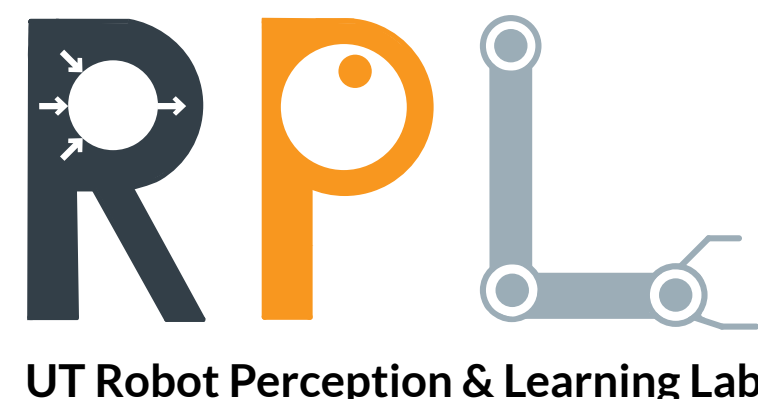


Pathway to Generalist Robots:

Scaling Law, Data Flywheel, and Humanlike Embodiment

Yuke Zhu

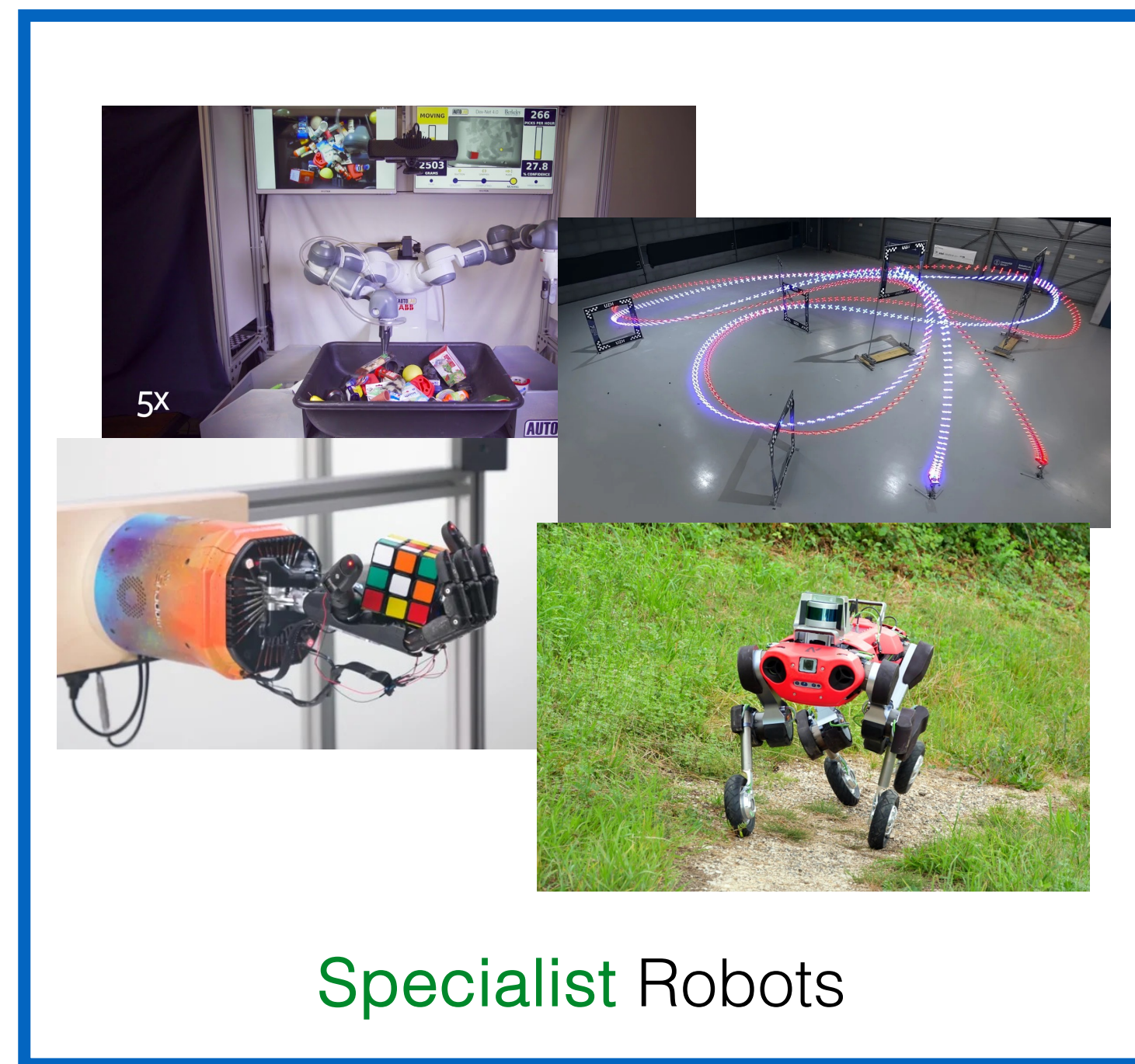
November 8th, 2023



TEXAS Robotics



Specialist → Generalist → Specializing Generalist



Generalist Robot Models



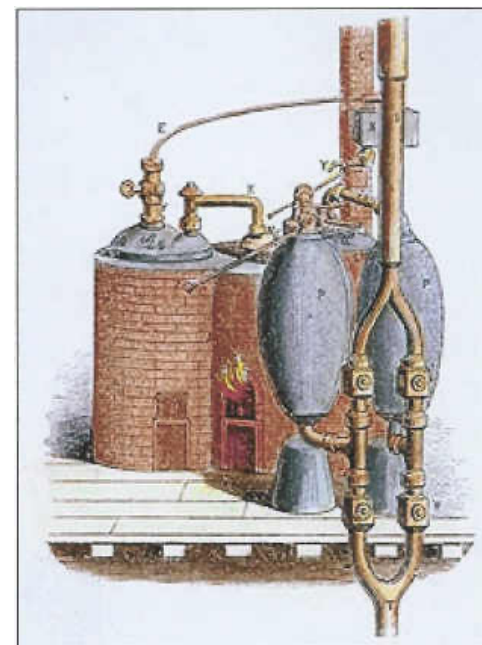
Specialist → Generalist → Specializing Generalist



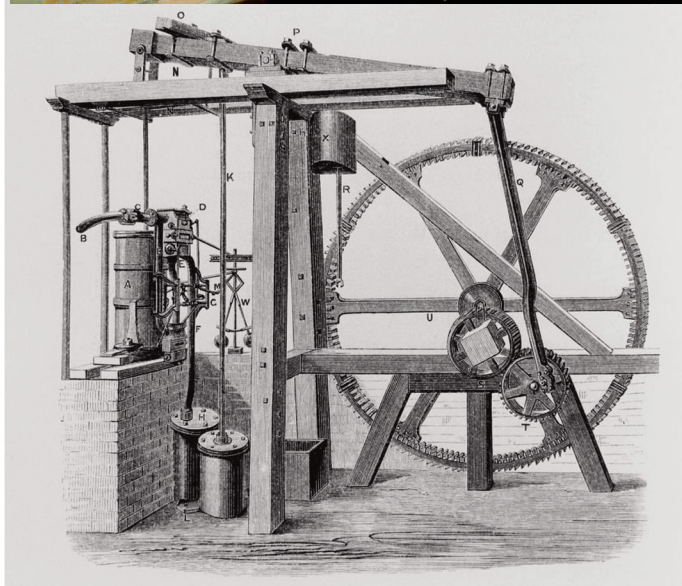
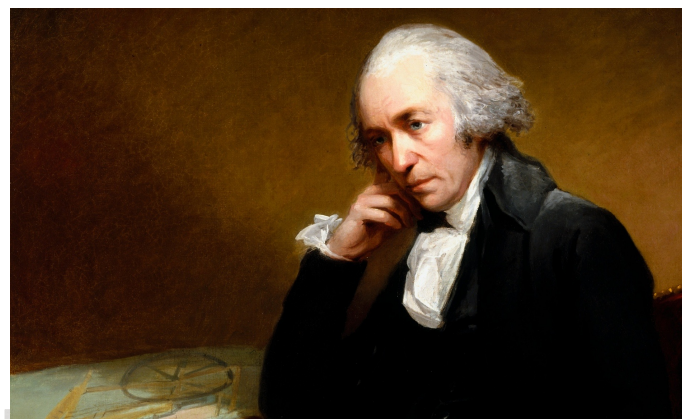
Aeolipile (Heron of Alexandria, 10–70 AD)



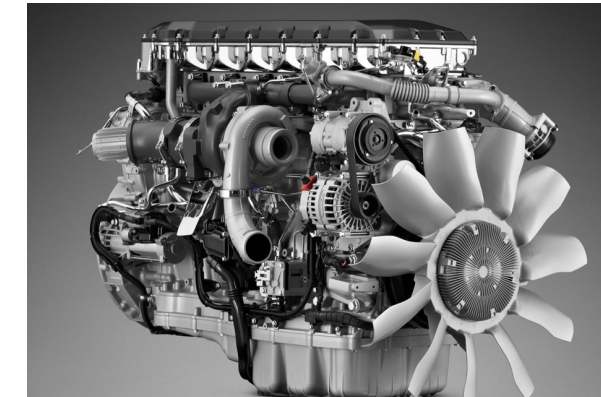
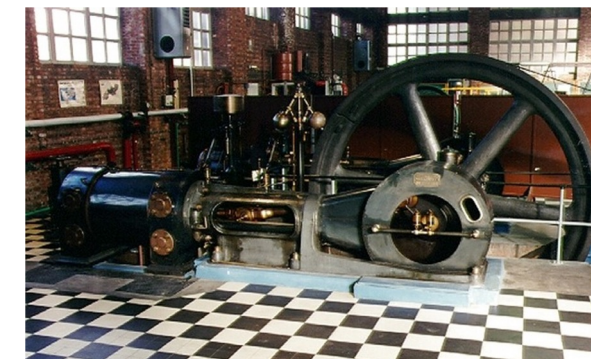
Rudimentary Steam Turbine (Taqi al-Din, 1551)



