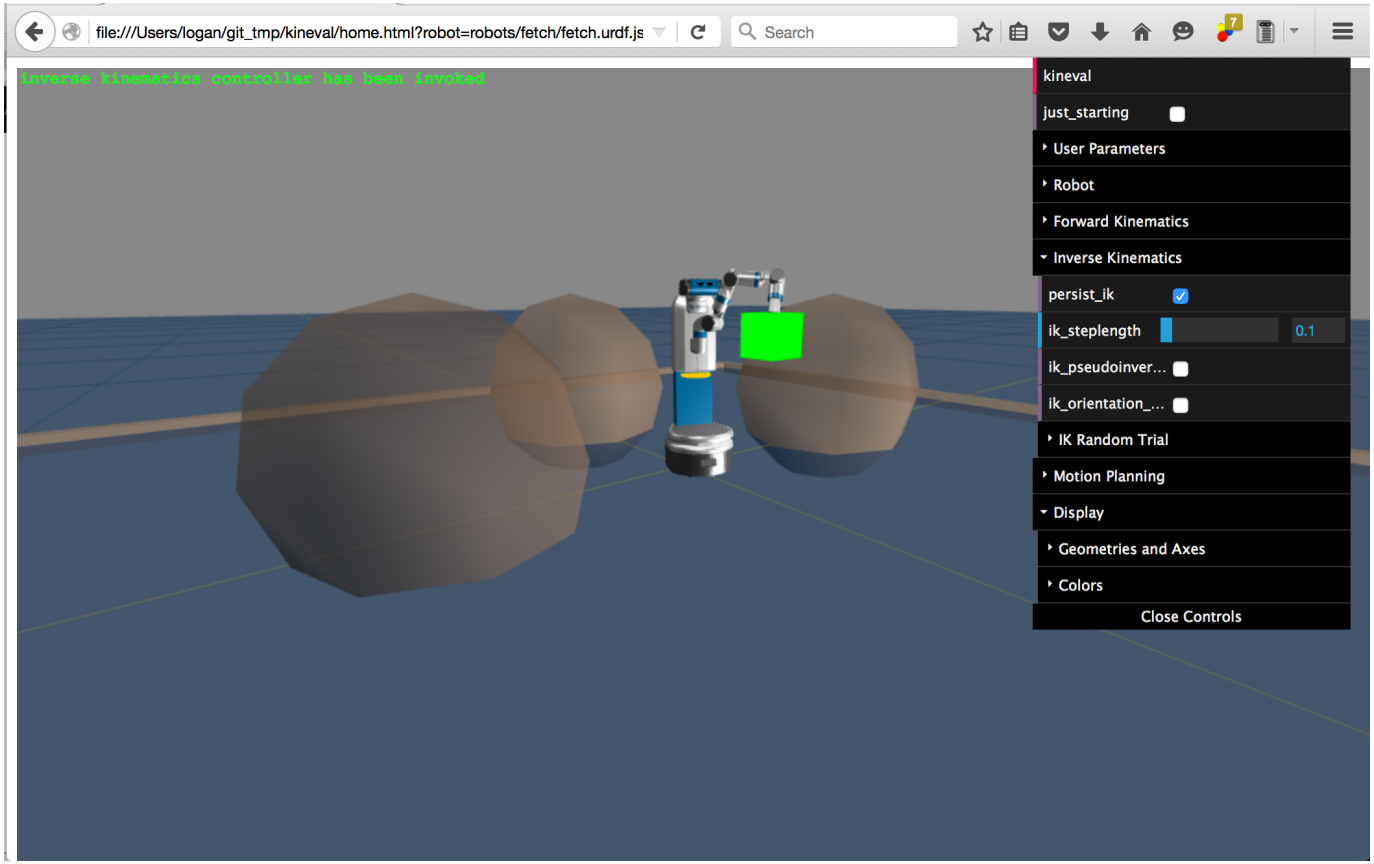
odestcj added grading for Final grading

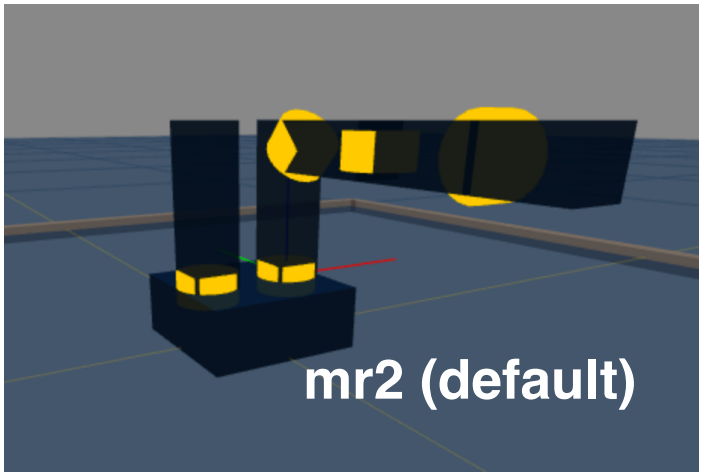
1 contributor

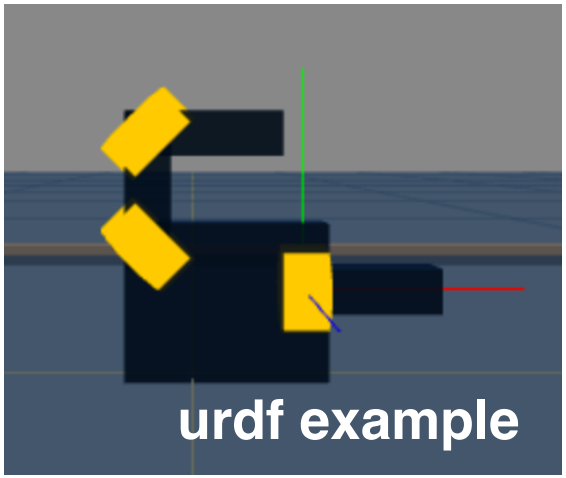
60 lines (58 sloc) | 2.26 KB Raw Blame

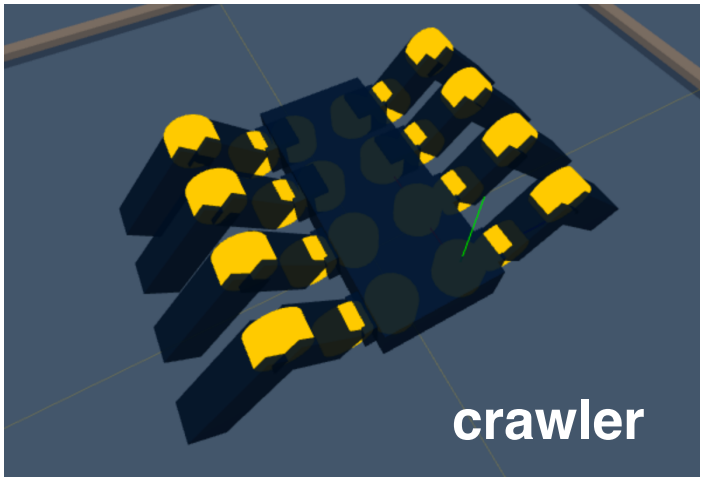
```
53: student name
EECS 398-004 F16
Assignment 1 feature 1 (4.00/4): PathPlan_Heap: CHECK
  comment: good work
Assignment 1 feature 2 (8.00/8): PathPlan_AStar: CHECK
  comment: good work
Assignment 2 feature 3 (4.00/4): Pendularm_Euler: CHECK
  error: Euler integrator is incorrect
  comment: why is this integrator stable?
  error: integration of dynamics is incorrect
  comment: double check computation of pendulum acceleration
  regrade: servo converges after several oscillations, borderline control performance
Assignment 2 feature 4 (4.00/4): Pendularm_VelocityVerlet: CHECK
  error: integration of dynamics is incorrect
  comment: double check computation of pendulum acceleration
  regrade: working
Assignment 2 feature 5 (4.00/4): Pendularm_PID: CHECK
  error: integration of dynamics is incorrect
  comment: modulo correction is not needed
Assignment 3 feature 6 (2.00/2): FK_MatrixRoutines: CHECK
```

