

CS 598 - Deep Learning for Robotic Manipulation

Perception, Decision Making, and Cutting-Edge Topics

Prof. Yunzhu Li
Spring 2024

TA: Mingtong Zhang

* Course materials adapted from Prof. Yuke Zhu's CS391R at UT Austin.



Traditional Form of Robotics (also what's currently in the industry)



General-Purpose Robotic Manipulation



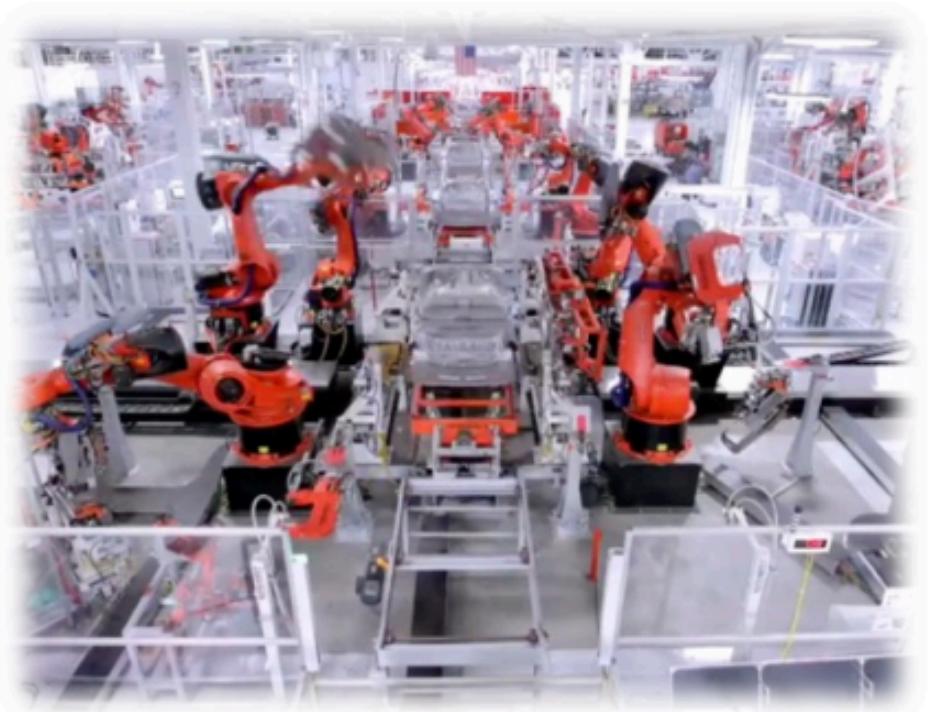
General-Purpose Robotic Manipulation



Today's Agenda

- What is Robot Learning?
- Why studying Learning in Robotic Manipulation now?
- Course topics overview
- Logistics

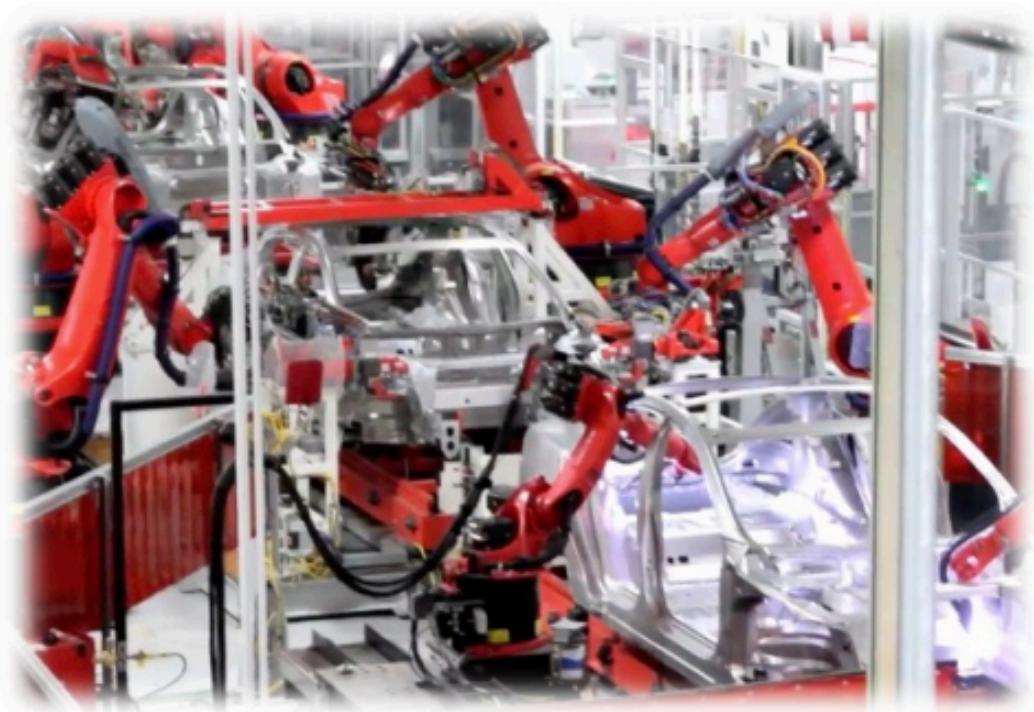
Special-Purpose Robot Automation



custom-built
robots

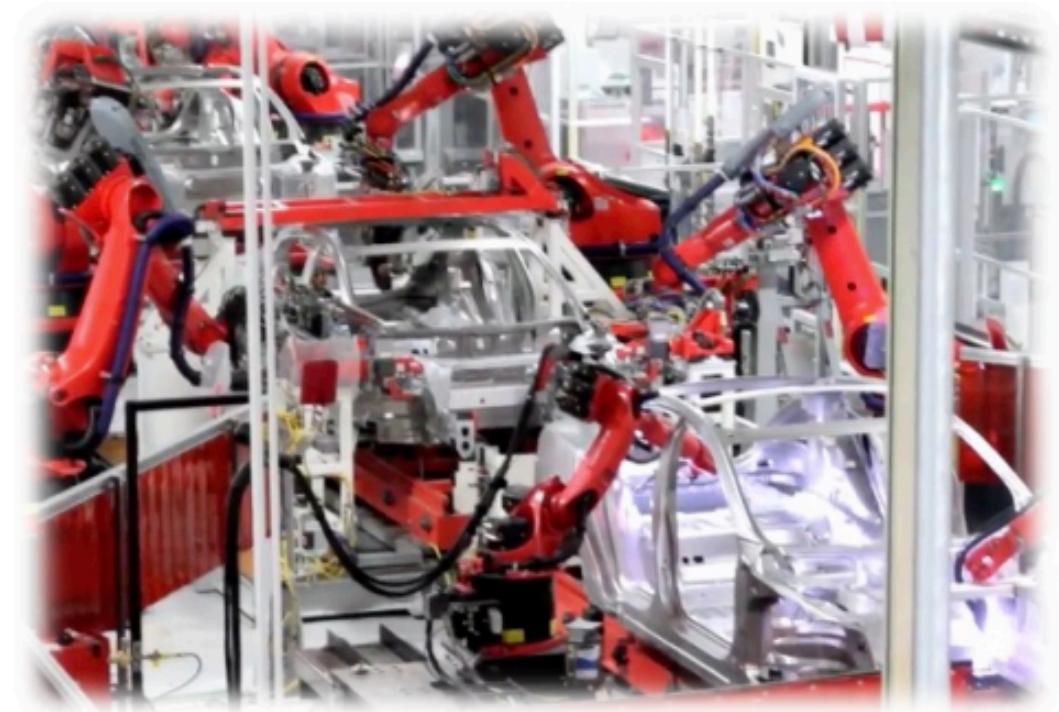
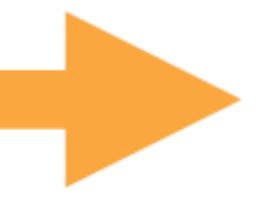
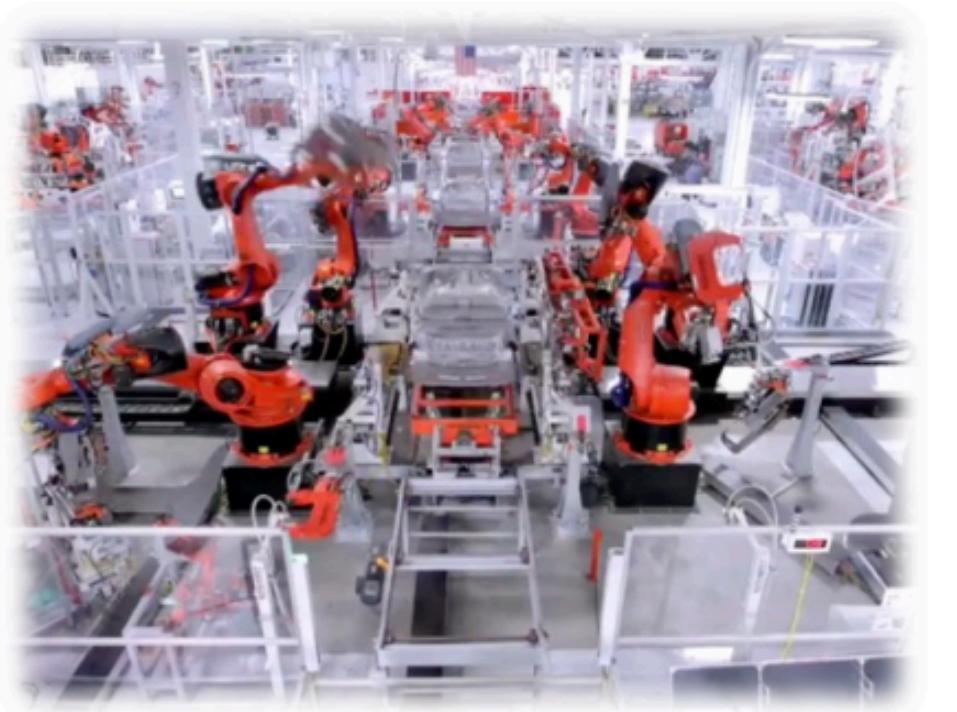


human expert
programming



special-purpose
behaviors

Special-Purpose Robot Automation



custom-built
robots

human expert
programming

special-purpose
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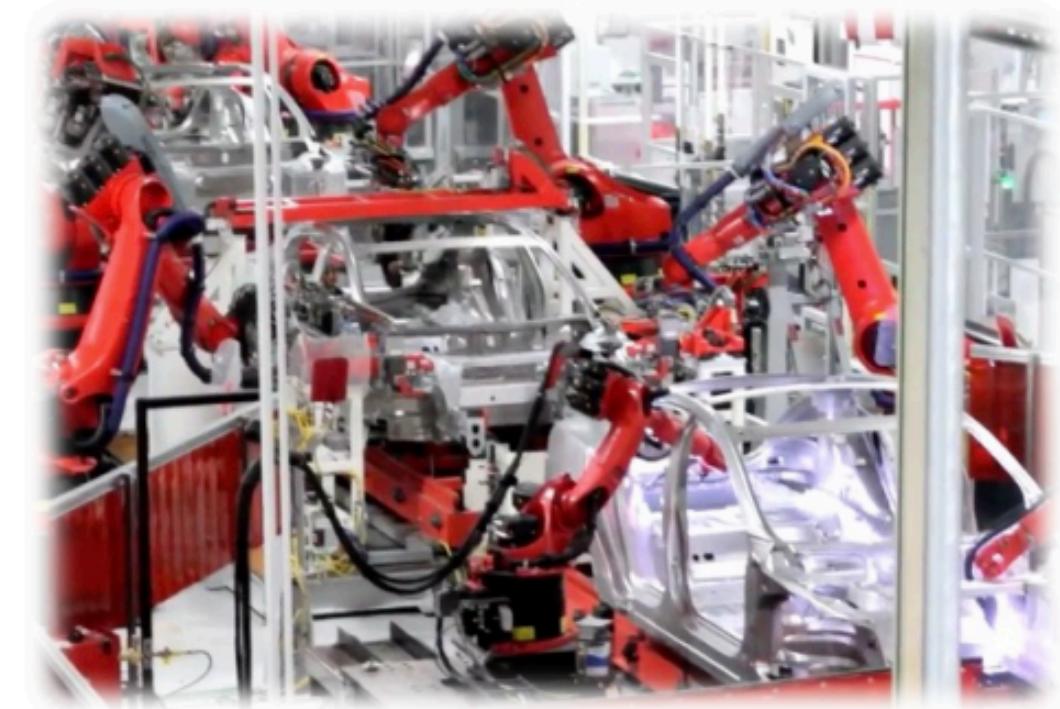
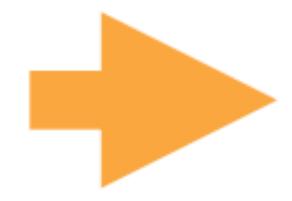
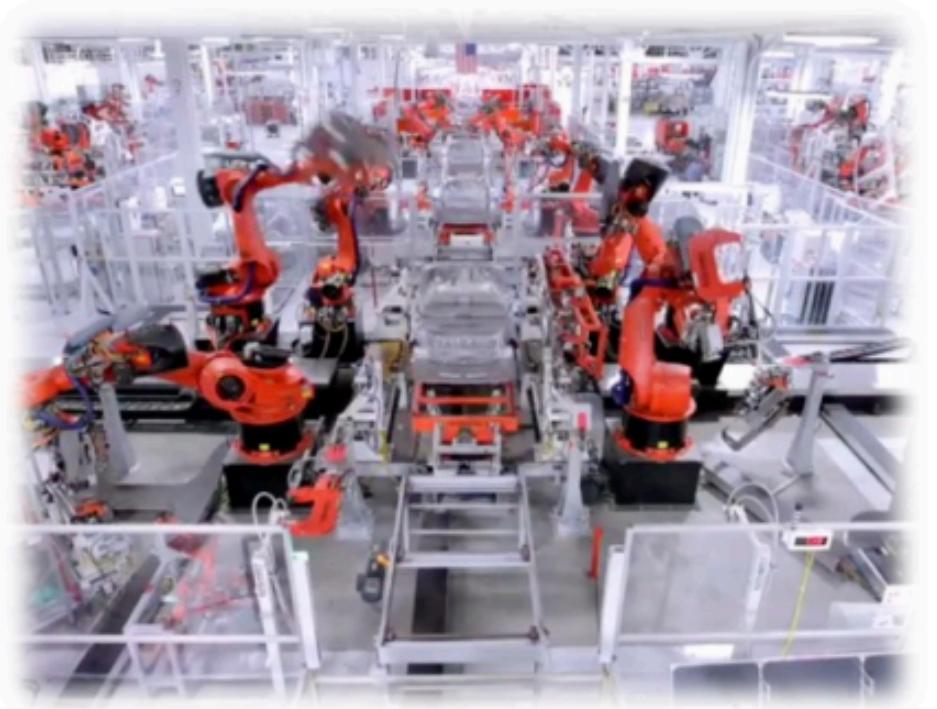
General-Purpose Robot Autonomy



