16-762: Mobile Manipulation

Zackory Erickson

Carnegie Mellon University
The Robotics Institute

DARPA Robotics Challenge

NATIONAL ROBOTICS ENGINEERING CENTER

Carnegie Mellon University
TARTAN RESCUE

PIs: Tony Stentz, Alonzo Kelly, Herman Herman, Eric Meyhofer
Systems Lead: David Stager

DARPA PM: Dr. Gill Pratt

https://www.youtube.com/watch?v=HfHAK3gVPak

Cloud

Overview

What is mobile manipulation?

Course organization

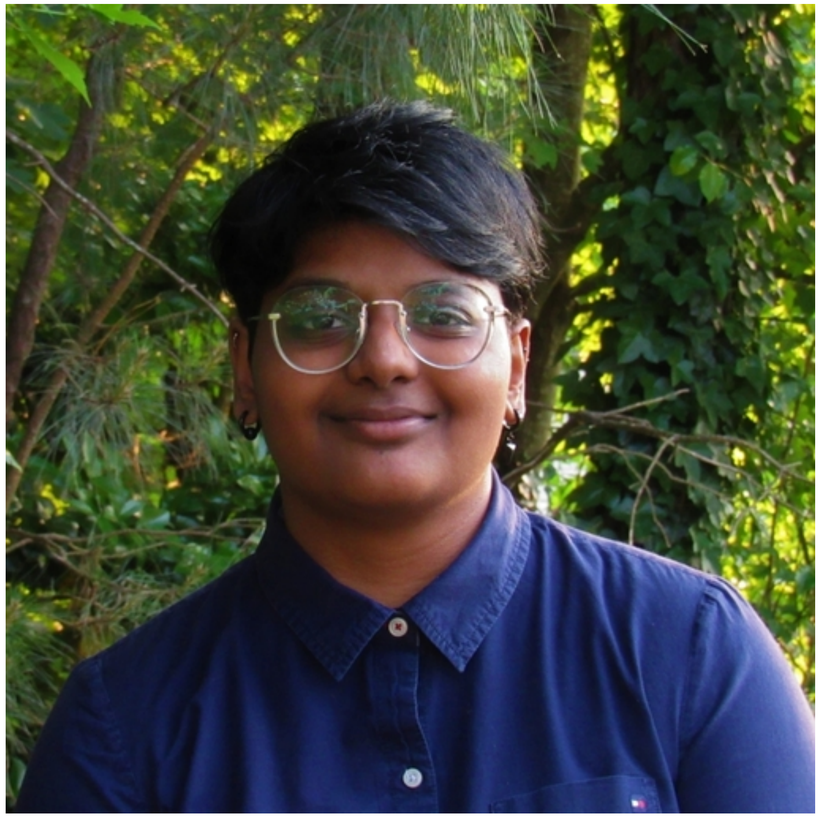
Course topics

Assignments and project

Getting start with Stretch 3

TA

Kavya Puthuveetil



Course website

https://zackory.com/mm2026/

Manipulation is

Definition 1 (etymological). Manipulation refers to the activities performed by hands.

…

Definition 5. Manipulation refers to an agent's control of its environment through selective contact.

Toward Robotic Manipulation. Matthew T. Mason. *Annual Review of Control, Robotics, and Autonomous Systems*, 2018.

Mobile Manipulation is

Definition 1 (etymological). Mobile manipulation refers to activities performed by hands mounted on a mobile base.

Definition 2. Mobile manipulation is when an agent moves things other than itself within a workspace effectively larger than its own kinematic reach.

Definition 3. Mobile manipulation refers to an agent's control of its environment through the coupling of gross motion (navigation) and fine motion (selective contact).

Course Organization

Hands-on course with a real mobile manipulator.

Monday — Lecture, learn a fundamental topic

Wednesday — Lab, implement on a real robot

Last half of course — Final project of your choosing (more details soon)

This is an active course, you learn by doing.

Meet Your Robot

Stretch 3 mobile manipulator
by Hello Robot

(more on the labs and projects later)

AI Maker Space

Can you work with the robots outside of lecture?

Yes!

Robots will be accessible from Wednesday (after lecture) to Monday (before lecture)

AI Maker Space

Examples of mobile manipulators or mobile manipulation tasks

Give me some examples:

- ???
- ???

What is Mobile Manipulation?

