Welcome to MAE 547
Modeling and Control of Robots

Wanxin Jin

Fall 2024

Welcome
To
The Robotics Community!

Who am I?

Wanxin Jin, Ph.D.
Assistant Professor
Mechanical and Aerospace Engineering
Intelligent Robotics and Interactive Systems (IRIS) Lab
Lab website: https://asu-iris.github.io/

2010-2016

2016-2017

2017-2021

2021-2023

The research in our IRIS lab (formed 2024!)

- How to make robot understand and serve humans?

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


- How to make robot interact with objects and environment via touch and contact?

  https://youtu.be/NsL4hbSXvFg?si=O-jDY1EHaBXmFDK1

  https://yangwen-1102.github.io/contactsdf.github.io/

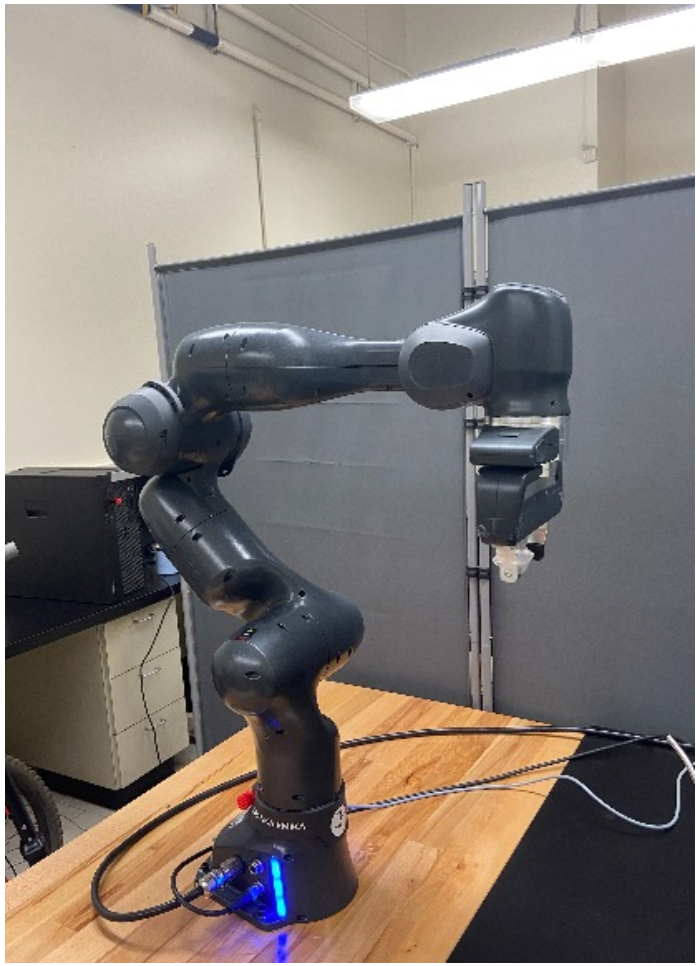


- Tackle the most challenging problems!

