Autonomous Robotics
Winter 2026

Abhishek Gupta, Siddhartha Srinivasa

TAs: Carolina Higuera , Entong Su, Rishabh Jain

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

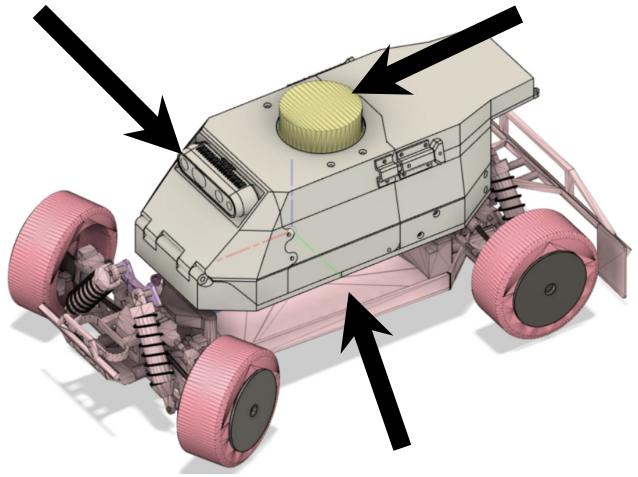

16
24


NPR

Overview of the RACECAR

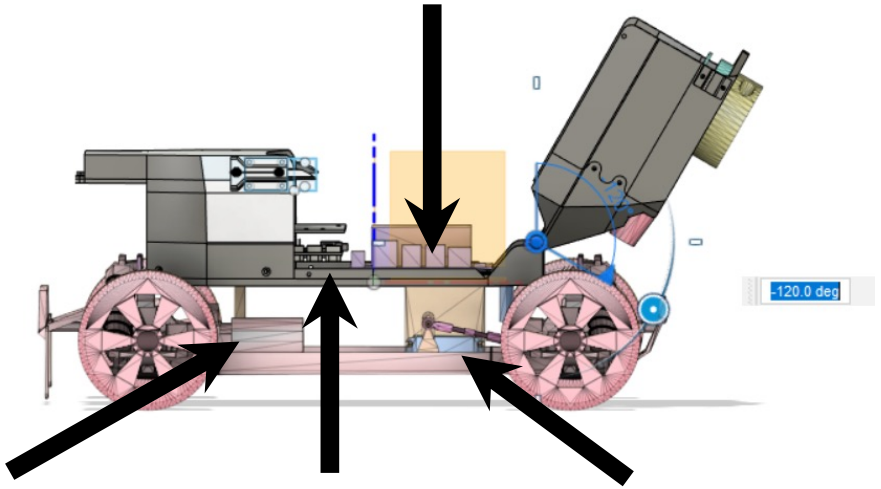
Intel Realsense D435i

YDLidar X4



Redcat Racing Blackout SC 1/10 chassis

Nvidia Jetson Orin NX



BLDC motor

Motor Driver

Servo

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

Highlights from Previous Years

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

Learning Objectives

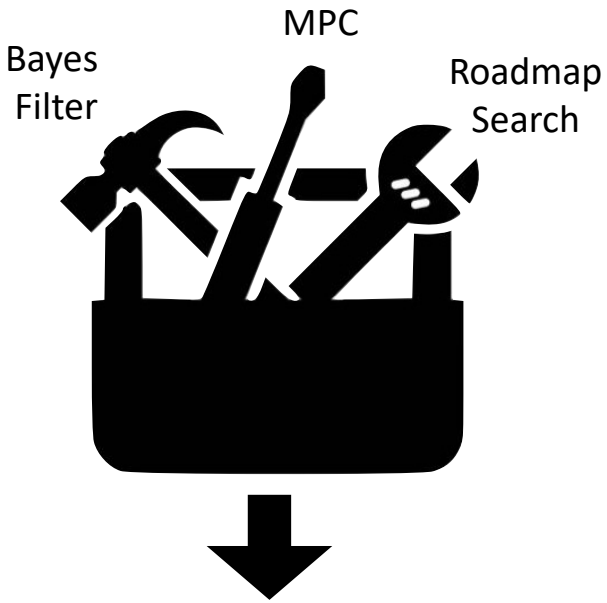
Objective 1

Learn algorithms for
autonomous driving and
implement them on the RACECAR

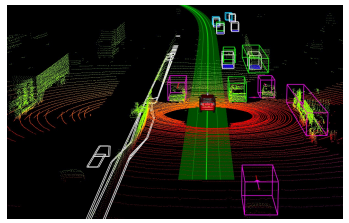
in 10 weeks!