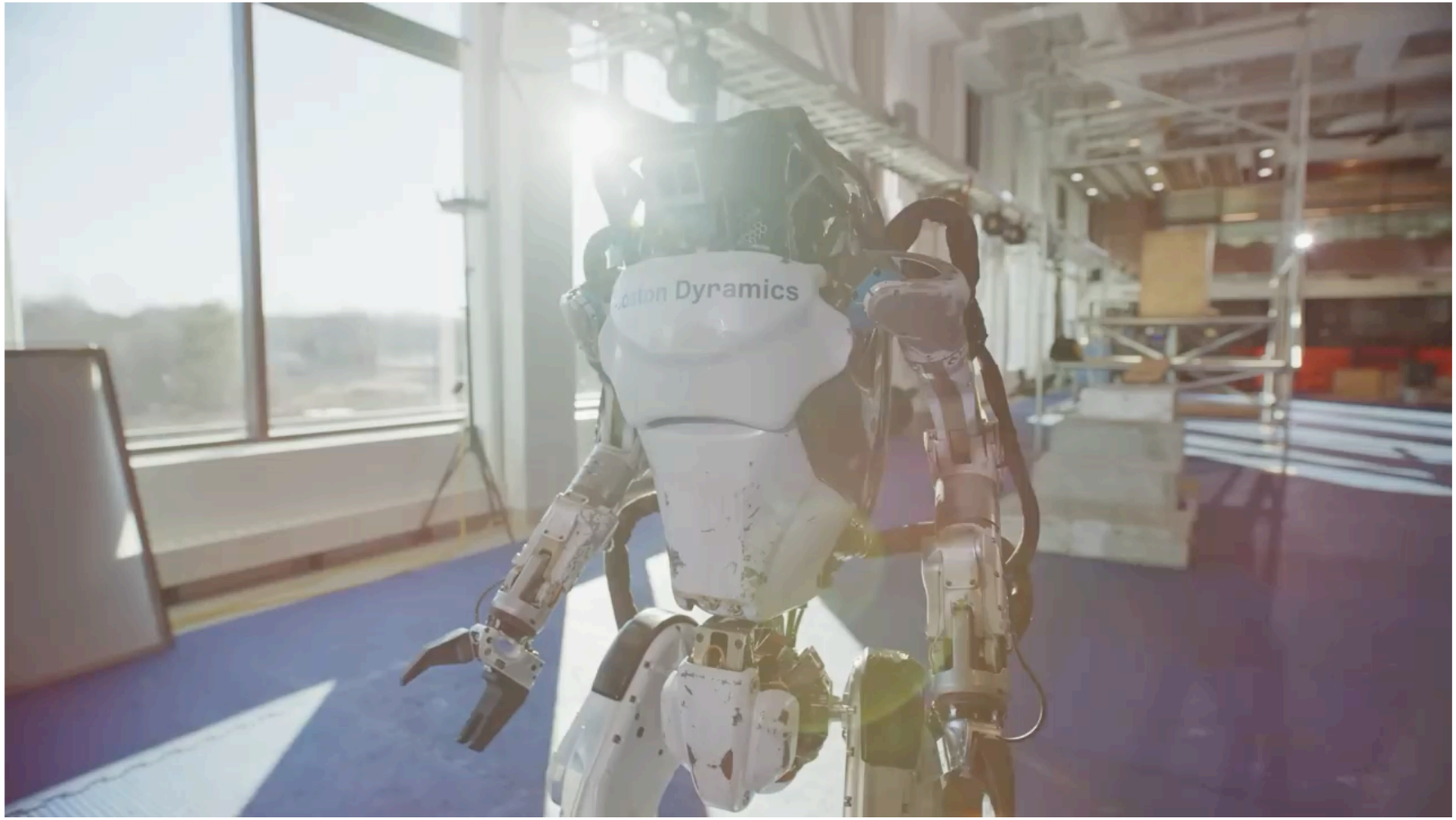
https://www.youtube.com/shorts/kRXQ-Evu8Xs

https://www.youtube.com/shorts/SJFPfwVReOI

What is Mobile Manipulation?

Hell’s Kitchen, https://www.youtube.com/watch?v=BQBvPypinoU

What is Mobile Manipulation?



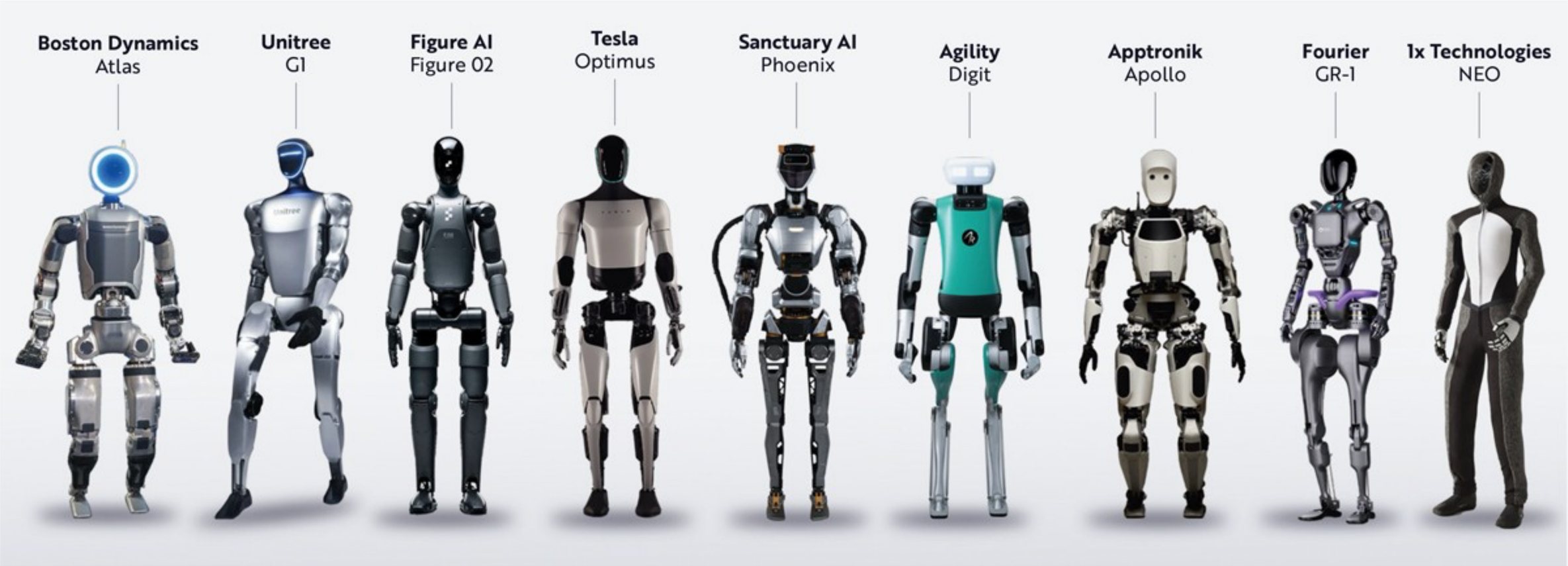
Boston Dynamics, https://www.youtube.com/watch?v=gS4rOqNDTBk

