CS 188 Robotics Week 8

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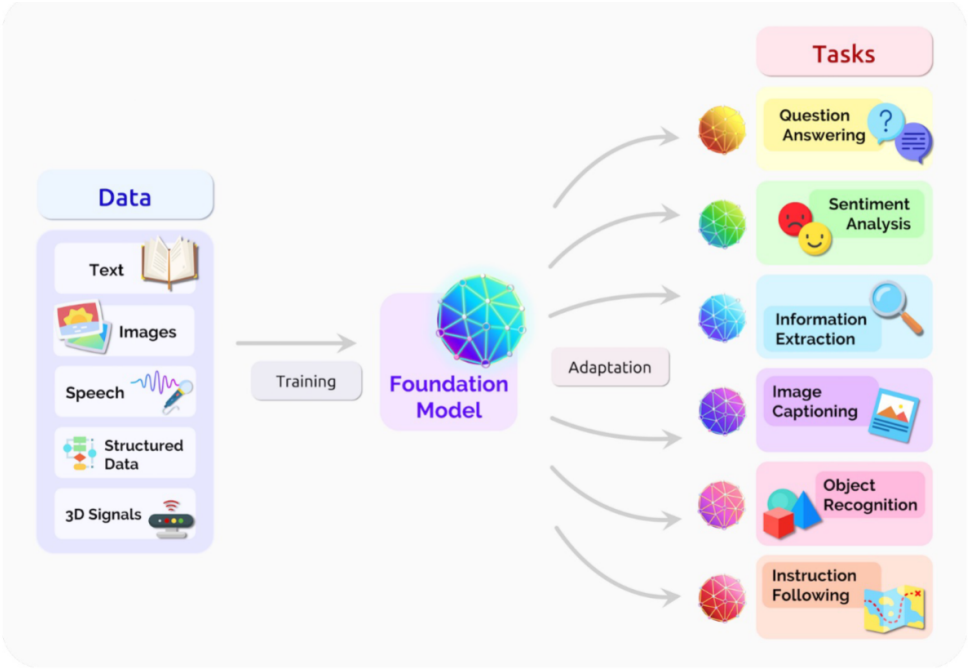
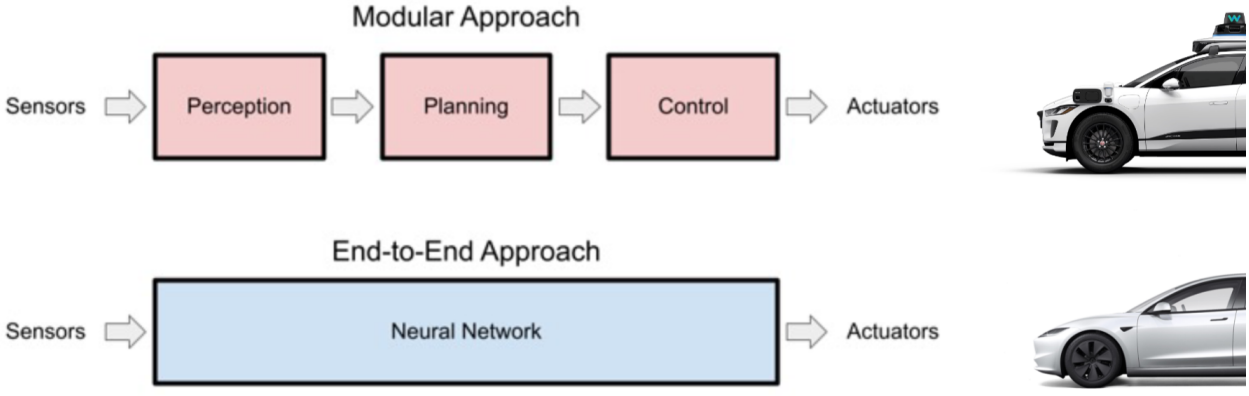
Foundation Models

The New Era of ML



Bommasani, Rishi, et al. **"On the opportunities and risks of foundation models."** (2021).