Savery Steam Pump (Thomas Savery, 1698)



Watt's Steam Engine (James Watt, 1764)



Internal Combustion Engine



Steam Turbine

Specialist → Generalist → Specializing Generalist

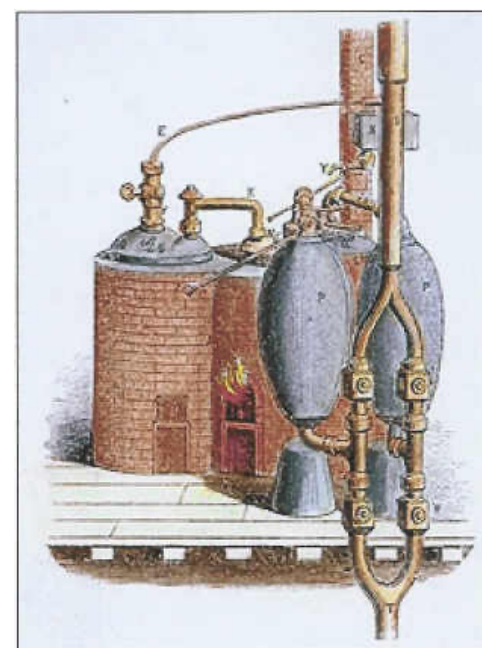
Specialist technology working in limited conditions



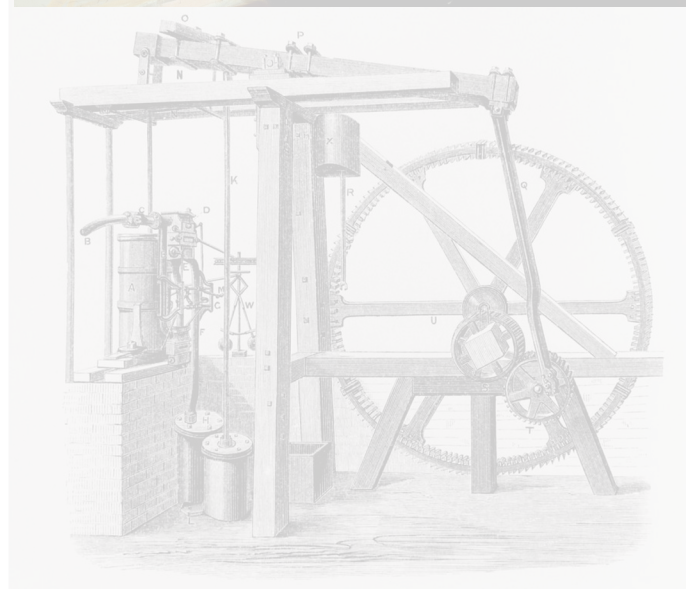
Aeolipile (Heron of Alexandria, 10–70 AD)



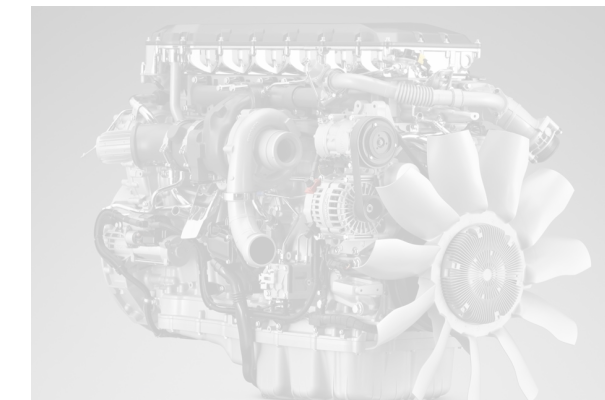
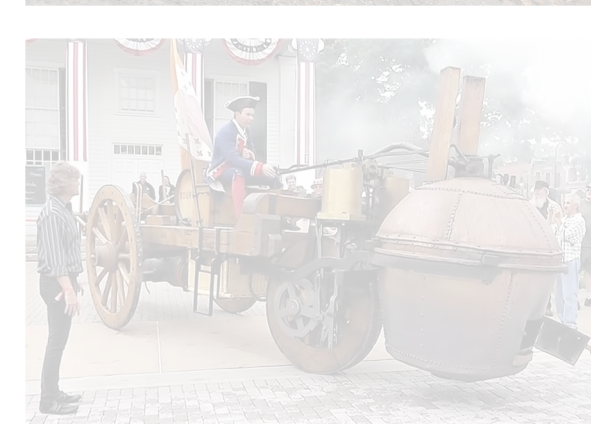
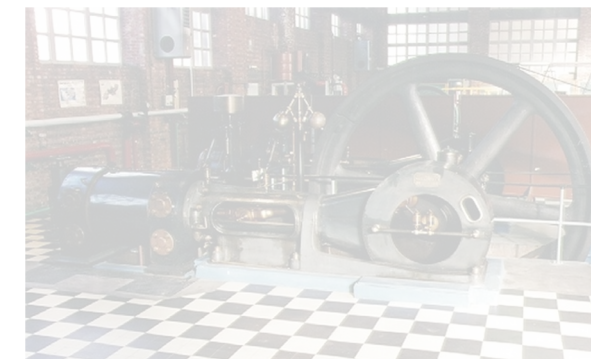
Rudimentary Steam Turbine (Taqi al-Din, 1551)



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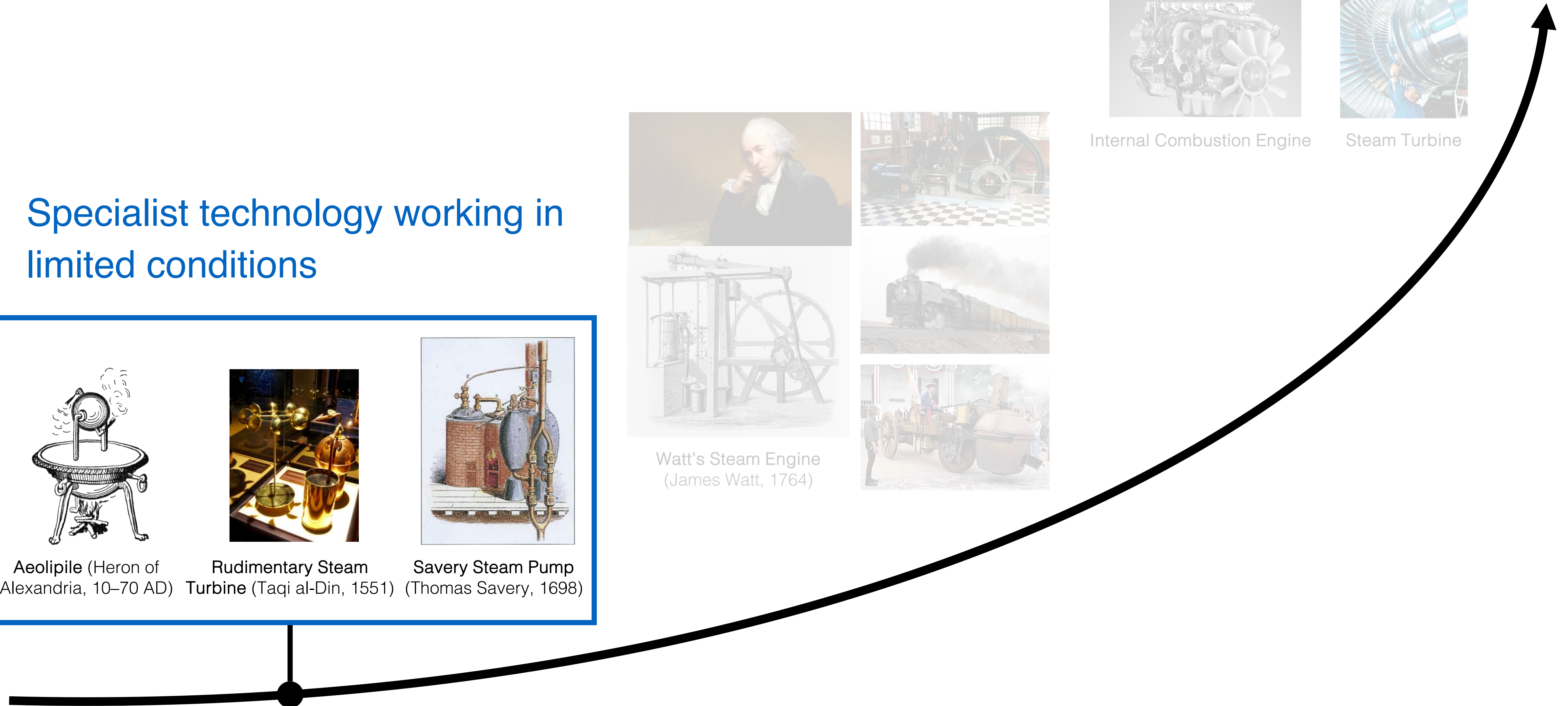
Watt's Steam Engine (James Watt, 1764)



Internal Combustion Engine



Steam Turbine



Specialist → Generalist → Specializing Generalist

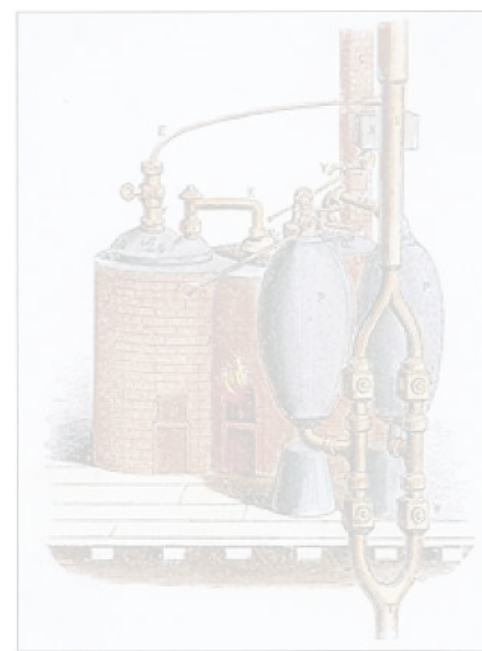
Generalist technology leading to widespread adoption