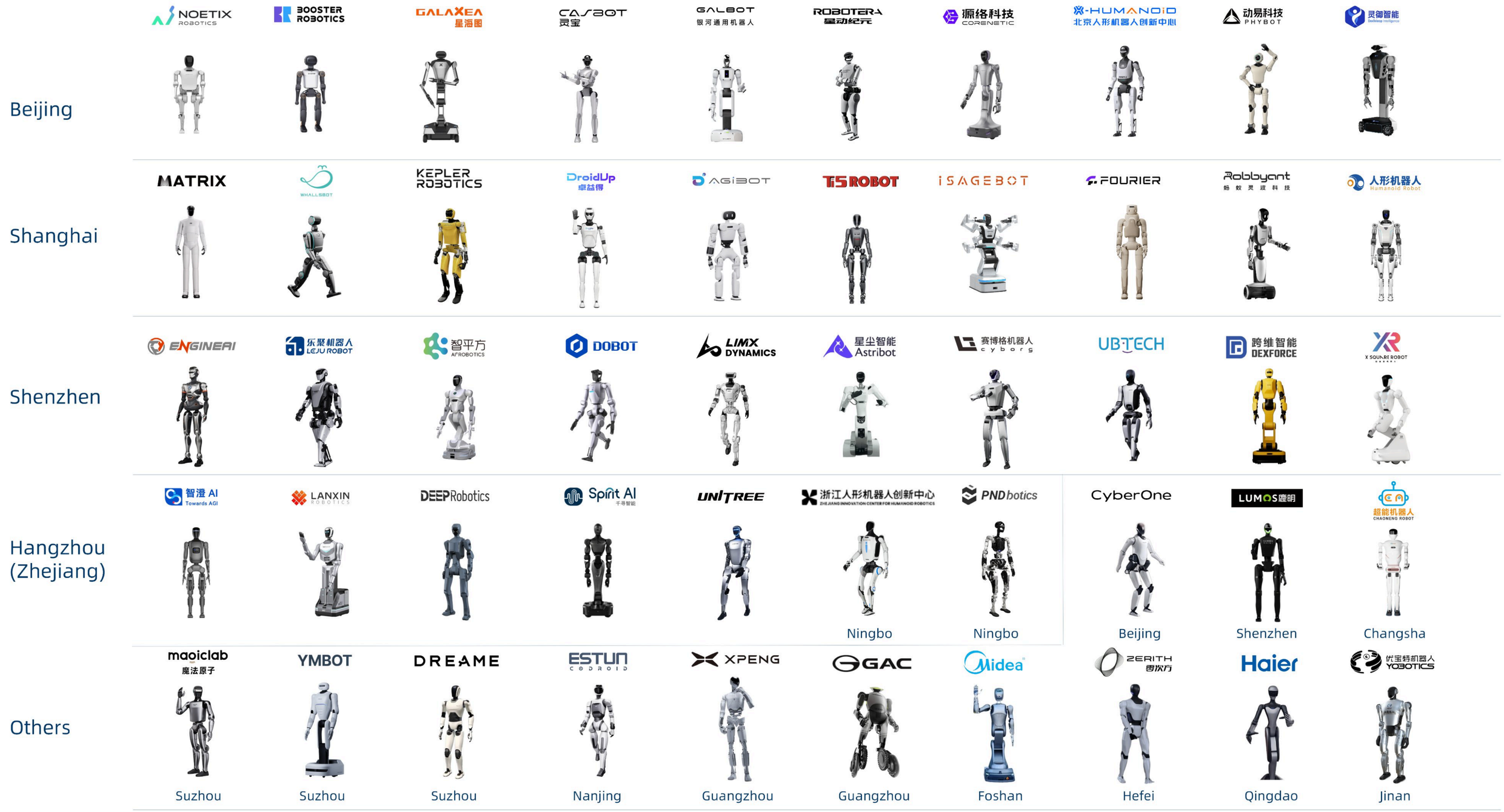
What is Mobile Manipulation?

IROS 2025

Hangzhou, China

What is Mobile Manipulation?