Two Paradigms of Robotics



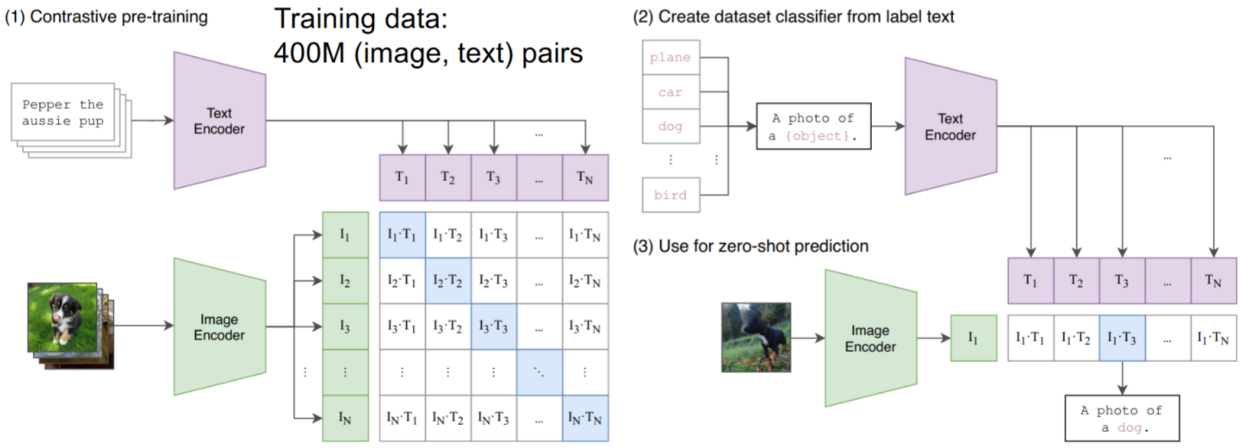
- The modular approach breaks down perception, planning, and control into three separate problems, each of which can be solved using some form of artificial intelligence.
  - Perception is the common computer vision problem of image recognization and classification.
  - Planning is the step to decide what the robot should do given its perception.
  - Control converts the plan into commands for hardware parts or actuators.
  - All of these sections can be solved with foundation models
- The end-to-end approach involves collecting data and throwing it into a neural network.

Integrating FMs in Robotics

1. FM as a **Perception** or Representation Backbone
2. FM as a **Planner or Reasoning** Engine
3. FM as an **End-to-End** Action Policy Prior or Decision-Maker

Computer Vision FMs

- **CLIP (Contrastive Language-Image Pretraining)** learns the relationship between **a whole sentence** and the **image** it describes