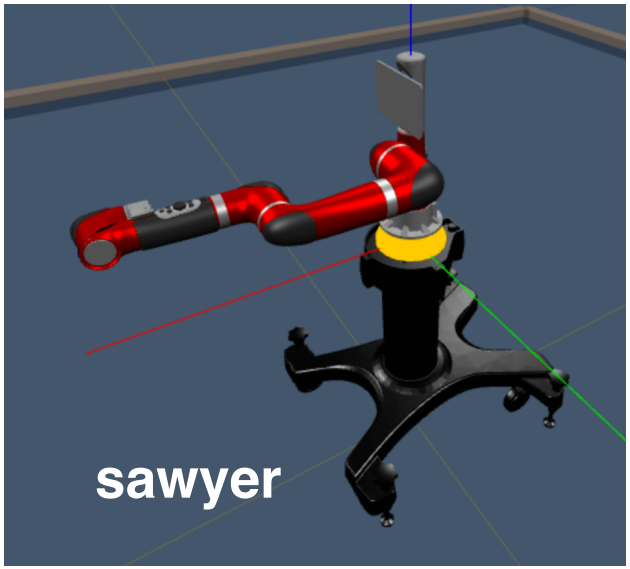
KinEval code stencil

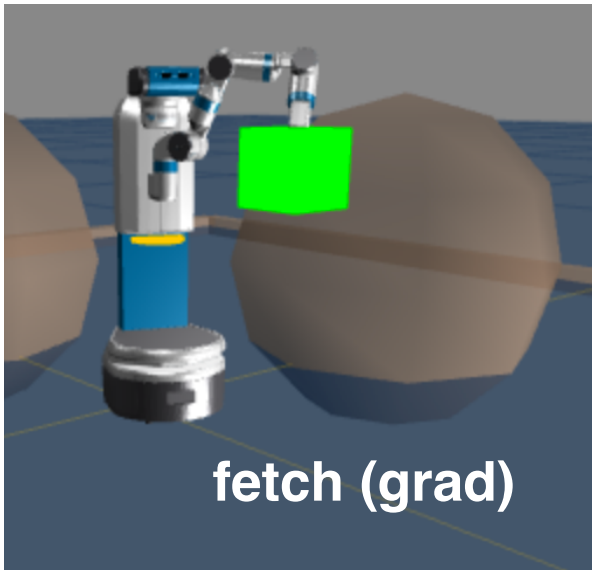


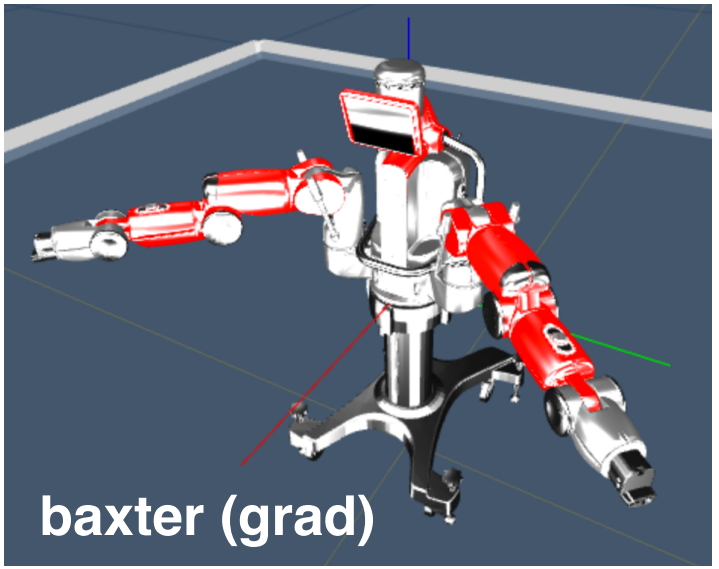

mr2 (default)


urdf example


crawler

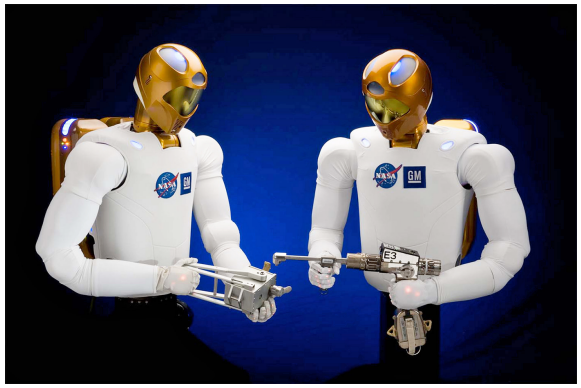

sawyer


fetch (grad)


baxter (grad)

Maybe also?


