Autonomous Robotics

Winter 2025

Abhishek Gupta

TAs: Carolina Higuera, Entong Su, Bernie Zhu

Many slides adapted from Sidd Srinivasa, Brian Hou, Dieter Fox

Zoom Recording Warning!

Ok so what is CSE 478 about?

We will be programming RACECARs!

RACECAR 1.0

RACECAR 2.0

RACECAR 3.0

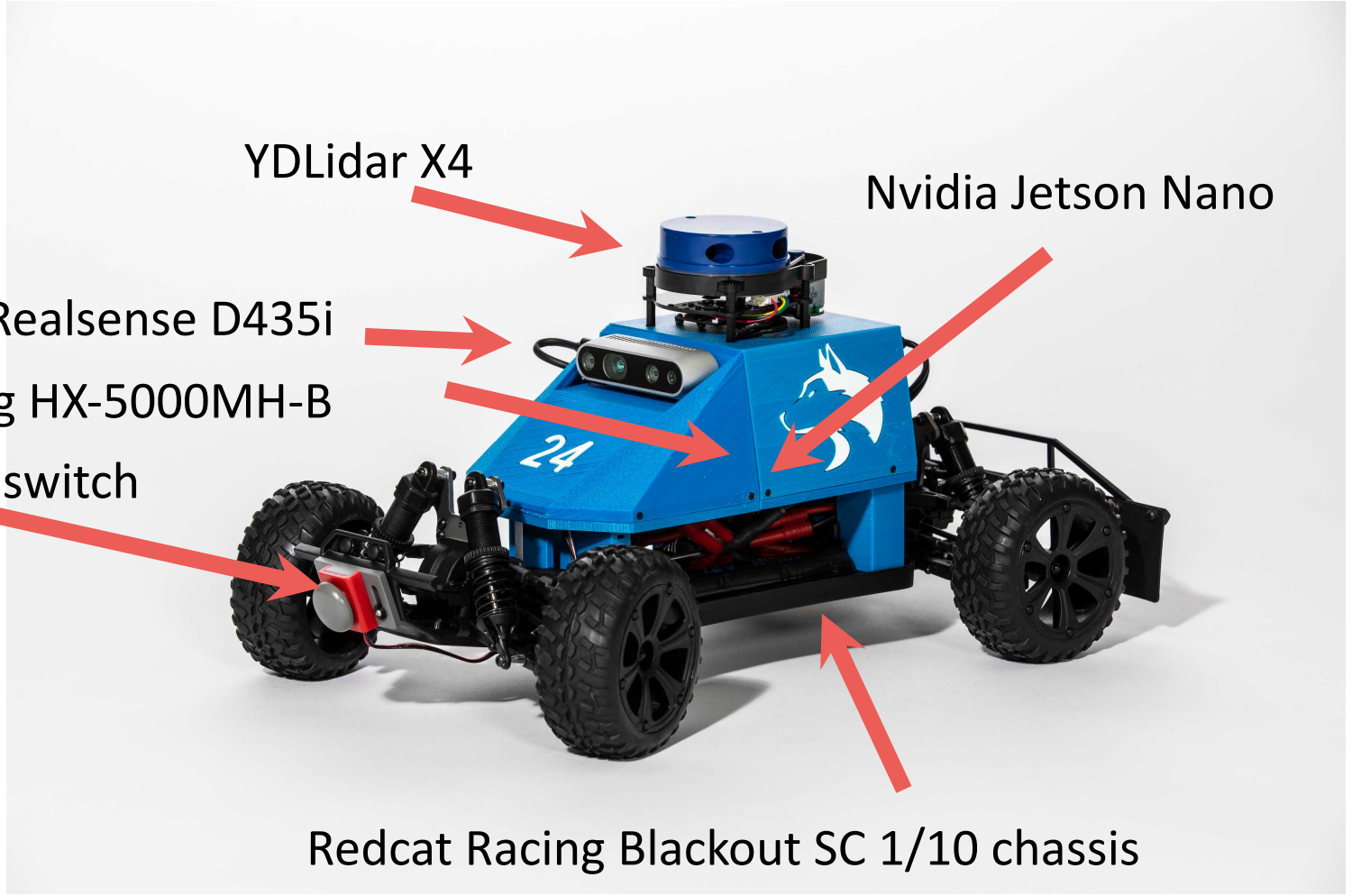
Multi-agent System for
non-Holonomic Racing

https://mushr.io


16
24


NPR

Overview of the RACECAR



Demo:
Given a known map of the environment,
follow a series of waypoints while avoiding obstacles

Thanks to Sanjiban Choudhury, Gilwoo Lee, Matt Schmittle, Matthew Rockett!

Learning Objectives

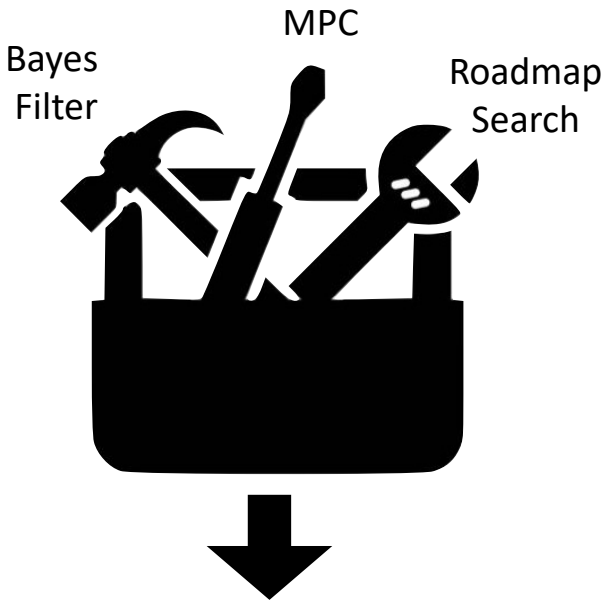
Objective 1

Learn algorithms for
autonomous driving and
implement them on the RACECAR

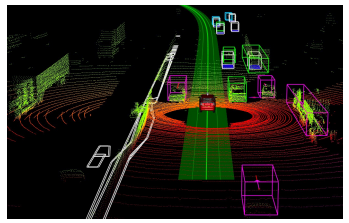
in 10 weeks!