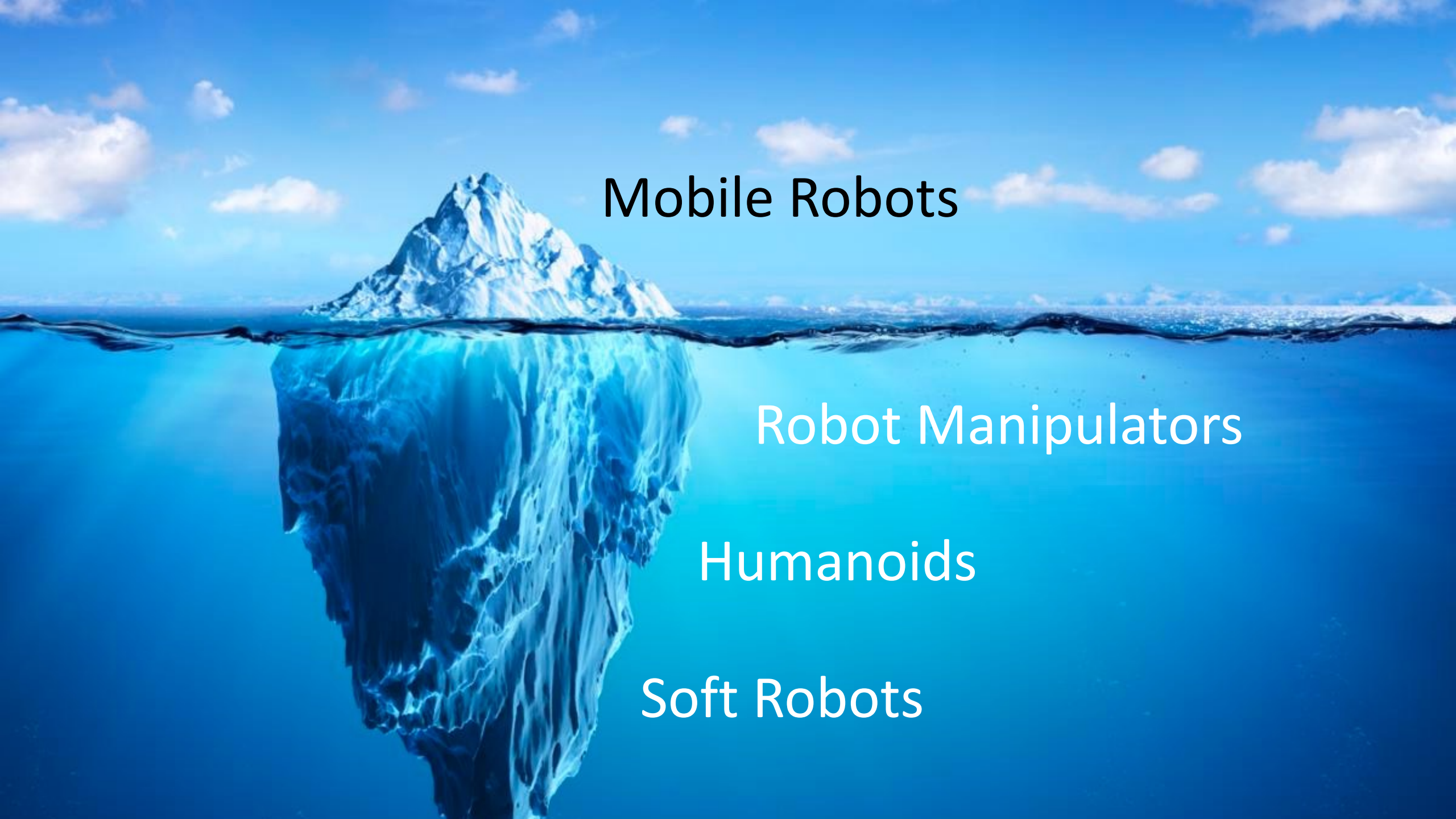
Objective 2

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

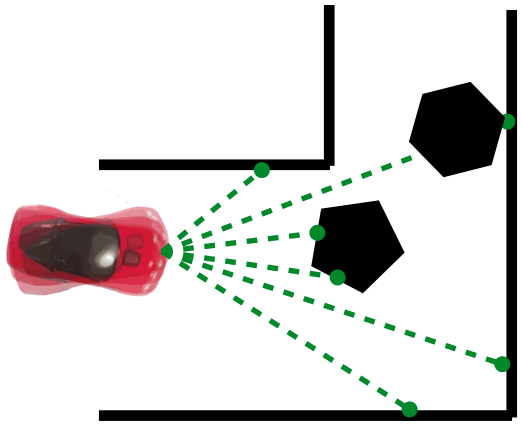
Mapping

Computer Vision

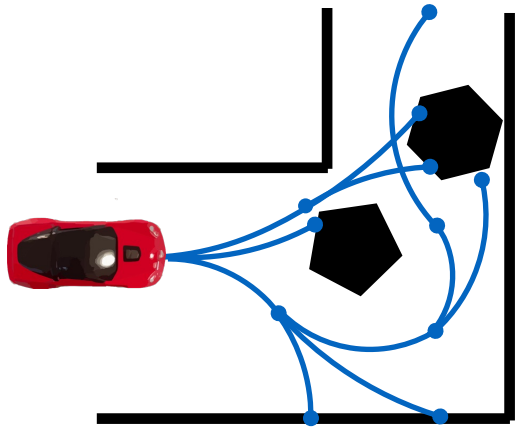
Robot and Actuator Design

Concrete Learning Objectives

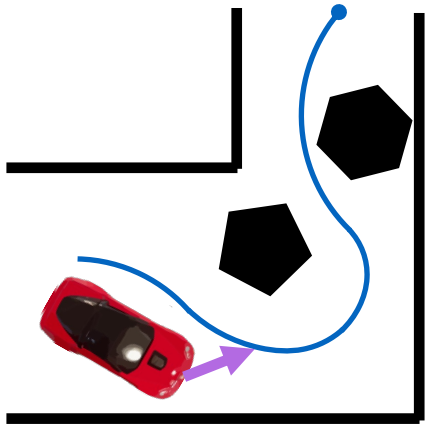
Estimate State



Plan a sequence of motions

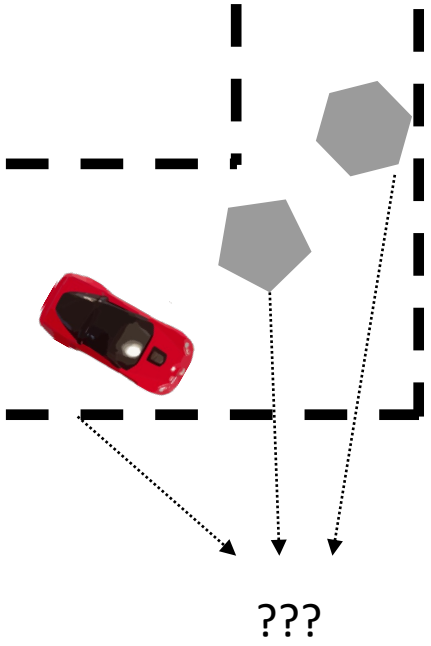


Control robot to follow plan

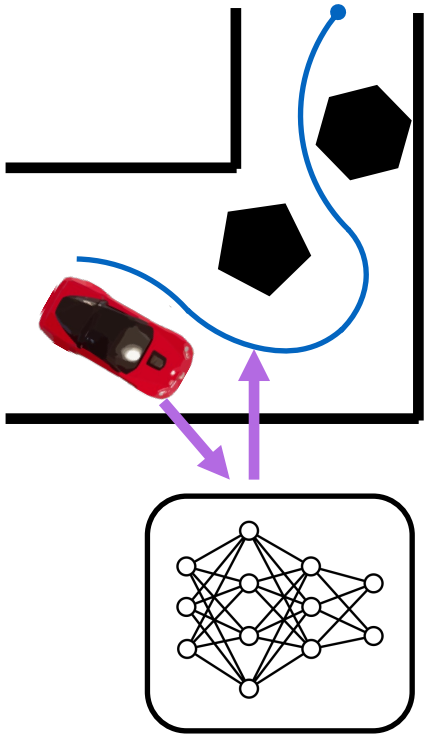


Additional Learning Objectives – no HW

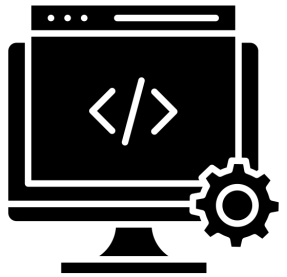
How to estimate maps



Where machine learning may be helpful?