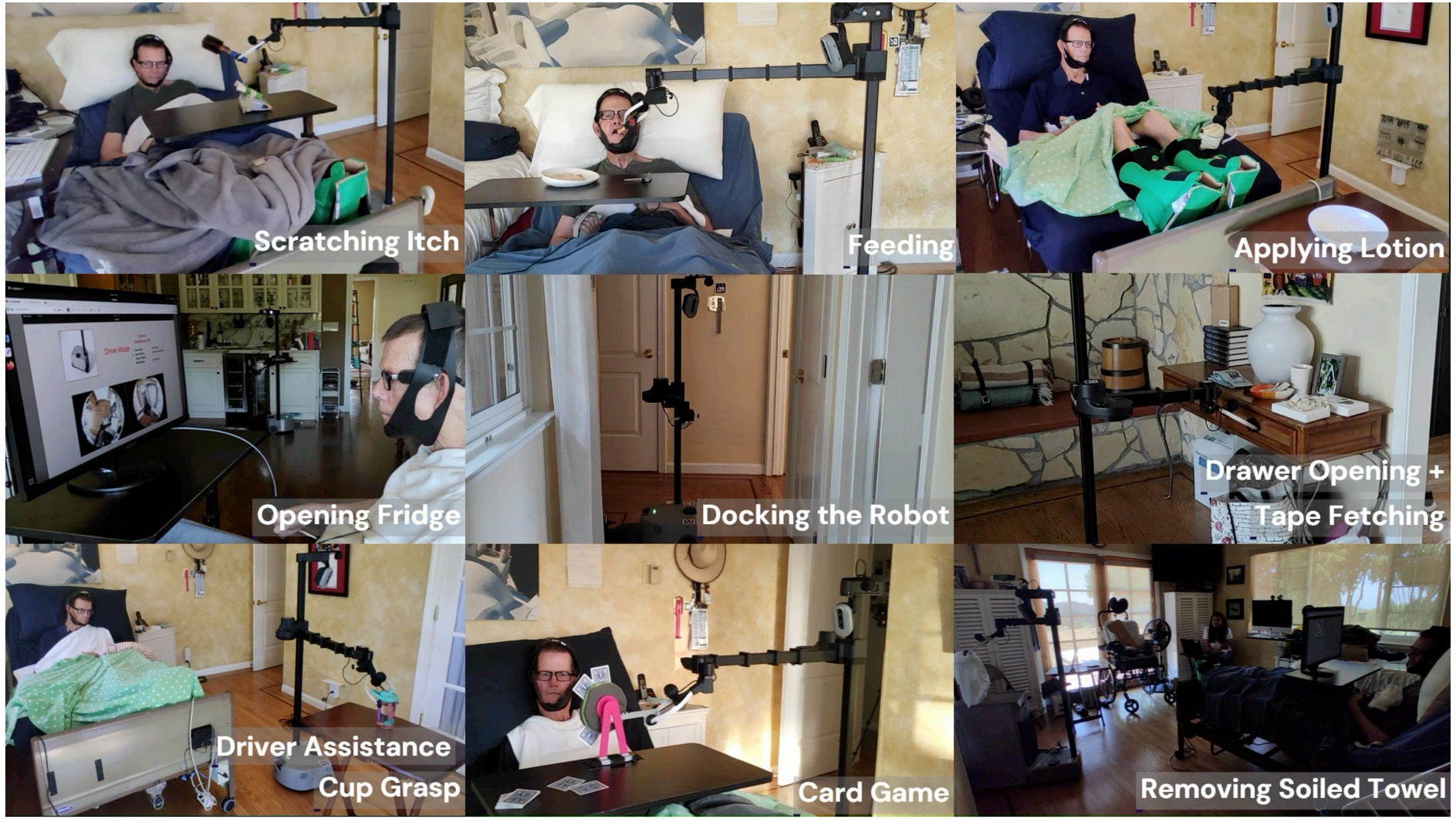
Humanoid Robotics Companies in China

Robotuo.com

What is Mobile Manipulation?

https://www.youtube.com/watch?v=6Zbhvaac68Y

What is Mobile Manipulation?

