

# Welcome to MAE 547

# Modeling and Control of Robots

Wanxin Jin

Mechanical and Aerospace Engineering

Fall 2023



# Who am I?

**Wanxin Jin, Ph.D.**

Assistant Professor

Mechanical and Aerospace Engineering

Personal website: <https://wanxinjin.github.io/>



2010-2016



2016-2017



2017-2021

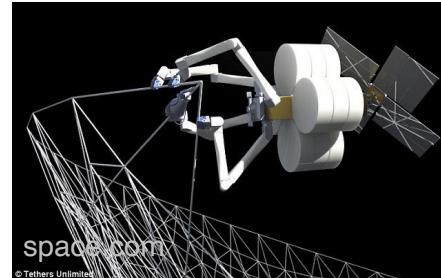


**Penn**  
UNIVERSITY of PENNSYLVANIA

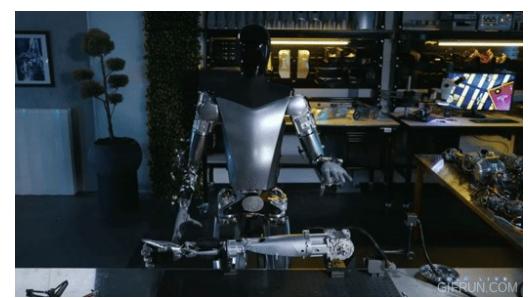
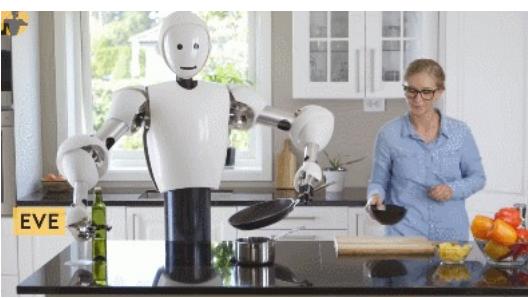
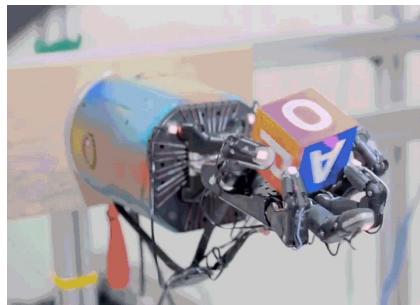
2021-2023

# What am I doing? & What are the trends?

Make robots more capable of **interacting** with humans and **objects/environments**

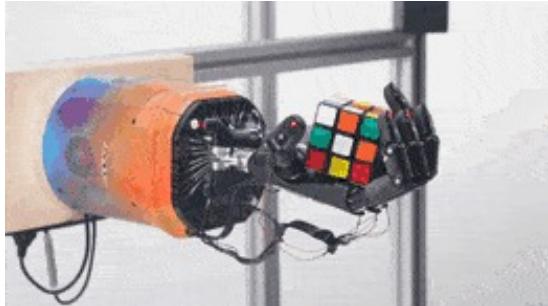


Current trends in robot research/development



Opportunities: Google robotics, Amazon robotics, Microsoft robotics, Tesla robotics, Boston Dynamics, Nvidia robotics, Toyota Research Institute ...

# A roboticist needs to be theoretical & practical



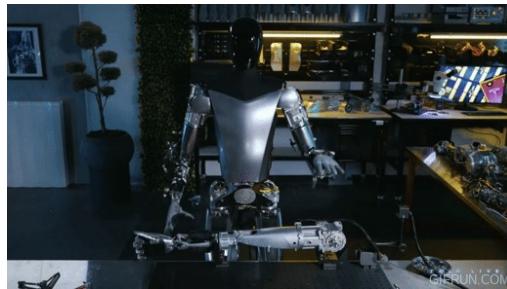
Open AI



Boston Dynamics



Halodi robotics



Tesla

- *Robot modeling*
- *Robot control*
- *Optimization*
- *Machine learning*
- *Perception (CV)*
- *Python*
- *C++*
- *Physics simulators*
- *Hardware programming*

# What will this course cover?

Robots! Particularly, manipulators!