Learn how to program robot software

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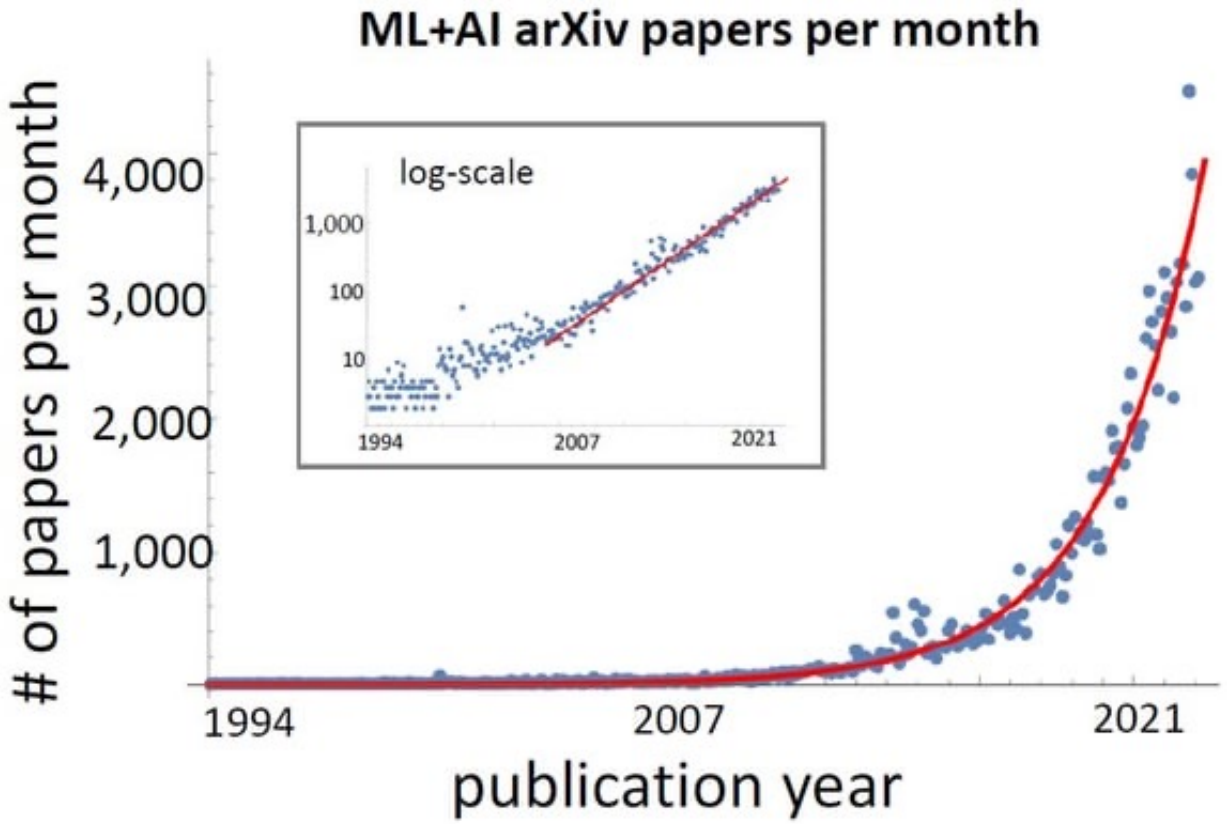
Objective 3

Learn how to read and analyze and propose research papers



arXiv

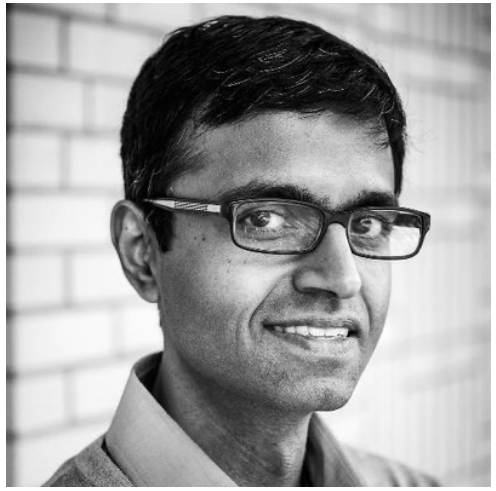
IEEE

NEURAL INFORMATION PROCESSING SYSTEMS

Course Logistics

Class Logistics

- Where: G01 Gates (CSE2)
- When: 8:30-9:20 MWF
- Who:
  - Abhishek Gupta (Co-Instructor)
  - Siddhartha Srinivasa (Co-Instructor)
  - Carolina Higuera (TA)
  - Entong Su (TA)
  - Rishabh Jain (TA)


Who is Abhishek?

- 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 Sidd?

- Professor @ CSE
- Research interests: motion planning, adaptive control, human-robot interaction
- Non-research interests: tennis, cooking
- Fun fact: I have an unreasonable love for Cheese Danish!

Who is Carolina?

- PhD student advised by Prof. Byron Boots
- 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
- Research interest: Reinforcement learning, robotics manipulation, imitation learning
- Outside of work: Piano, Badminton
- Email: ensu@cs.washington.edu

Who is Rishabh?

- 4th Year Undergrad Computer Engineering Student
- Research Interest: Robotic Path-Planning
- Outside of Work: Basketball, Video-Games
- Email: jrishabh@cs.washington.edu

Who are y’all?