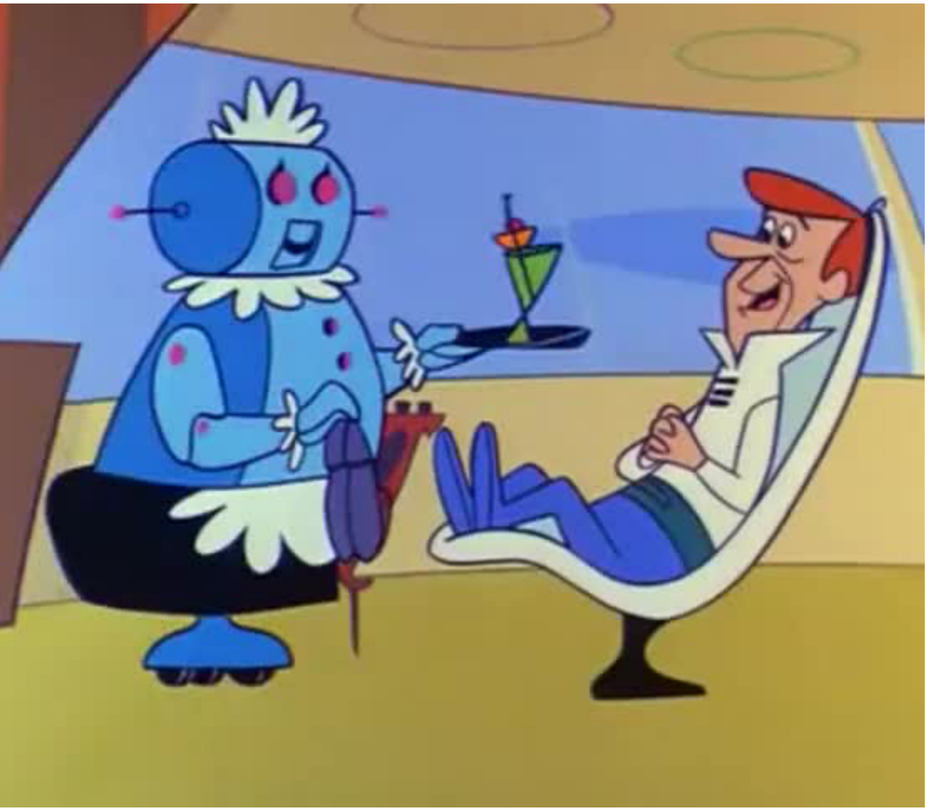


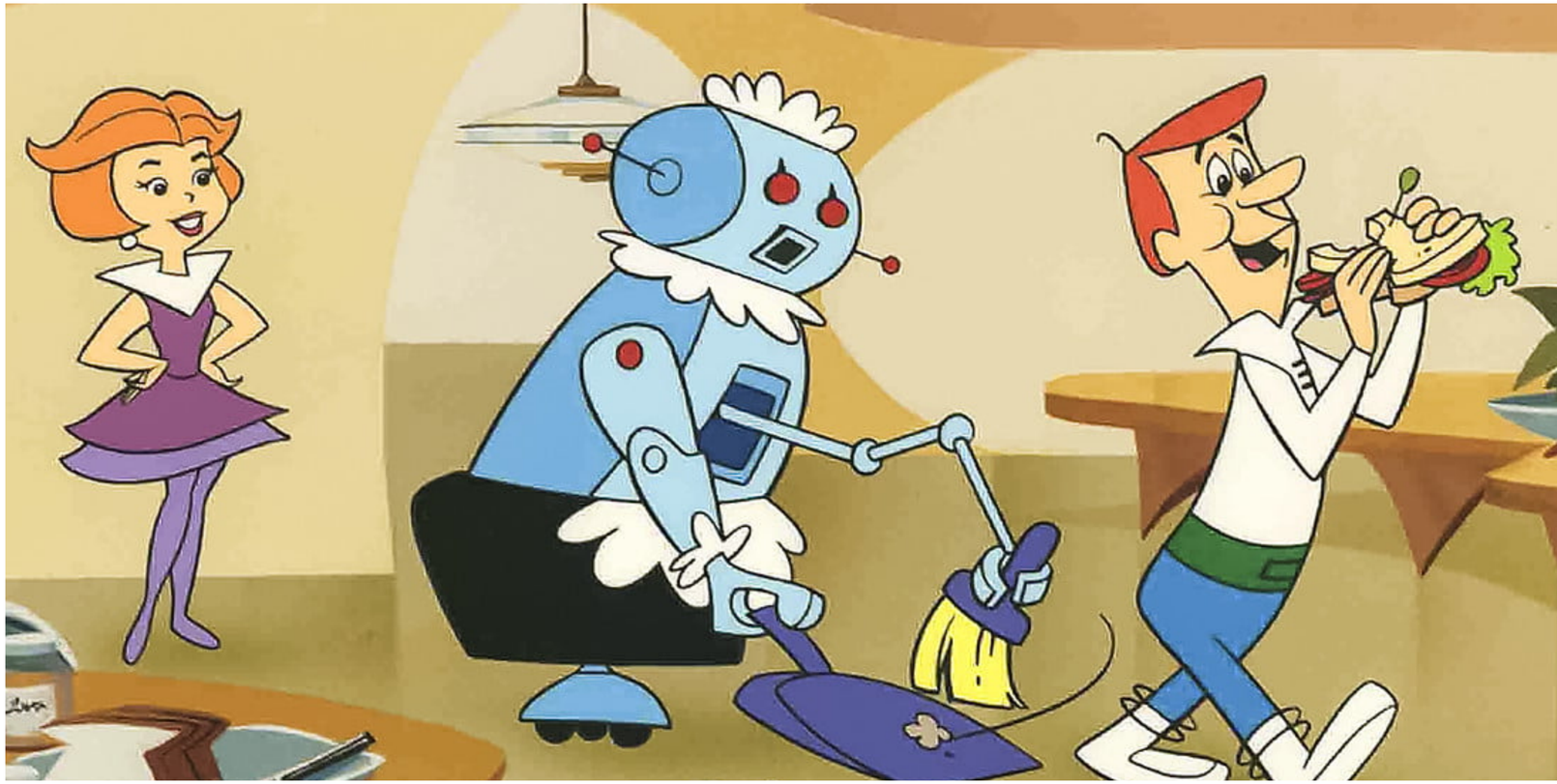
Wearables for teleoperation

Padmanabha, A., Gupta, J., Chen, C., Yang, J., Nguyen, V., Weber, D.J., Majidi, C. and Erickson, Z., Independence in the home: A wearable interface for a person with quadriplegia to teleoperate a mobile manipulator. HRI, 2024.