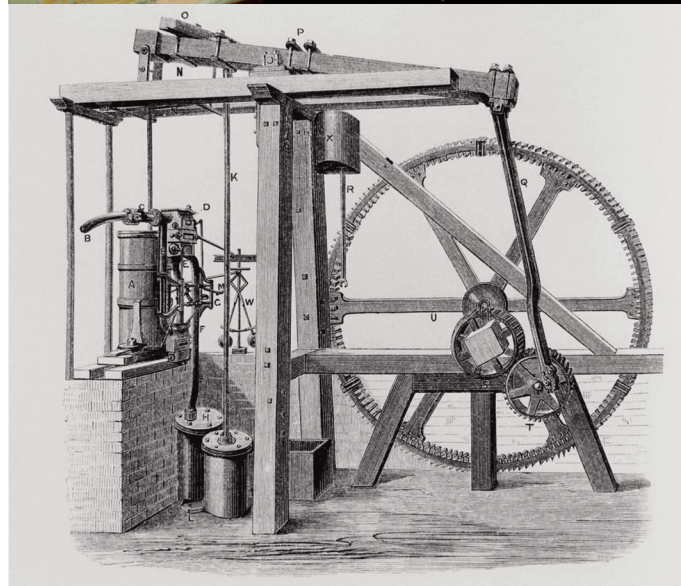
Aeolipile (Heron of Alexandria, 10–70 AD)



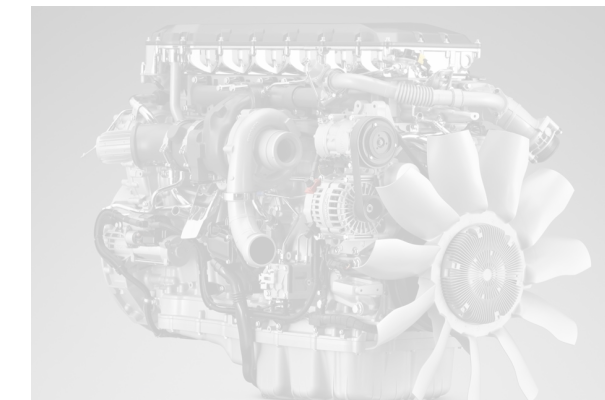
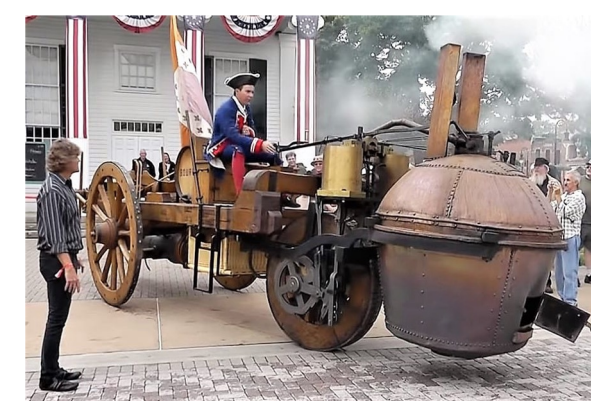
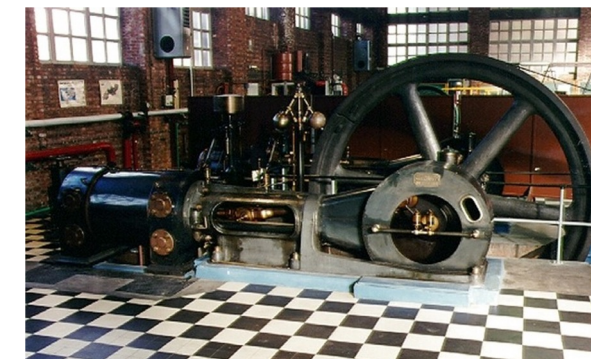
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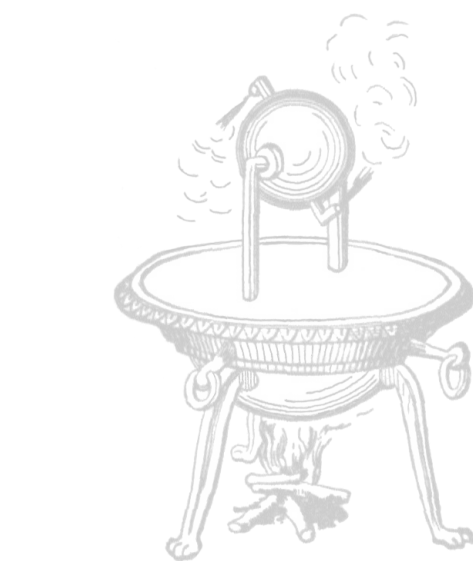
Internal Combustion Engine



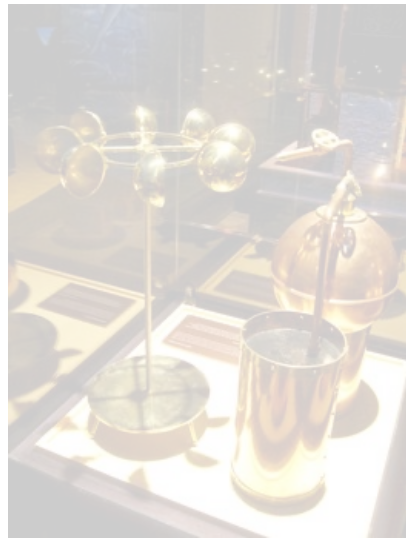
Steam Turbine

Specialist → Generalist → Specializing Generalist

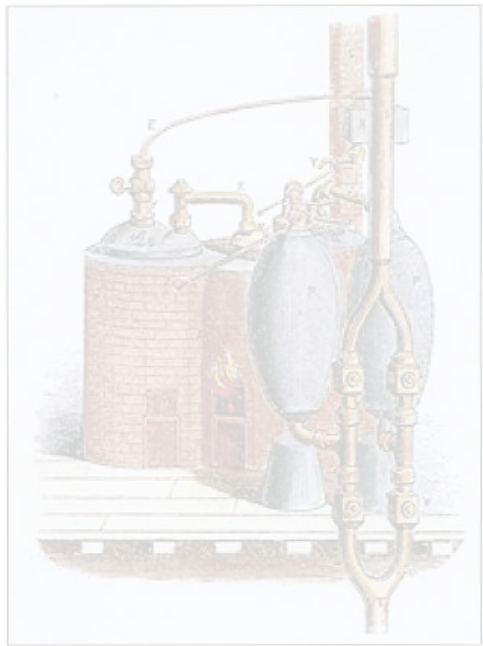
Further specialization in various problem domains



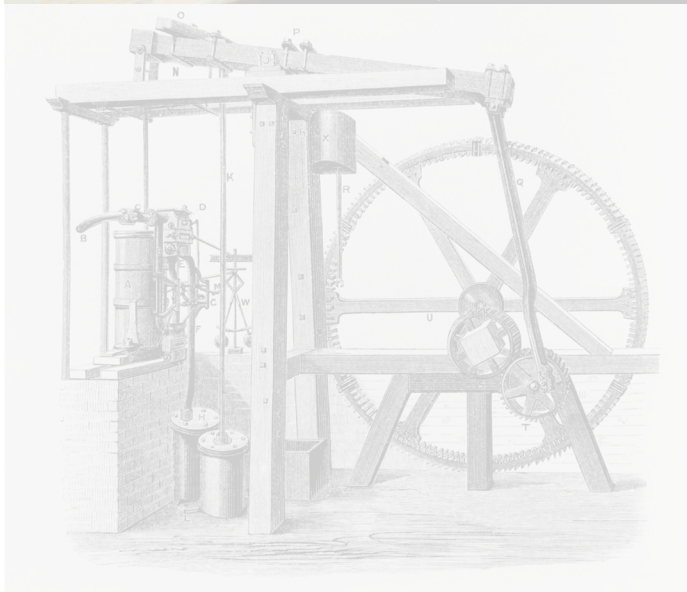
Aeolipile (Heron of Alexandria, 10–70 AD)