Grading - Approximate

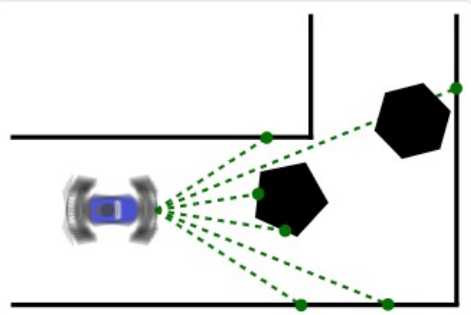
- **Programming projects** and writeups (4), graded on an SN scale [10% of the grade each]
  - N will come with TA feedback and guidance; revise and resubmit
  - Due dates are paced throughout the quarter
- **Seeded Paper Discussions** [20% of grade]
  - Present new paper ideas and provide 2-3 paragraphs of commentary
- **Quizzes** (15 minutes in class) [30% of grade]
  - Test out your conceptual knowledge in MCQ format
- **Final Project** [10% of grade] + Extra Credit [5% of grade]
  - Combine projects for a full stack racecar solution

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)

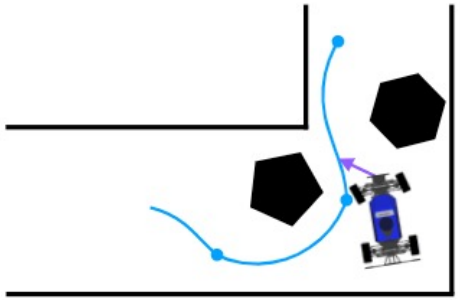
Project 1: Introduction

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



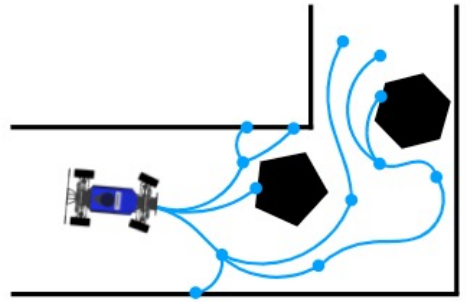
Project 2: Localization

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

- 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!

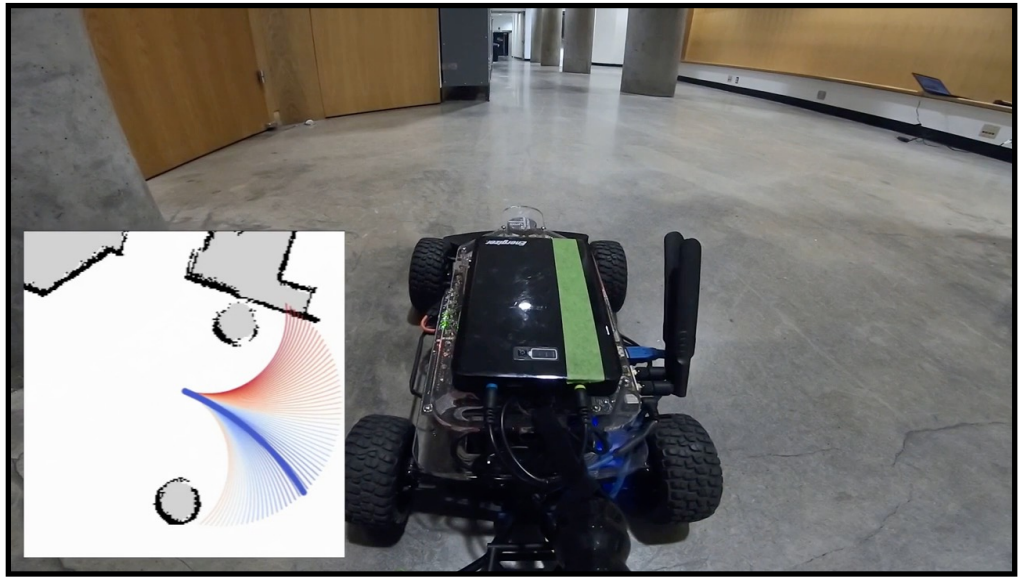
Grading – Quizzes

- Multiple choice questions about each module – state estimation, control, planning, learning
- Mix of questions to test your conceptual and problem solving understanding.
- 15 minutes in class, no laptops/phones – old school!

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)



Please come to class and participate!

(Approximate) 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 Thu 1/8 EOD for us to assign teams
- Same team for the 4 projects and final project:
  - If there are any issues, let us know and we will help make changes.
- 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

Project 1: Introduction

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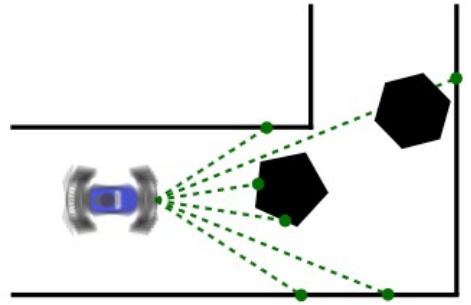

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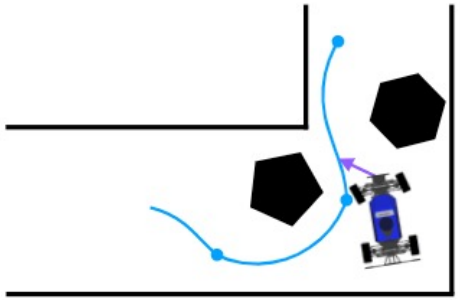

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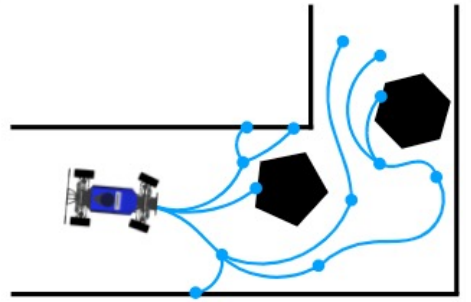


Project 4: Planning

Implement Lazy A* and postprocessing to plan new trajectories.