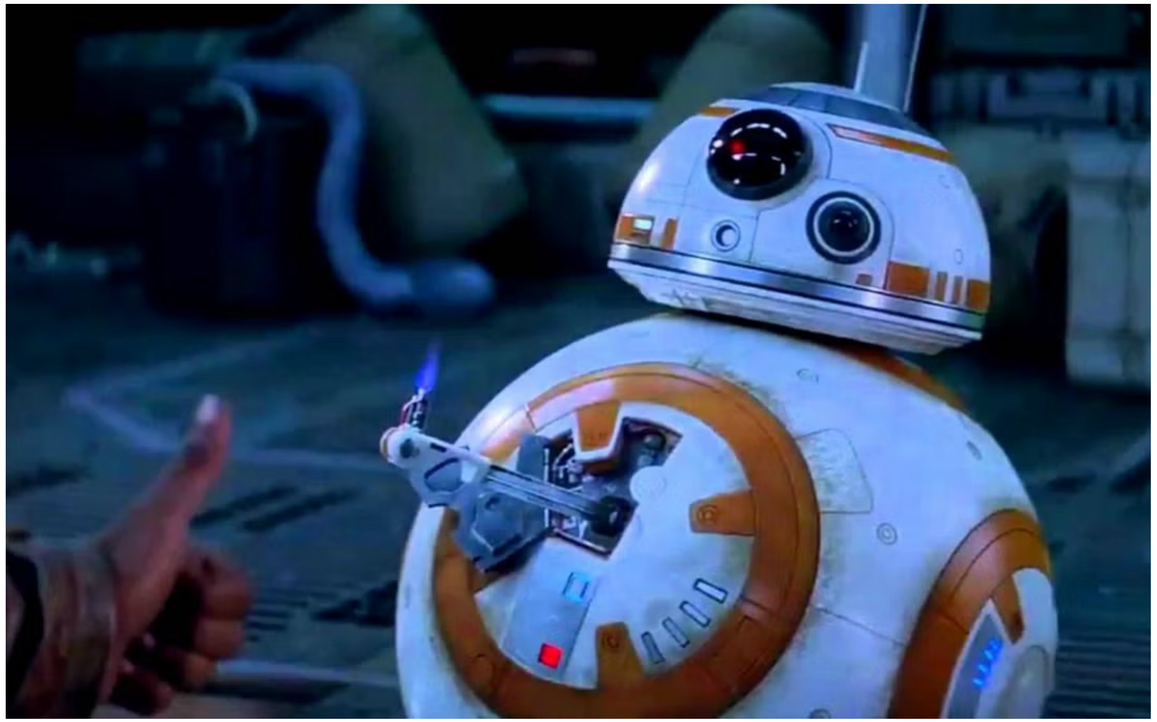
How about mobile manipulators in movies/media?

1962 - The Jetsons (Rosey)