general-purpose
robots

general-purpose
behaviors

Special-Purpose Robot Automation



custom-built
robots

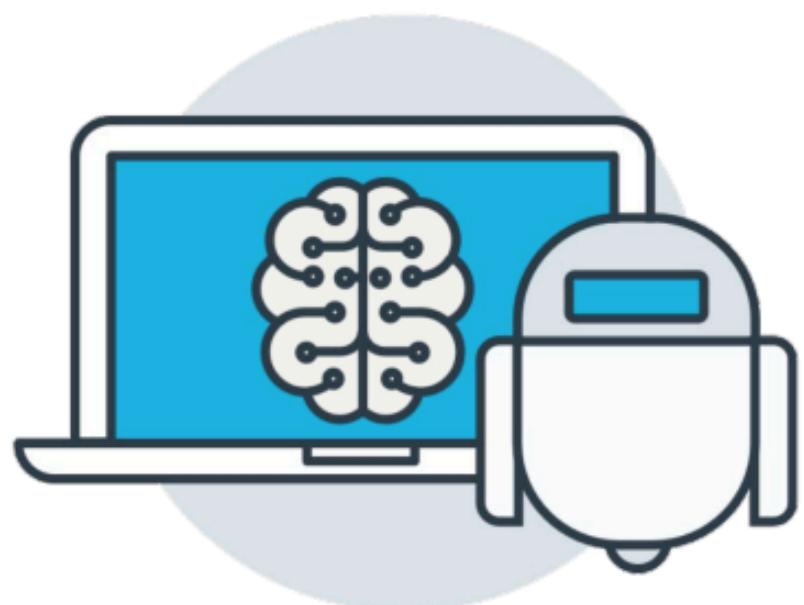
human expert
programming

special-purpose
behaviors

General-Purpose Robot Autonomy



Robot Learning



general-purpose
robots

general-purpose
behaviors

General-Purpose Robotic Manipulation



Stanford
University

General-Purpose Robotic Manipulation

Clean Restroom
(teleop)



10x speed

General-Purpose Robotic Manipulation: Challenges



Stanford
University

Moravec's paradox

- Moravec wrote in 1988
- “it is comparatively easy to make computers exhibit adult level performance on **intelligence tests or playing checkers**, and difficult or impossible to give them the skills of a one-year-old when it comes to **perception and mobility**”

Moravec's paradox







EATER

General-Purpose Robot Automation

Progress



Manipulation
OpenAI
2019

General-Purpose Robot Automation

Progress



Locomotion
ETH Zurich
2020

General-Purpose Robot Automation

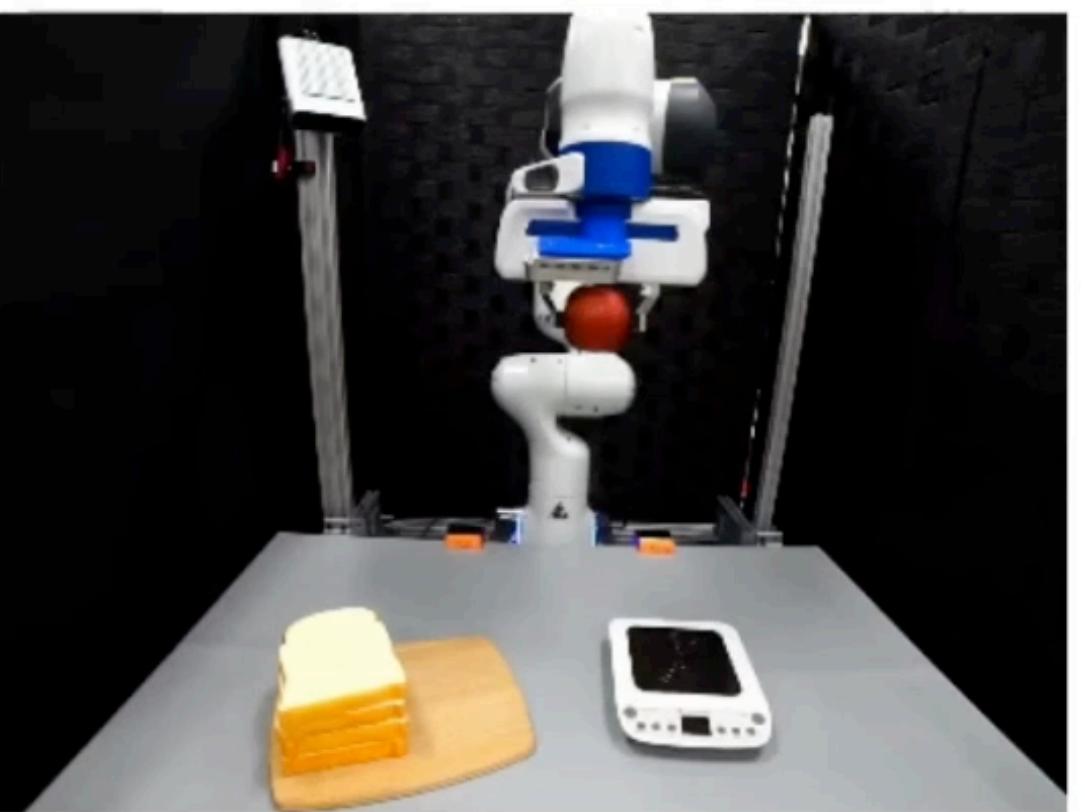
Progress



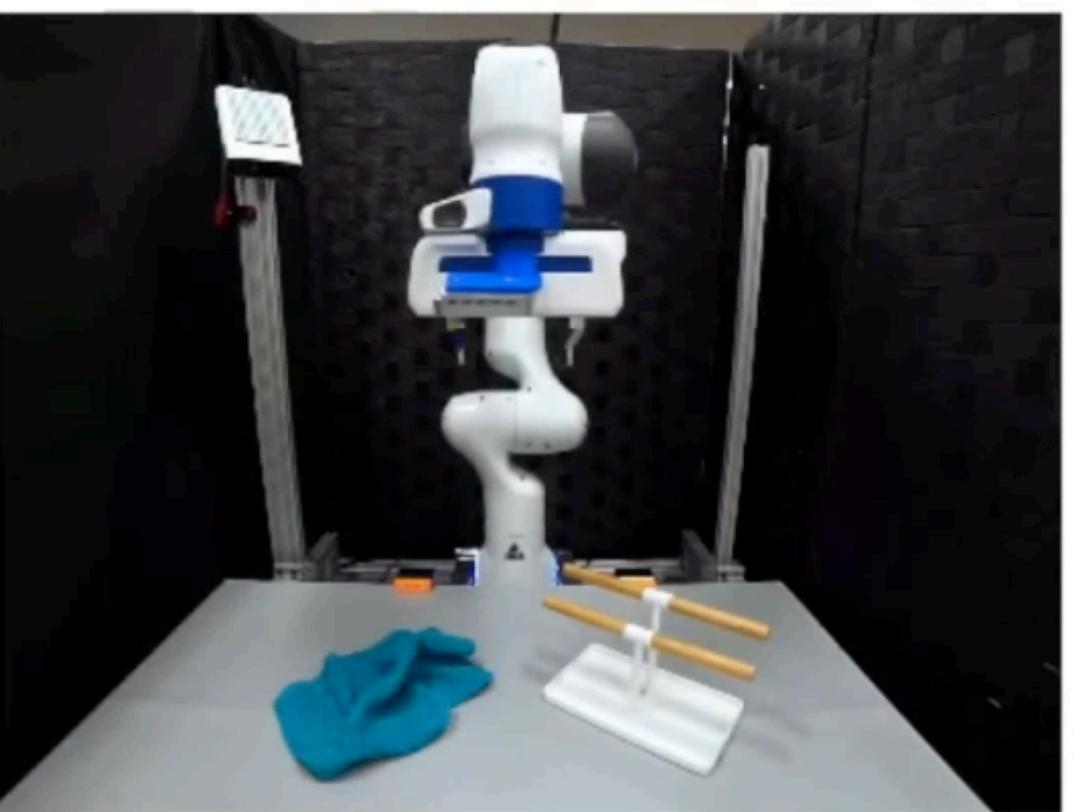
Mobile Manipulation
Google Robotics
2023



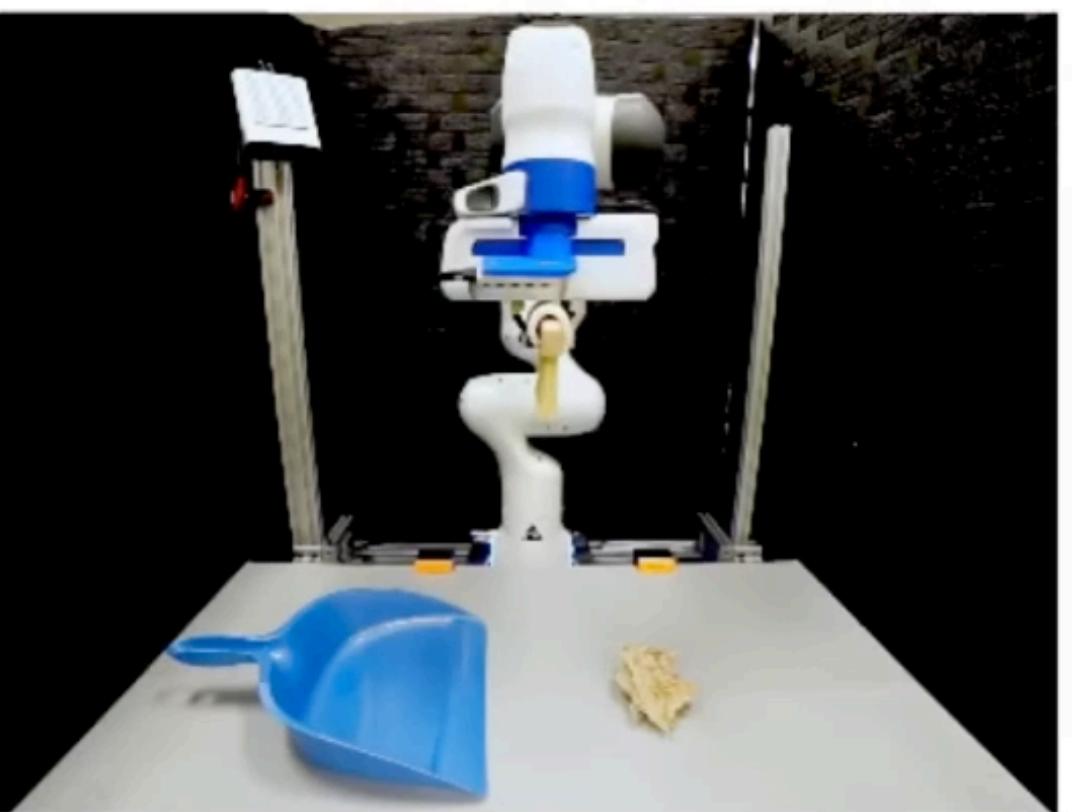
"Turn open vitamin bottle"



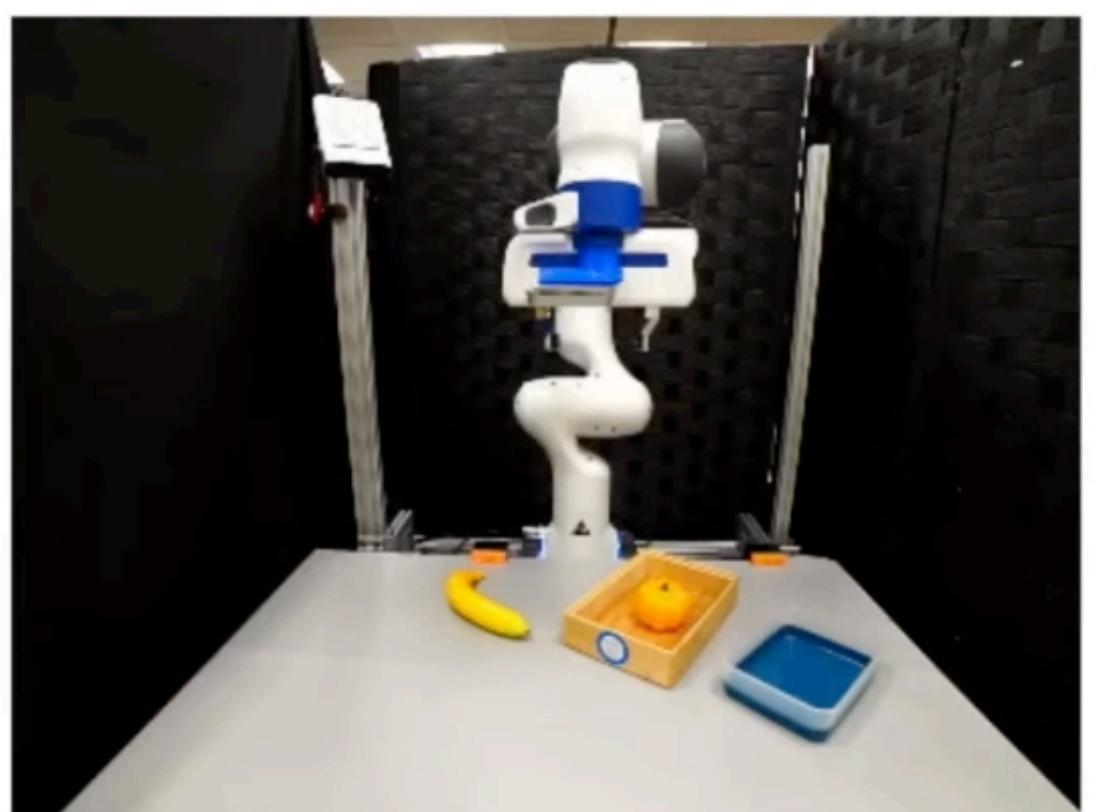
"Measure weight of apple"



"Hang towel on rack"