Lab / Office hours

- Lectures - MWF 8:30 - 9:20AM, Gates G01
- Conceptual office hours (CSE2 215):
  - Abhishek: Monday 4-5pm, by appointment otherwise
- Lab Office Hours (CSE1 002):
  - Tue 2:30-3:30 (Rishabh, Carolina)
  - Wed 3:30-4:30 (Entong, Carolina)
  - Thu 2:30-3:30 (Rishabh)
  - Fri 3:30-4:30 (Entong)
  - 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 (Allen) 002 (Basement)
  - Card-key operated (let us know if your keycard doesn't work)
- Each team gets a dedicated workstations with Ubuntu + Python + ROS pre-installed.
- Each team gets 1 dedicated RACECAR (same for duration of class)
- We will make an announcement on EdStem to come pick up your cars

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!

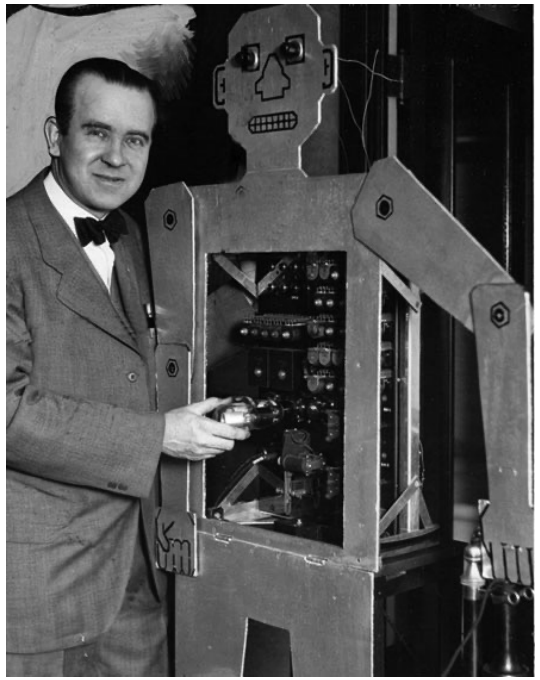
Course Logistics - Integrity

- 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).
- Don't just ChatGPT the whole solution, you're not really going to get what you're looking for from the class!

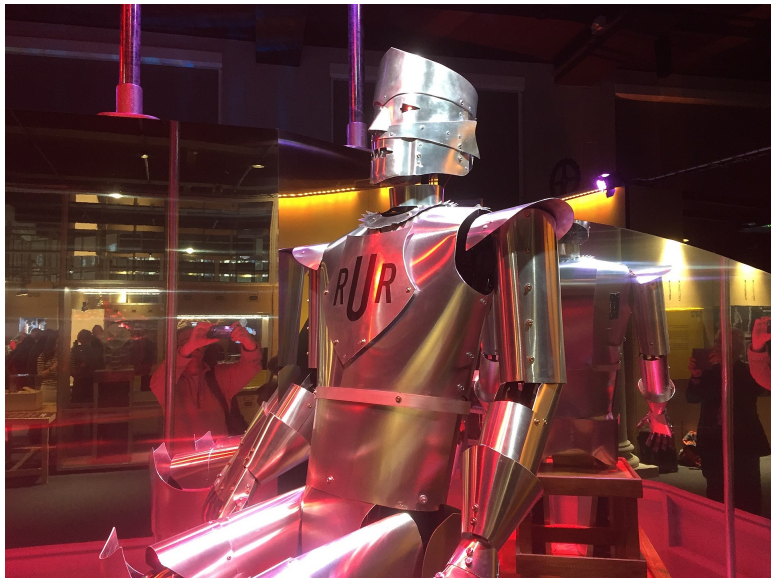
Let’s take a bit of a historical detour

What is a robot?

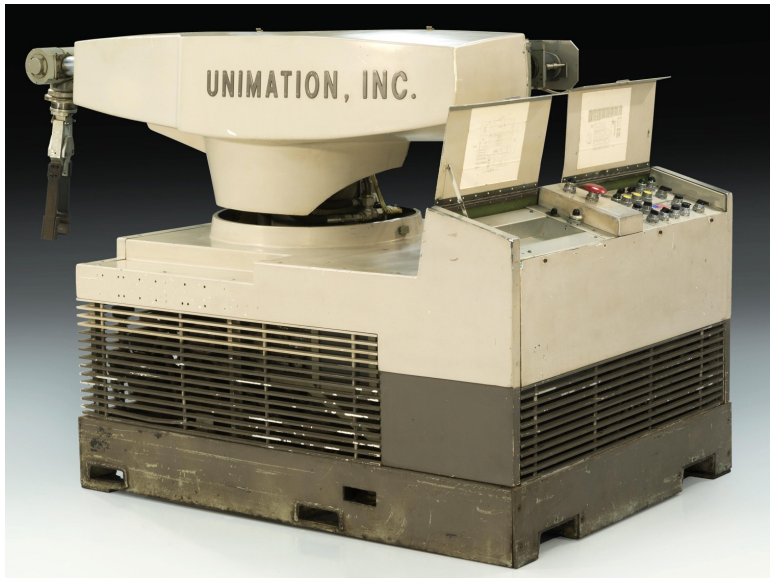
- First definitions:
  - Karel Capek → robots were biological beings performing unpleasant labor.



Herbert Televox (1927)



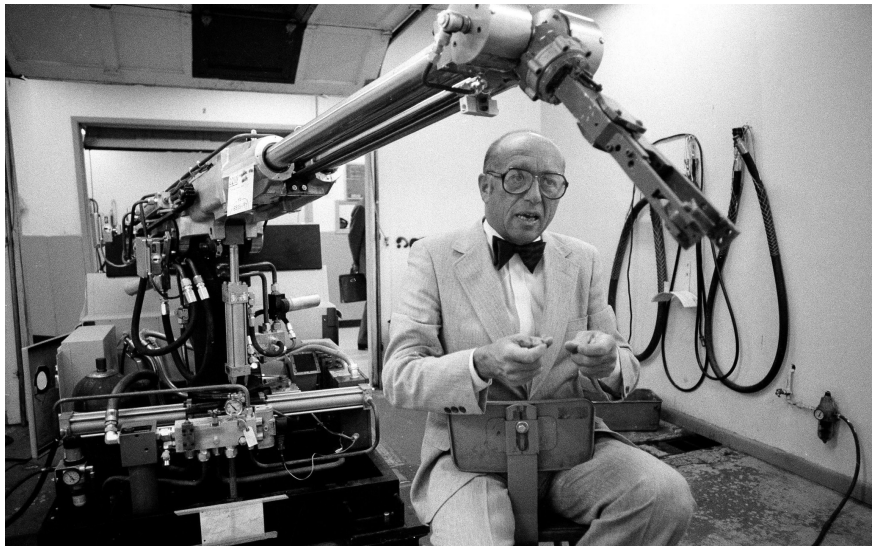
Eric (1928)