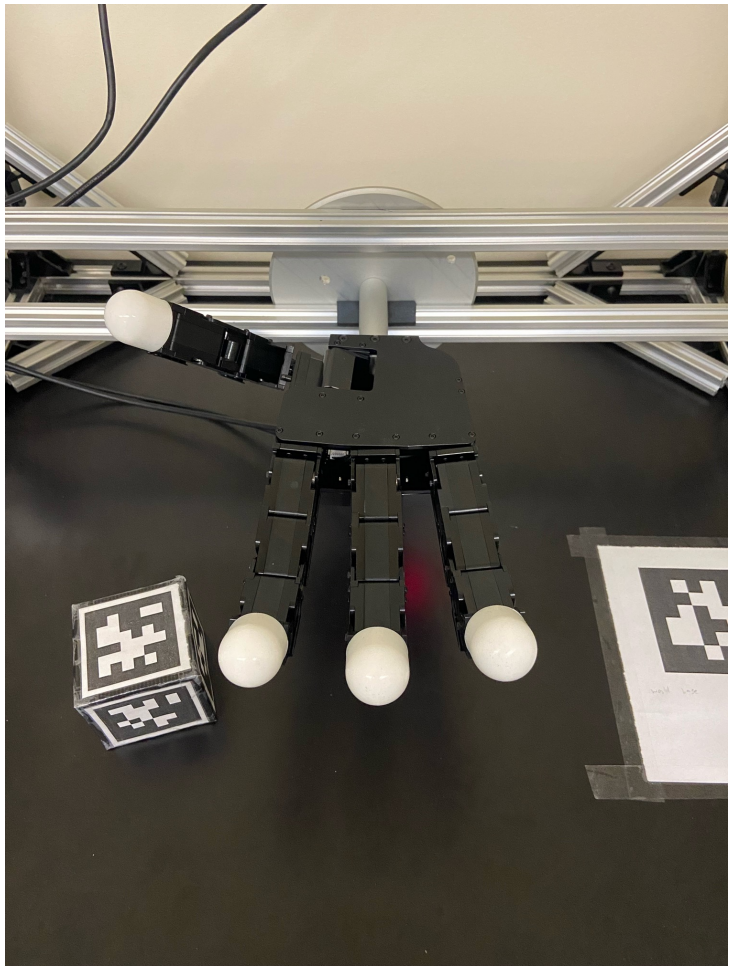
  https://youtu.be/5Jsu772Sqcg?si=xdOwboKSdH7JBqw0

Follow us: YouTube @robotics-iris-lab @jinwanxin

Robots in our IRIS lab



Franka Research 3

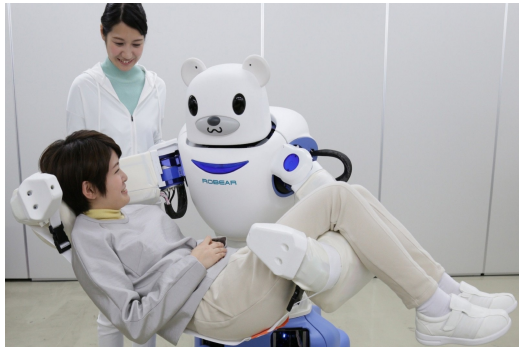


Allegro hand V4

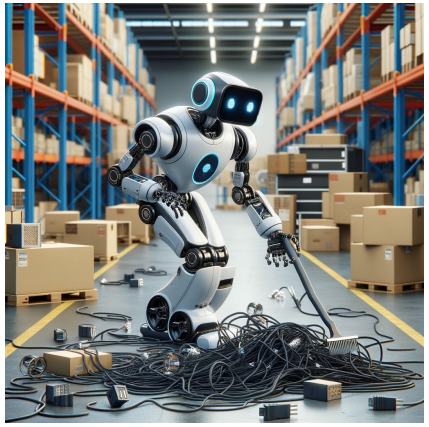
4x RTX 4090 GPU

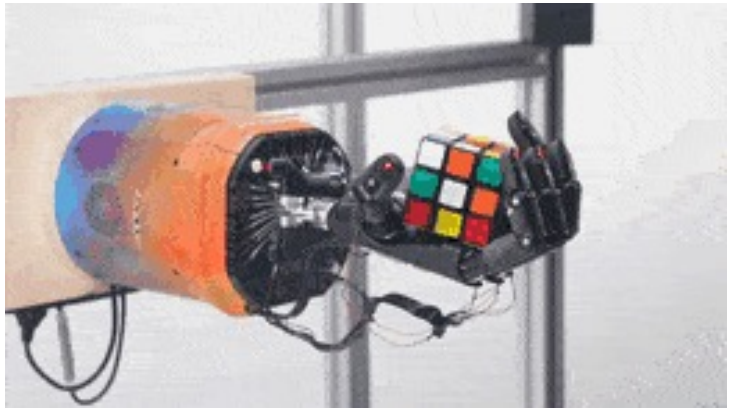
The open problems in robotics community

Smooth human-robot interaction



Dexterous manipulation





A roboticist needs to be theoretical & practical

- **Robot modeling**
- **Robot control**
- Perception (CV)
- Optimization
- Machine learning

- **C++**
- **Python/MATLAB**
- **Physics simulators**
- **Hardware programming**

Opportunities:

Google robotics, Amazon robotics, Microsoft robotics, Tesla robotics, Boston Dynamics, Nvidia robotics, a lot of startups

What will this course cover?