KINOVA
MOVO BETA
A MOBILE
MANIPULATOR
PLATFORM
kinovaMOVO.com

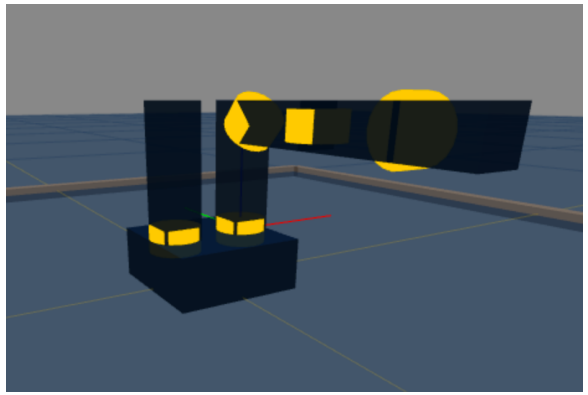



Boston Dyn

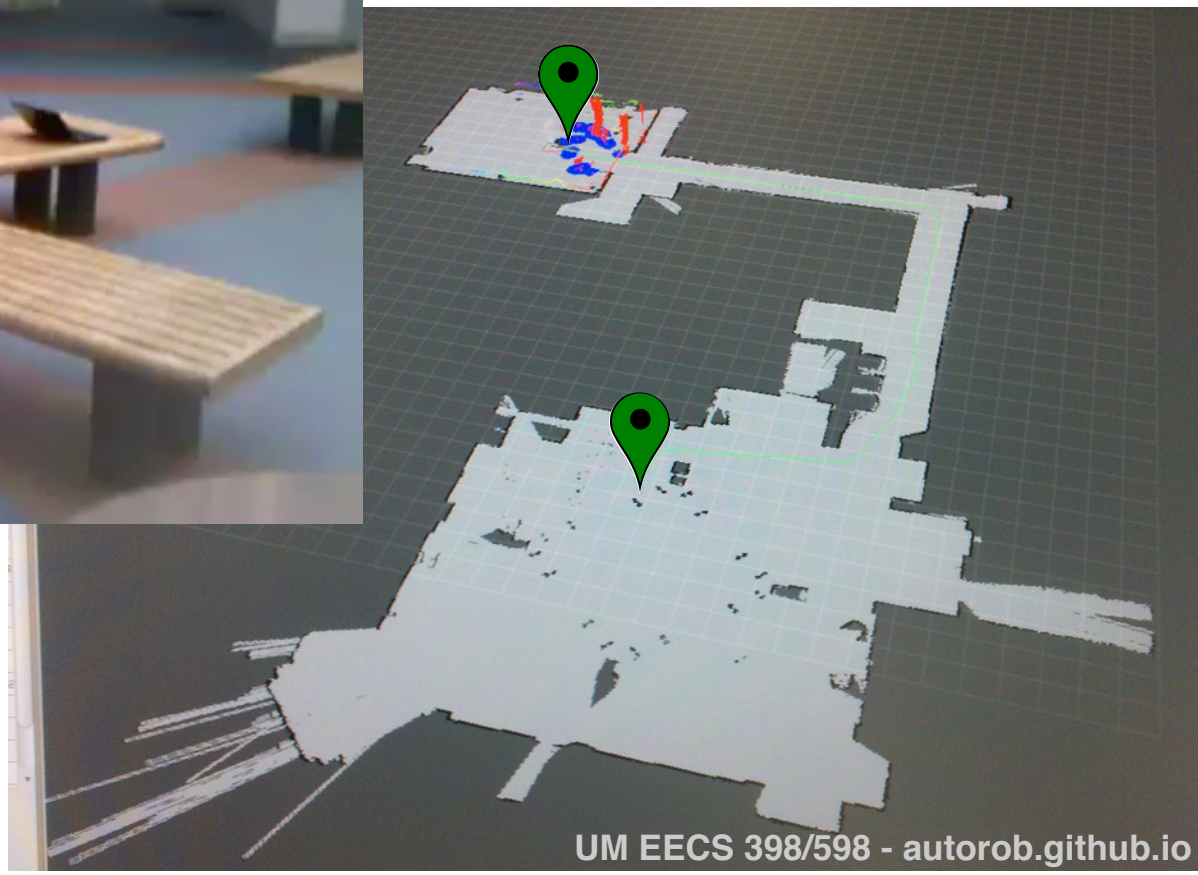

PR2
CODY
like
DAD

KinEval code stencil

- Code stencil for AutoRob projects in 3D
- Uses threejs 3D rendering library and WebGL
- URDF-like robot description
- Usable, but not perfect, camera and UI controls
- AABB collision detection provided for planning
- Warning: professor-level coding