List of topics:

- Translation and rotation in 2D and 3D
- Forward and inverse kinematics for manipulators
- Velocity kinematics
- Dynamics
- Motion & trajectory planning
- Robot control

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

# TAs & Office hours

Our teaching assistant:

- Mukesh Ghimire
- Email: [mghimire@asu.edu](mailto:mghimire@asu.edu)

Office Hour:

- TA: Tuesday & Thursday  
2:00-3:00 PM @ TBD

Our grader:

- Divya Prakash
- Email: [divyaprakas@gmail.com](mailto:divyaprakas@gmail.com)

- Me: Wednesday 2:30 - 3:30 pm or by email appointment @ GWC 464 (temporary)

# Course textbooks/notes & logistics

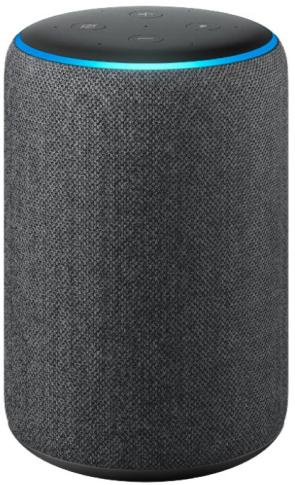
See details in the syllabus:

<https://www.overleaf.com/read/zrxmggrfmhv>

# 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/>]

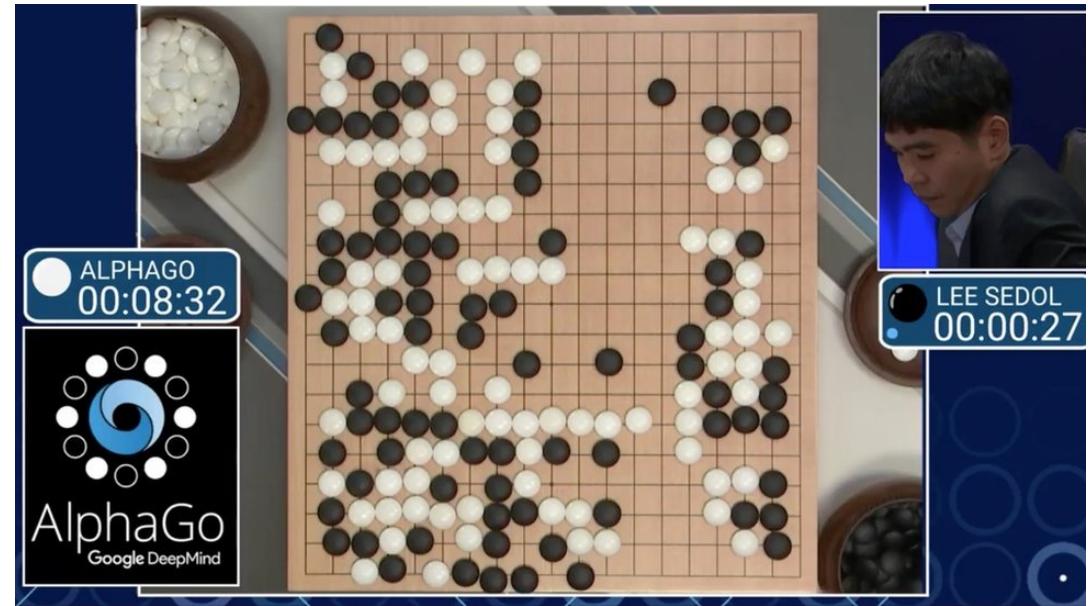
# Are those robots?