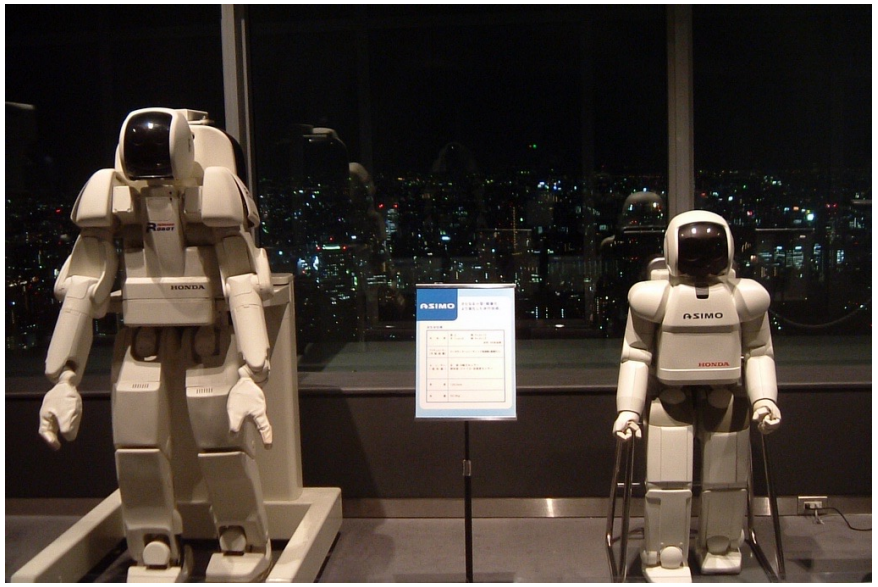
Unimate (1961)

The first wave of robots

Shakey



Engelberger
(Unimate ++)