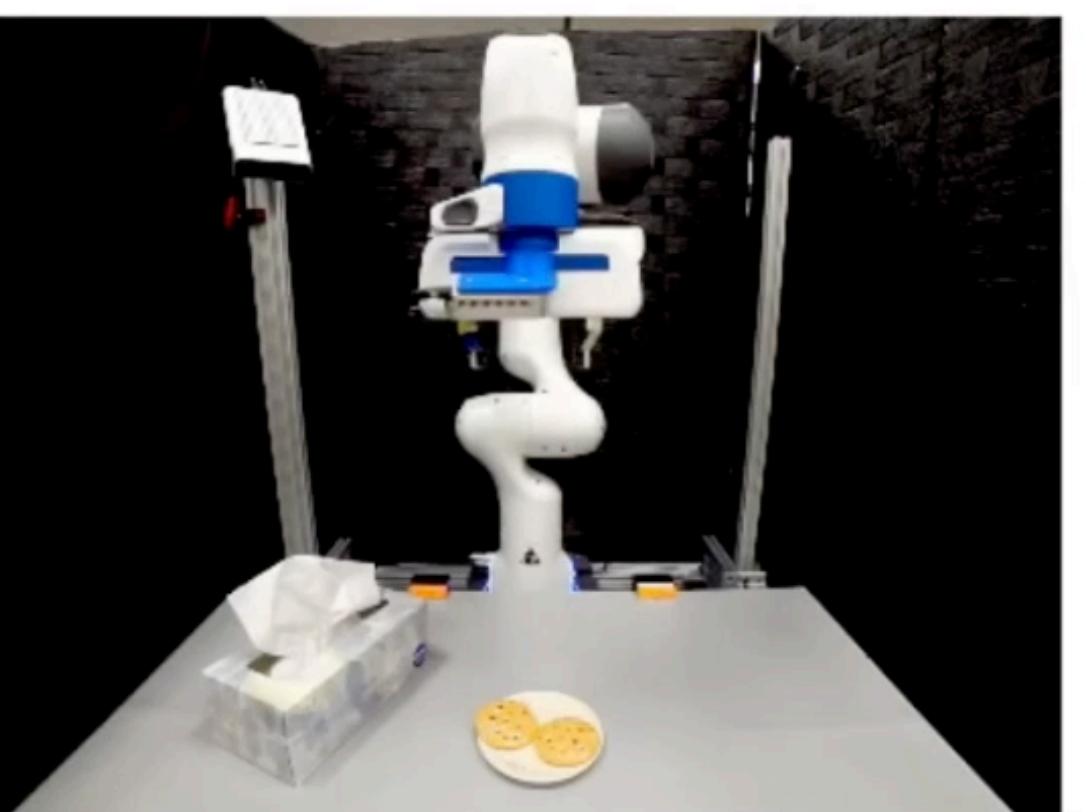
"Sweep trash into dustpan"



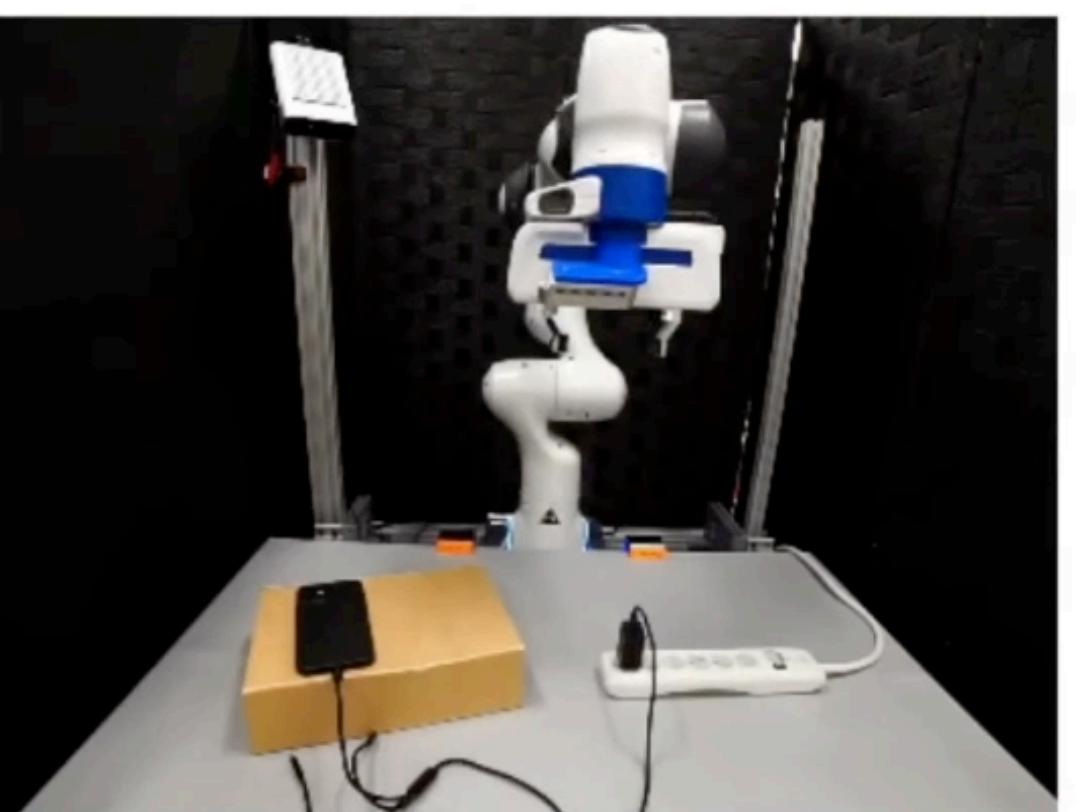
"Sort trash to blue tray"



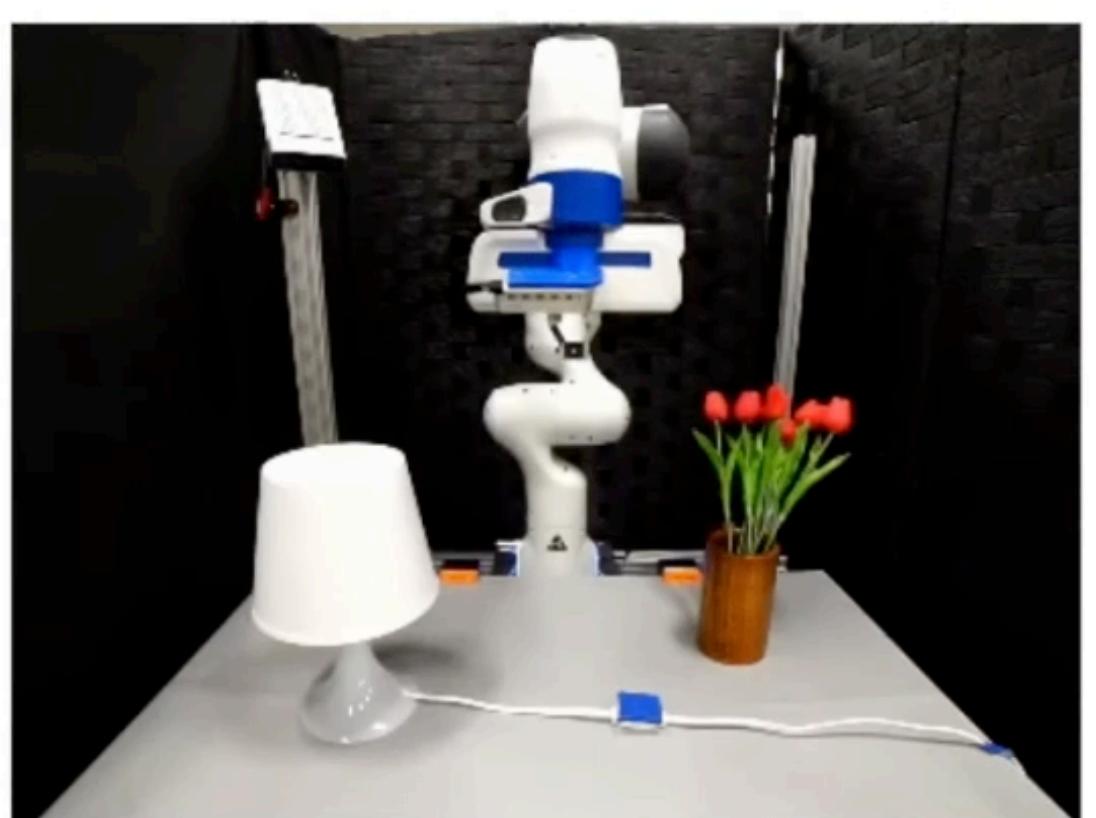
"Press down moisturizer pump"



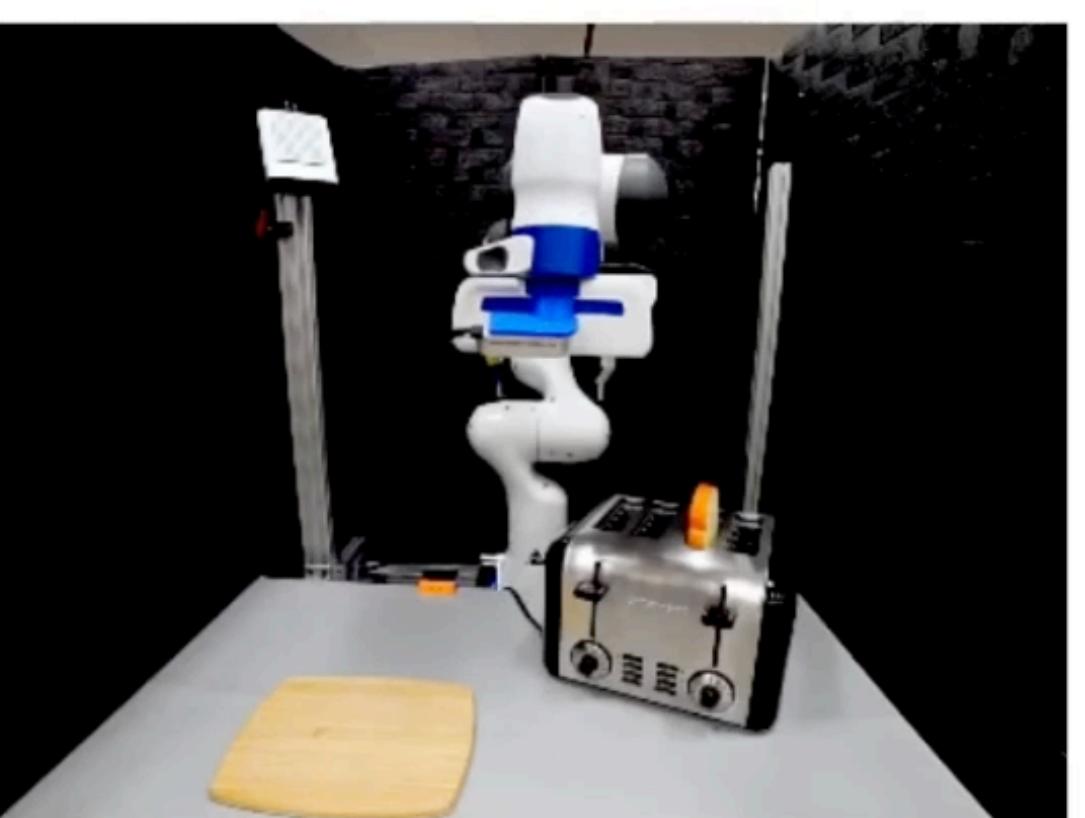
"Take out a napkin"



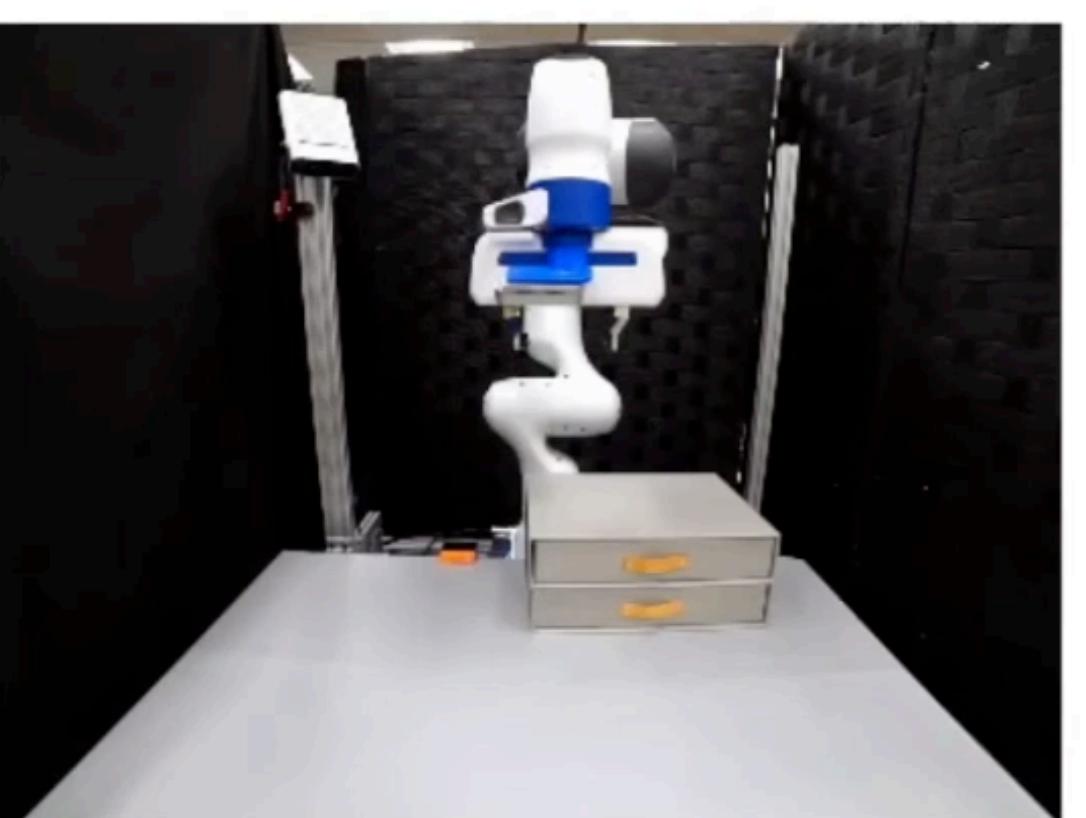
"Unplug charger for phone"



"Turn on lamp"



"Take out bread from toaster"