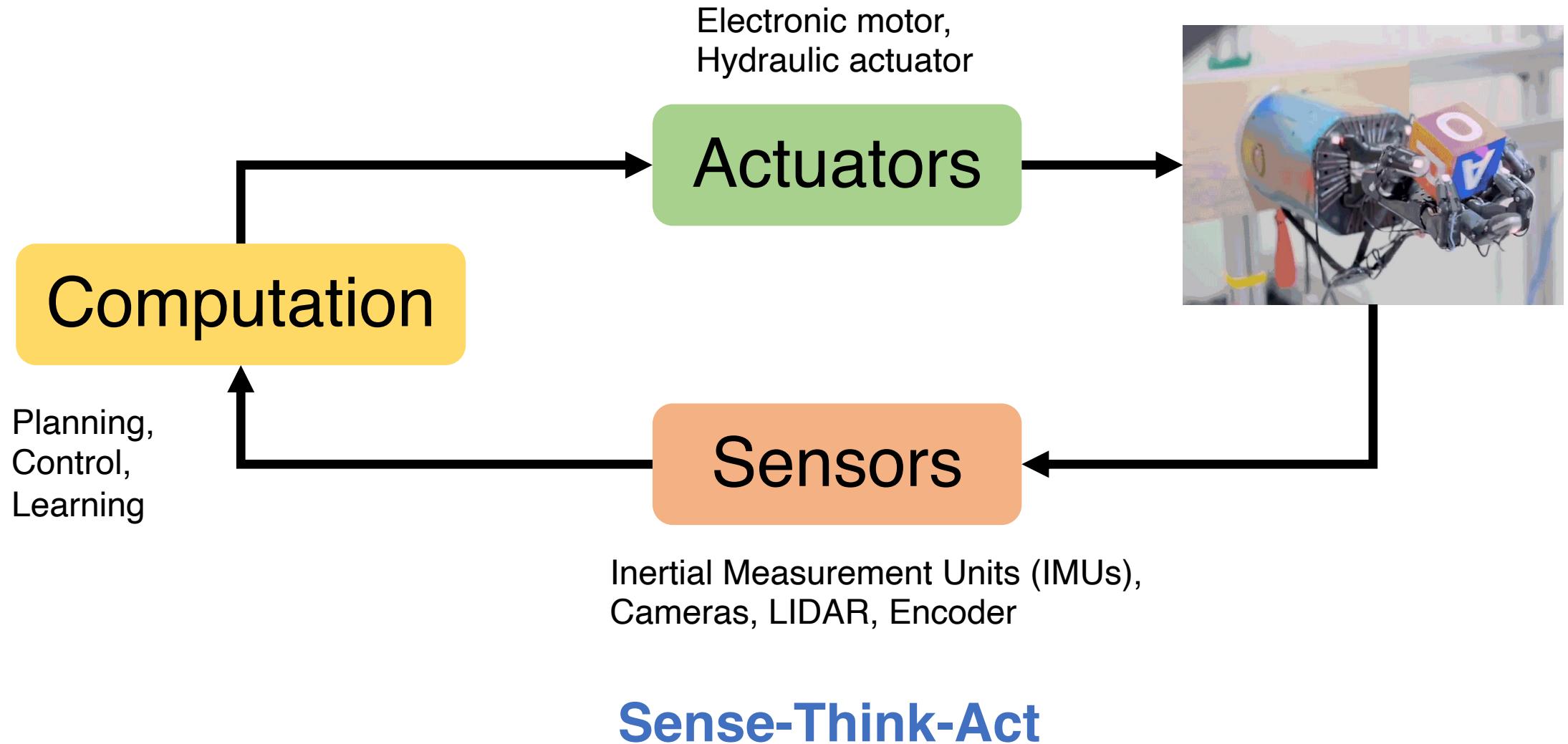
- This is a discussion article: <https://www.wired.com/story/what-is-a-robot/>
- Lack of universally acceptable definition means that **there could be certain level of robotics: *physical embodiment, autonomy, complexity, programmability....***