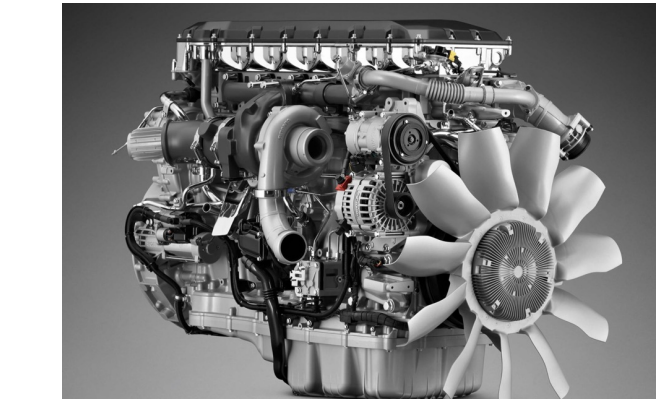
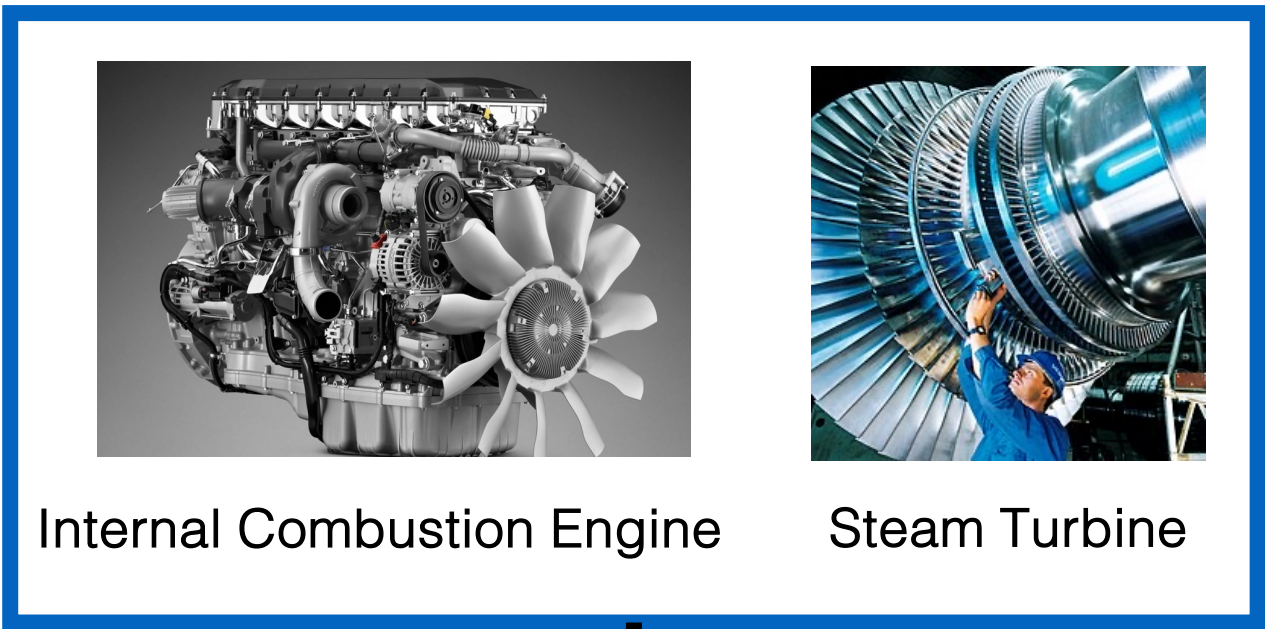
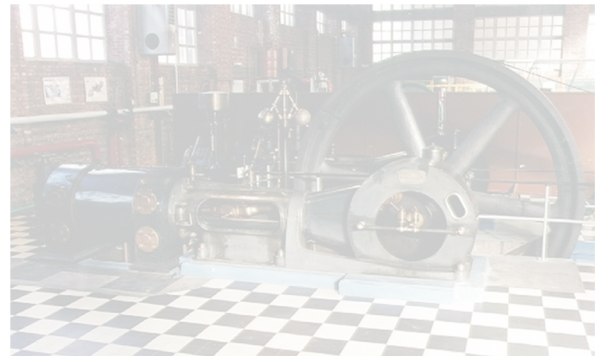
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