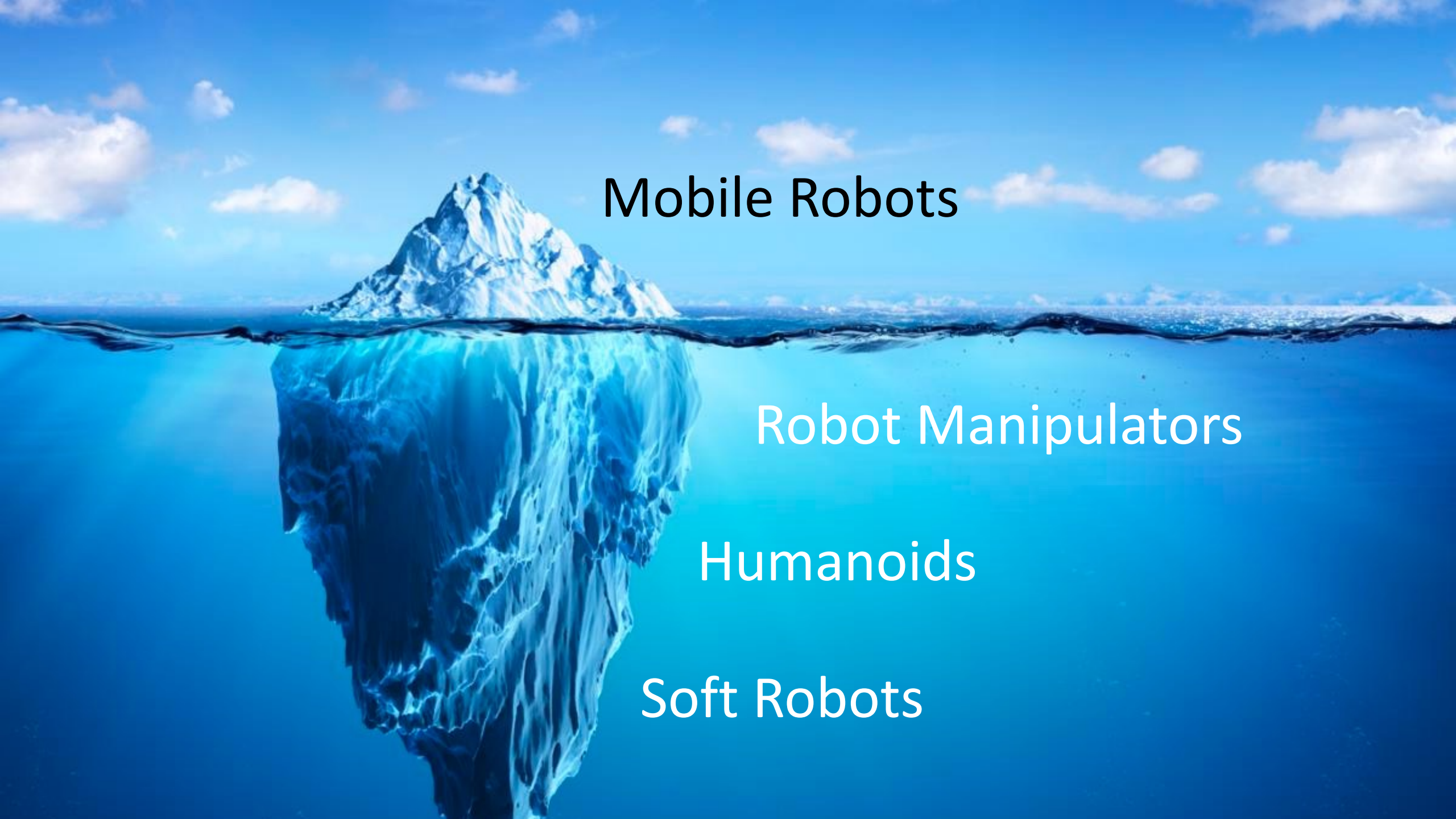
Objective 2

Learn a small set of fundamental tools



that solve a wide range of robotics problems




Mobile Robots
Robot Manipulators
Humanoids
Soft Robots

Localization

Planning

Control

Reinforcement/Imitation Learning

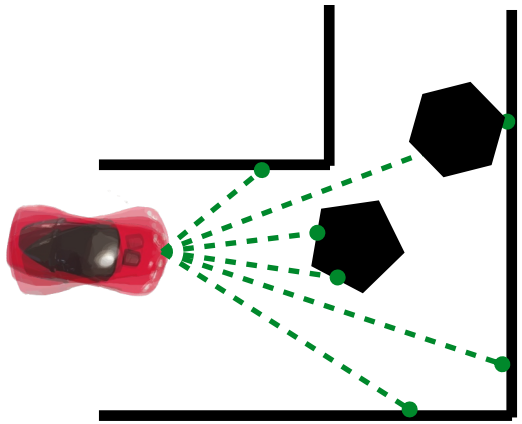
Mapping

Computer Vision

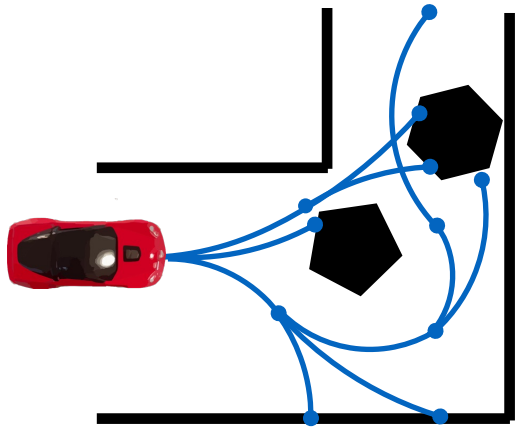
Robot and Actuator Design

Concrete Learning Objectives

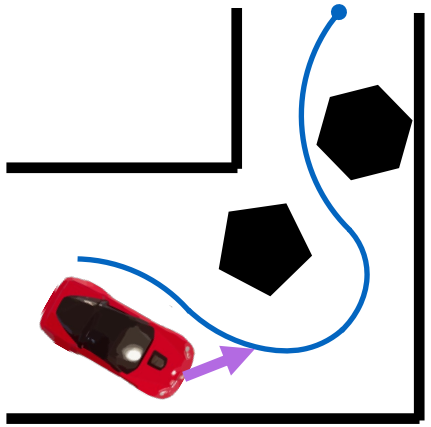
Estimate State



Plan a sequence of motions

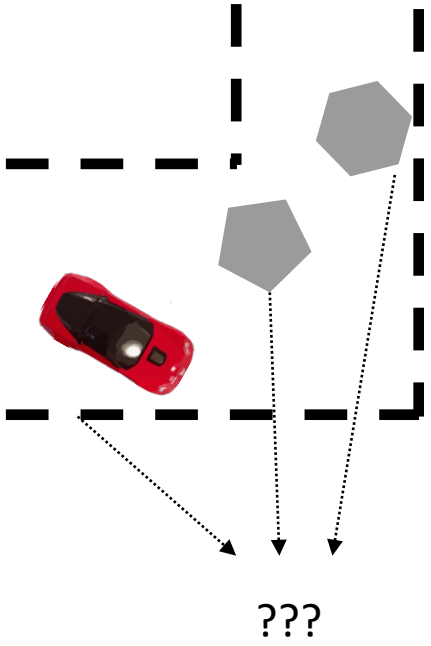


Control robot to follow plan

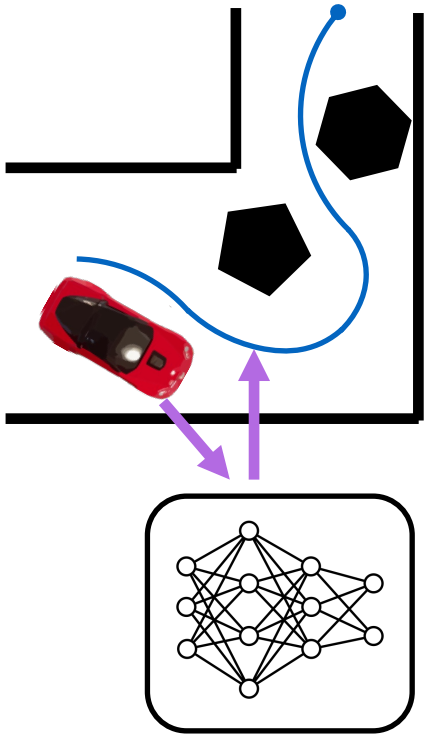


Additional Learning Objectives – no HW

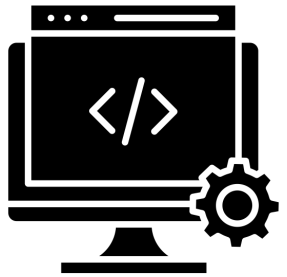
How to estimate maps



Where machine learning may be helpful?