# Robotics vs Artificial Intelligence

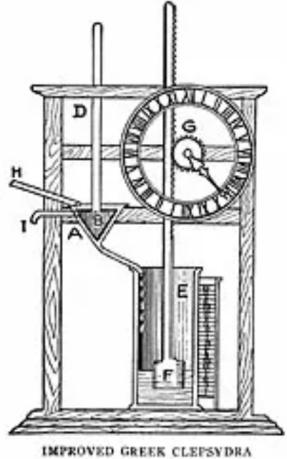
- Robots are usually physically embodied
- Artificial Intelligence is usually not



# Anatomy of a robotic system



# History of robotics (old)



**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."



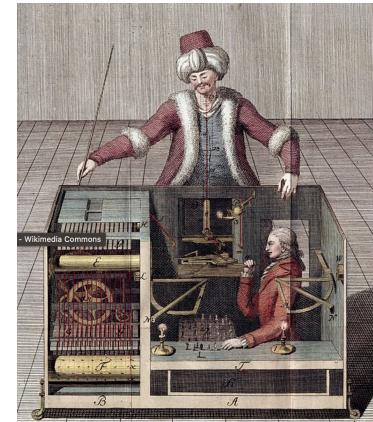
**322 BC**

"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**

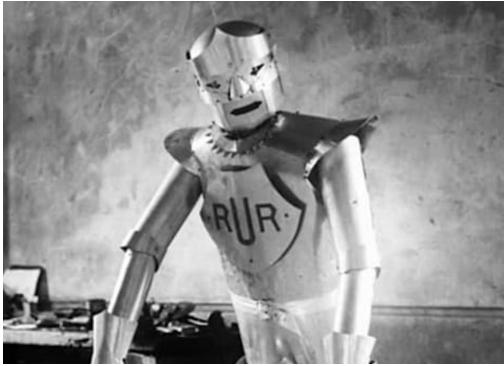
"Leonardo da Vinci designs a clockwork knight that sits up, waves its arms and moves its head and jaw. The design may constitute the first humanoid robot."



**1796**

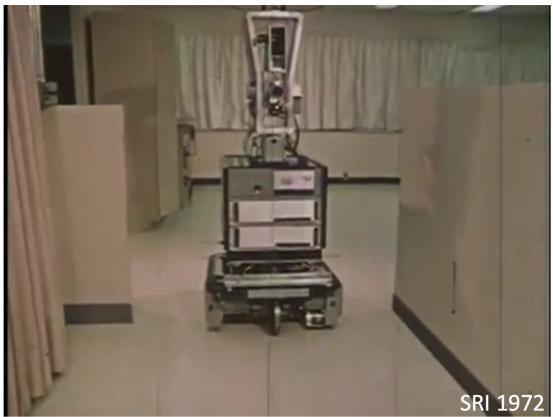
"Wolfgang von Kempelen builds 'The Turk,' which gains fame as an automaton capable of playing chess – until the hidden human operator was discovered!"