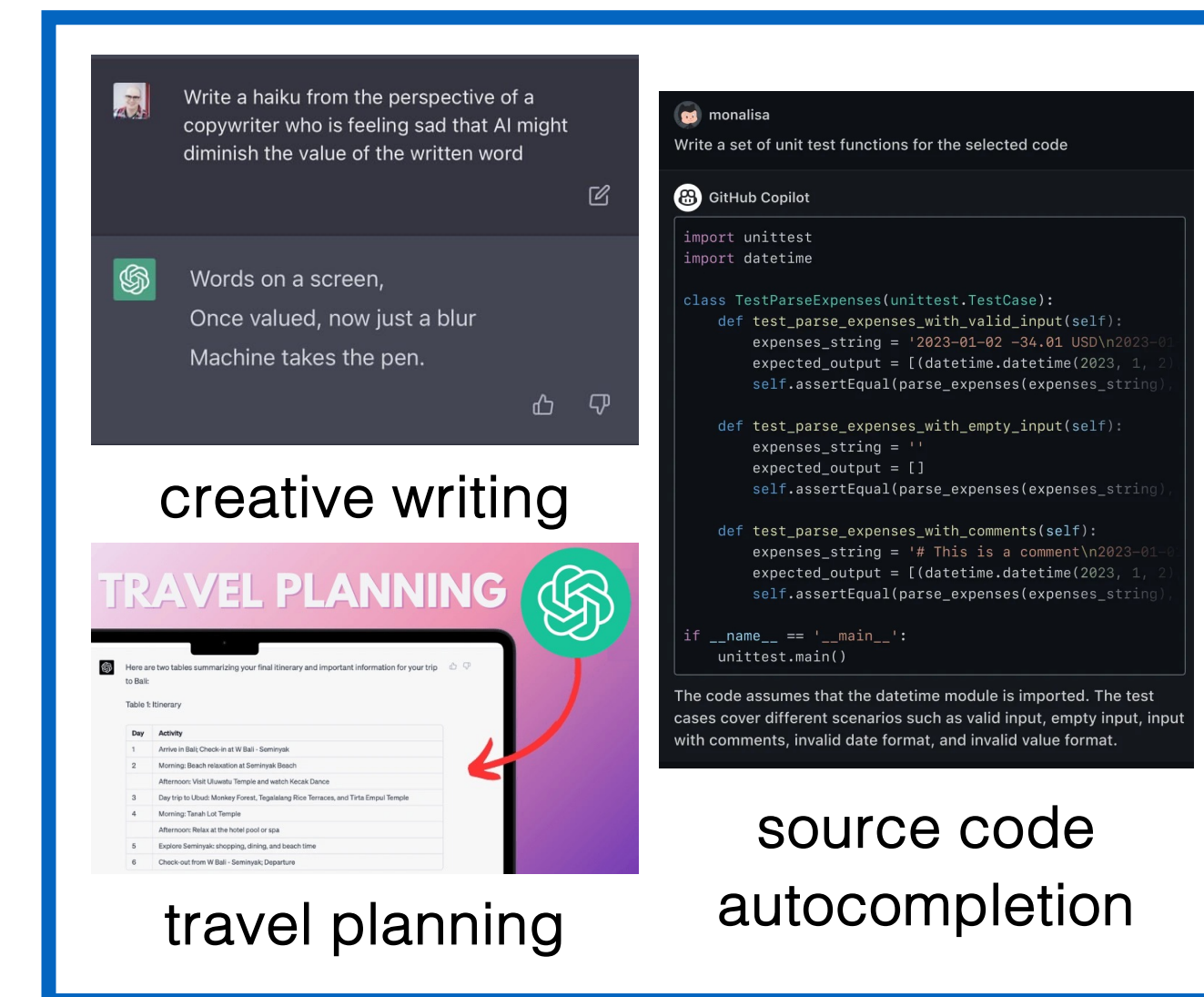
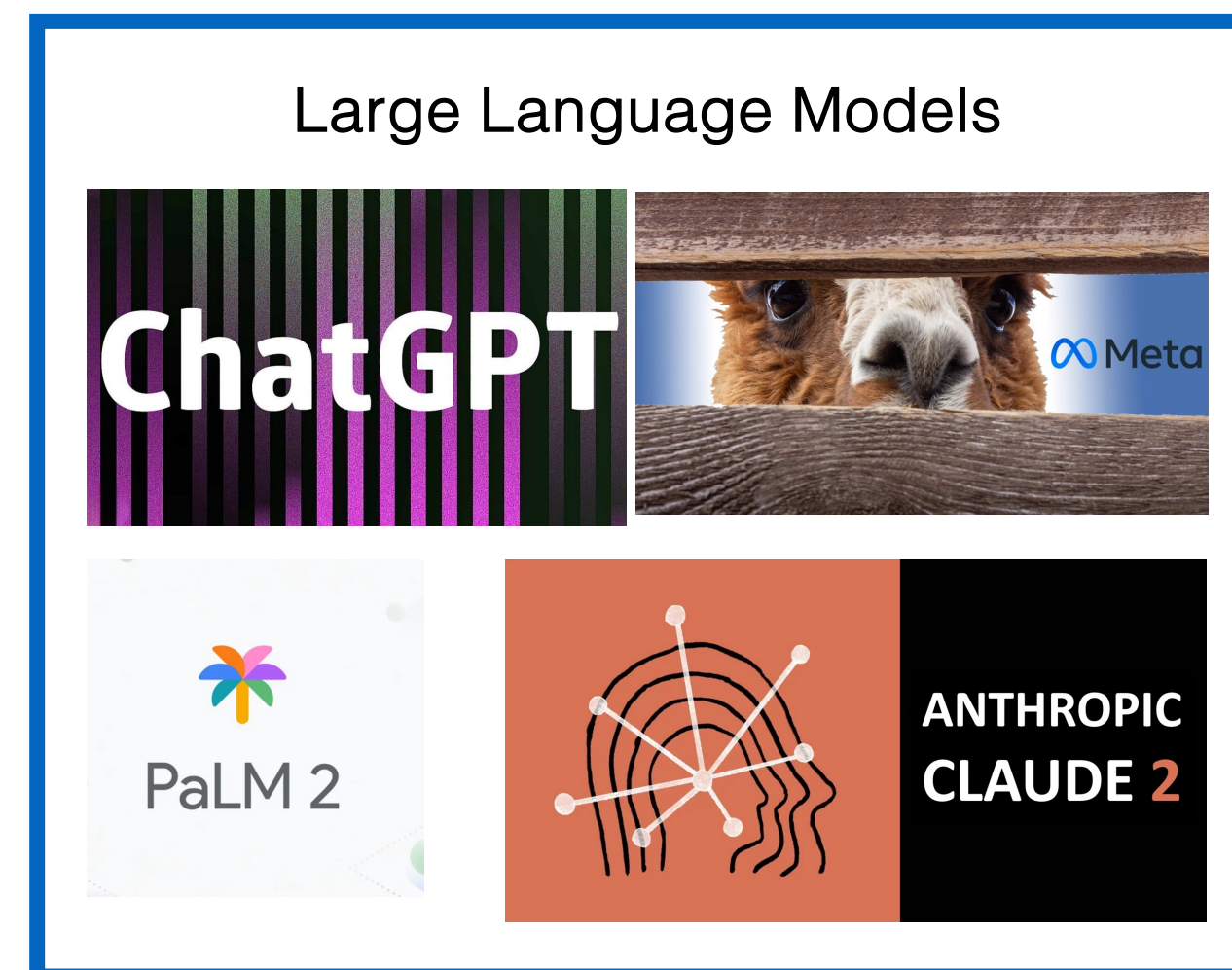
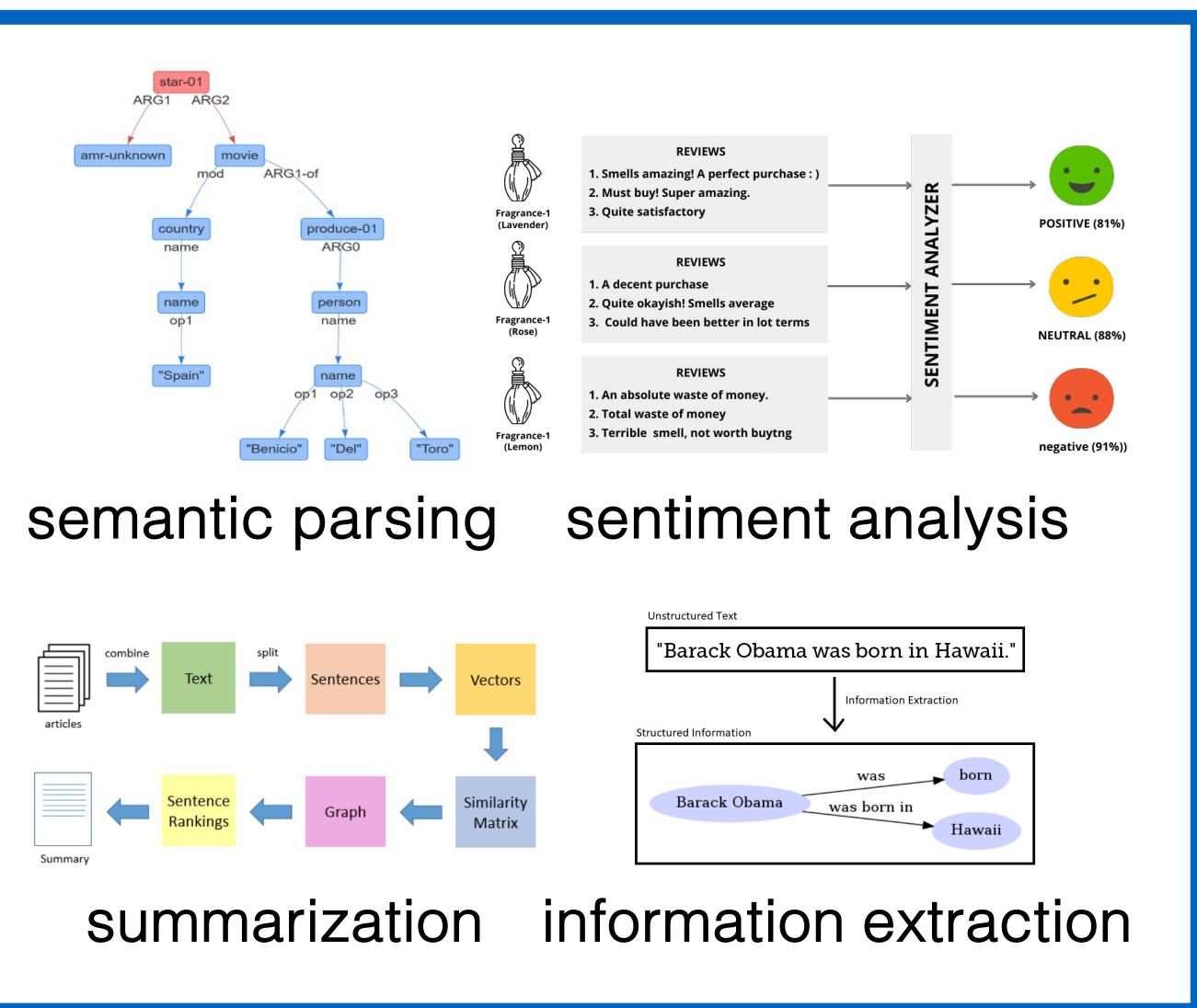