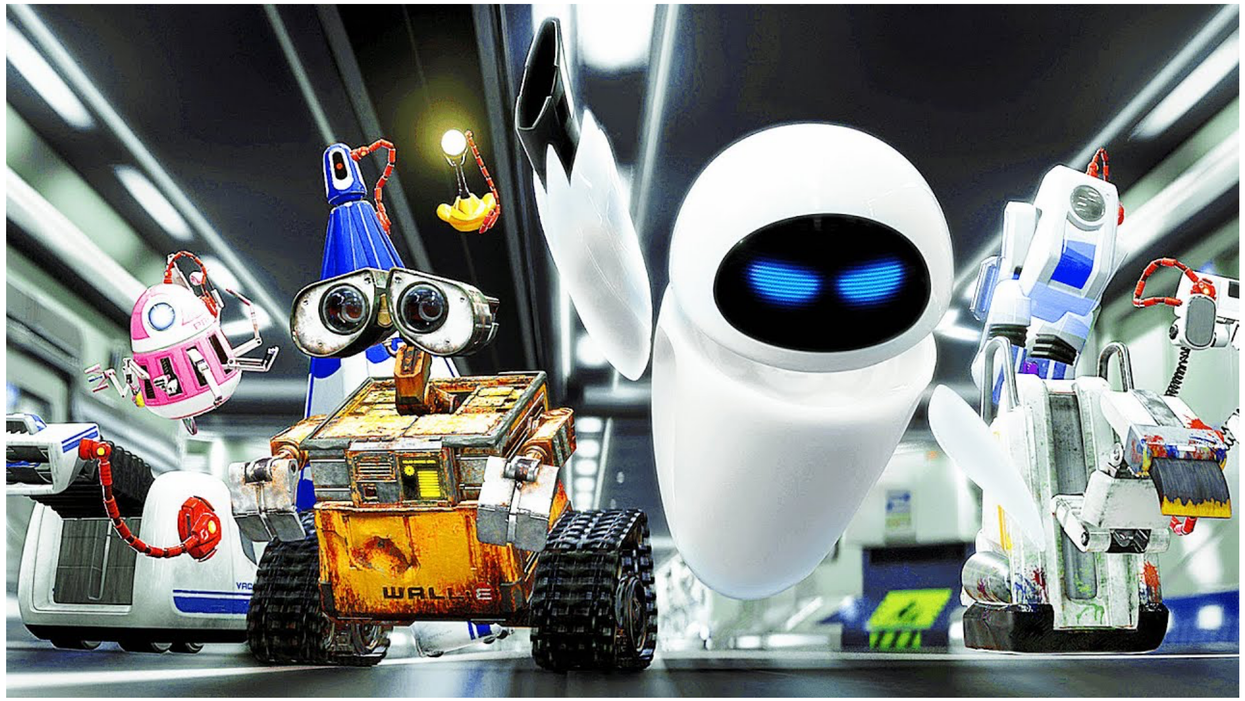




Star Wars

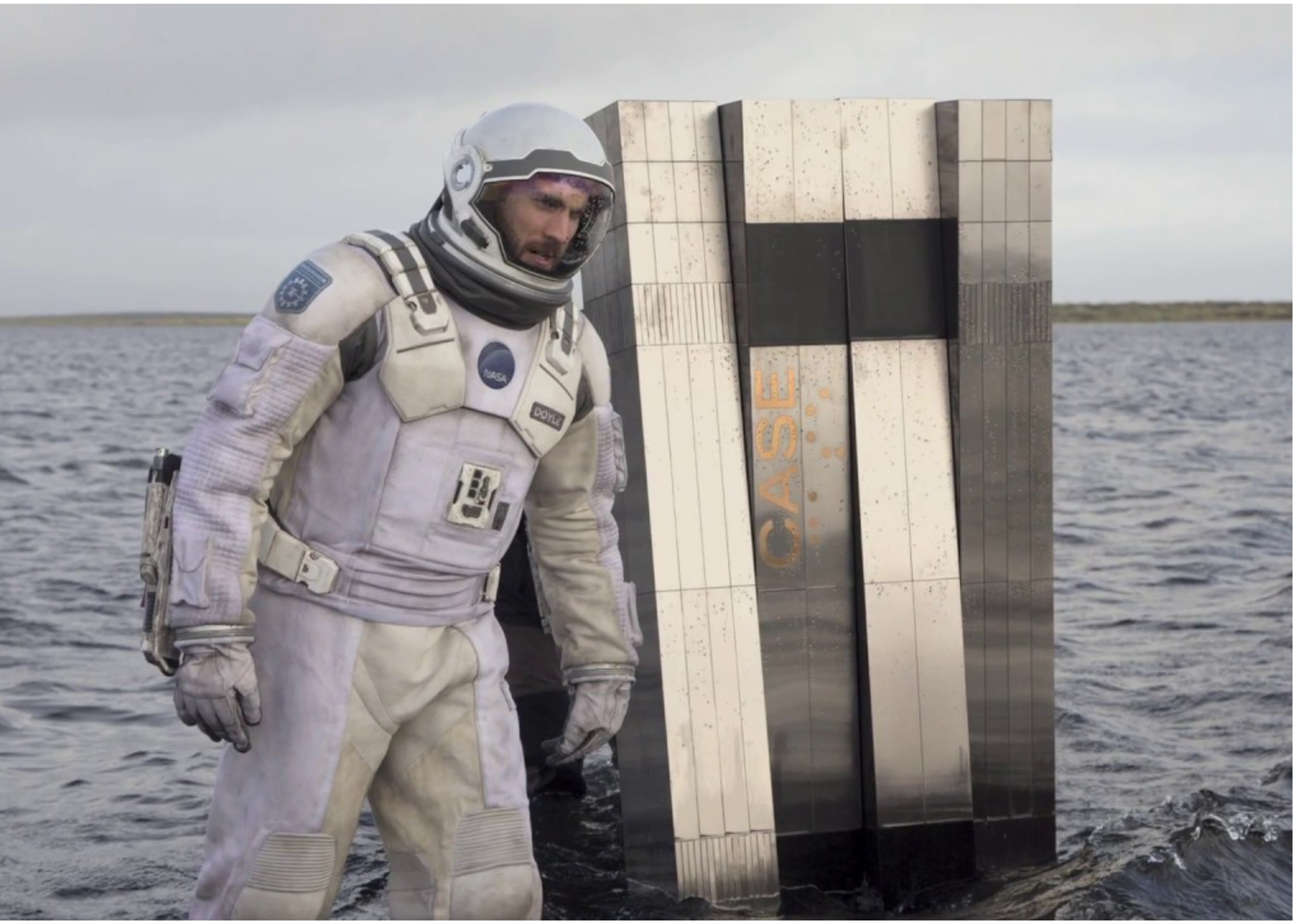


2008 - WALL-E



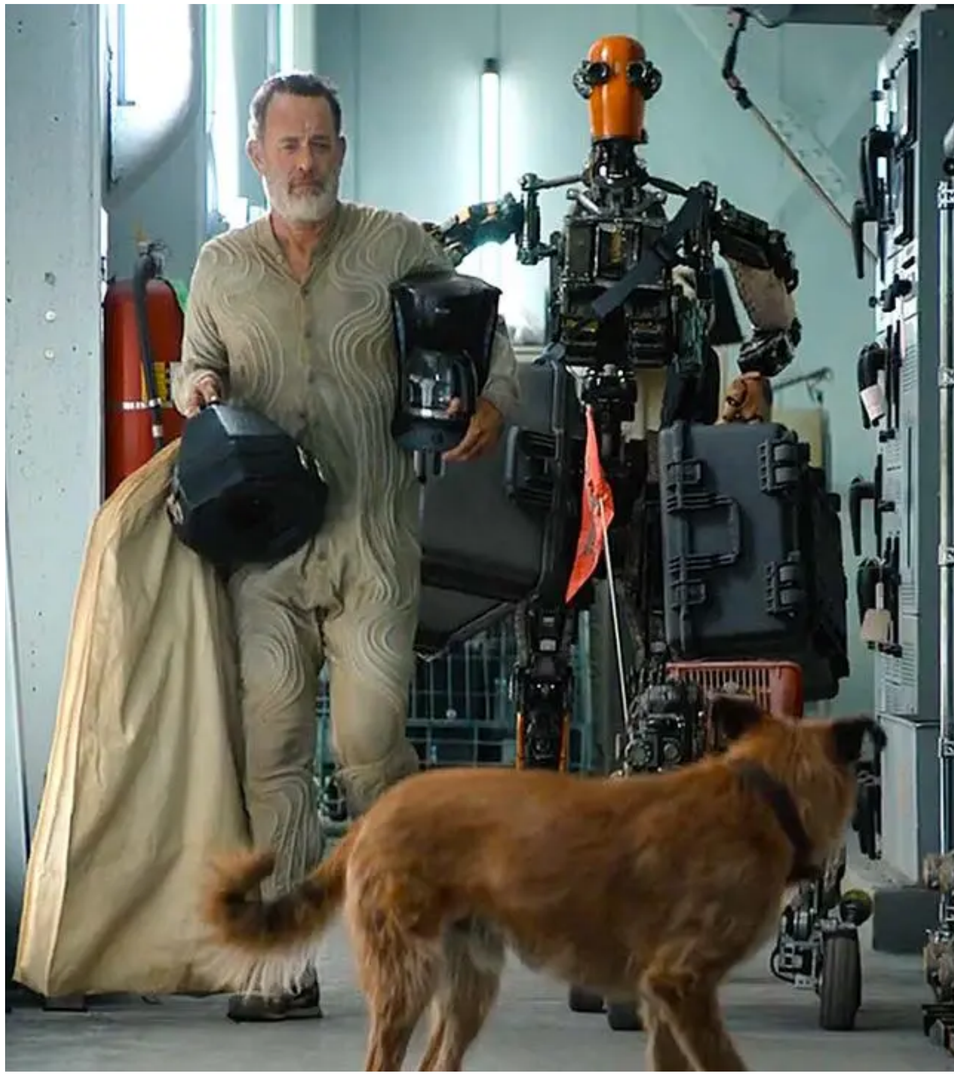
2012 - Robot & Frank

2014 - Interstellar



2014 - Big Hero 6

2021 - Finch



Course topics

- Forward and Inverse Kinematics
- Motion Planning
- Visual Servoing and Grasp Synthesis
- Perception for Manipulation (2D & 3D)
- Navigation & Localization
- Whole-Body Control
- Simulation
- Learning for Mobile Manipulation

Grades

60%: Lab assignments

40%: Course Project

Lab Assignments

- ~5 assignments
- Emphasizes implementing concepts covered in lecture and deploying them on the Stretch 3.
- Teams of 3 students.
- New lab every 2 weeks. Previous one due on the Wednesday the new one is released.
- Late submissions: -5% each day after deadline.

Course project

- Goal: learn about mobile manipulation through the act of doing it on a topic you are interested in!

Examples

  - Picking up clothes scattered around the floor and dropping them into the right colored bin (whites, colors, pinks).
  - Dinner prep, pulling the correct set of ingredients from shelves and placing them on the countertop.
  - Drinking assistance, grabbing a drink from the fridge and helping someone take a sip.
  - Mobile artist, drawing a large painting.
  - Implement a new user interface (maybe wearable?) to control a mobile manipulator (potentially for collecting demos for imitation learning).
  - Implement an existing research paper relating to mobile manipulation.

- Teams of 3 students.
- Both experimental and research projects are encouraged.

Project reports

Project Proposal

- One page or less, describing what you want to do.
- Due mid semester.

Project Report

- IEEE format report of your project motivation, methodology, implementation, and results.
- No page limits (but your report must be complete).
- Due at the end of the semester.

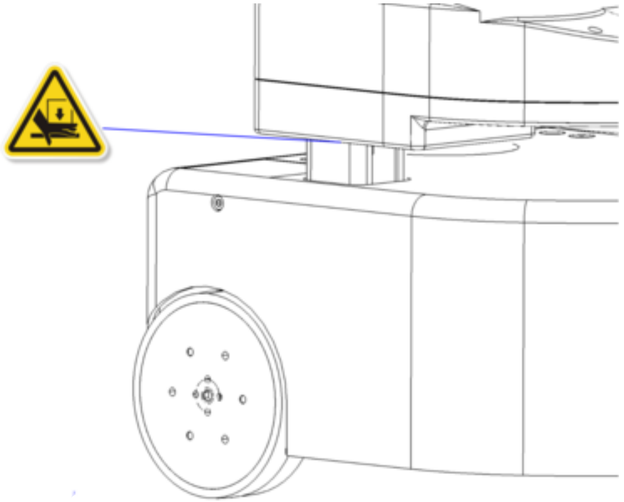
Project Presentations

- Last 2 lectures of the semester
- Live demos are encouraged (but also record a video just in case)