# History of robotics (Modern)



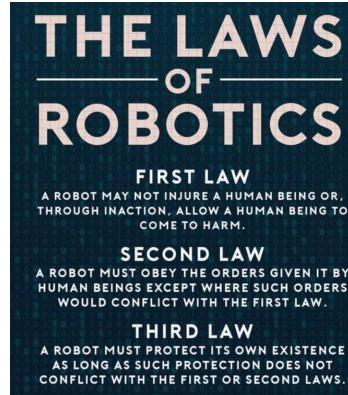
1921

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



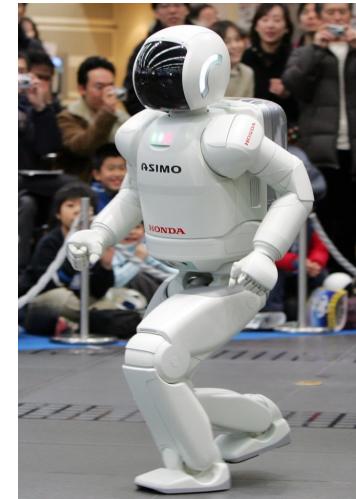
1966

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



1942

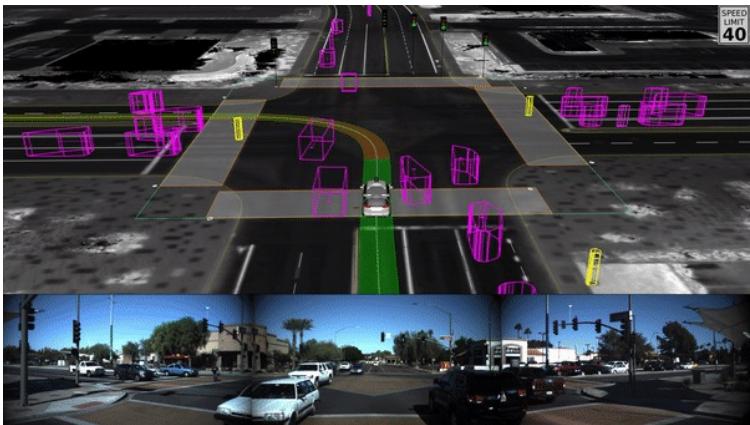
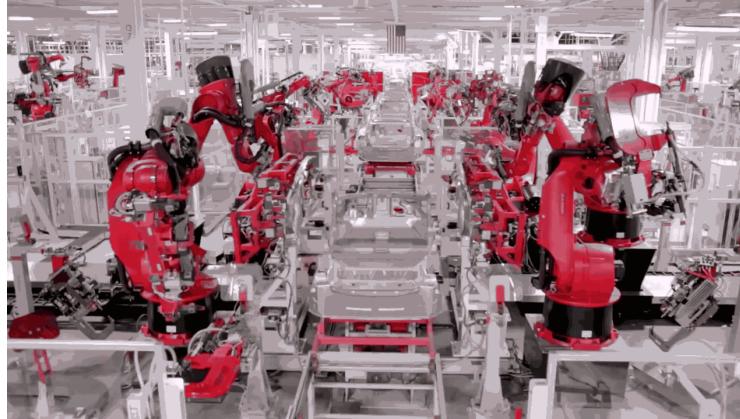
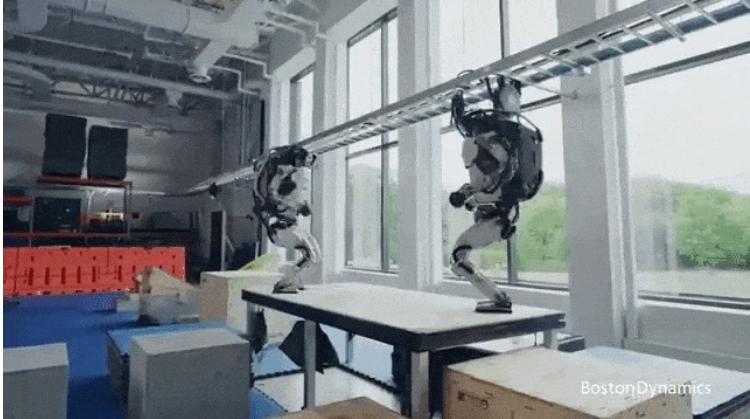
"Sci-fi author Isaac Asimov introduced the "Three Laws of Robotics"--rules that every robot is programmed to obey."