Internal Combustion Engine

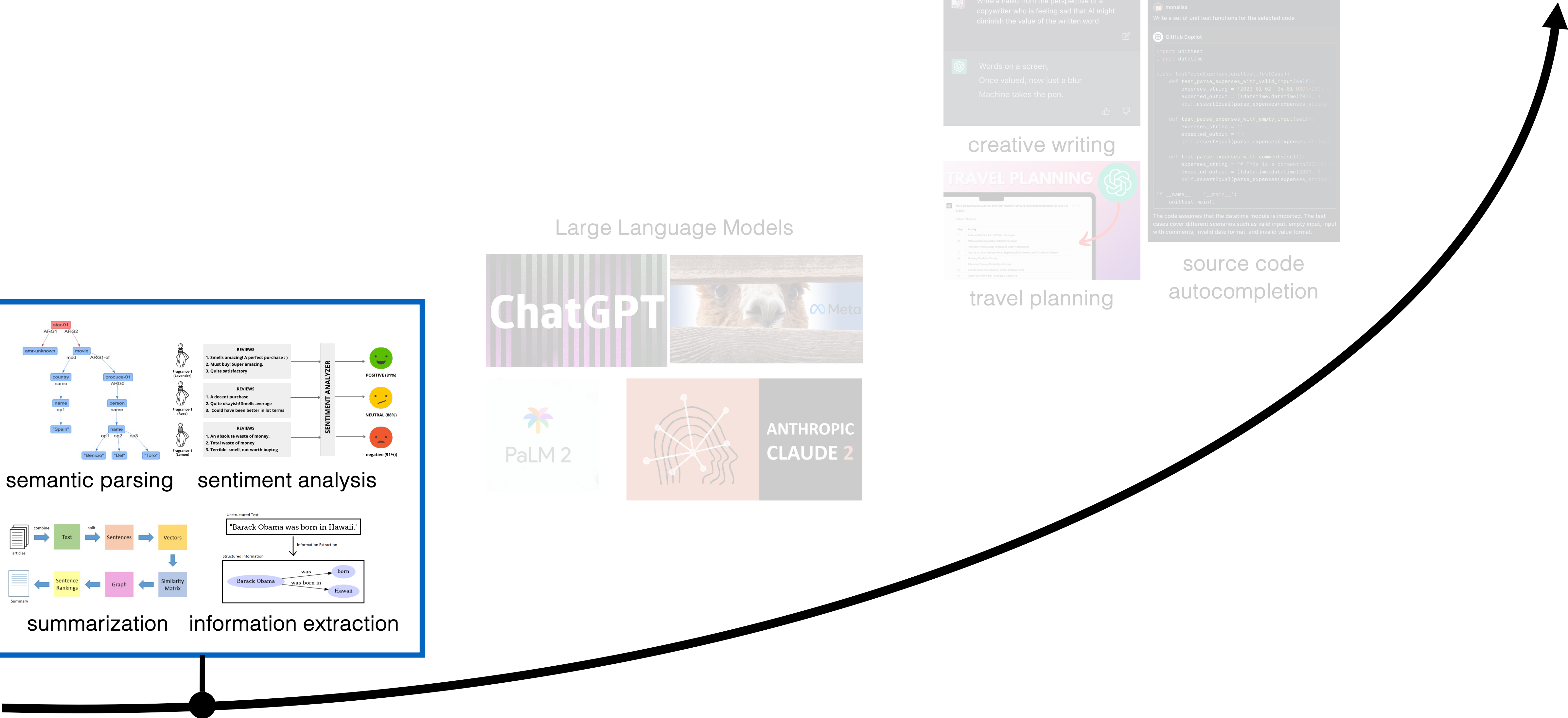
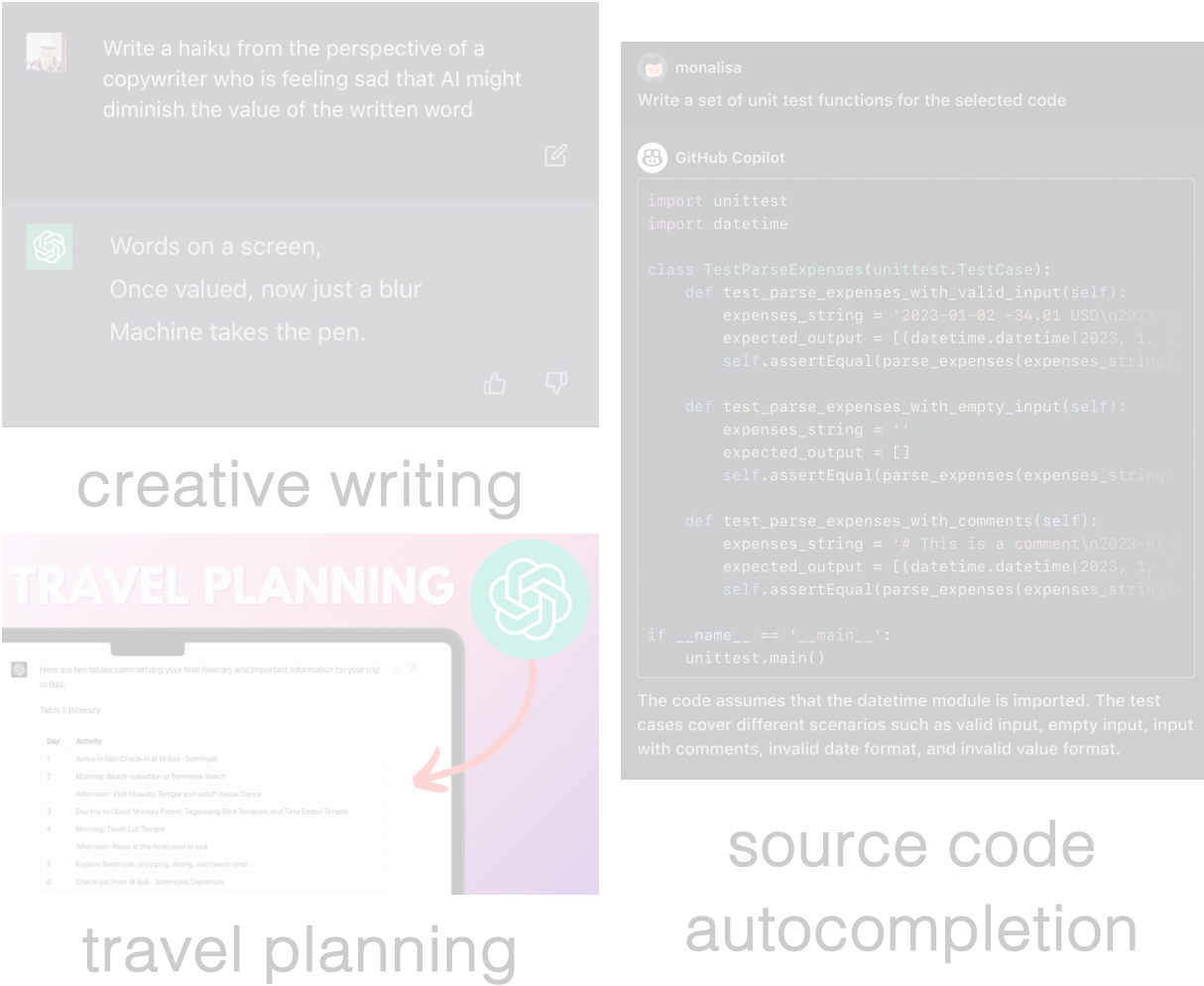
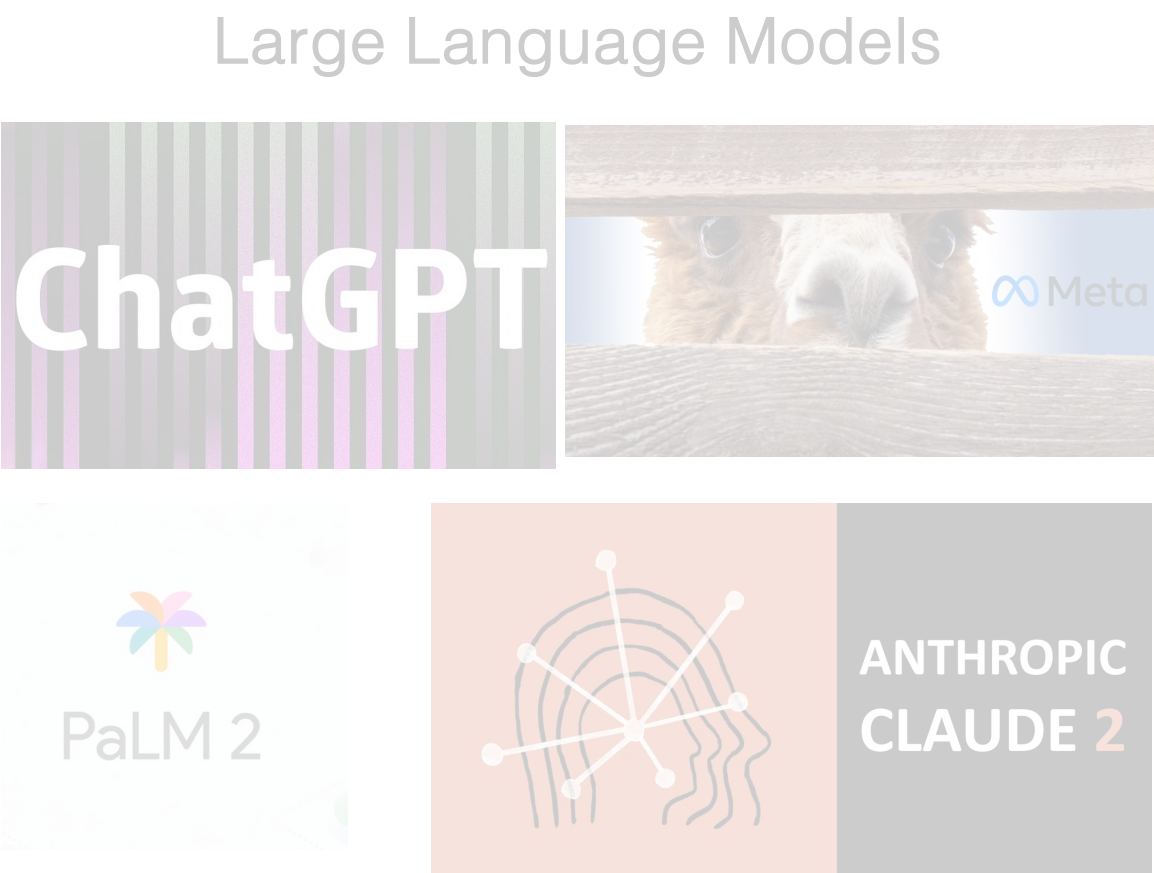
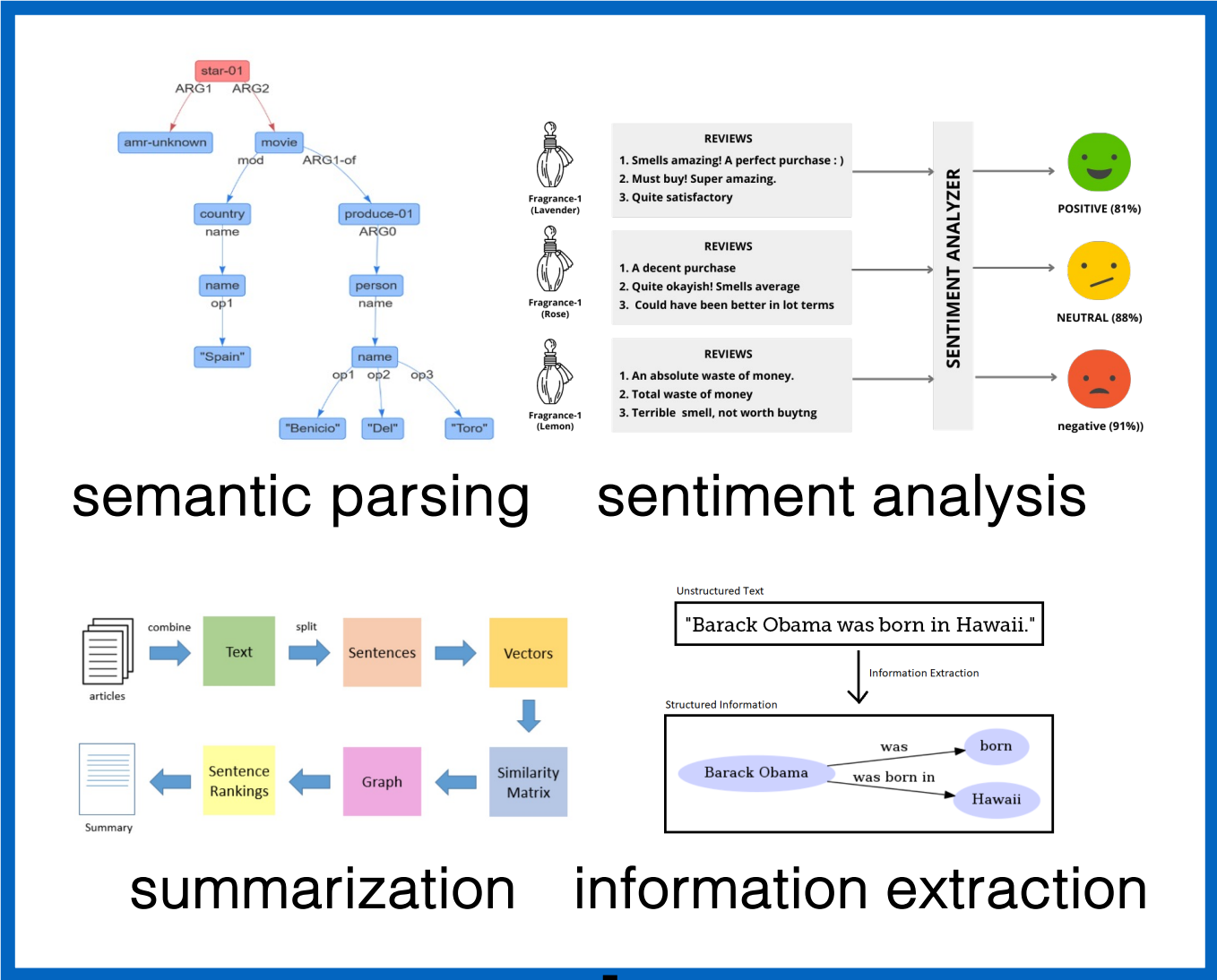