Stretch 3

Next lecture (Wednesday) we will look at a bunch of code examples for doing common things with Stretch (movement, sensors, etc.).

Before then, here are some things to know about Stretch 3.



Read the safety manual for Stretch 3.

https://docs.hello-robot.com/0.3/hardware/safety_guide/

Robot Safety

- Stretch robots are potentially dangerous machines with safety hazards. **If improperly used they can cause injury or death**.

- All users must carefully read the safety information on the Stretch website before using the robot.

https://docs.hello-robot.com/0.3/hardware/safety_guide/

Runstop

- Stretch has a runstop button (near head camera).
- When pressed, the runstop pauses the motion of all the motors.
- This is a software runstop, not an Emergency Stop. Electrical current to motors is not cut.
- Press-and-hold button to release runstop.

Robot Battery

- Stretch 3 utilizes two 12V AGM SLA batteries NOT Lithium Ion
- Is the robot turned off? Plug battery charger in and put in **12V AGM**
- Powered on and plugged in? **SUPPLY**

Press and hold MODE to switch between the two rows

Robot Battery

- Charge: 80%+ Color: Green
- Charge: 40%-80% Color: Orange
- Charge: <40% Color: Red

Make sure you know Python 3
and Linux terminal (e.g. ssh, git, …)

Python in this Course

- Controlling Stretch
  - Navigation and manipulation
  - Teleoperation and autonomy
- Sensing
- Machine learning / computer vision
- Physics simulation

Next Lecture

- A “cheat sheet” of how to move, perform transformations, capture sensor data, and use ROS with Stretch 3.
- Everything we do this semester will build on these foundational robot functions.
- This will also feed directly into Lab 1.

First Lab <u>Next Week</u> (Wednesday)

- Bring your laptop to class!
- No teams for the first lab.
- Getting connected to the robot
- Setting up version control (GitHub), shared robot so you should expect your code will be deleted after you log off the robot.
- Write a script to perform a series of simple robot motions.