Honda P series

The second wave of robots

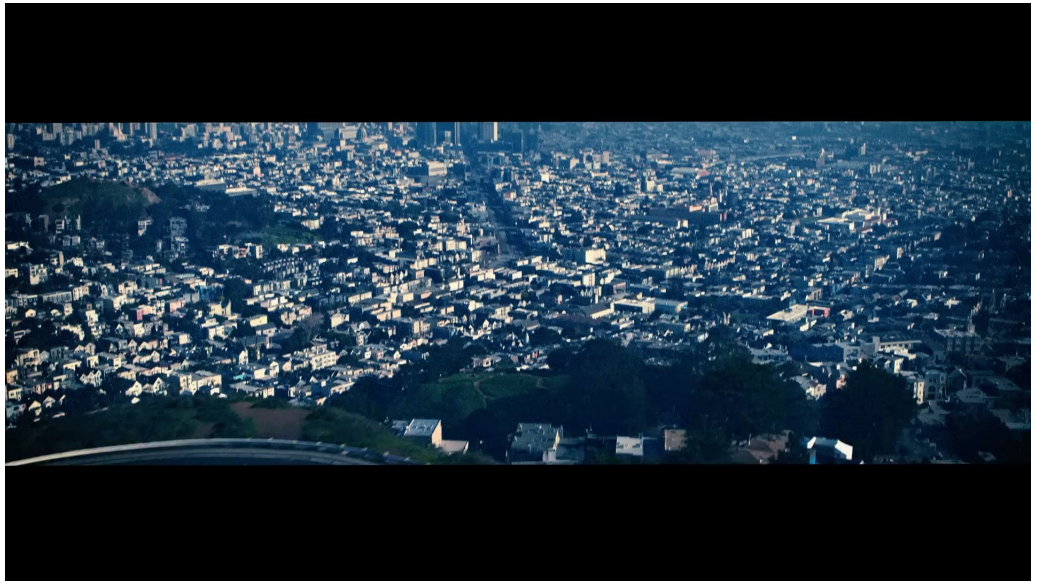
DARPA Grand Challenge

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

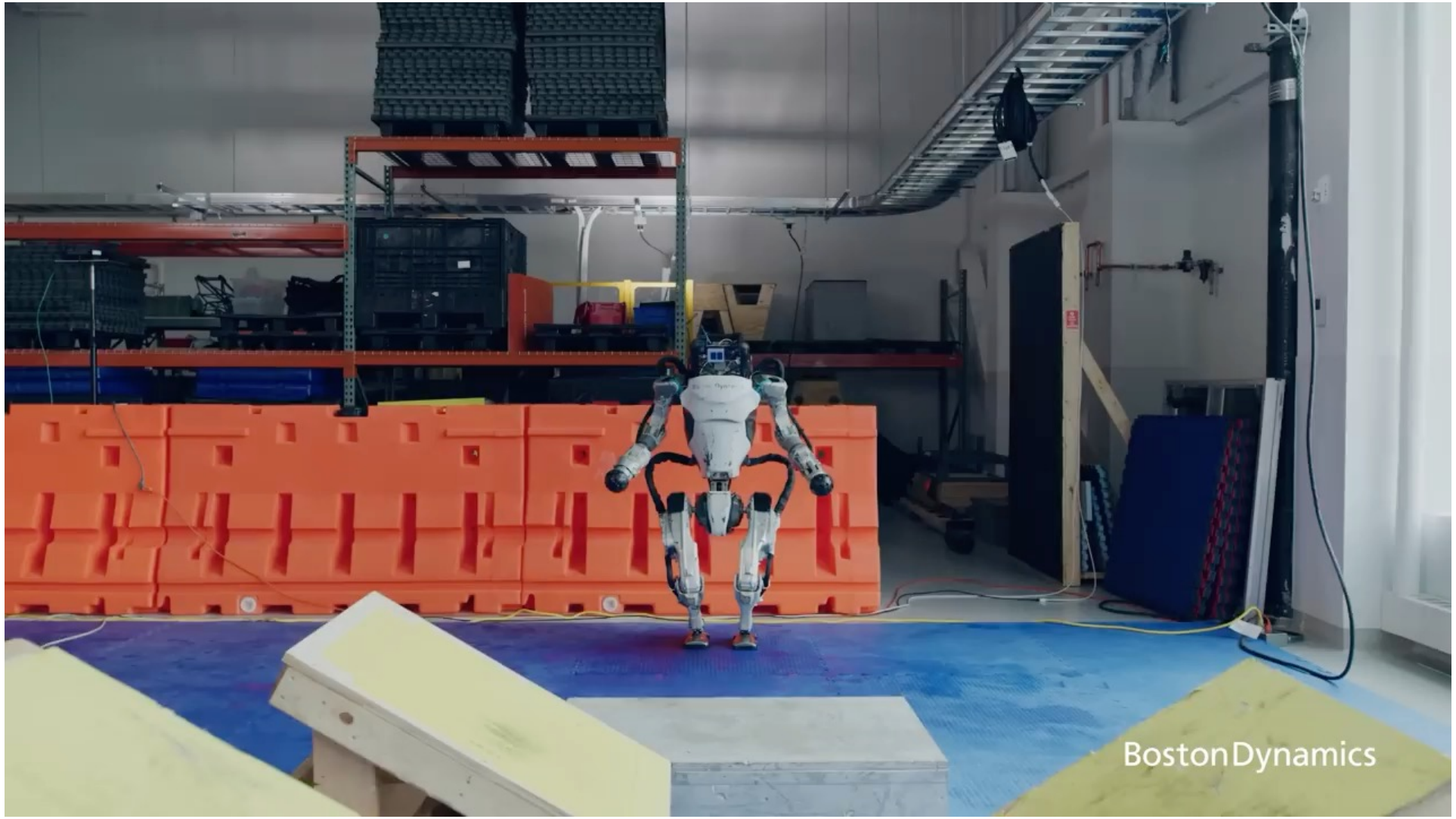
Self-Driving Cars

High-Speed Autonomous Drifting

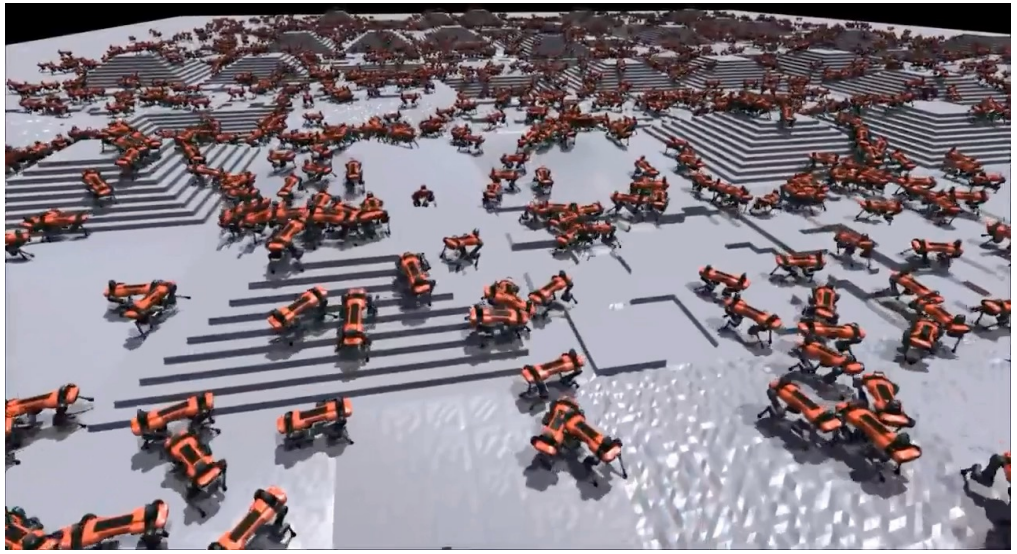
Locomotion

Boston Dynamics BigDog (2008)