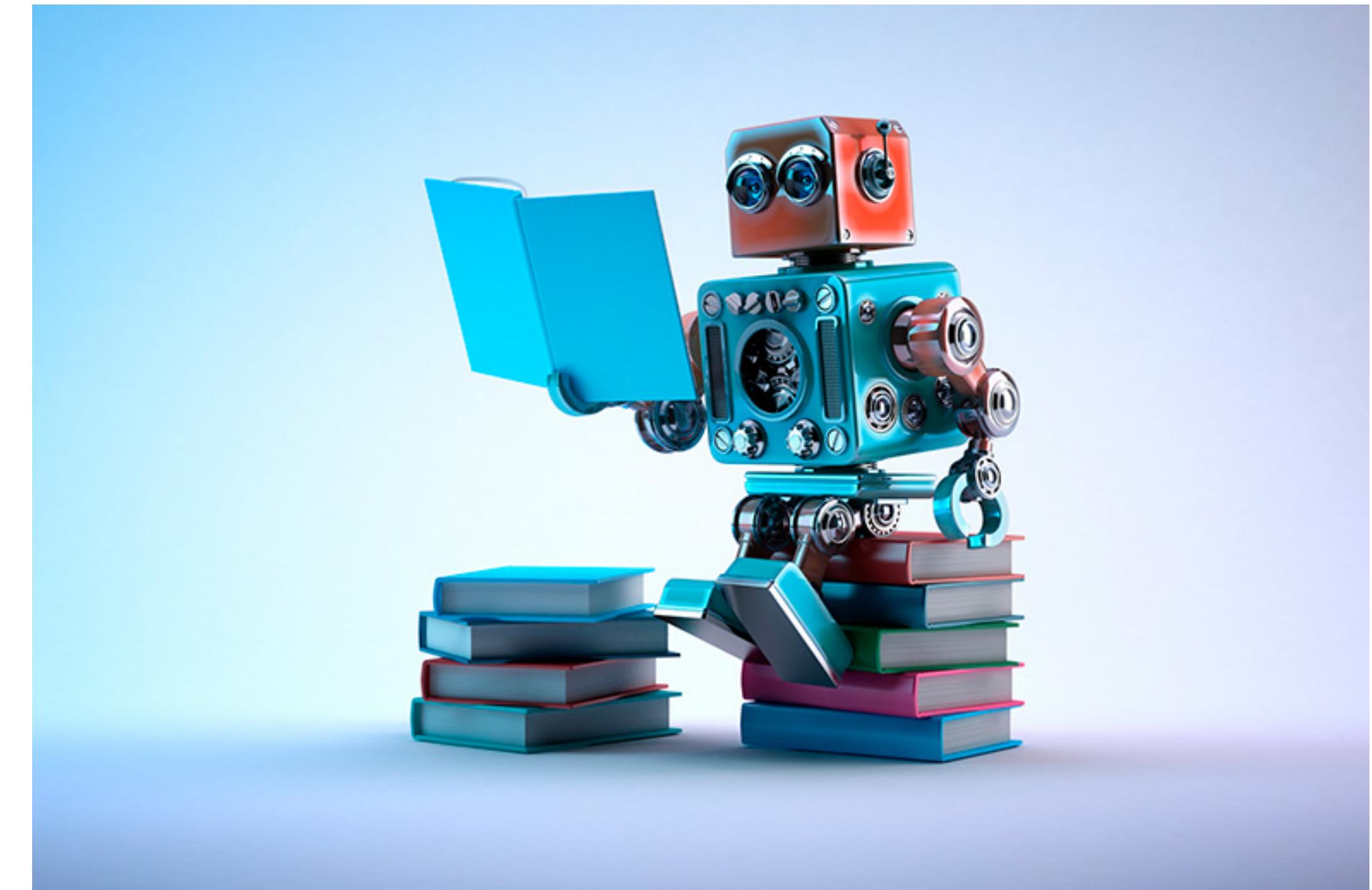
"Close top drawer"



"Set table for pasta"

What is Robot Learning?

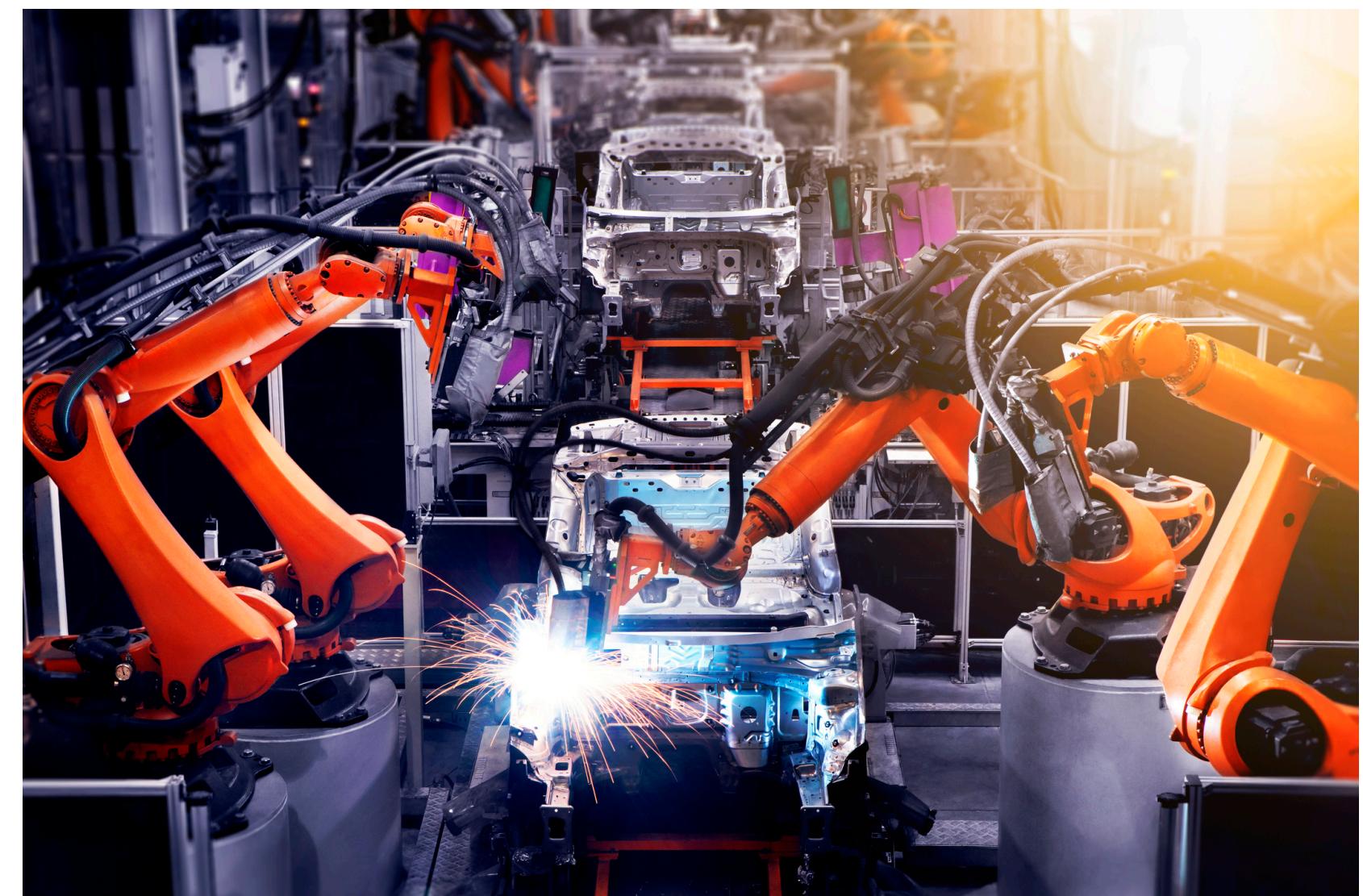
- **Definition #1:** The study of machine learning algorithms and principles with their applications to robotics problems
- **Definition #2:** The study of methods and principles that make robots learn from data
- **Definition #3:** The research field at the intersection of machine learning and robotics (copied from Wikipedia)



When **Not** to Make Robots Learn?

Learning is not the solution to every problem in robotics

When we already have a good understanding
of the system and the problem



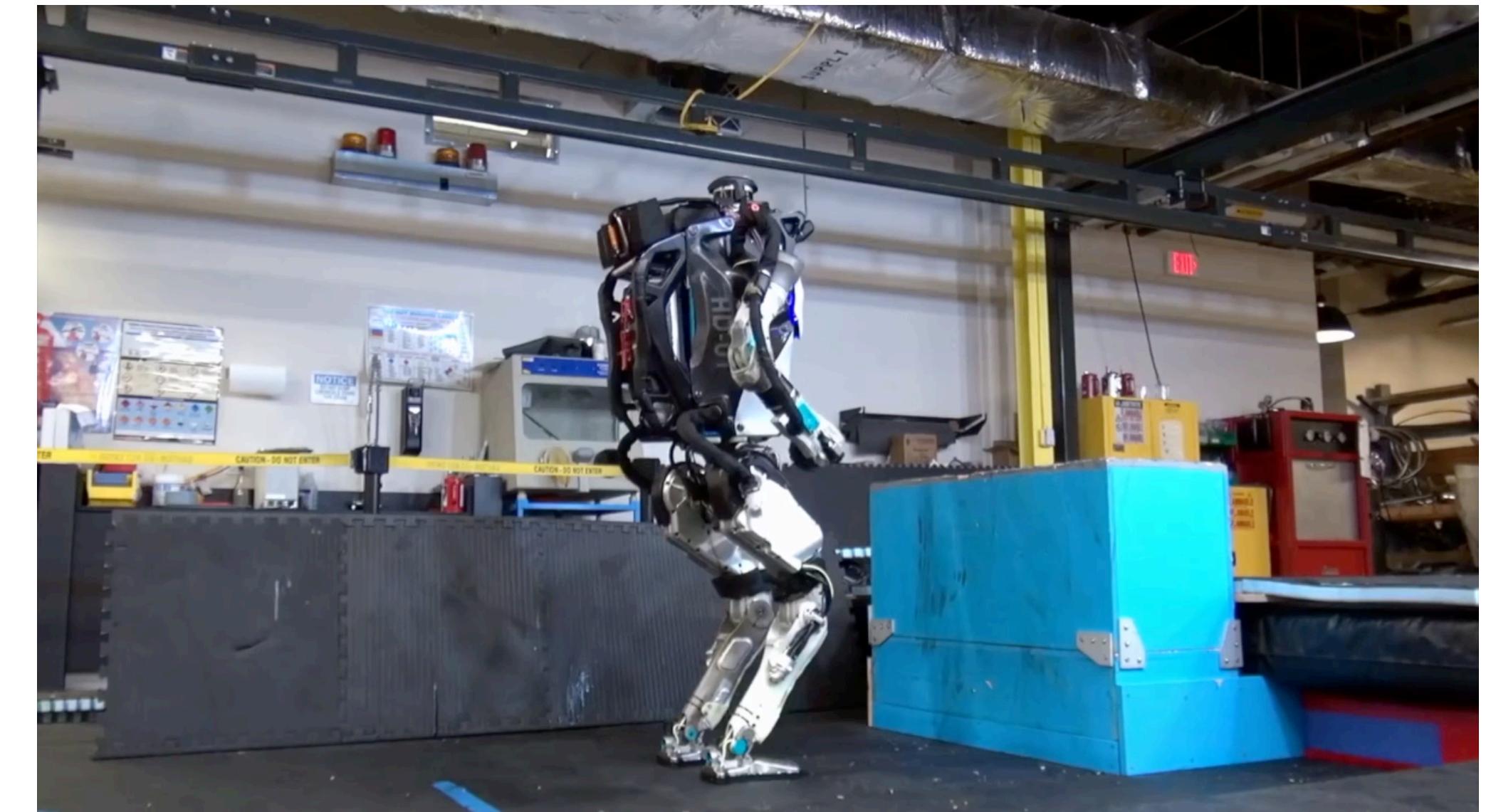
When **Not** to Make Robots Learn?

Learning is not the solution to every problem in robotics

Harnessing the priors and structures of a problem goes a long way...



Learning is the most effective when used together with modeling.



When to Make Robots Learn?