Learn how to program robot software

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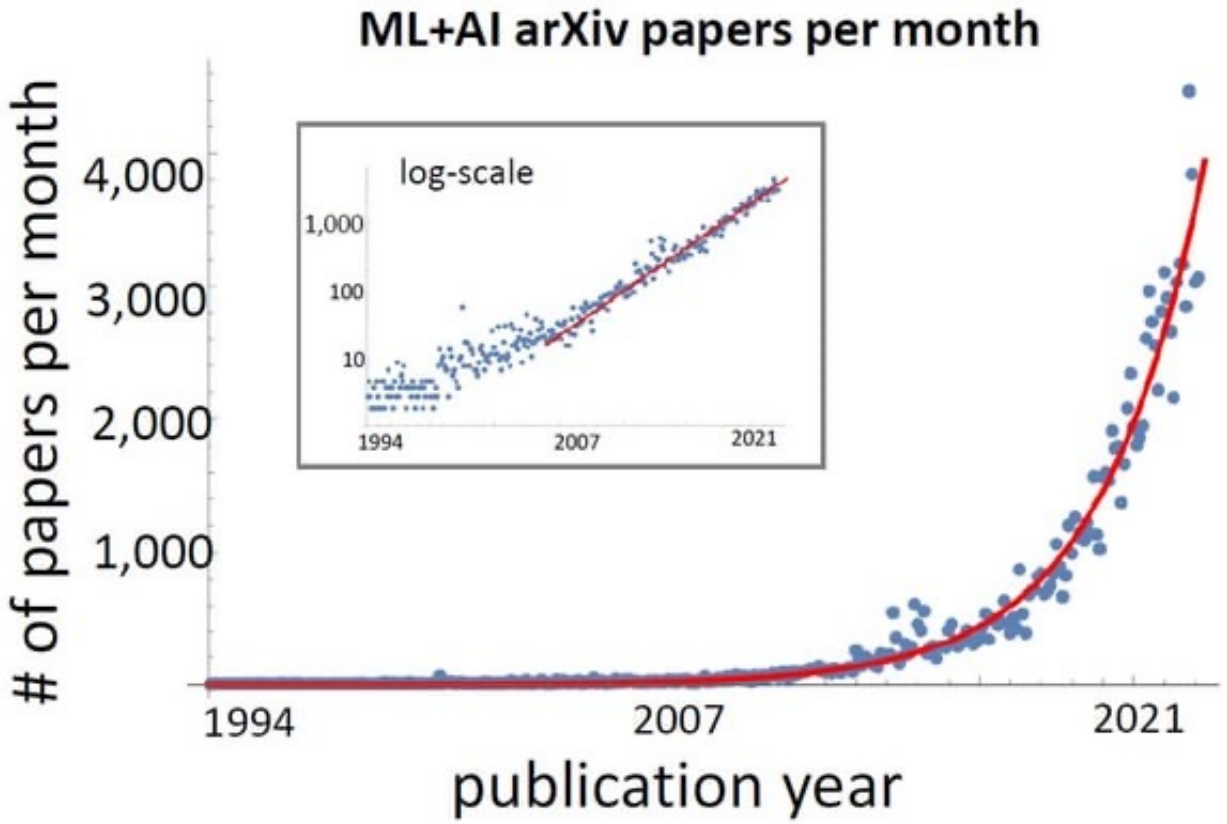
Objective 3

Learn how to read and analyze and propose research papers



arXiv

IEEE

NEURAL INFORMATION PROCESSING SYSTEMS

Course Logistics

Class Logistics

- Where: G10 Gates (CSE2)
- When: 1:30-2:20 MWF
- Who:
  - Abhishek Gupta (Instructor)
  - Carolina Higuera (TA)
  - Entong Su (TA)
  - Bernie Zhu (TA)




Who am I?

- New assistant professor in CSE
- Grew up in Oregon/India, last 10 years in Berkeley
- Undergrad Berkeley, Ph.D. Berkeley, Postdoc MIT.
- Interests: RL/robotics/optimization and control/robustness and generalization
- Outside of work: Tennis/soccer/sketching/dog enthusiast

Who is Carolina?

- PhD student advised by Prof. Byron Boots
- Visiting Researcher at Meta
- Research interest: tactile sensing for robot manipulation, self-supervised learning
- Outside of work: oil painting, jigsaw puzzles
- Email: chiguera@cs.washington.edu

Who is Entong?

- PhD student advised by Prof. Abhishek Gupta and Maya Cakmak
- Research interest: Reinforcement learning, robotics manipulation, imitation learning
- Outside of work: Piano, Badminton
- Email: ensu@cs.washington.edu

Who is Bernie?

- PhD student at UW CSE
- Born in China, worked in Africa, traveled the world.
- Research interest: humanoid manipulation, physical embodied AI
- Outside of work: trading, cooking, adventuring
- Email: haozhu@cs.washington.edu

Who are y’all?

Grading - Approximate

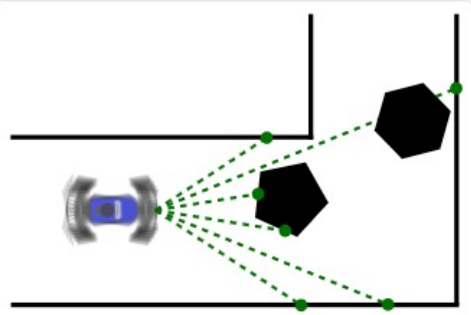
- **Programming projects** and writeups (4), graded on an SN scale [17.5% of the grade each]
  - N will come with TA feedback and guidance; revise and resubmit
  - Due dates are paced throughout the quarter
- **Seeded Paper Discussions** [15% of grade]
  - Present new paper ideas and provide 2-3 paragraphs of commentary
- **Final Project** [10% of grade]
  - Combine projects for a full stack racecar solution
- **Participation** (guest lectures/class) [5% of grade]
  - Come talk in class, ask hard questions!