Robots! Particularly, robot arms!

List of topics:

- Translation and rotation in 2D and 3D
- Forward kinematics
- Inverse kinematics
- Dynamics
- Motion & trajectory planning
- Robot control

We will use **MATLAB** to implement computation/simulation.

TAs & Office hours

Our office hour TA

- Aravind Prakash Senthil
- asenth24@asu.edu

Our grader:

- Swetha Tirumala
- stirum10@asu.edu

TA office hour:

3:00-4:00 PM, every **Mon, Wed, Fri**.

Address: TBD (will be announced in Canvas)

My office hour:

1:00-2:00 PM, every **Tue**

Address: ERC 473

Course Notes are Online

https://asu-iris.github.io/course_robotics/intro.html

Also, my notes will be uploaded to Canvas.
Using those notes should suffice.

What is a robot ?

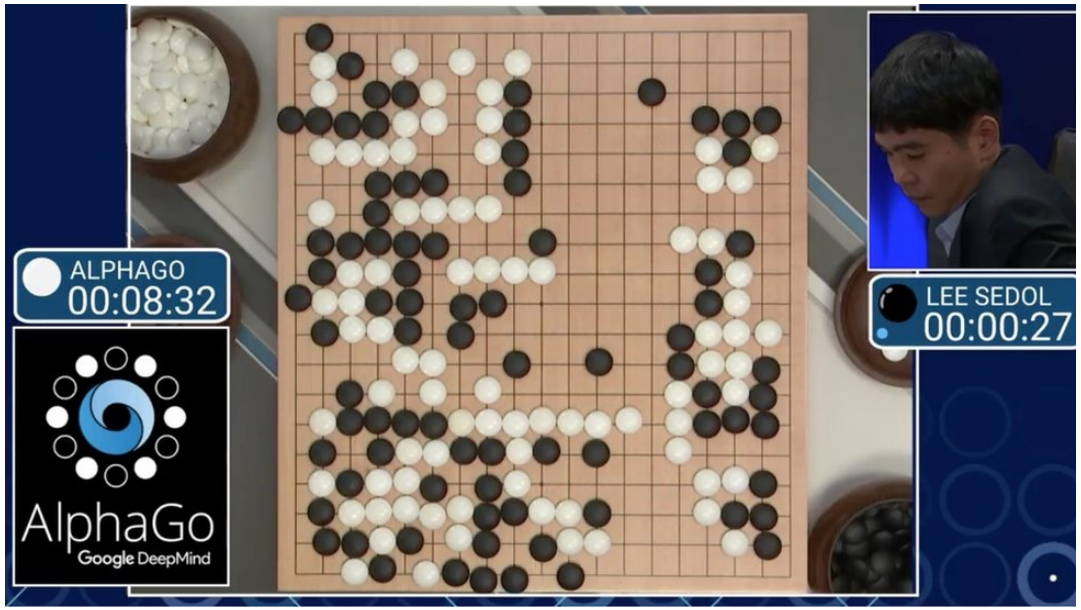
- A machine— especially one **programmable** by a computer — capable of carrying out a complex series of actions **automatically** [Wikipedia]

- A **reprogrammable**, **multifunctional** manipulator designed to **move** material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of **tasks** [Robotics Industries Association]