Learning is critical in unstructured and uncertain environments

Real-world variations



Environment uncertainty



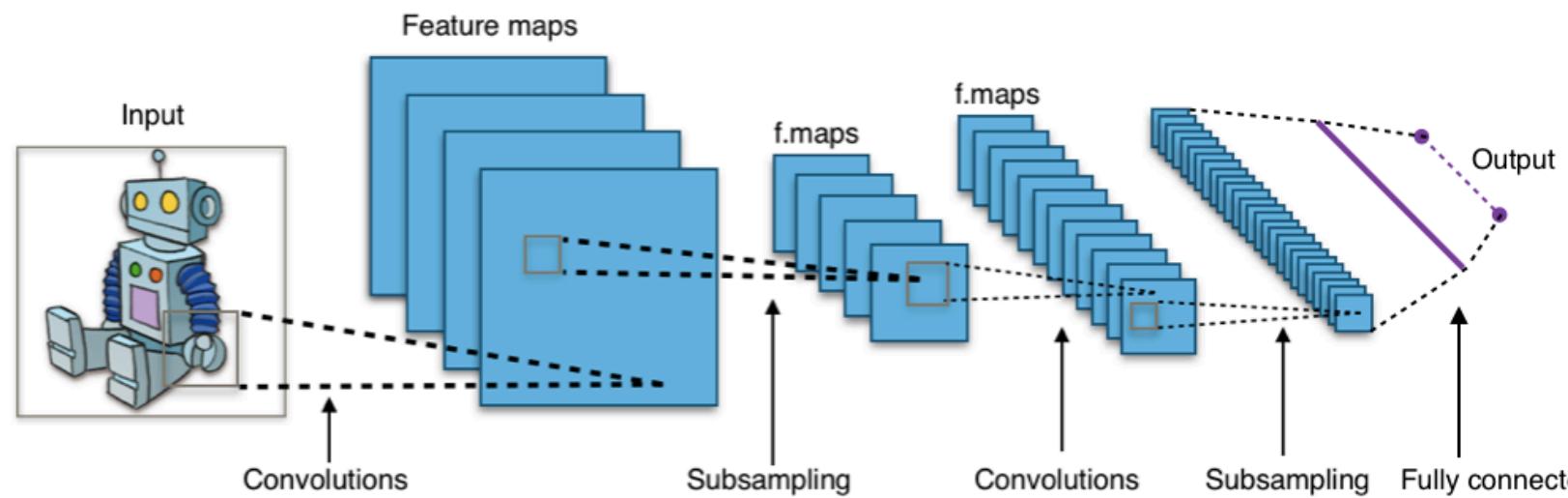
Need for adaptation



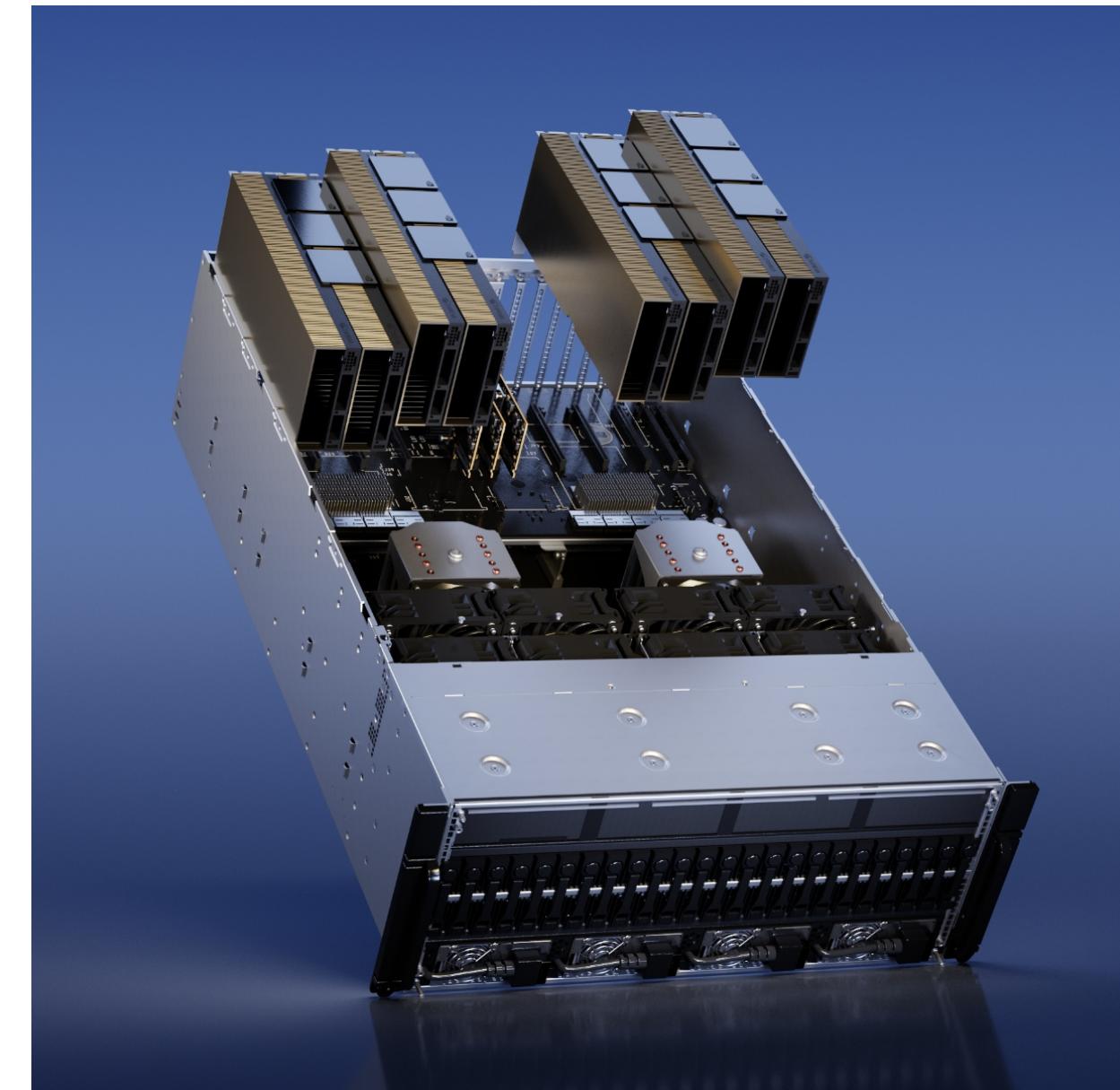
When to Studying Robot Learning?

Now is the best time!!

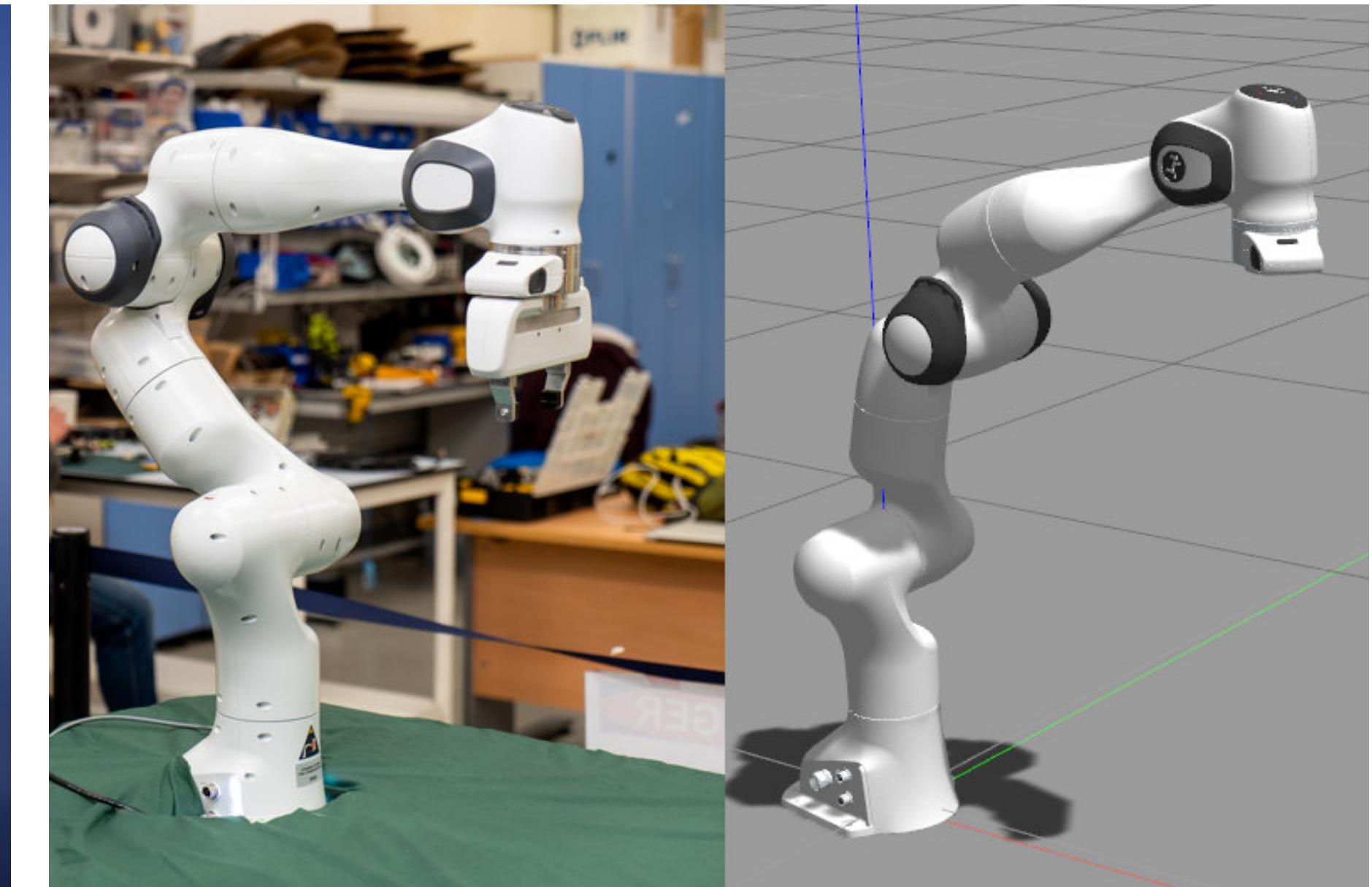
Artificial Intelligence



Compute & Data



Robot Hardware



Recent breakthroughs in AI, such as deep learning (Turing awards 2018) in computer vision, natural language processing, etc.

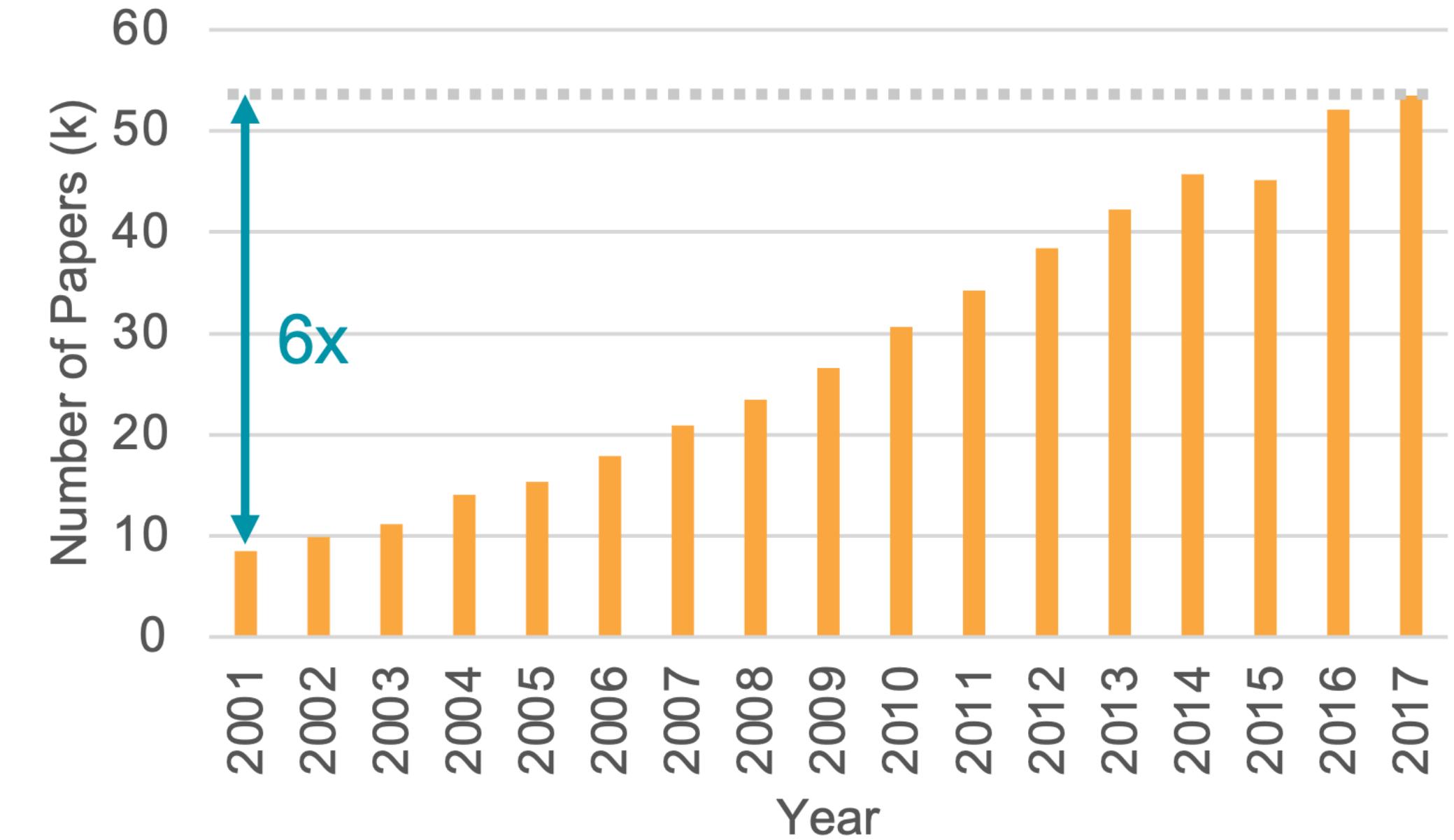
Your smartphone is millions of times more powerful than all of NASA's combined computing in 1969.

Reliable and affordable robot hardware that costs around annual salary of American workers

Robot Learning is a Fast Growing Community



Conference on Robot Learning is only 6 years old.



Growth of "Robot Learning" Publications
[Source: Google Scholar]

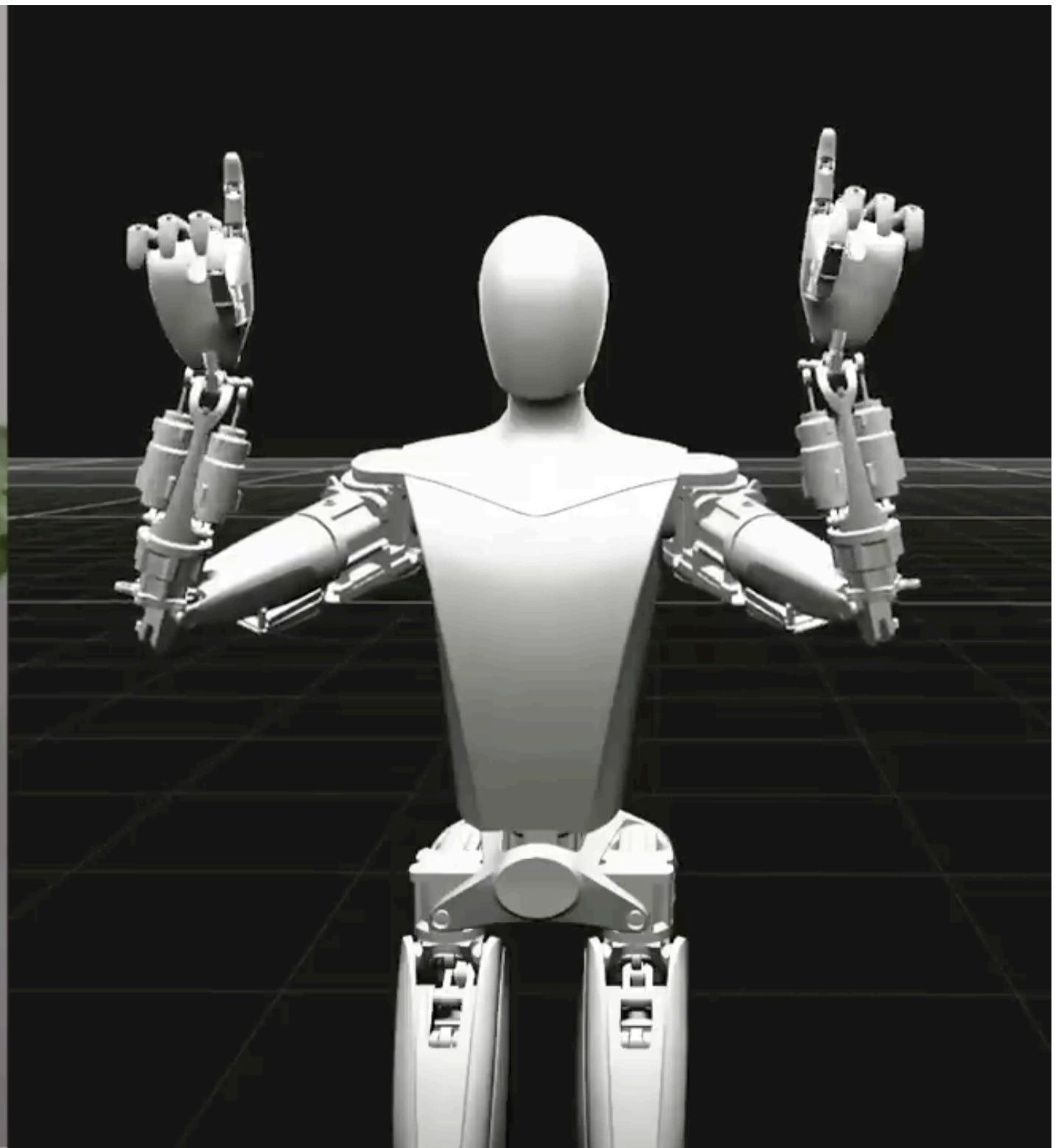
Robot Learning is a Fast Growing Community