Grading - MuSHR Programming Projects

- Learn to program the MuSHR car with Python and the Robot Operating System!
- Teams of 4/5
- Autograding for all homeworks! (no hidden tests)

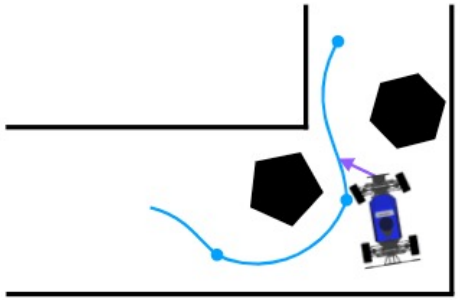
Project 1: Introduction

Get acquainted with the ROS ecosystem and the MuSHR virtual machine.



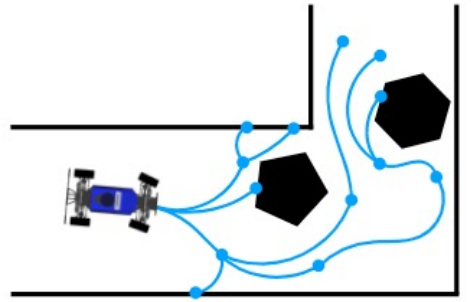
Project 2: Localization

Localize your car by implementing the particle filtering algorithm.



Project 3: Control

Implement feedback controllers to follow pre-planned trajectories.



Project 4: Planning

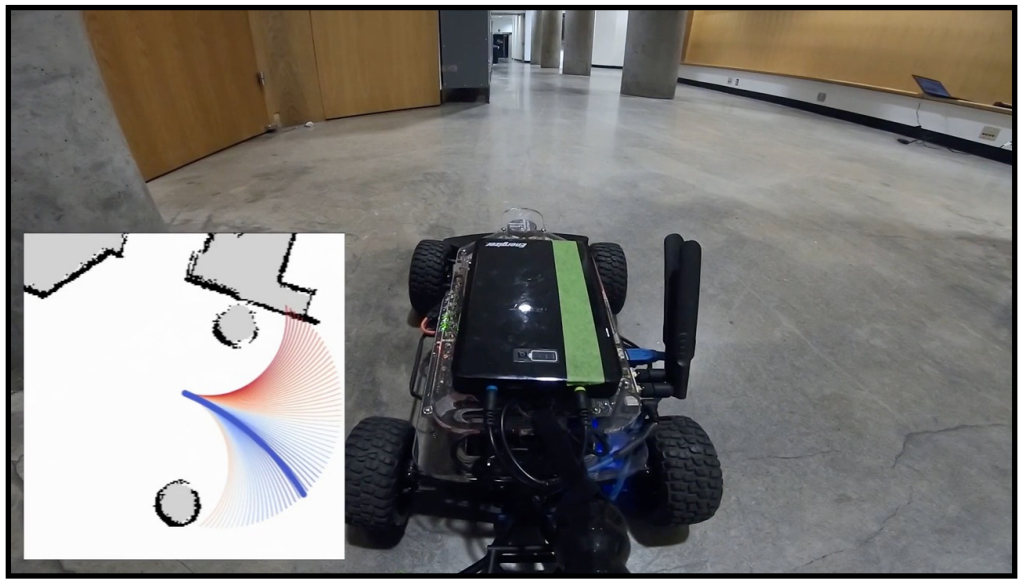
Implement Lazy A* and postprocessing to plan new trajectories.

Grading – Seeded Paper Discussion

- We will try out a new format for discussions
- Key idea: we will seed ideas with a ”seed paper”. Your job is to build from the seed paper and suggest a new paper-level idea, and defend it to the class.
  - **Motivation:** Tell us why we should care about your idea
  - **Technical Idea:** Tell us your idea
  - **Experiments:** Tell us how you would validate your idea and what experiments you’d run
  - **Related Work:** Tell us how your idea will position itself in the literature
- Everyone not presenting posts constructive commentaries about the idea on EdStem!

Grading – Final Project

- Combine all 4 previous projects into a final racecar that can complete a track
- Special prizes for teams with top 3 fastest times (no grades)
- Bonus prize if you can do another map



Grading – Participation

- Short 1 question quiz every class based on previous class materials

Course Outline

Week	Lectures	Assignments
Week 1	Introduction	Project 1: Introduction to ROS, Python, Simulation, RACECAR
Weeks 2-4	State Estimation + SLAM	Project 2: Localize robot on a known map with particle filters
Weeks 5-6	Control	Project 3: Feedback control to track paths while avoiding obstacles
Weeks 7-8	Planning	Project 4: Plan a complex maneuver around obstacles at high speeds
Weeks 9-10	Learning for Control	Final project

Week 11, Final project: Combine modules to navigate around a track and solve tasks!

Teams

- Teams will be assigned by the staff
- Complete the Knowledge Survey (on website) by Wed 1/8 EOD for us to assign teams
- Same team for the 4 projects and final project
- Please let us know if you'd like to change teams early!

Ensuring Fair Participation

- We will try and enforce equity in terms of effort contributed to group projects
  - Every student fills out a self and peer evaluation for every project. Factored into grades

MuSHR Programming Projects - Tips

Each assignment has two parts:

1. Simulation - easier
2. Real-robot execution - 10X harder

Budget ***contiguous*** chunks of time ***early*** for the robot

Work as a team! Divide and conquer

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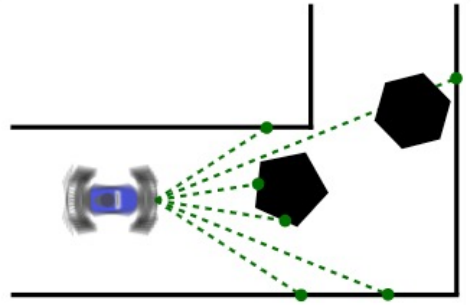

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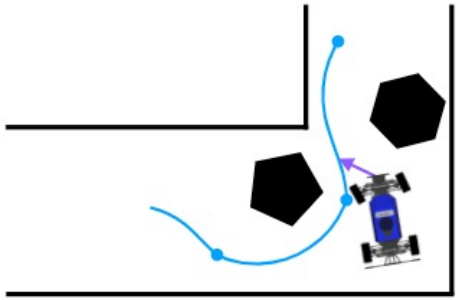

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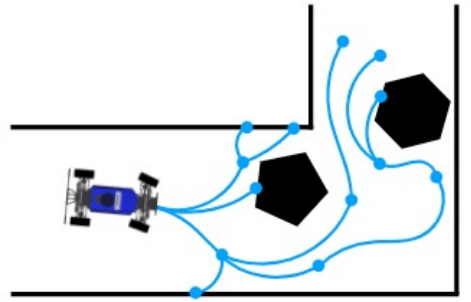


Project 4: Planning

Implement Lazy A* and postprocessing to plan new trajectories.