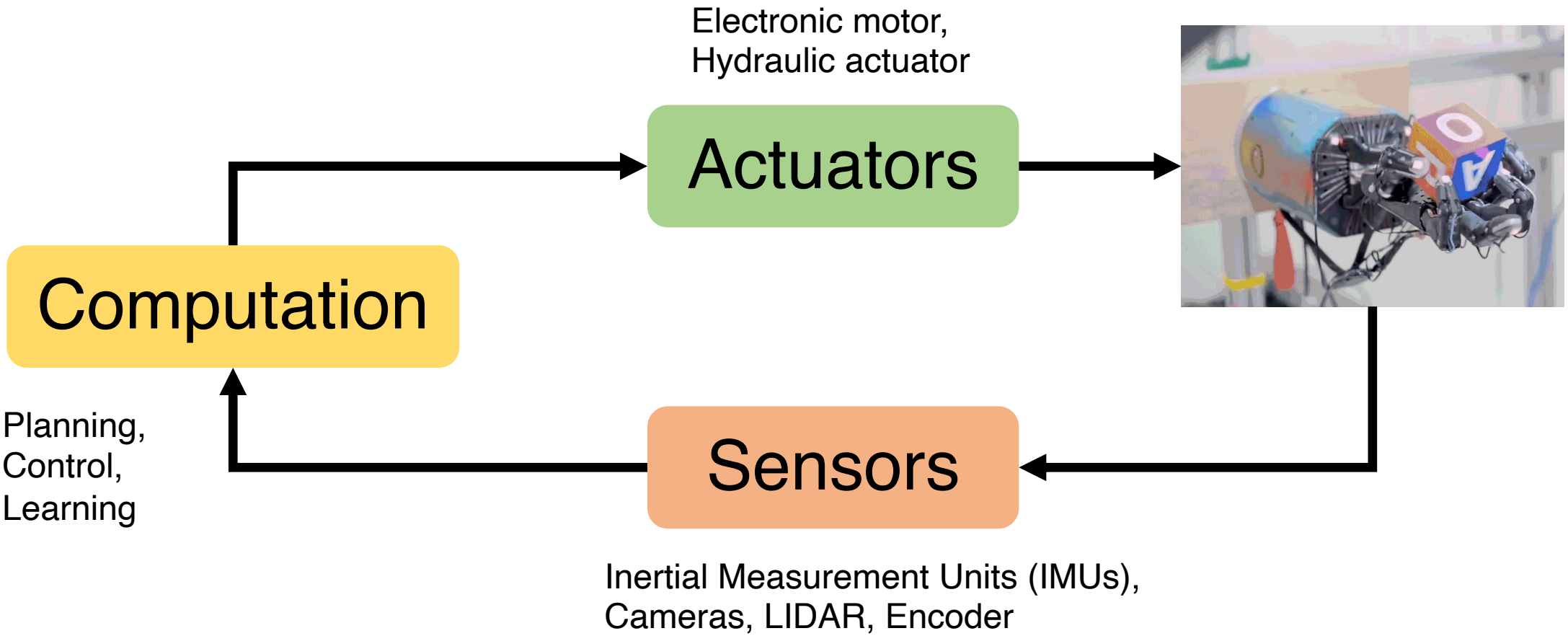
- An autonomous machine capable of **sensing** its environment, carrying out **computations** to make decisions, and performing **actions** in the real world [https://robots.ieee.org/learn/]

Robotics vs Artificial Intelligence

- Robots are usually physically embodied
- Artificial Intelligence is usually not

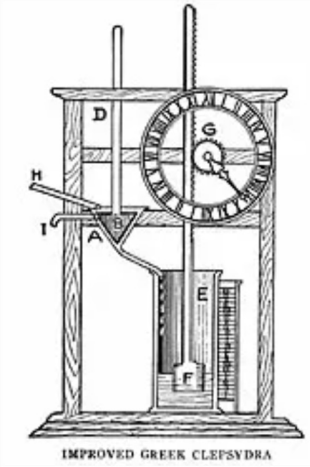


Anatomy of a robotic system



Sense-Think-Act

History of robotics (old)



IMPROVED GREEK CLEPSYDRA

1400 BC

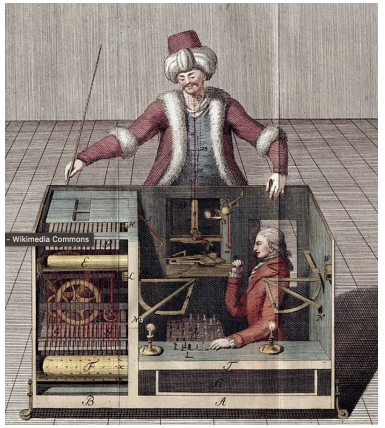
“Babylonians develop the clepsydra, a clock that measures time using the flow of water. It's considered one of the first "robotic" devices in history.”