1X Technologies
Backed by OpenAI



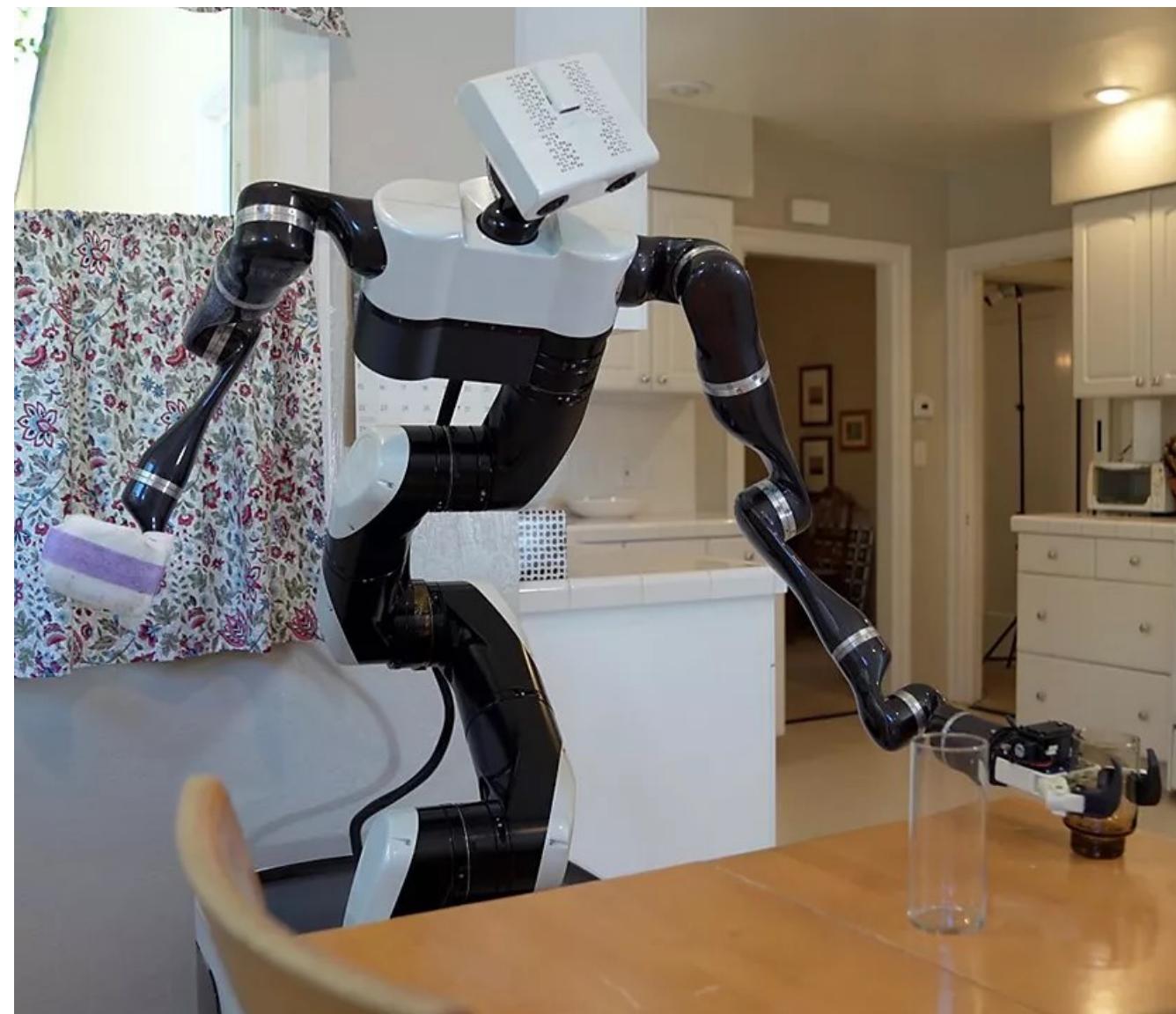
Tesla Bot



Robot Learning is a Fast Growing Community



Robot Learning is a Fast Growing Community



Toyota Research Institute

Meta AI Research

Google Robotics

Nvidia Research

Course Overview

- Part 1: Review of Basic Concepts
 - Robotics, Computer Vision, Machine Learning
- Part 2: Robot Perception
 - Seeing and understanding the physical world
- Part 3: Robot Decision Making
 - Planning and controlling the robot actions
- Part 4: Cutting-Edge Topics
 - Latest research advances and open problems

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Review related Robot Learning literature in these topics

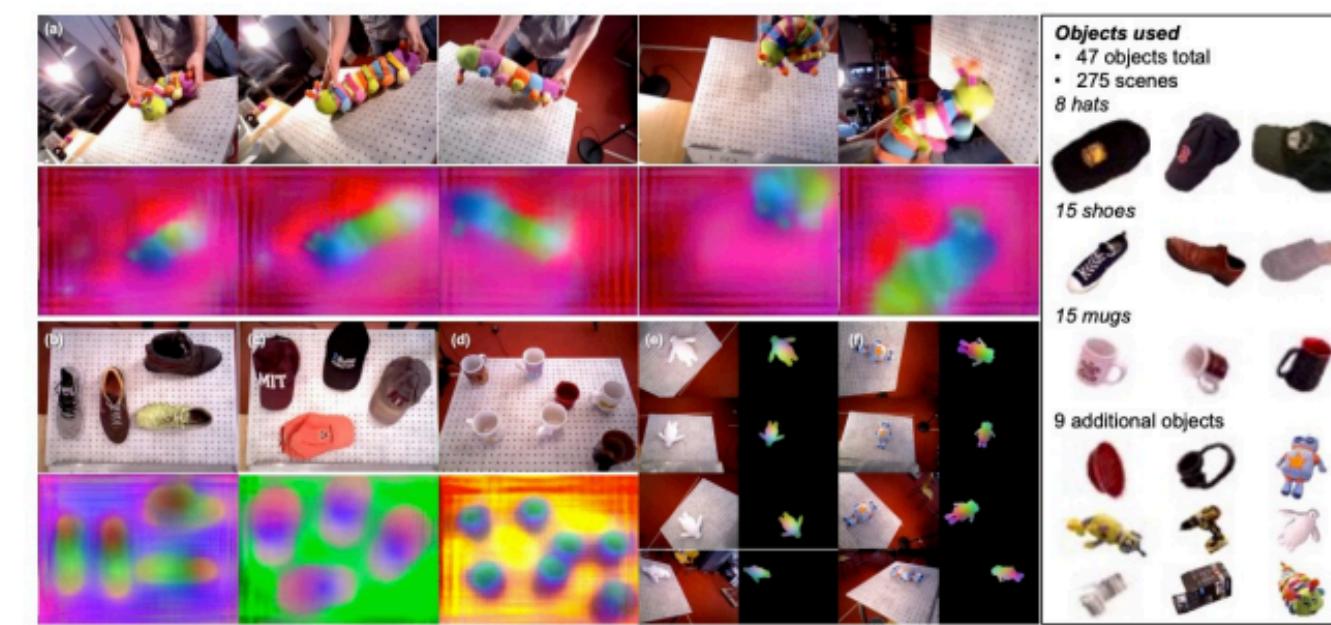
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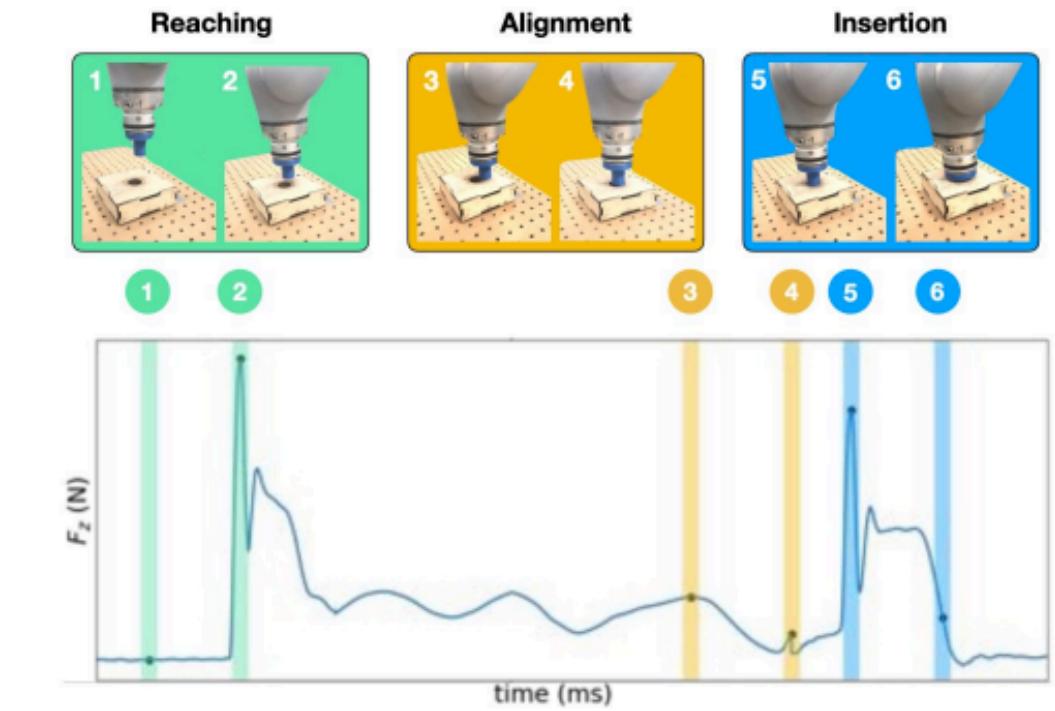
Robot Perception