Let’s start with base navigation

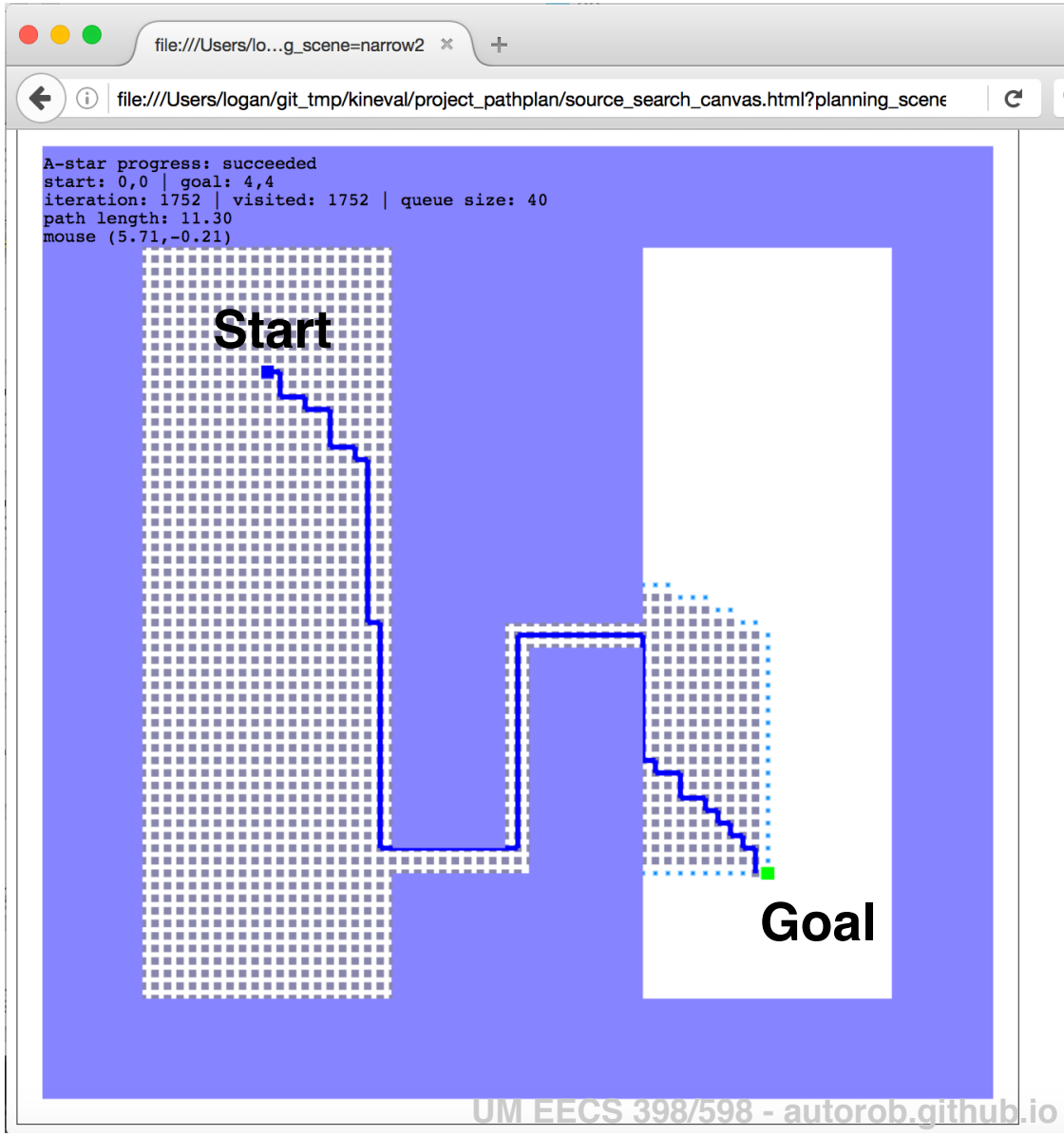


Let's start with base navigation

How to get from Location A to Location B?

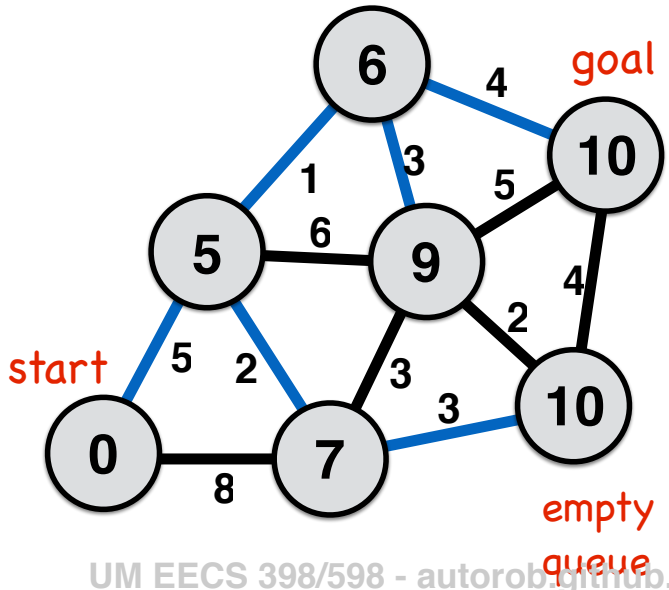
Project 1:
2D Path Planning

- A-star algorithm for search in a given 2D world
- Implement in JavaScript/ HTML5
- Heap data structure for priority queue
- Grad: DFS, BFS, Greedy
- Submit through your git repository



Dijkstra shortest path algorithm

all nodes ← {$dist_{start}$ ← infinity, $parent_{start}$ ← none, $visited_{start}$ ← false}
start_node ← {$dist_{start}$ ← 0, $parent_{start}$ ← none, $visited_{start}$ ← true}
visit_queue ← start_node
    while visit_queue != empty ~~&& current_node != goal~~
        cur_node ← min_distance(visit_queue)
        $visited_{cur\_node}$ ← true
        for each nbr in not_visited(adjacent(cur_node))
            enqueue(nbr to visit_queue)
            if $dist_{nbr}$ > $dist_{cur\_node}$ + distance(nbr,cur_node)
                $parent_{nbr}$ ← current_node
                $dist_{nbr}$ ← $dist_{cur\_node}$ + distance(nbr,cur_node)
            end if
        end for loop
    end while loop
output ← parent, distance