322 BC

“If every tool, when ordered, or even of its own accord, could do the work that befits it … then there would be no need either of apprentices for the master workers or of slaves for the lords.” – Aristotle

1495

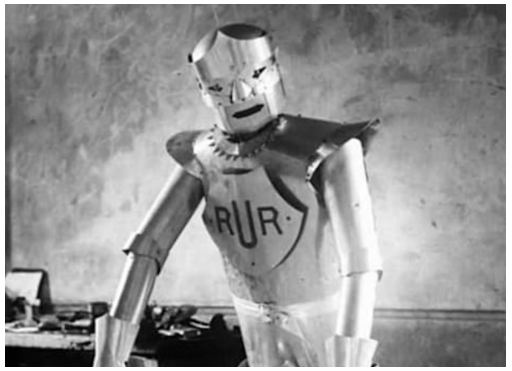
“Leonardo da Vinci designs a clockwork knight that sits up, waves its arms and moves its head and jaw. The design may constitute the first humanoid robot.”



1796 (mechanical Turk)

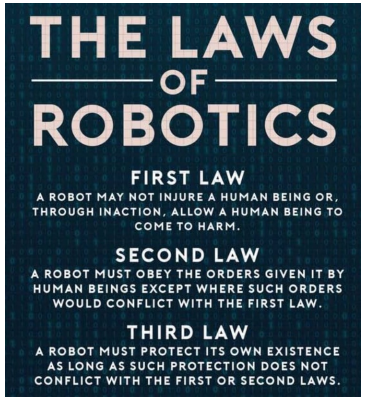
"Wolfgang von Kempelen builds “The Turk,” which gains fame as an automaton capable of playing chess – until the hidden human operator was discovered!"

History of robotics (Modern)



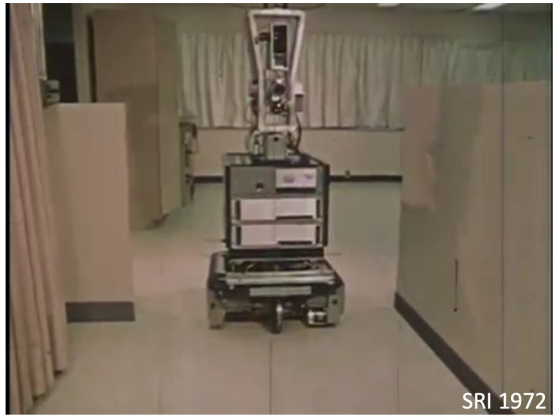
1921

“Karel Capek popularizes the term ‘robot’ in a play called R.U.R. (Rossum’s Universal Robots), wherein robot workers take over the earth. ”



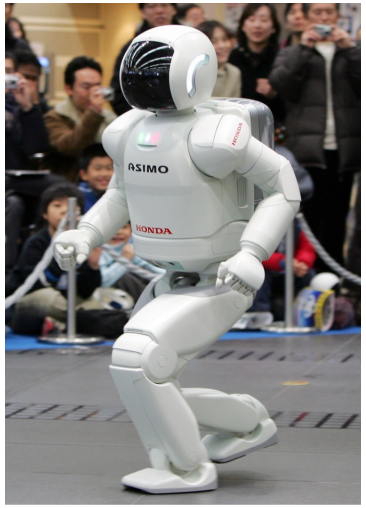
1942

“Sci-fi author Isaac Asimov introduced the "Three Laws of Robotics"--rules that every robot is programmed to obey.”