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

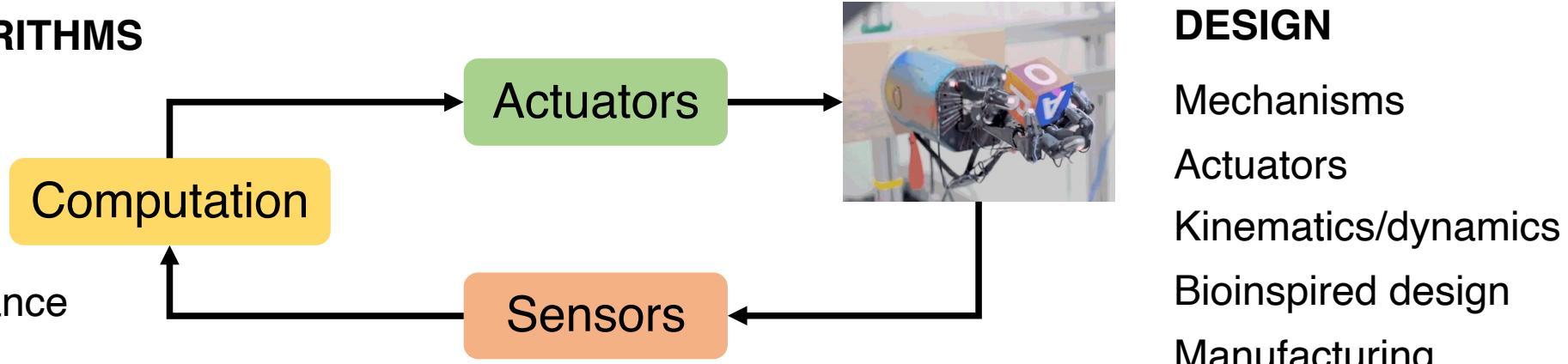
Robot learning

Motion planning

Navigation and mapping

Multi-robot coordination

Human-robot interaction



## SENSING

Force and tactile sensing

Computer vision

Range sensing

Sensor fusion



## DESIGN

Mechanisms

Actuators

Kinematics/dynamics

Bioinspired design

Manufacturing

## SYSTEMS/TYPES

Legged

Mobile

Aerial

Underwater

Micro/nano

Manipulators & graspers

Parallel robots

Soft robots

# Why you need to care about robotics?

Bloomberg

US Edition ▾ Sign In Subscribe

Live Now Markets Economics Industries Tech AI Politics Wealth Pursuits Opinion Businessweek Equality Green CityLab Crypto More : We've updated the dispute procedures in our [Terms of Service](#) ("Terms"). By continuing to use the site, you accept and agree to these updated Terms. X

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

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

LIVE ON BLOOMBERG  
Watch Live TV >  
Listen to Live Radio >

Share this article Gift this article

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

NEWS PROVIDED BY  
**BIS Research** →  
May 07, 2019, 08:30 ET



SHARE THIS ARTICLE

## Industrial Robotics Market Size to Reach USD 77.31 BN by 2032

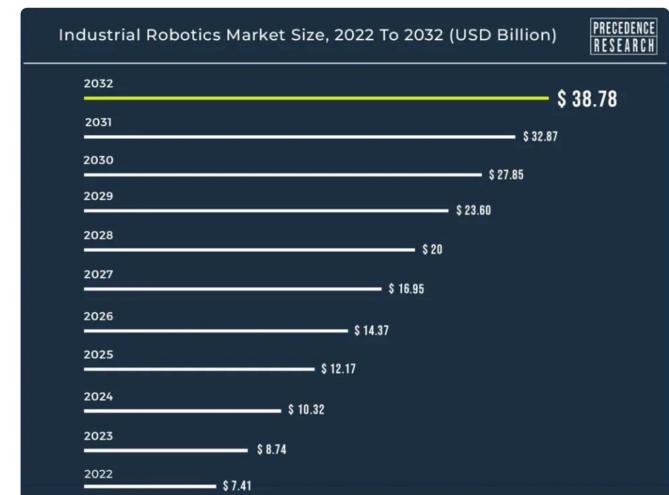
Precedence Research  
Tue, May 23, 2023 • 9 min read



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.



# Why you need to care about 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 is human physical intelligence?
- It's really cool.

# IRIS Lab is looking for “robotics enthusiasts”

IRIS: Intelligent Robotics and Interactive System

Three directions:

- Robot learning with human-on-the-loop
- Robot manipulation
- General fundamental robotics research

How to apply:

- Check research: <https://asu-iris.github.io/research/>
- Check ``requirement'': <https://asu-iris.github.io/joining/>
- Shoot me an email if you are interested (hopefully at end of this semester)