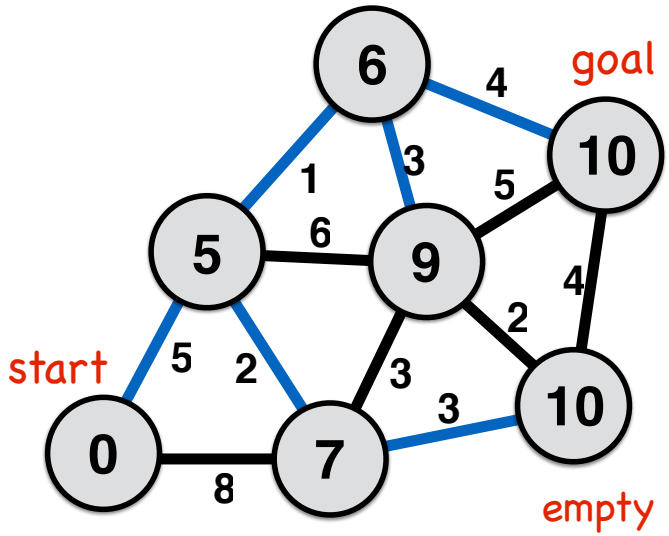
A-star shortest path algorithm

all nodes ← {$dist_{start}$ ← infinity, $parent_{start}$ ← none, $visited_{start}$ ← false}
start_node ← {$dist_{start}$ ← 0, $parent_{start}$ ← none, $visited_{start}$ ← true}
visit_queue ← start_node
    while (visit_queue != empty) && current_node != goal
        dequeue: cur_node ← f_score(visit_queue)
        $visited_{cur\_node}$ ← true
        for each nbr in not_visited(adjacent(cur_node))
            enqueue: nbr to visit_queue
            if $dist_{nbr}$ > $dist_{cur\_node}$ + distance(nbr,cur_node)
                $parent_{nbr}$ ← current_node
                $dist_{nbr}$ ← $dist_{cur\_node}$ + distance(nbr,cur_node)
                f_score ← $distance_{nbr}$ + $line\_distance_{nbr,goal}$
            end if
        end for loop
    end while loop
output ← parent, distance

implement min binary heap for priority queue

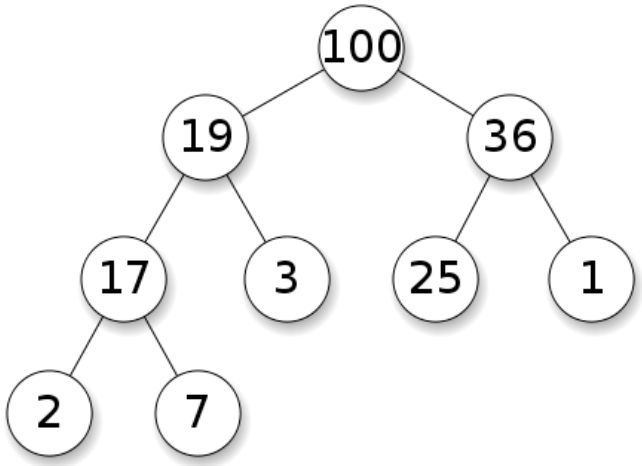
g_score: distance along path

h_score: best distance to goal

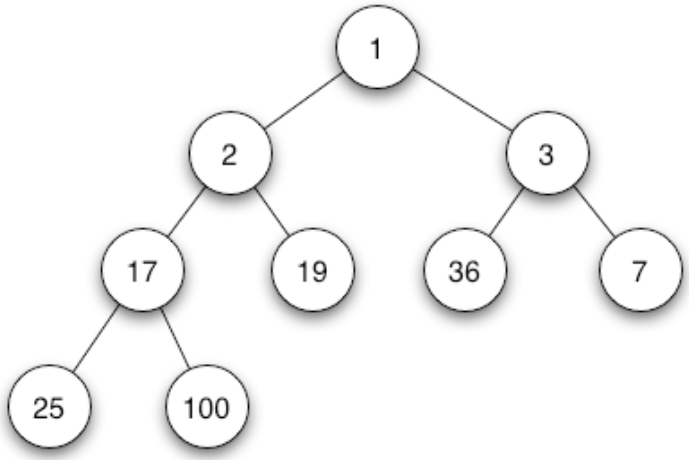


Heaps

A heap is a tree-based data structure satisfying the heap property:
every element is greater (or less) than its children