Lab / Office hours

- Lectures - MWF 1:30-2:20AM
- Conceptual office hours (CSE2 215):
  - Abhishek: Monday 4-5pm, Thursday 3:30-4:30pm
- Lab Office Hours (CSE1 002):
  - Tuesday: Bernie, Carolina, 4:30-5:30pm
  - Wednesday: Bernie, 4:00-5:00pm
  - Thursday: Entong, 2:00-3:00pm
  - Friday: Entong, Carolina, 3:00-4:00pm
  - Welcome to come in and use the resources unguided at other times!
- Ask questions asynchronously through EdStem

MuSHR Lab CSE 002

- We have a separate lab for teams to work on robots
  - CSE1 002 (Basement)
  - Card-key operated
- Each team gets a dedicated workstations with Ubuntu + Python + ROS pre-installed.
- Each team gets 1 dedicated RACECAR (same for duration of class)
- Get your RACECAR at one of two **special** Lab Office Hours in CSE 002:
  - 1/14: 4:30-5:30pm
  - 1/15: 4:00-5:00pm

RACECAR Logistics

- Please treat cars with respect
- Do not change the passwords on the cars
- Each team maintains their own batteries - don’t use others
- Keep your space clean
- Cars stay in 002 – Absolutely no taking them home!

Course Logistics - Integrity

- Late policy

  No late days allowed, unless there are exceptional circumstances

- Academic Honesty Policy

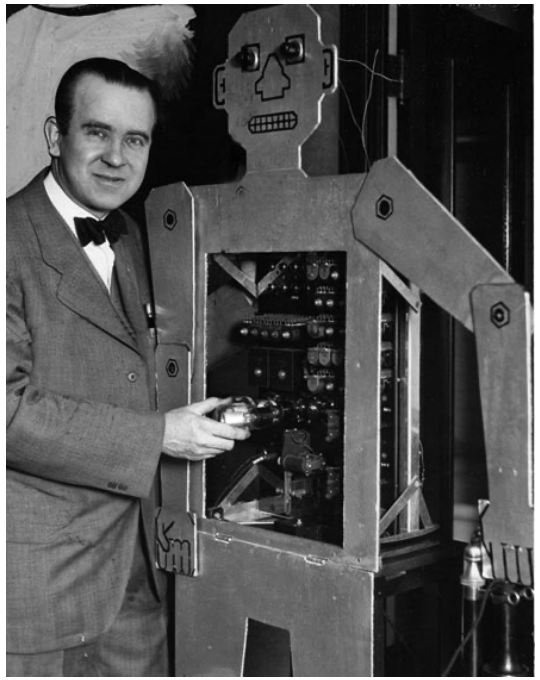
  It's fine to use a source for generic algorithms (with attribution), but it is not allowed to copy solutions to the problems. Additionally, **students may not post their code online**. If we determine that a student posted their code online, they will get an automatic 50% reduction on the entire assignment and if they copy code for the problems from another student or from online, they will get an automatic 0% for the entire assignment (and possibly reported to the college).

Please don't cheat, make my life easier

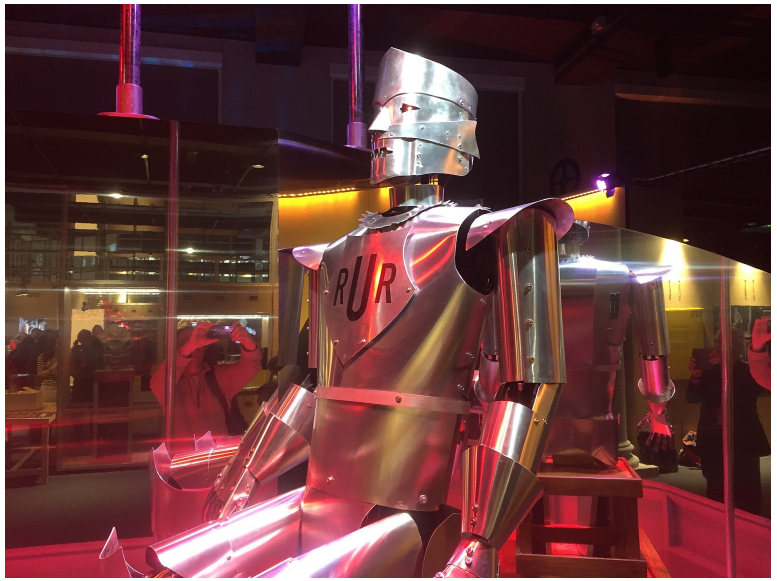
Let’s take a bit of a historical detour

What is a robot?

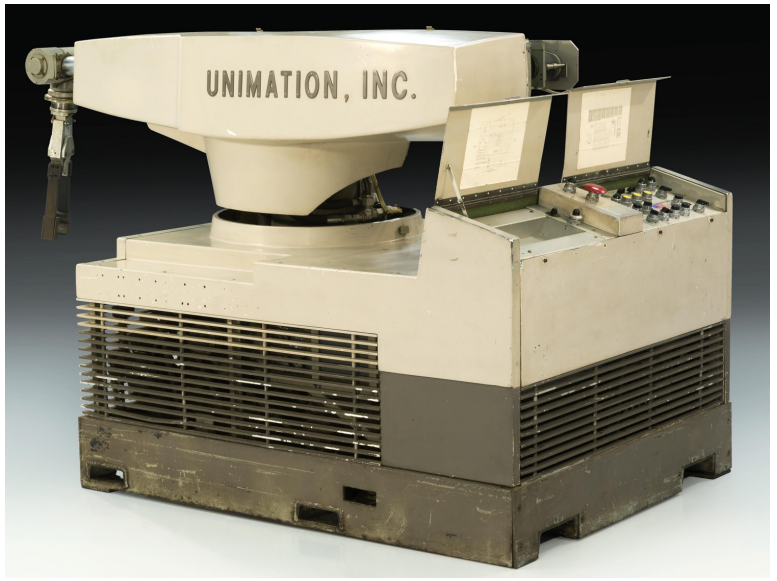
- First definitions:
  - Karel Capek → robots were biological beings performing unpleasant labor.



Herbert Televox (1927)



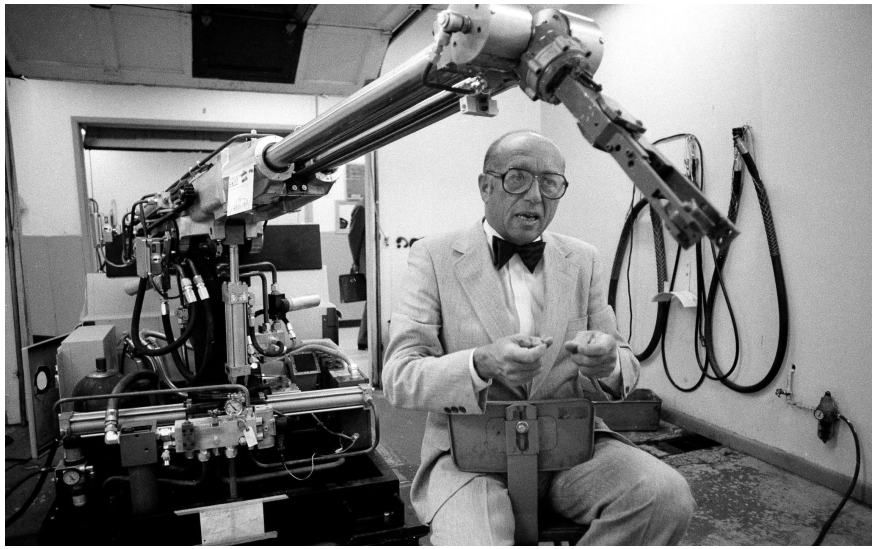
Eric (1928)