1966

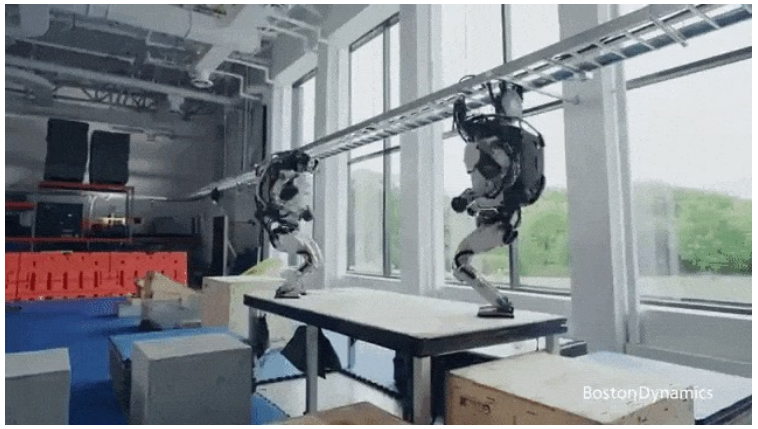
“Stanford Research Institute makes Shakey, the first mobile robot to navigate autonomously”

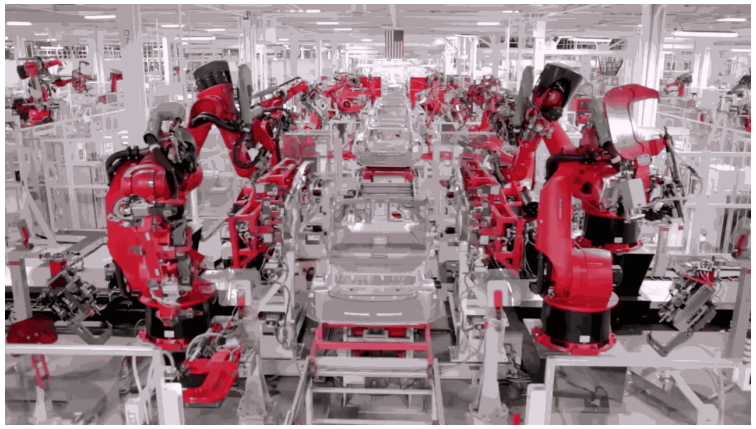


2000

“Honda's humanoid robot ASIMO steps onto the stage. Standing 1.3 meters tall, it can walk and run with a near-human gait.”

Nowadays





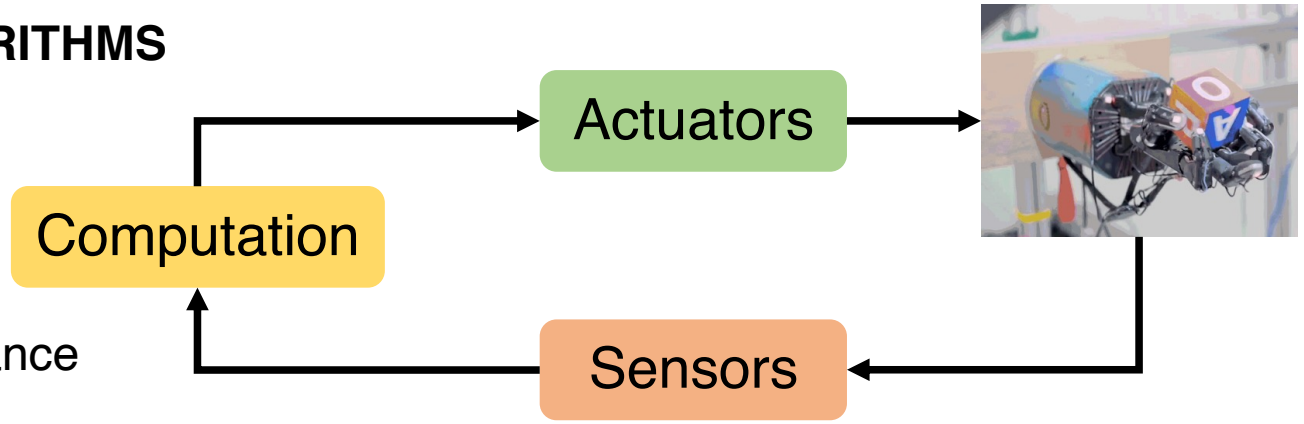
What are the next breakthroughs?