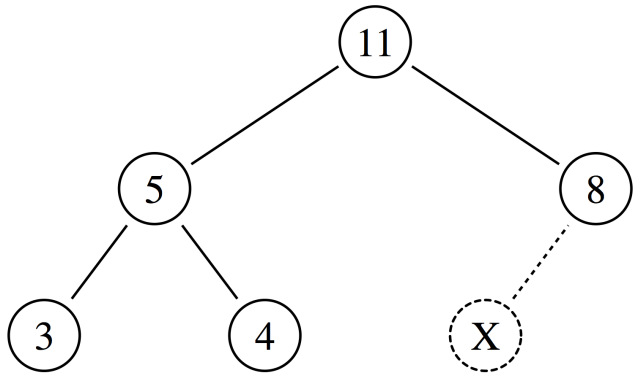
max heap



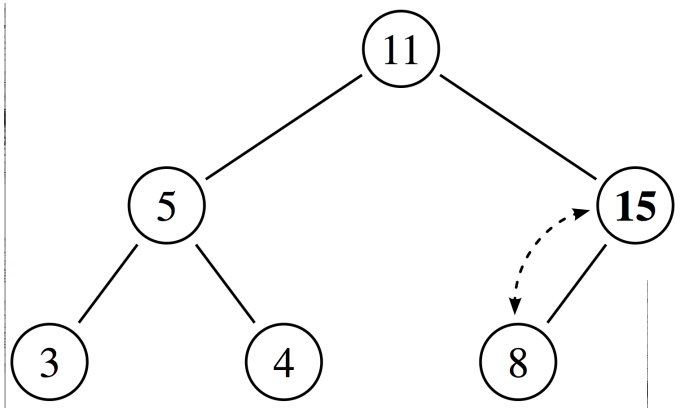
min heap

Heap operations: Insert

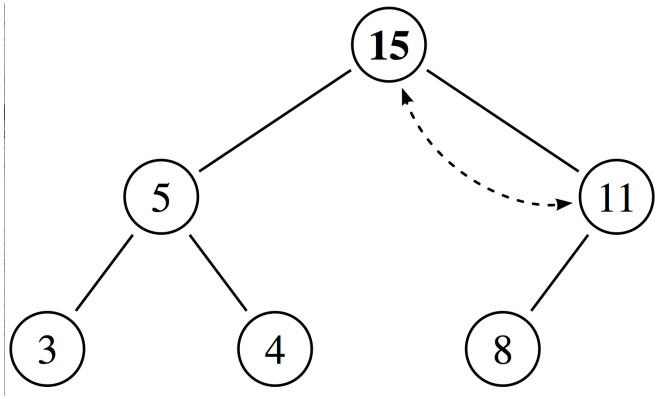
1) add new element to end of tree



2) swap with parent

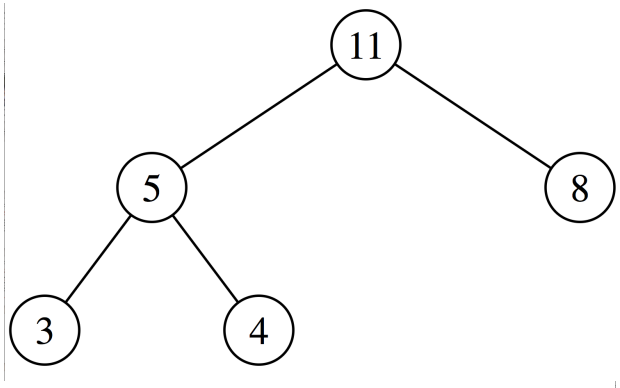


3) until heaped, do (2)

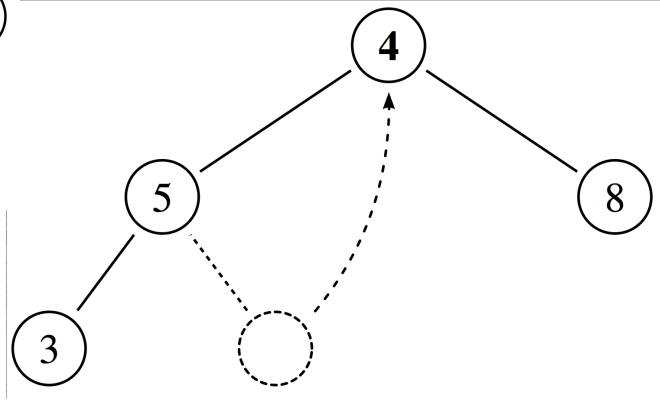


Heap operations: Extract

1) extract root element

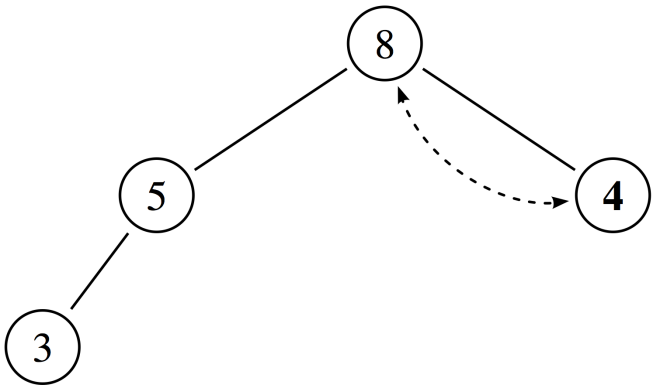


2) put last element at root



3) swap with smaller child

4) until heaped, do (3)



heapsort.html

```
<!DOCTYPE html>
<html>
  <head>
    <title>Heap Sort by Chad Jenkins</title>
  </head>
   <body onload=startMeUp()>
       <a href="http://ohseejay.org"><h1>My Heap Sort</h1></a>
       <canvas width=900 height=200 id="myCanvas"></canvas>
       <div id="output">hello world</div>
  </body>
</html>

<script>
function startMeUp() {
    .. executable code to perform heapsort; will depend on heap.js …
}
</script>
```