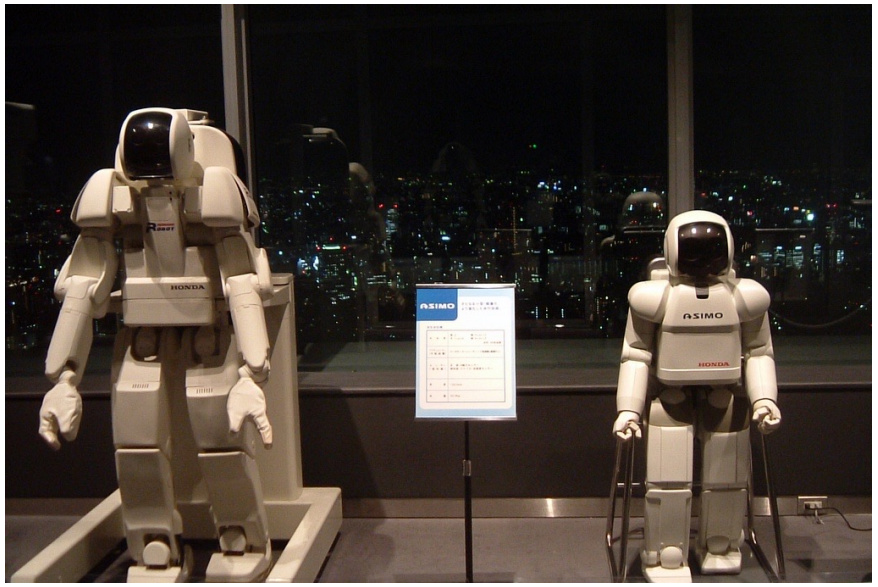
Unimate (1961)

The first wave of robots

Shakey



Engelberger
(Unimate ++)



Honda P series

The second wave of robots

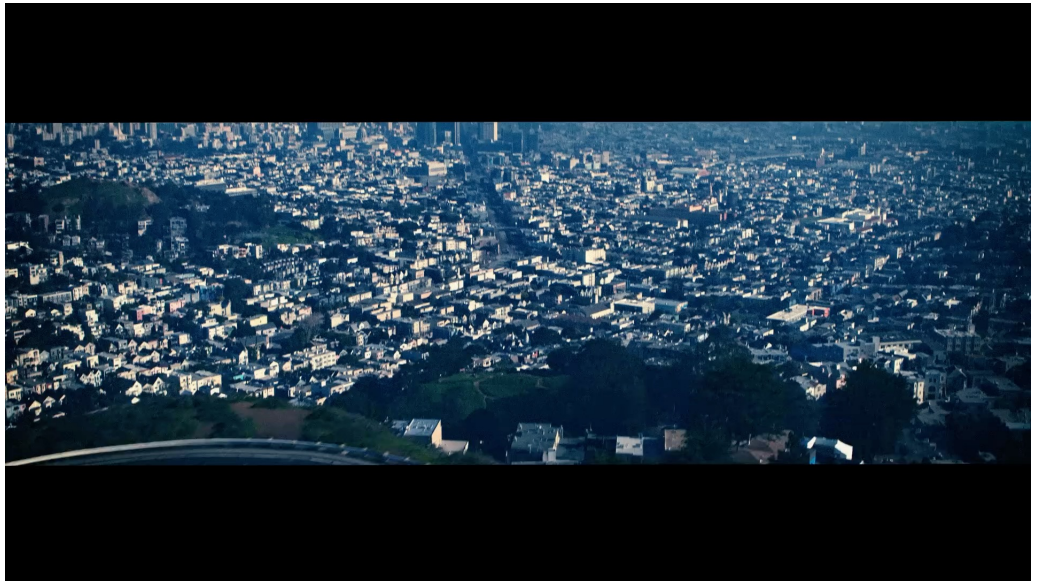
DARPA Grand Challenge

PR1 Robot

Robots Today

Everyday Robotics - Google

Atlas – Boston Dynamics



Waymo – self driving cars

Robotics Spans Applications and Industries

- Applicable in a variety of industries and spaces:
  - Industry:
    - Industrial manufacturing
    - Warehouse navigation
  - Outdoor navigation/locomotion:
    - Legged locomotion
    - Outdoor navigation
    - Last mile delivery
    - Self driving cars
  - Home and office manipulation
    - Mobile manipulation
    - Dexterous manipulation

Industrial Robotics

Industrial Robotics Today

Robots in Warehouses (Kiva@Amazon)