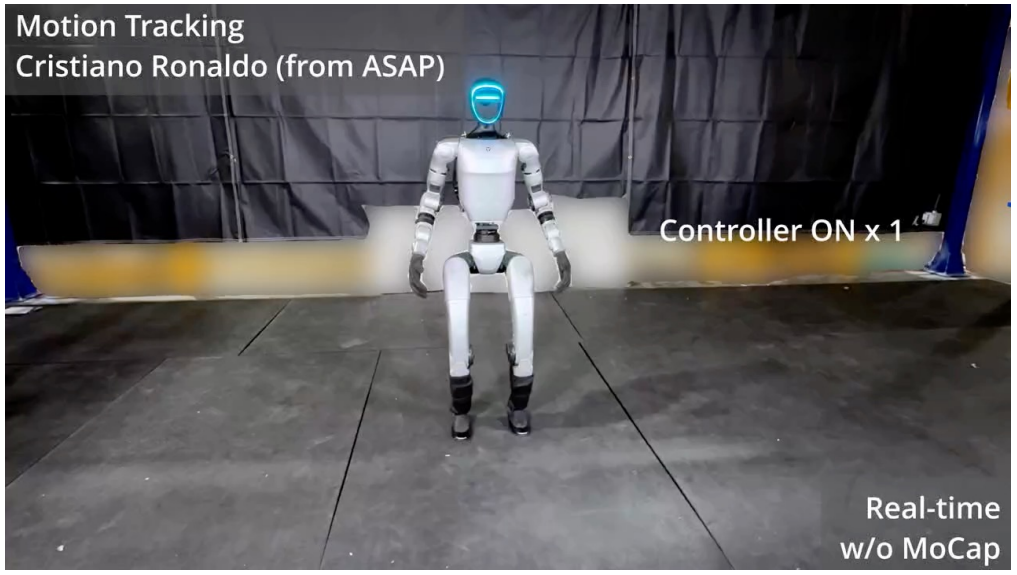
Humanoid Parkour

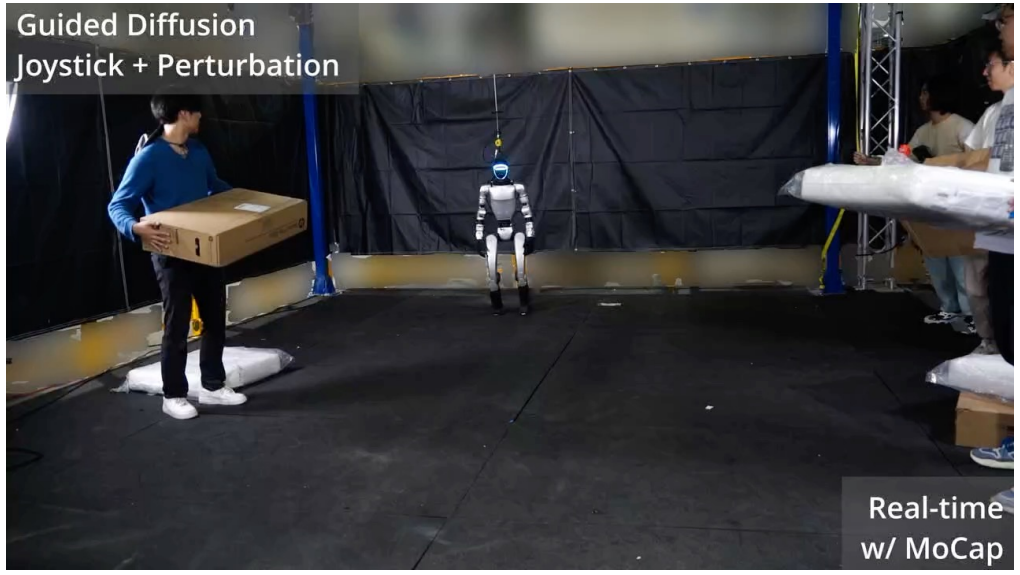


RL-Based Locomotion



ETHZ





BeyondMimic

Manipulation

Dexterous Manipulation (circa 2016)

OpenAI

Mobile Manipulation

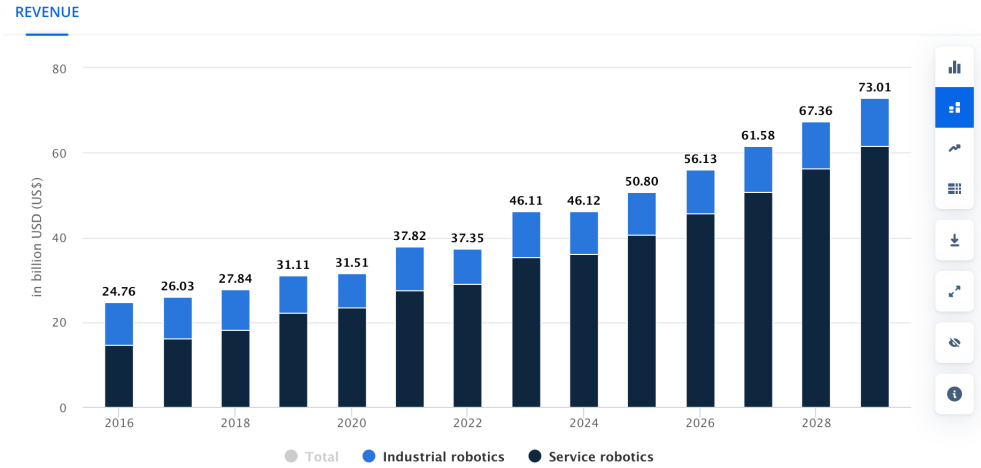
Dexterous Manipulation with Foundation Models

GR-Dex

Why should we care about robotics?

Societal Impact

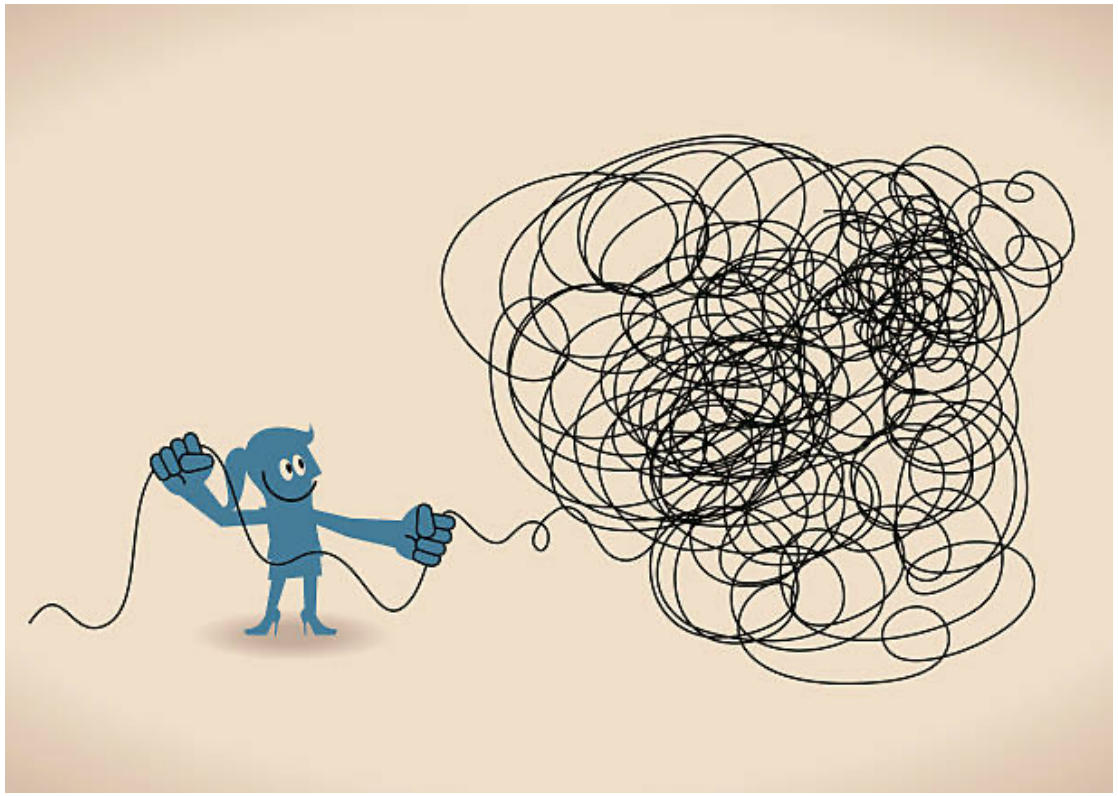
$$



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!