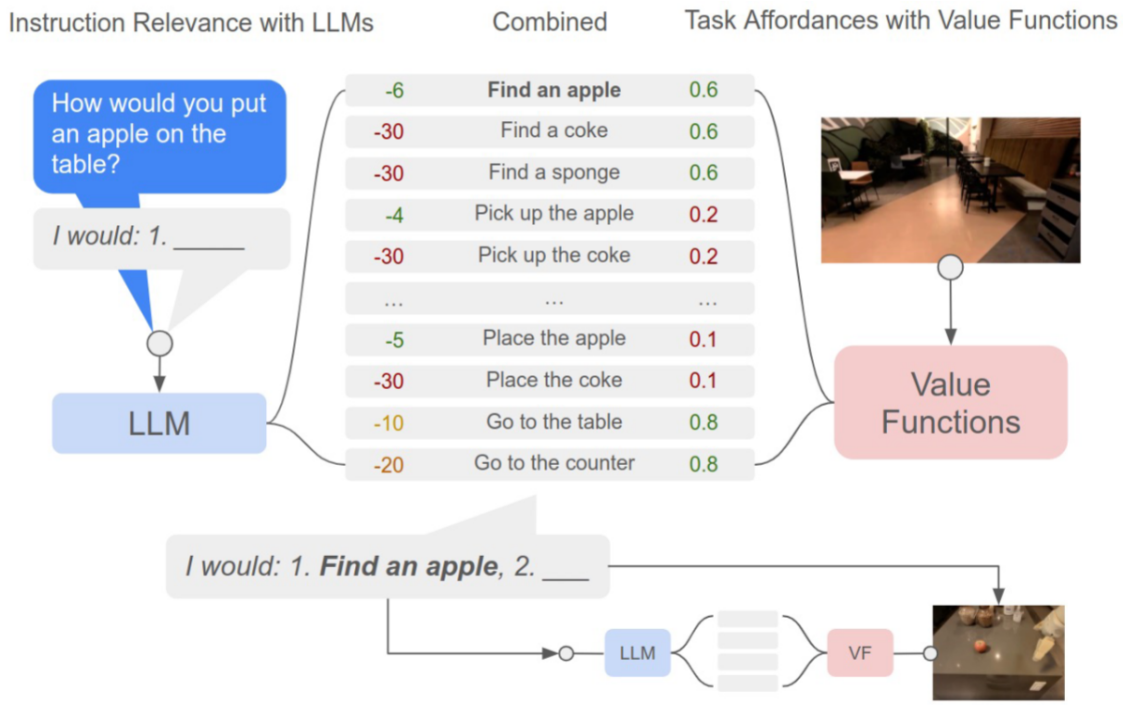
Example: SAM

SAM: Segment Anything Model

- Website: https://segment-anything.com/demo
- Documentation: https://docs.ultralytics.com/models/sam/