HTML5 document will invoke JavaScript function at start

git basics

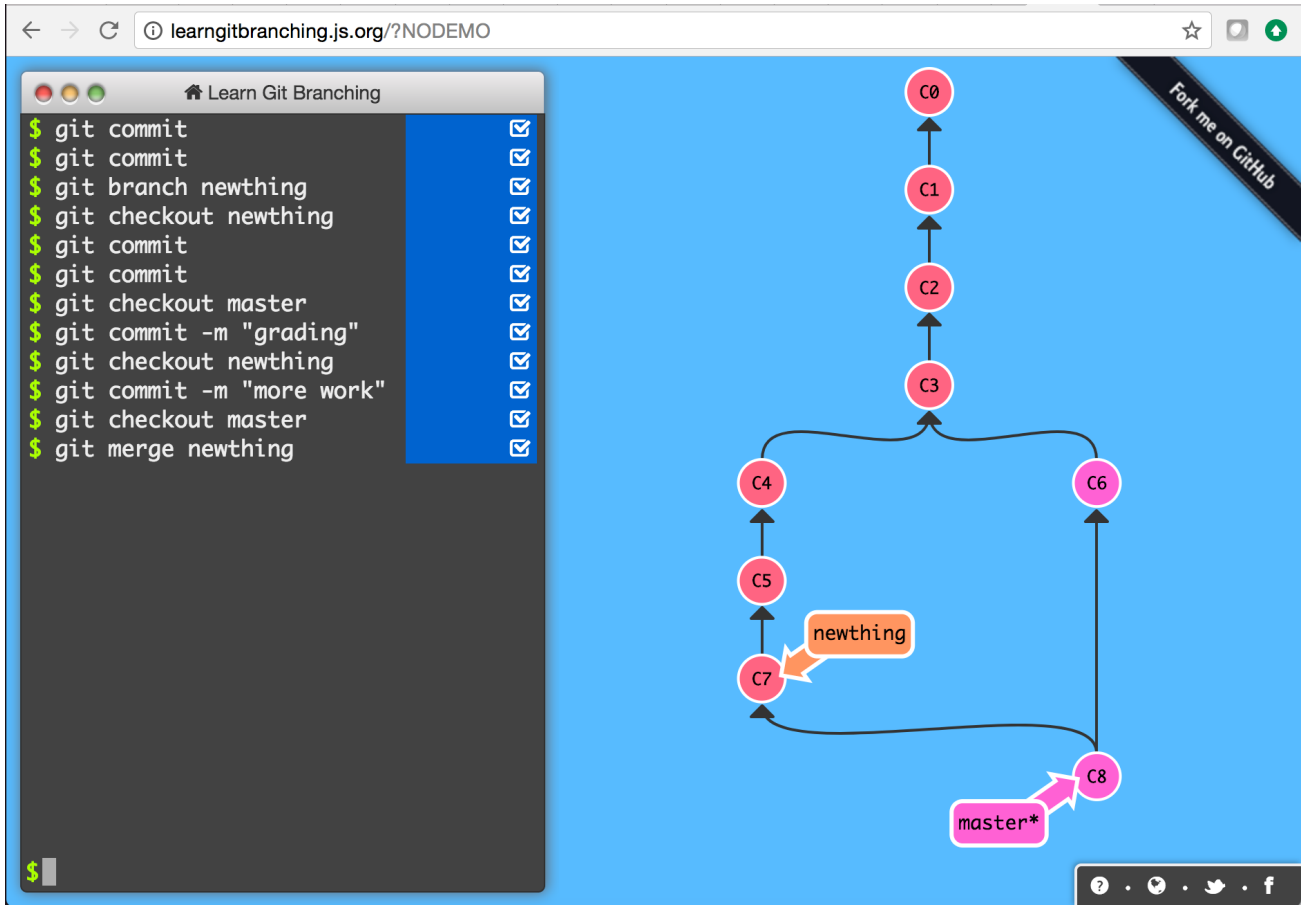
- Create a git repository from gitlab, github, or bitbucket website
- Install git on your machine
  - https://git-scm.com/book/en/v2/Getting-Started-Installing-Git
  - OSX: https://code.google.com/p/git-osx-installer/

git basics

- create a local copy of a repository: `git clone <repo url>`
- add files to a repository: `git add <file listing>`
- commit changes to local repository: `git commit -a -m "<msg>"`
- push local changes to a remote repository: `git push`
- pull remote changes to a local repository: `git fetch` or `git pull`
- create a code branch in a repository: `git branch <branch name>`
- checkout a code branch from a repository : `git branch <branch name>`
- merge branches in a repository:

```
git checkout <branch name>
git merge <other branch name>
```

Highly recommended tutorial



http://learngitbranching.js.org/

Can I enroll in this class?

- Most likely! Probably yes!
- We will try to enroll all who want to take the course
- Additional office hours to discuss enrollment issues
  - Thursday (tomorrow) 3-5pm in Beyster 3644
  - Friday 11am-12pm in Beyster 3644

What I need from you **now**

- Accept invitation to the course discussion channel (coming tonight)
  - https://autorob.slack.com
- Install git and setup your working environment
  - create a git repository: https://gitlab.eecs.umich.edu/
  - ensure you can clone, commit, and push files to your repository
- Over the discussion channel, send me:
  - informal introduction confirming your name, email, and enrollment
  - your favorite picture of yourself
  - pointer to your git repo for the course

What I need from you **next week**

- Get started on Assignment 1 (Path Planning)
  - Clone kineval-stencil-fall18 repository (release this weekend)
  - Study examples in tutorial_js subdirectory
  - Complete tutorial_heapsort (noted with “STENCIL” in files)
  - Complete project_pathplan (concepts covered next week)