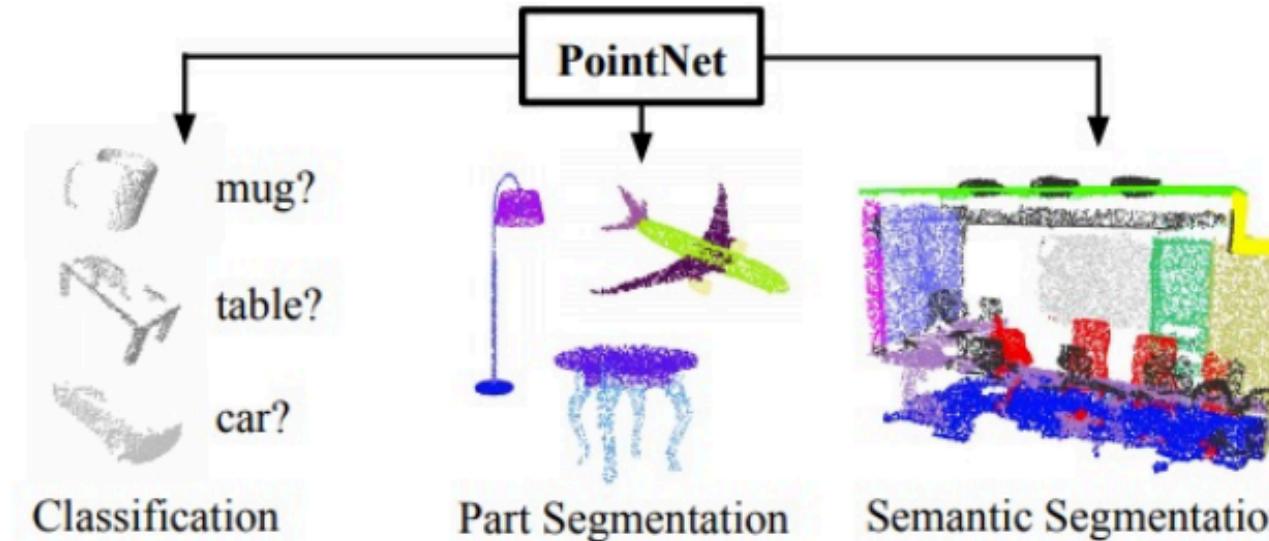
2D visual recognition



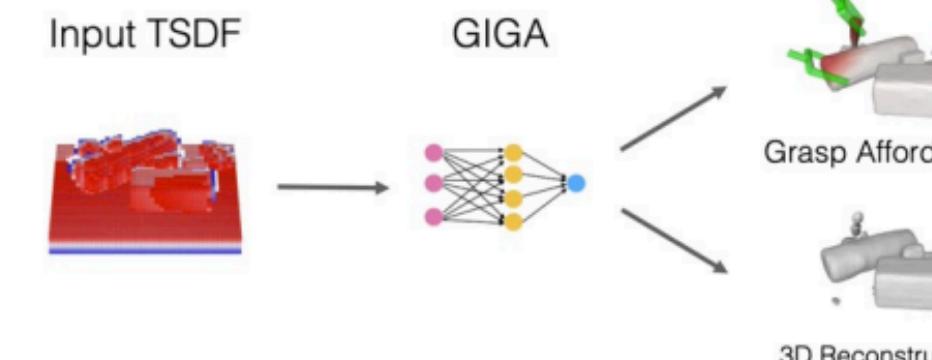
representation learning for robotics



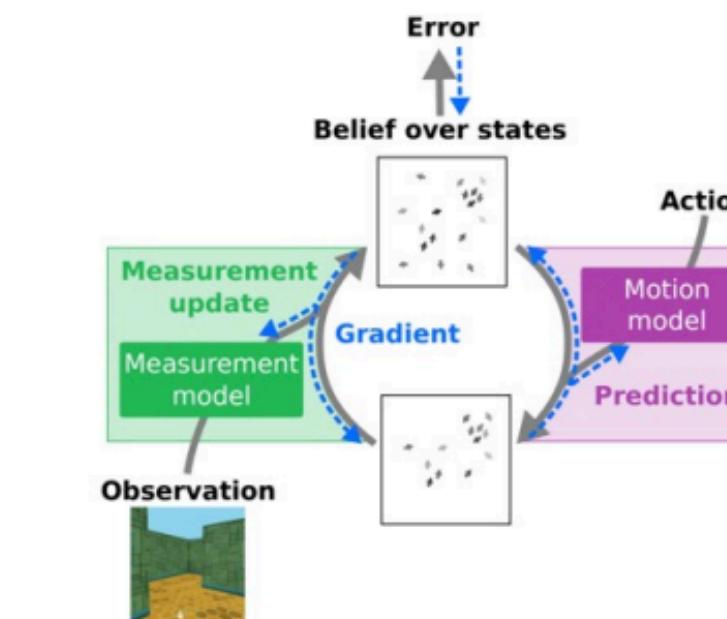
multimodal perception



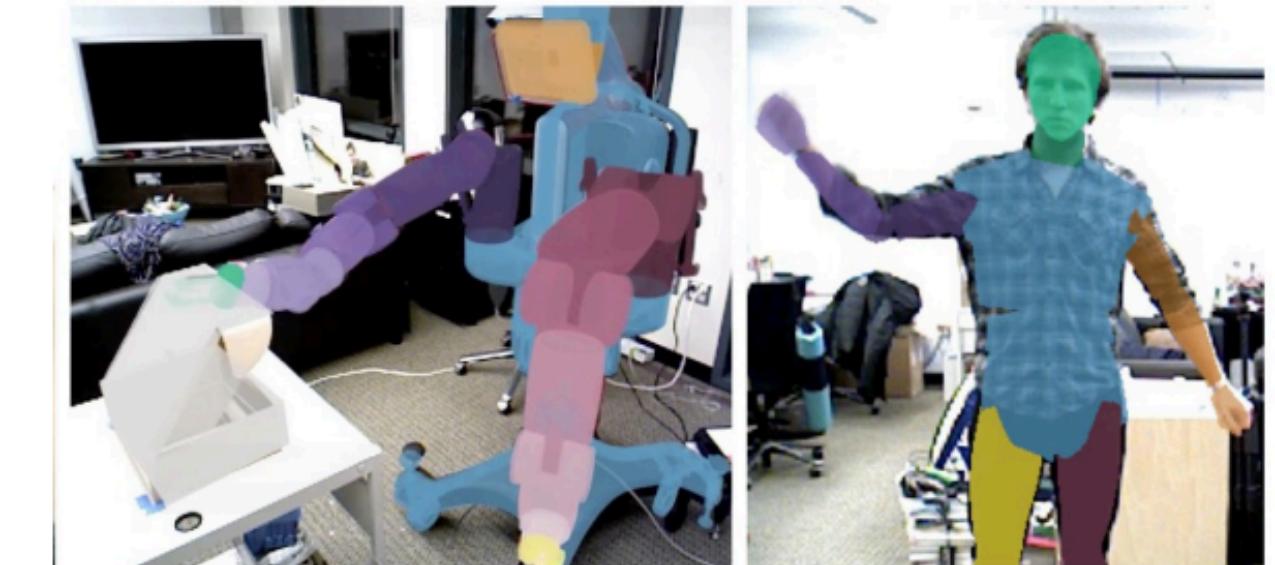
3D data processing



neural fields



state estimation

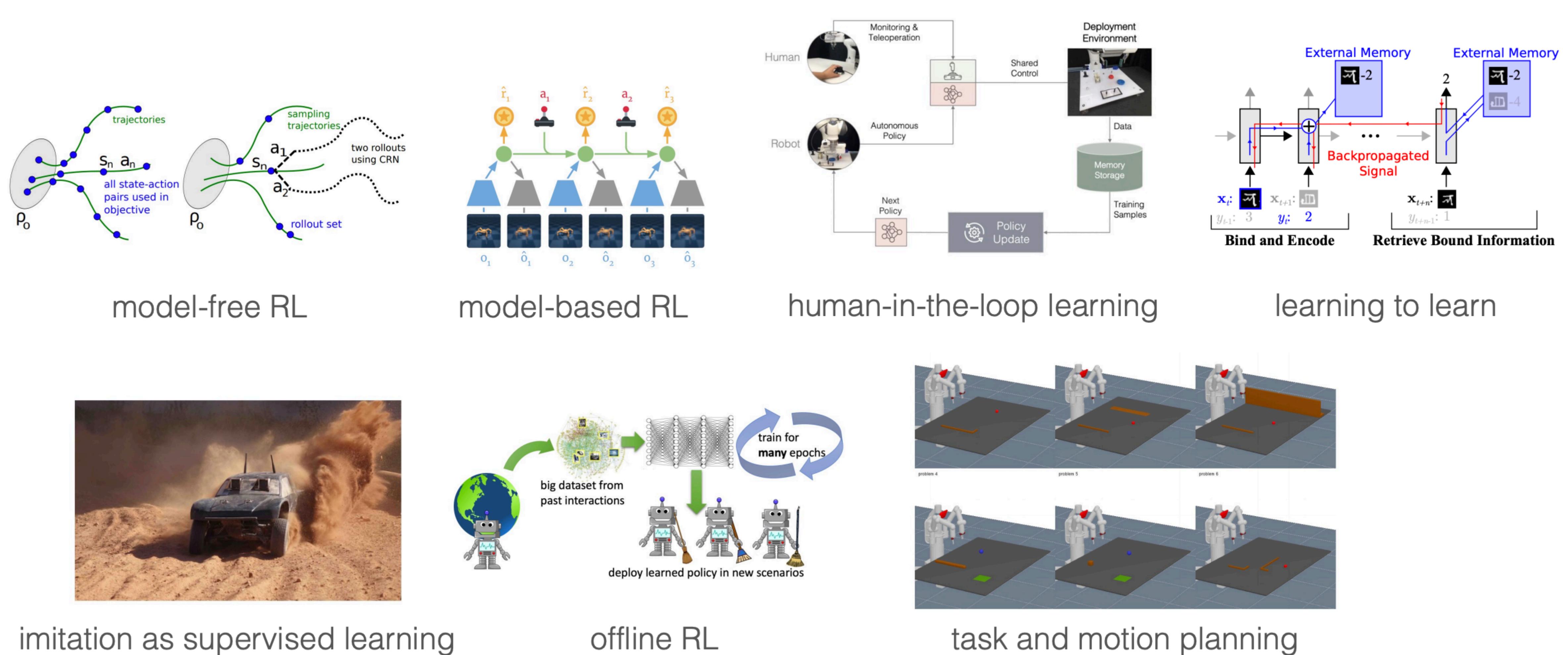


visual tracking

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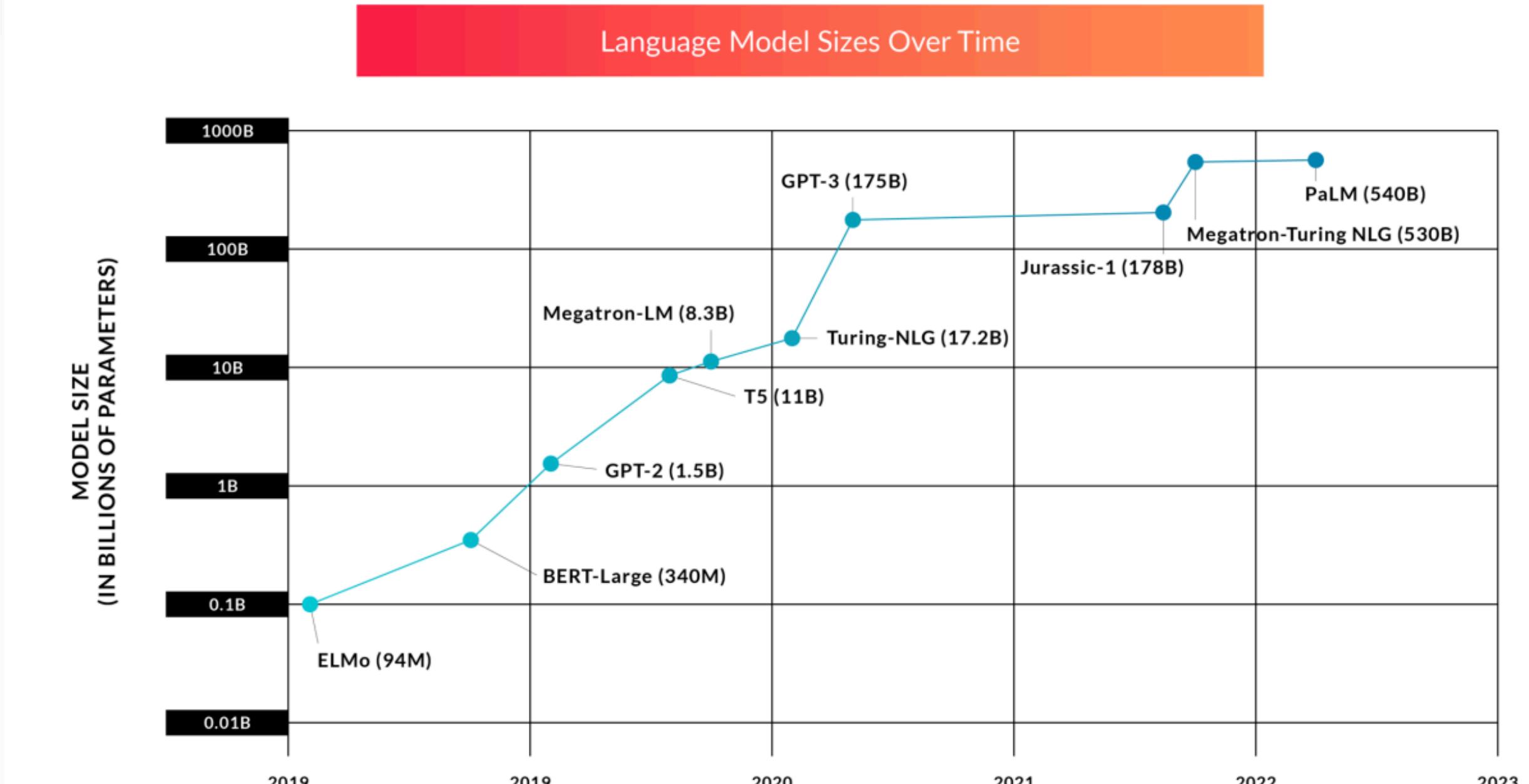
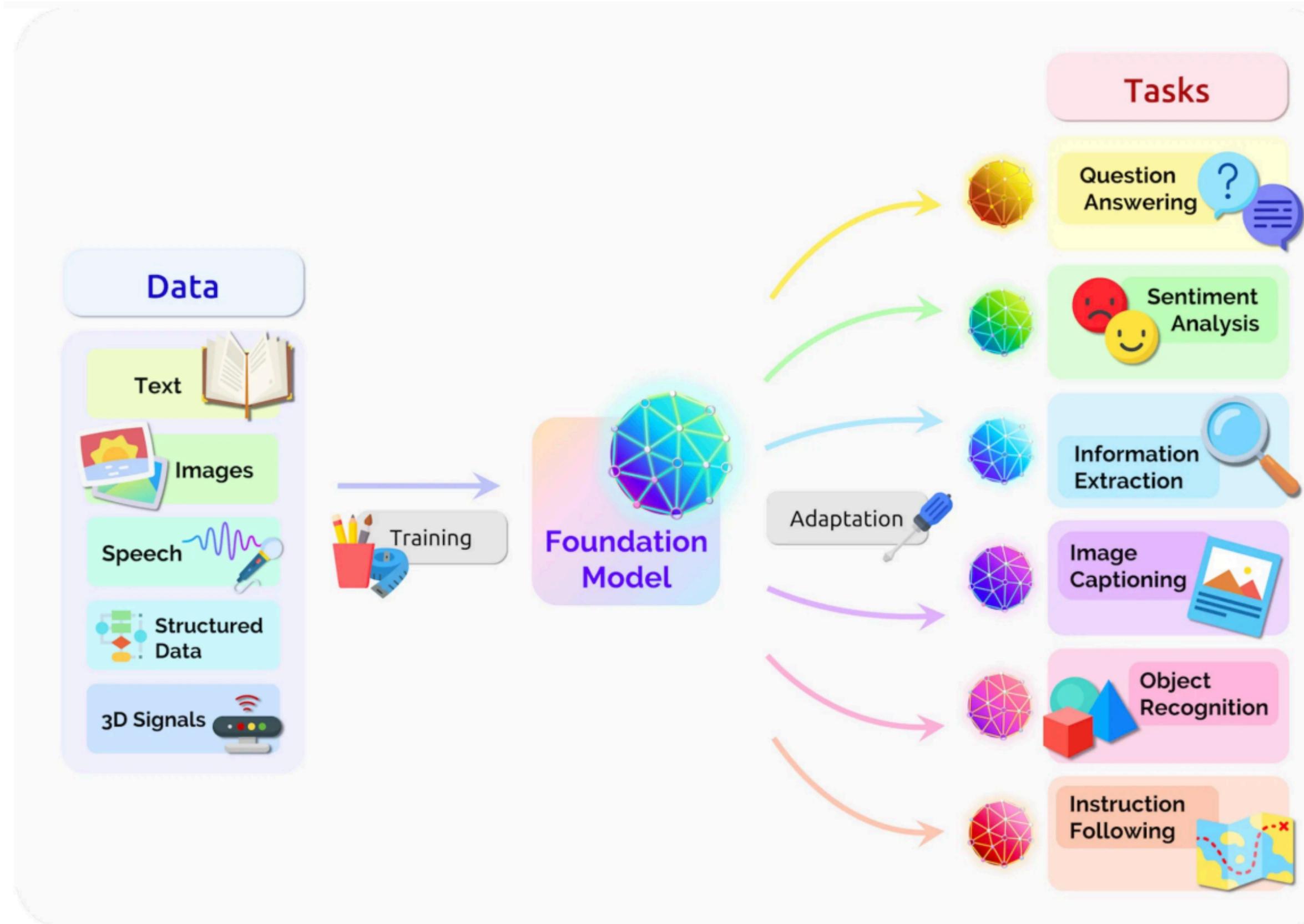
Robot Decision Making