Navigation

DARPA Urban Challenge 2007

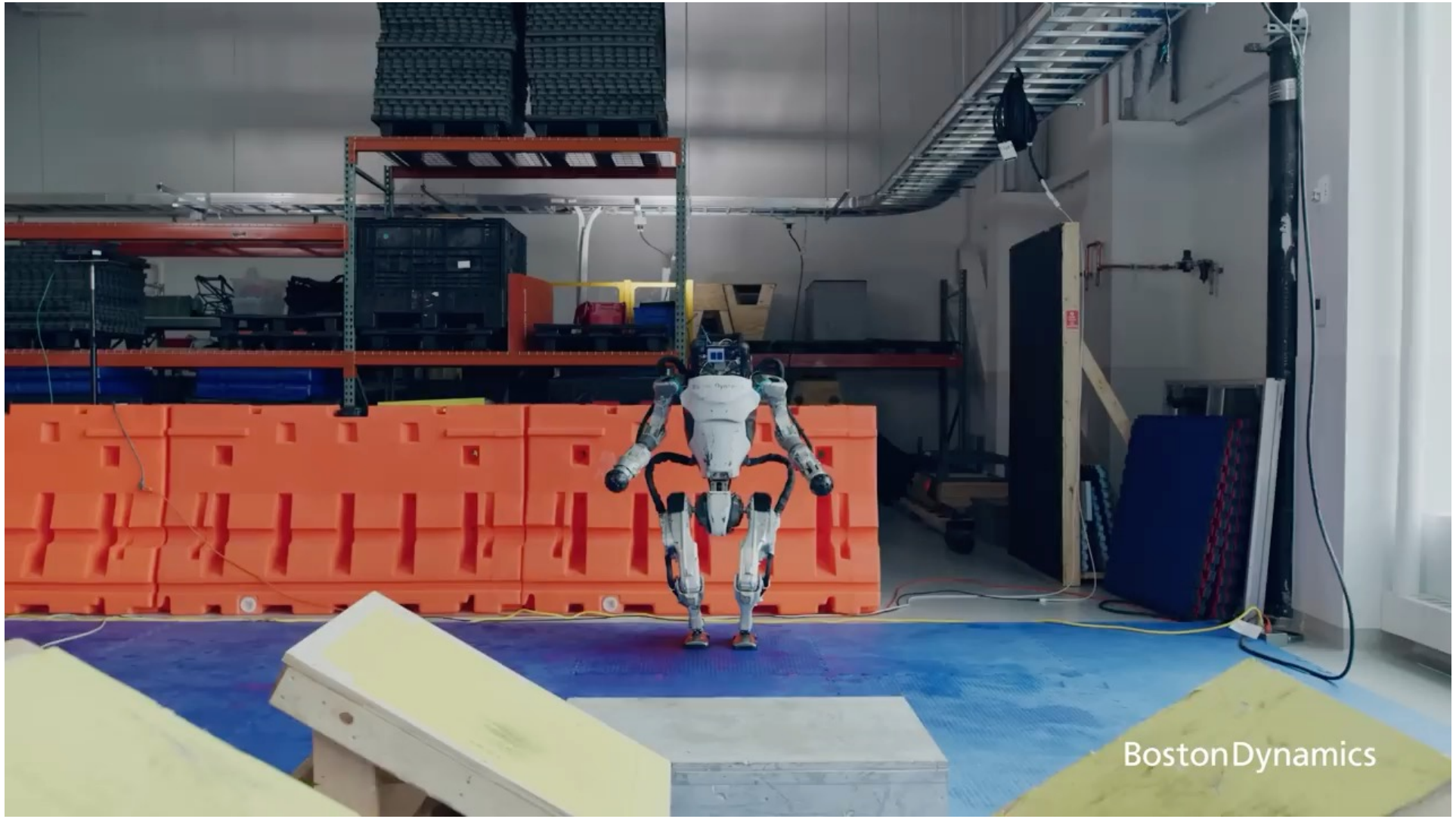
Self-Driving Cars

High-Speed Drone Navigation

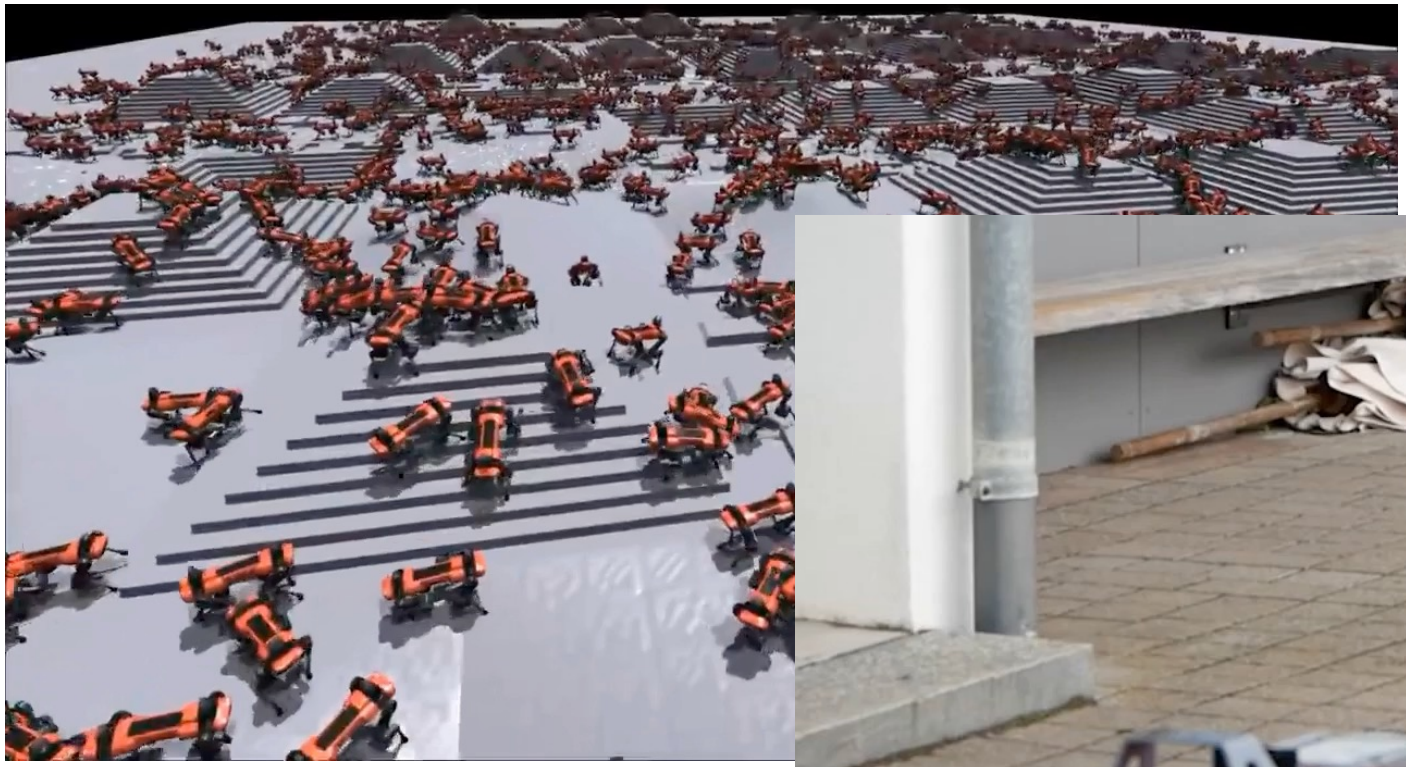
Locomotion

Boston Dynamics BigDog (2008)