- Manufacturing
- Autonomous cars
- Household assistance
- Undersea exploration
- Planetary exploration
- Satellite retrieval/repair
- Defusing explosion
- Handling materials
- Rescue
- Military
- Pack carrying
- Exoskeletons
- Surgery and medical
- Entertainment

Sub-fields in Robotics (non-exclusive)

COMPUTATION & ALGORITHMS

Robot modelling & control
Optimization
Optimal control
Safety and collision avoidance
Manipulation
Robot learning
Motion planning
Navigation and mapping
Multi-robot coordination
Human-robot interaction



DESIGN

Mechanisms
Actuators
Kinematics/dynamics
Bioinspired design
Manufacturing

SENSING

Force and tactile sensing
Computer vision
Range sensing
Sensor fusion

SYTEMS/TYPES

Legged
Mobile
Aerial
Underwater
Micro/nano
Manipulators & graspers
Parallel robots
Soft robots

Why you need to care about robotics?

Bloomberg

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Business

Global Commercial Robotics Market Size is Unveiling the Projected CAGR of 11.52% to Reach USD 40.59 Billion by 2030.

May 25, 2023 at 8:15 AM MST

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Global Commercial Robotics Market Size is Unveiling the Projected CAGR of 11.52% to Reach USD 40.59 Billion by 2030.

PR Newswire

NEW YORK, May 25, 2023

Industrial Robotics Market Size to Reach USD 77.31 BN by 2032

Precedence Research
Tue, May 23, 2023 • 9 min read

PRECEDENCE RESEARCH

Precedence Research

The global industrial robotics market size is predicted to reach around USD 77.31 billion by 2032, and it is growing at a notable CAGR of 10.93% from 2023 to 2032, as per study by Precedence Research.

Ottawa, May 23, 2023 (GLOBE NEWSWIRE) -- The global **industrial robotics market** size was valued at USD 27.4 billion in 2022. As the manufacturing and industrial sectors continue to evolve, industrial robots are becoming more widespread.

Global Agriculture Drones and Robots Market to Reach $23.06 Billion by 2028

BIS Research
Emerging Technology Market Intelligence

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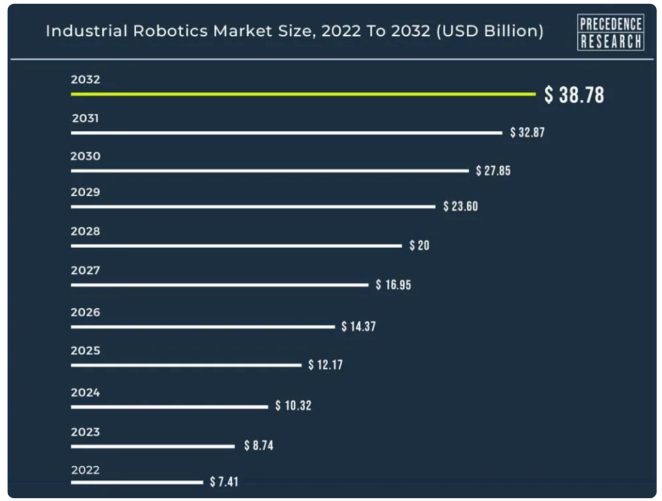

Why robotics?

- The global robotics market was projected to reach around $135 billion by 2025, with a CAGR of approximately 16% from 2020 to 2025.
- Lots of really fascinating technical challenges (we will mention some along the class progress)
- Beautiful connections with many fields: AI, machine learning, control theory, computer vision, optimization, information theory, applied math…
- A field where you can ask big questions: what is physical intelligence? What us human physical intelligence?
- It’s really cool.

Questions?