Course Overview

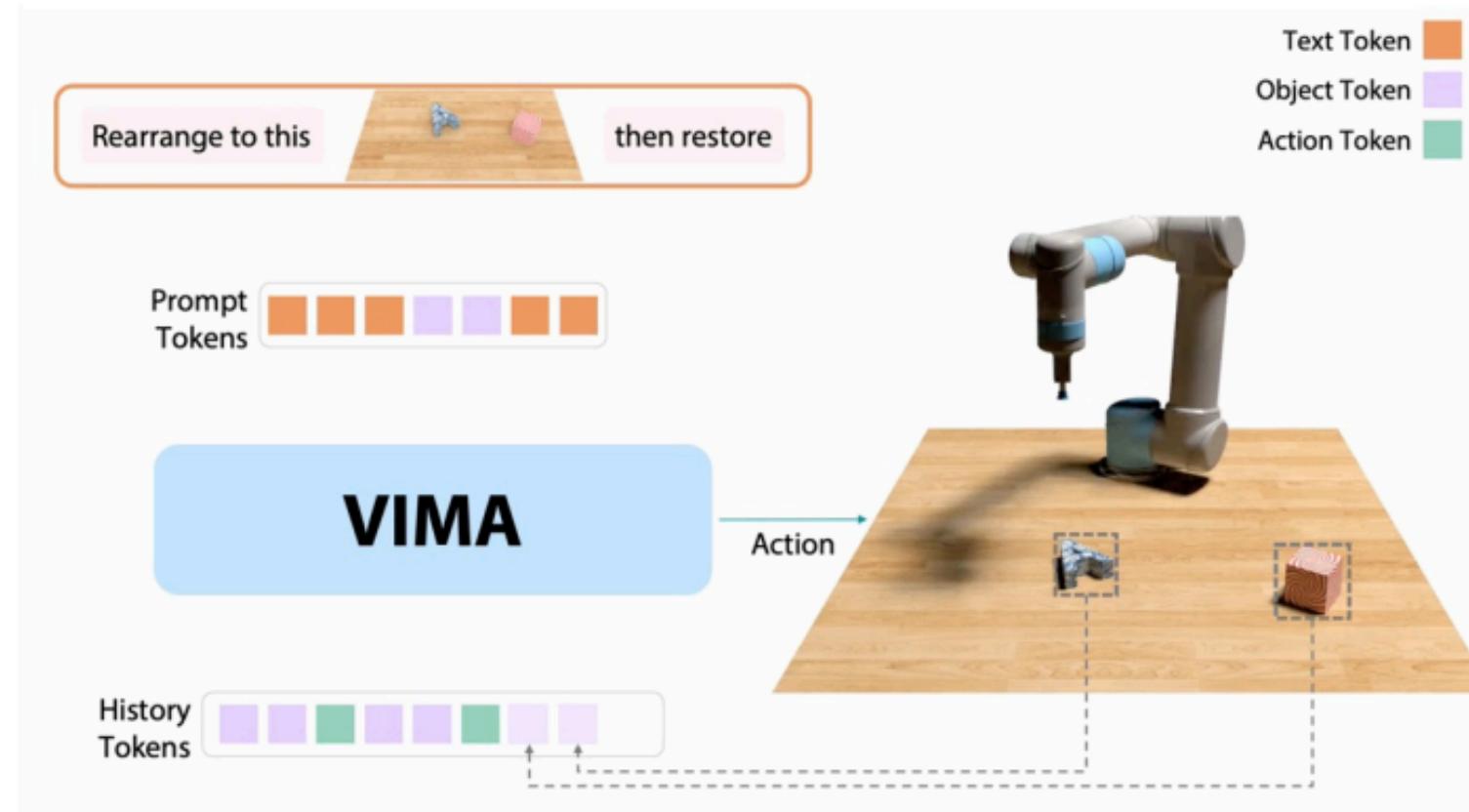
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Cutting-Edge Topics

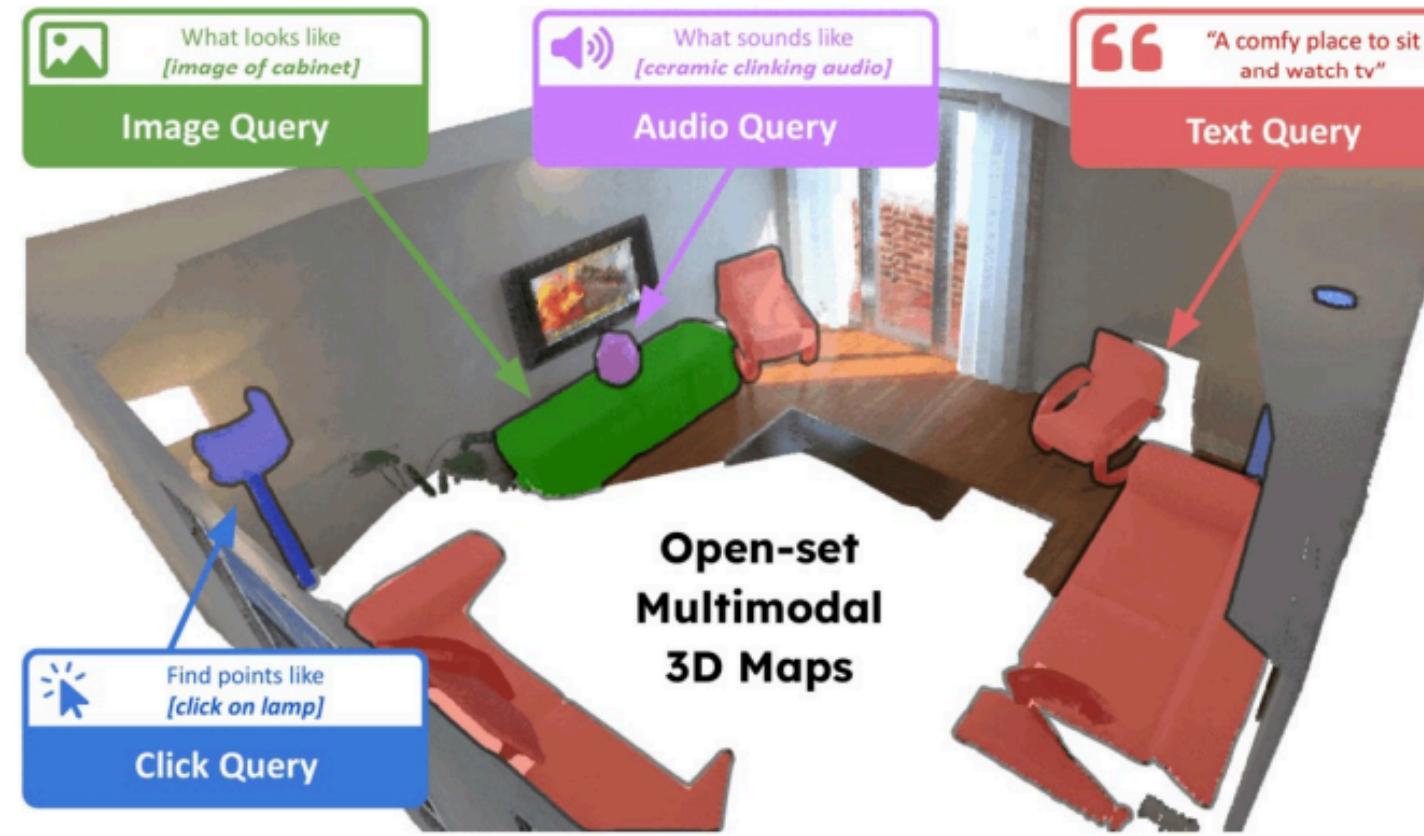


“the era of big models”

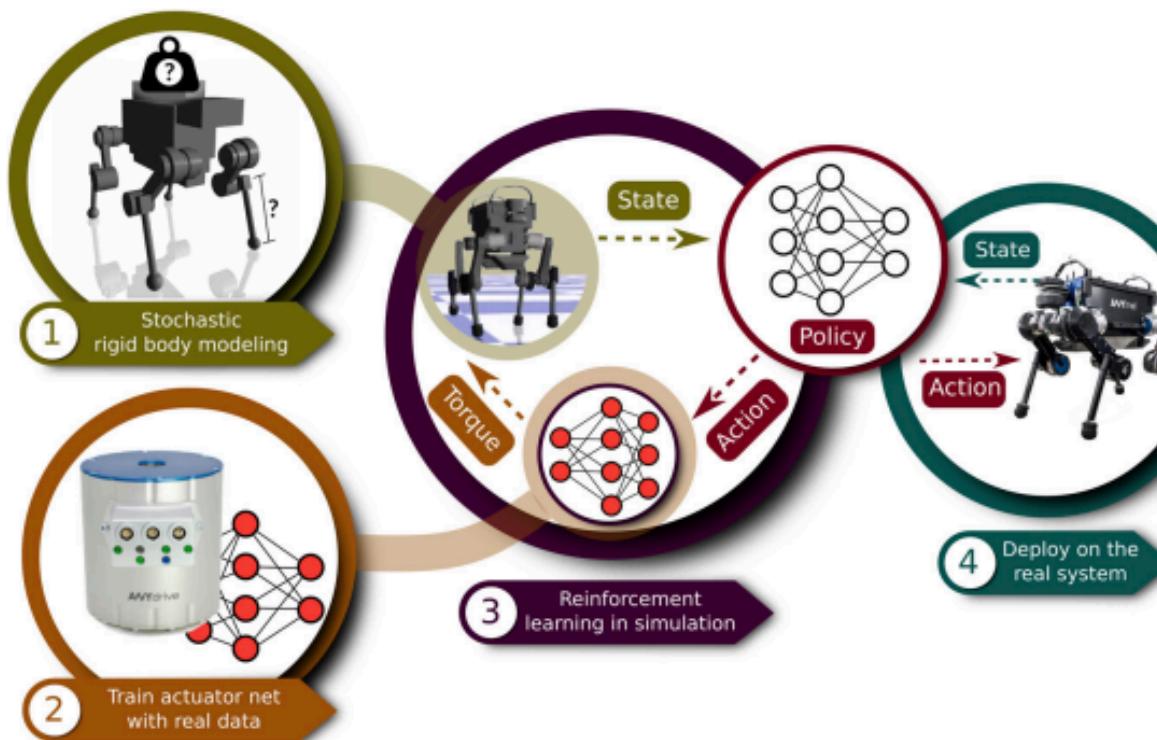
Cutting-Edge Topics



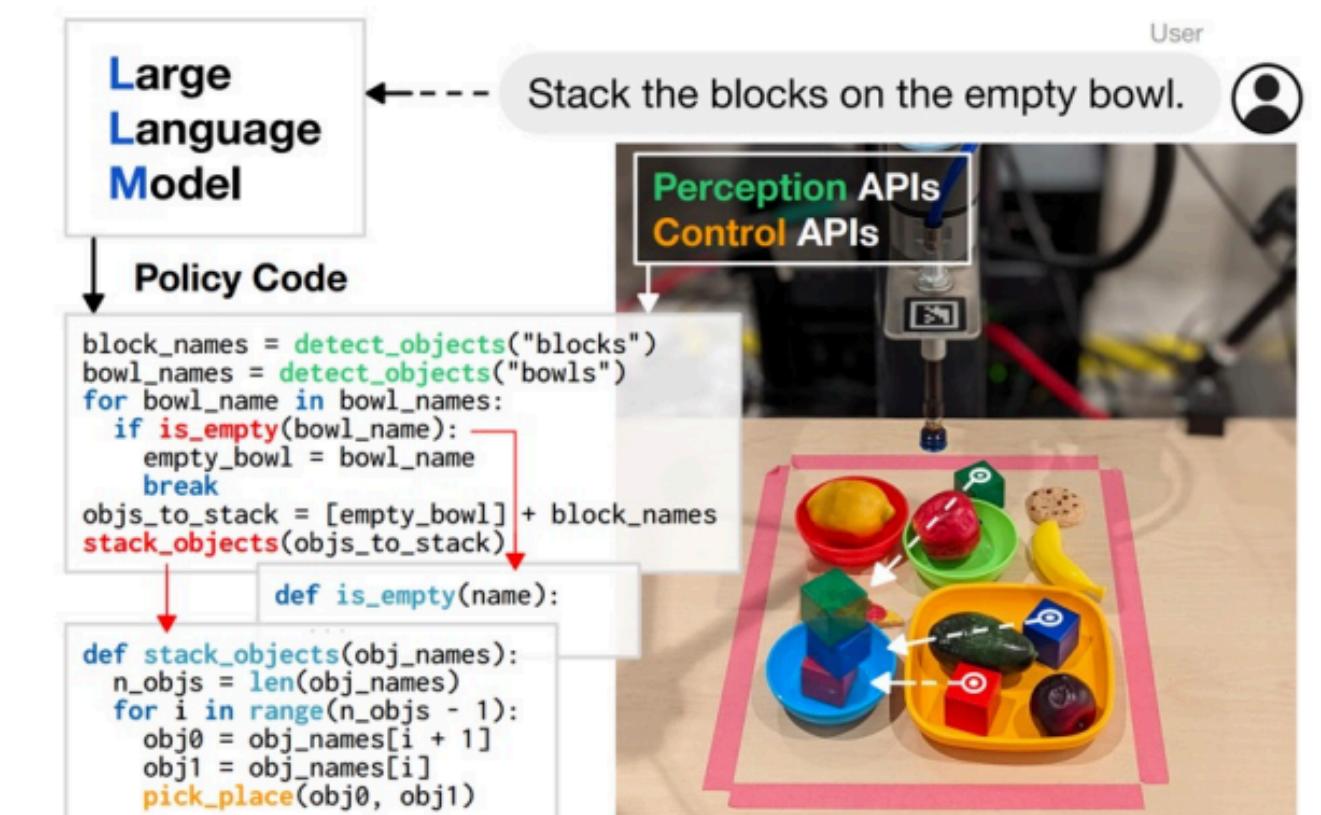
attention architectures



language in robotics



sim-to-real gap



program synthesis for embodied agents

Learning Objectives

- understand the potential and societal impact of general-purpose robotic manipulation in the real world, the technical challenges arising from building it, and the role of machine learning and AI in addressing these challenges;
- get familiar with a variety of model-driven and data-driven principles and algorithms on robot perception and decision making;
- be able to evaluate, communicate, and apply advanced AI-based techniques to robotic manipulation problems.
- ... through literature reviews, research presentations, and course projects

Learning Objectives

- Get a taste of Robot Learning research in the full circle



Logistics

- **Lectures**
 - Time: 3:30-4:45 pm CT, Tuesdays and Thursdays
 - Location: Campus Instructional Facility | Room 1035 (in person)
- **TA: Mingtong Zhang**
 - Second-year MSCS student working with me
 - Robot Learning & Computer Vision
 - Knows more about course arrangement at UIUC than I do :)