Humanoid Parkour



Outdoor Locomotion

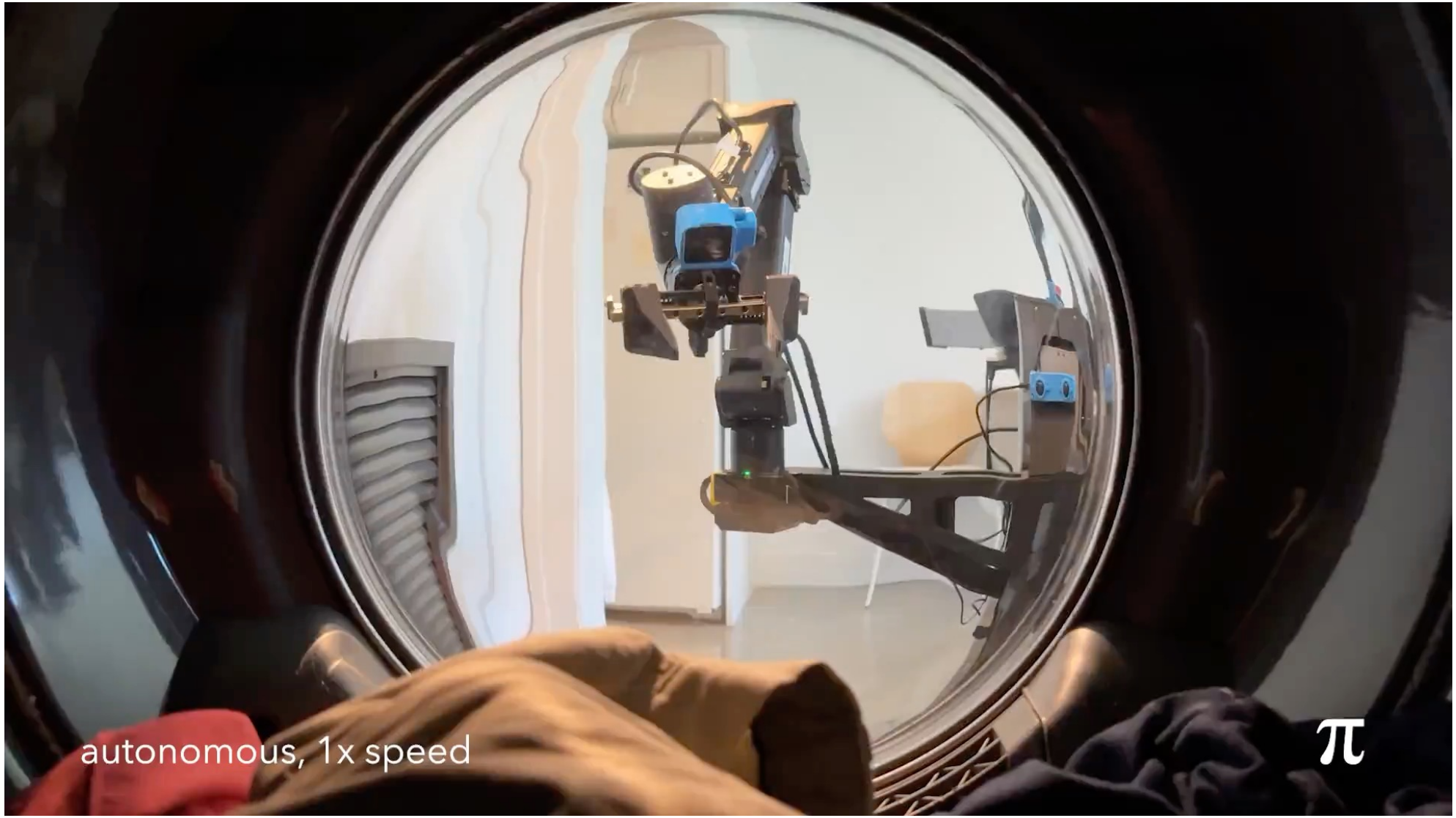


Manipulation

Dexterous Manipulation

Mobile Manipulation

Bimanual Manipulation with Foundation Models



Why should we care about robotics?

Societal Impact

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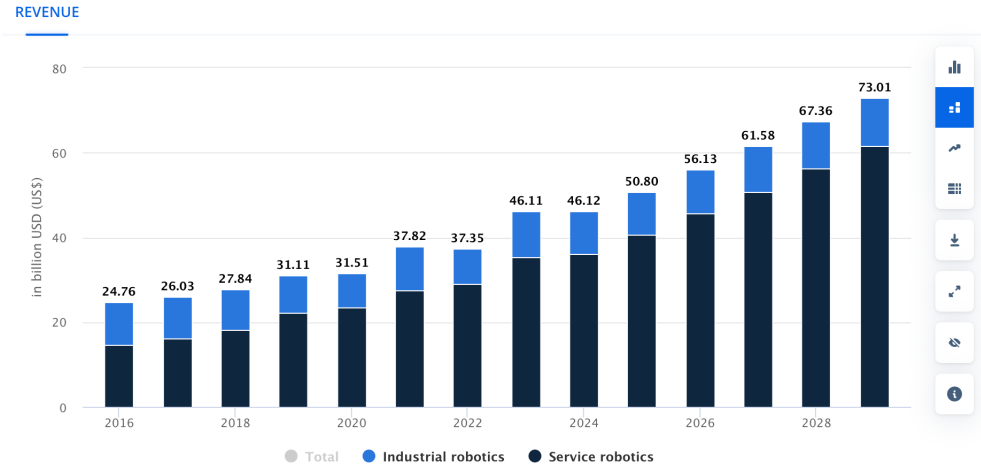
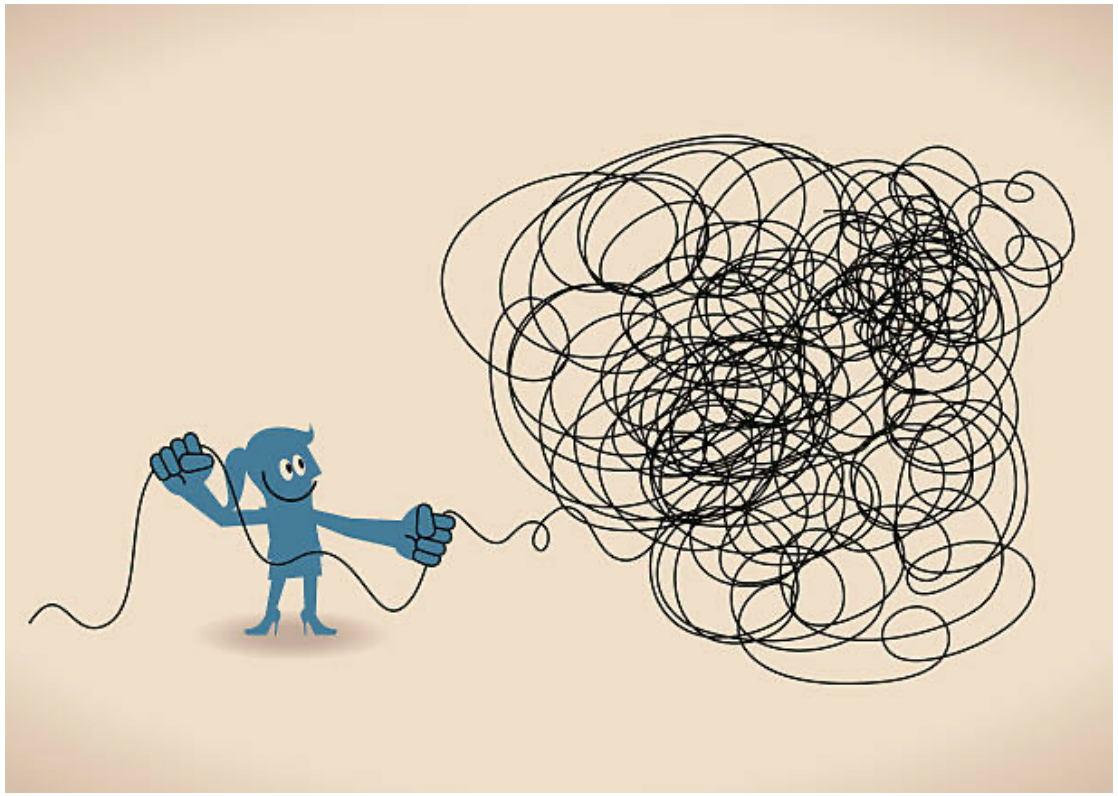


Not solved yet!

Ok this is great – how do we build these robots?

- Need a formal framework for problem definition and a set of tools to solve them



- Sense-plan-act framework with probabilistic inference. More on this next time!