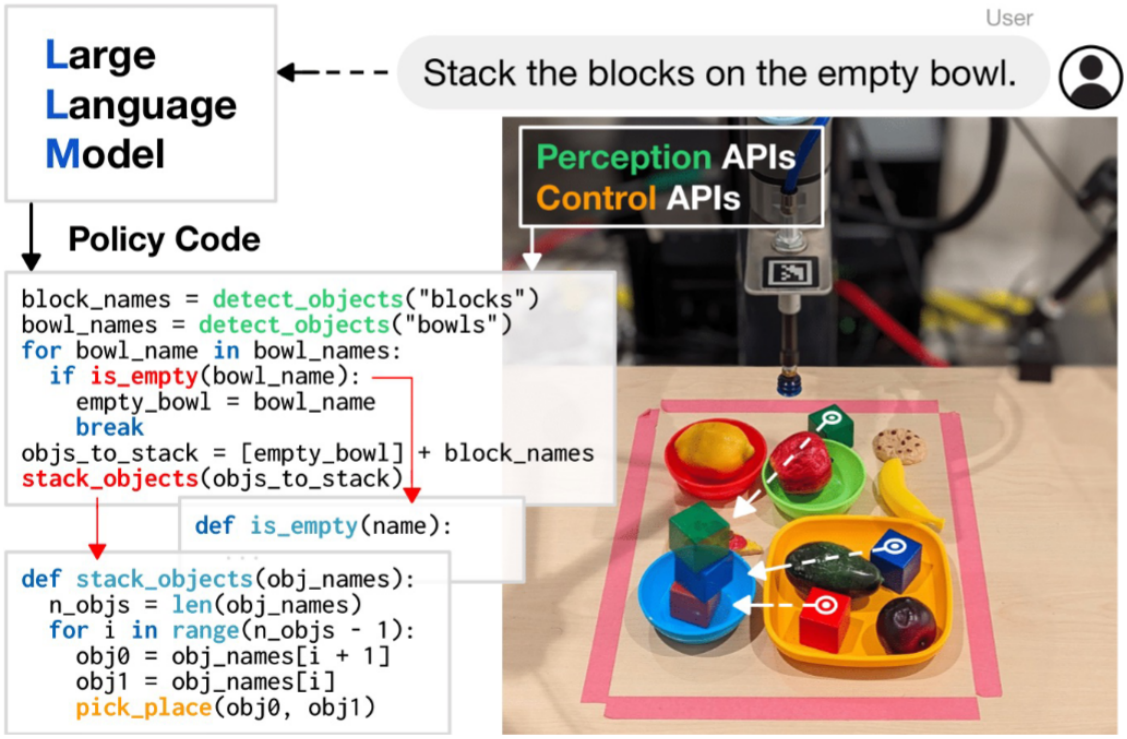
LLM as Planner

SayCan



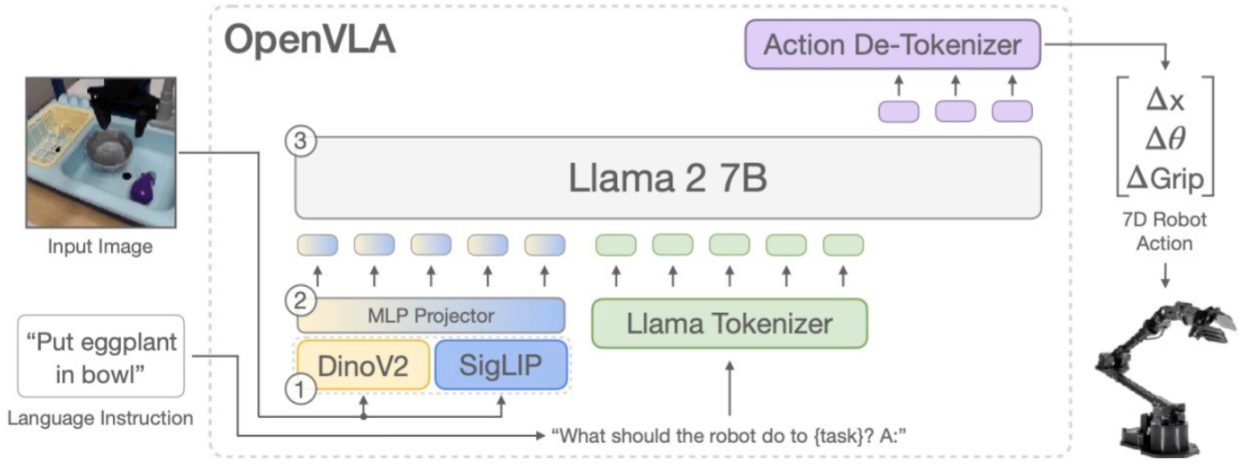
LLM / VLM Code Generation

Code As Policies (https://code-as-policies.github.io/)



Vision Language Action Models (VLAs)

- Multi-task
- Language-conditioned



- https://openvla.github.io/

Challenges?

Challenges in Embodiment and Grounding

- FMs lack embodied experience; they process abstract data (e.g., text, images), not the physical effects of actions.
- Aligning abstract representations (like "grasp the cup") with real motor commands and sensor feedback.
- A model that understands "grasping" in language may still not control a gripper effectively.

Challenges in Data Efficiency and Cost

- Robotic data is expensive and slow to collect compared to web-scale text/image data.
- FMs need to learn or adapt using relatively little robotic data.
- Scaling up robotic training like we do with vision/language is not yet feasible.

Challenges in Real-Time Constraints

- FMs are large and computationally intensive.
- Running inference fast enough for real-time control on embedded hardware.
- Robots often need millisecond-level decision-making; FMs often can't meet these latencies natively.

Challenges in Safety and Reliability

- FMs can be unpredictable or "hallucinate."
- Ensuring safe, explainable, and fail-safe actions in physical environments.
- Mistakes can cause real-world damage or harm.

Challenges in Multimodal Integration

- FMs typically operate on specific modalities (e.g., text, vision).
- Fusing multimodal sensory input (e.g., vision, proprioception, tactile) with high-level reasoning.
- Effective robotic control requires coordinated understanding across many input streams.

Challenges in Generalization

- FMs don't always generalize across different embodiments or tasks.
- Making a single model work across varied robots (arms, legs, drones) and diverse manipulation goals.
- One of the key promises of FMs is general-purpose utility, but robotics tasks are often highly specific.