Steam Turbine

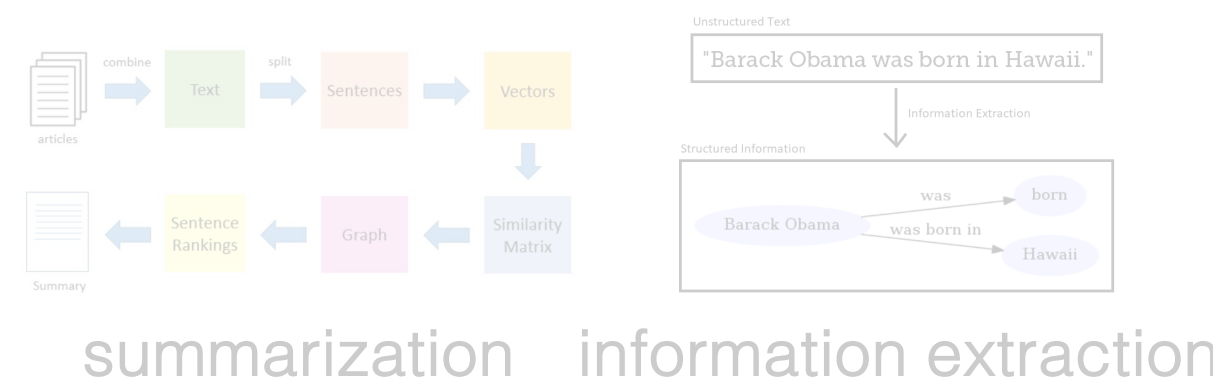
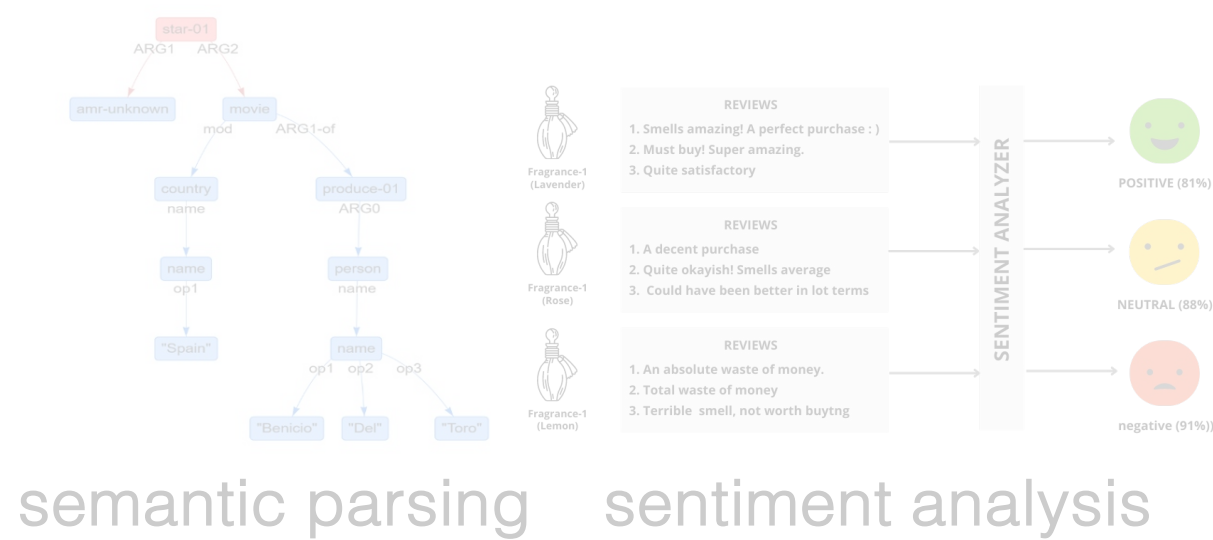
Specialist → Generalist → Specializing Generalist





Specialist → Generalist → Specializing Generalist





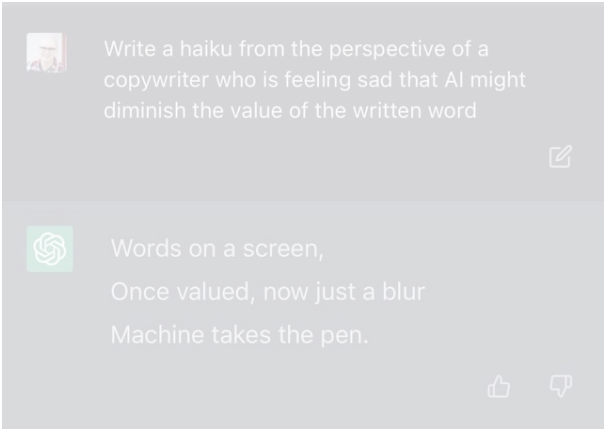
Specialist → Generalist → Specializing Generalist



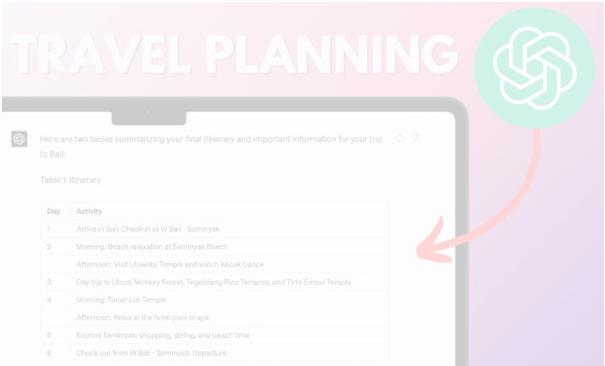
Large Language Models








creative writing

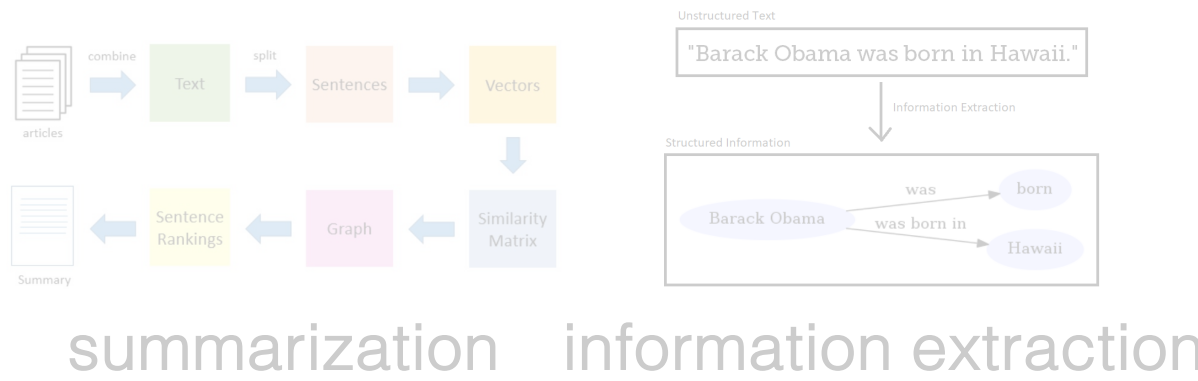
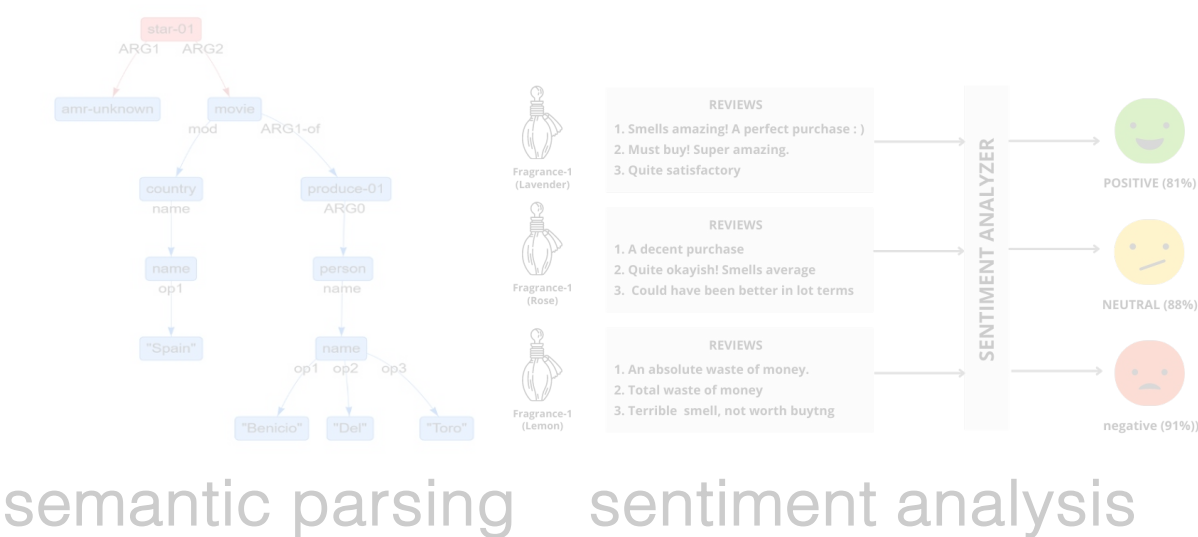


travel planning



source code autocompletion

Specialist → Generalist → Specializing Generalist



Write a haiku from the perspective of a copywriter who is feeling sad that AI might diminish the value of the written word

Words on a screen,
Once valued, now just a blur
Machine takes the pen.

creative writing

Write a set of unit test functions for the selected code

```
import unittest
import datetime

class TestParseExpenses(unittest.TestCase):
    def test_parse_expenses_with_valid_input(self):
        expenses_string = '2023-01-02 -34.01 USD\n2023-01-03 12.34 USD\n2023-01-04 56.78 USD'
        expected_output = [(datetime.datetime(2023, 1, 2), -34.01, 'USD'), (datetime.datetime(2023, 1, 3), 12.34, 'USD'), (datetime.datetime(2023, 1, 4), 56.78, 'USD')]
        self.assertEqual(parse_expenses(expenses_string), expected_output)

    def test_parse_expenses_with_empty_input(self):
        expenses_string = ''
        expected_output = []
        self.assertEqual(parse_expenses(expenses_string), expected_output)

    def test_parse_expenses_with_comments(self):
        expenses_string = '# This is a comment\n2023-01-02 -34.01 USD\n2023-01-03 12.34 USD\n2023-01-04 56.78 USD'
        expected_output = [(datetime.datetime(2023, 1, 2), -34.01, 'USD'), (datetime.datetime(2023, 1, 3), 12.34, 'USD'), (datetime.datetime(2023, 1, 4), 56.78, 'USD')]
        self.assertEqual(parse_expenses(expenses_string), expected_output)

if __name__ == '__main__':
    unittest.main()
```

The code assumes that the datetime module is imported. The test cases cover different scenarios such as valid input, empty input, input with comments, invalid date format, and invalid value format.

source code autocompletion

Here are two tables summarizing your travel history and important information for your trip to Bali:

Day	Activity
1	Arrive in Bali, Check-in at W Bali - Sanuraya
2	Morning: Beach relaxation at Sanuraya Beach
3	Afternoon: Visit Ubud, Temples and watch Kapatihan Dance
4	Day trip to Mount Merapi Forest, Tegayutan Rice Terraces, and Tirta Empul Temple
5	Morning: Tegal Lela Temple
6	Afternoon: Relax at the hotel pool or spa
7	Evening: Dinner at a local warung, shopping and learn time
8	Check-out from W Bali - Sanuraya, Departure

travel planning



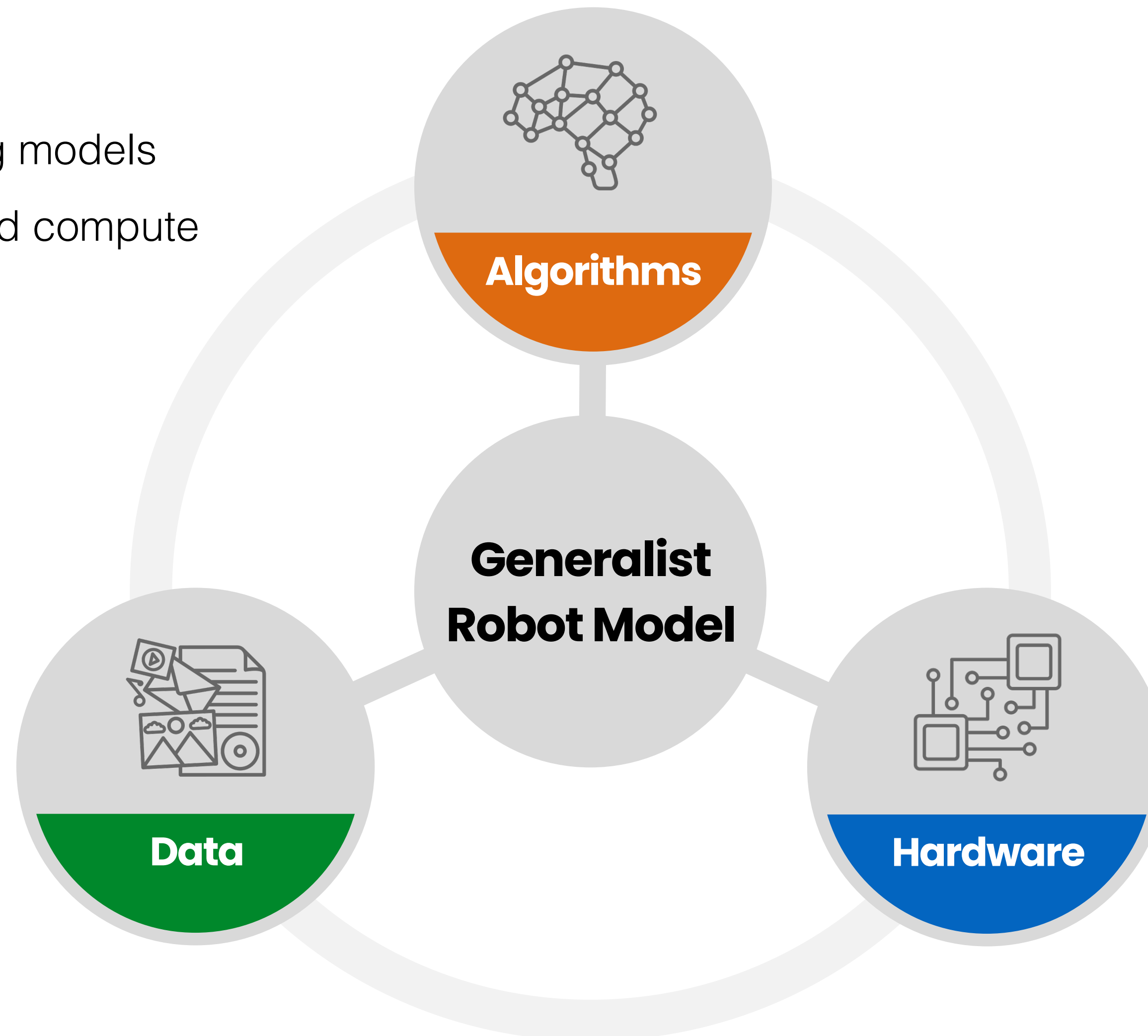
Recipe for Building Generalist Robot Models

Scaling Law

Powerful robot learning models
that scale with data and compute

Data Flywheel

New mechanism to collect
massive training data



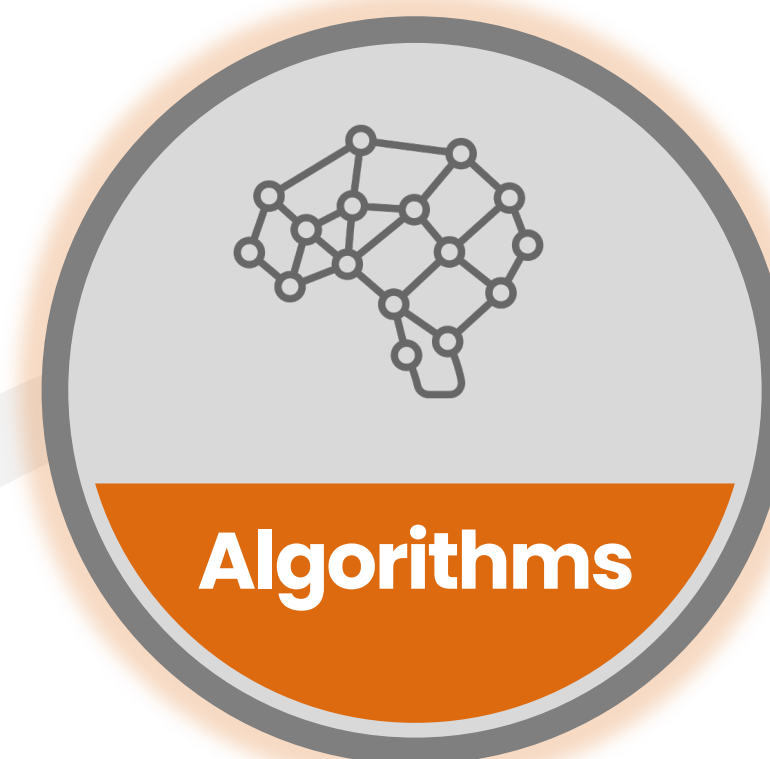
Humanlike Embodiment

Humanoid robot platform for
broad applications

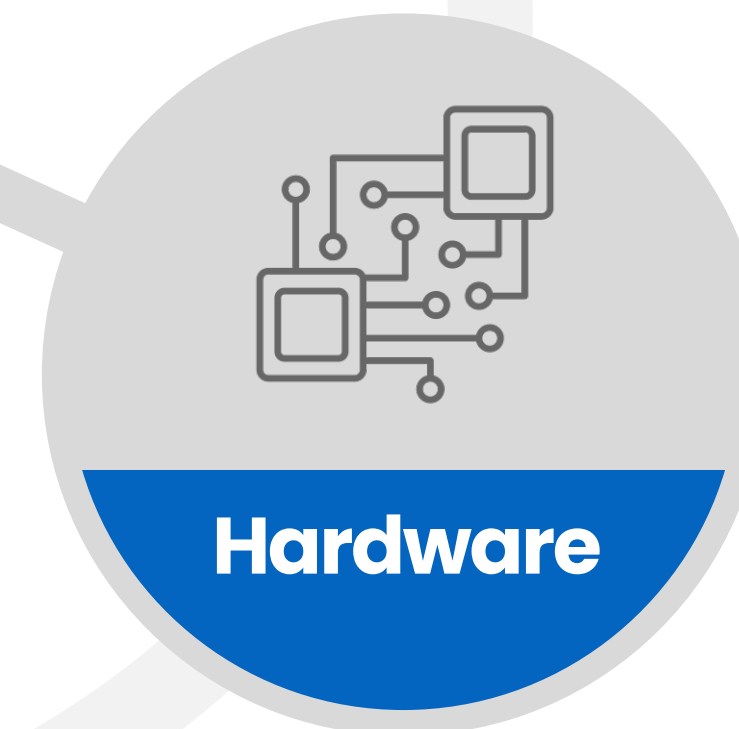
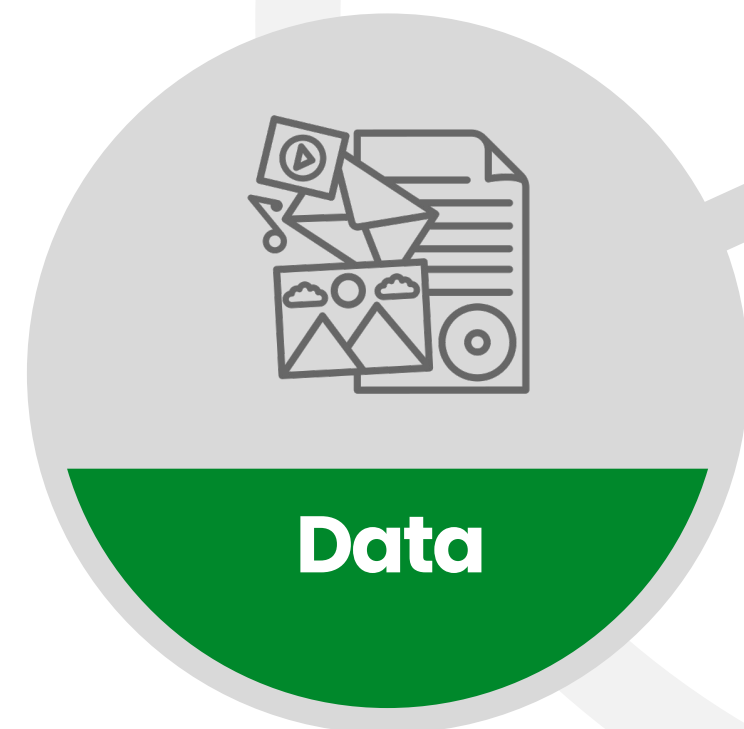
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**Generalist
Robot Model**



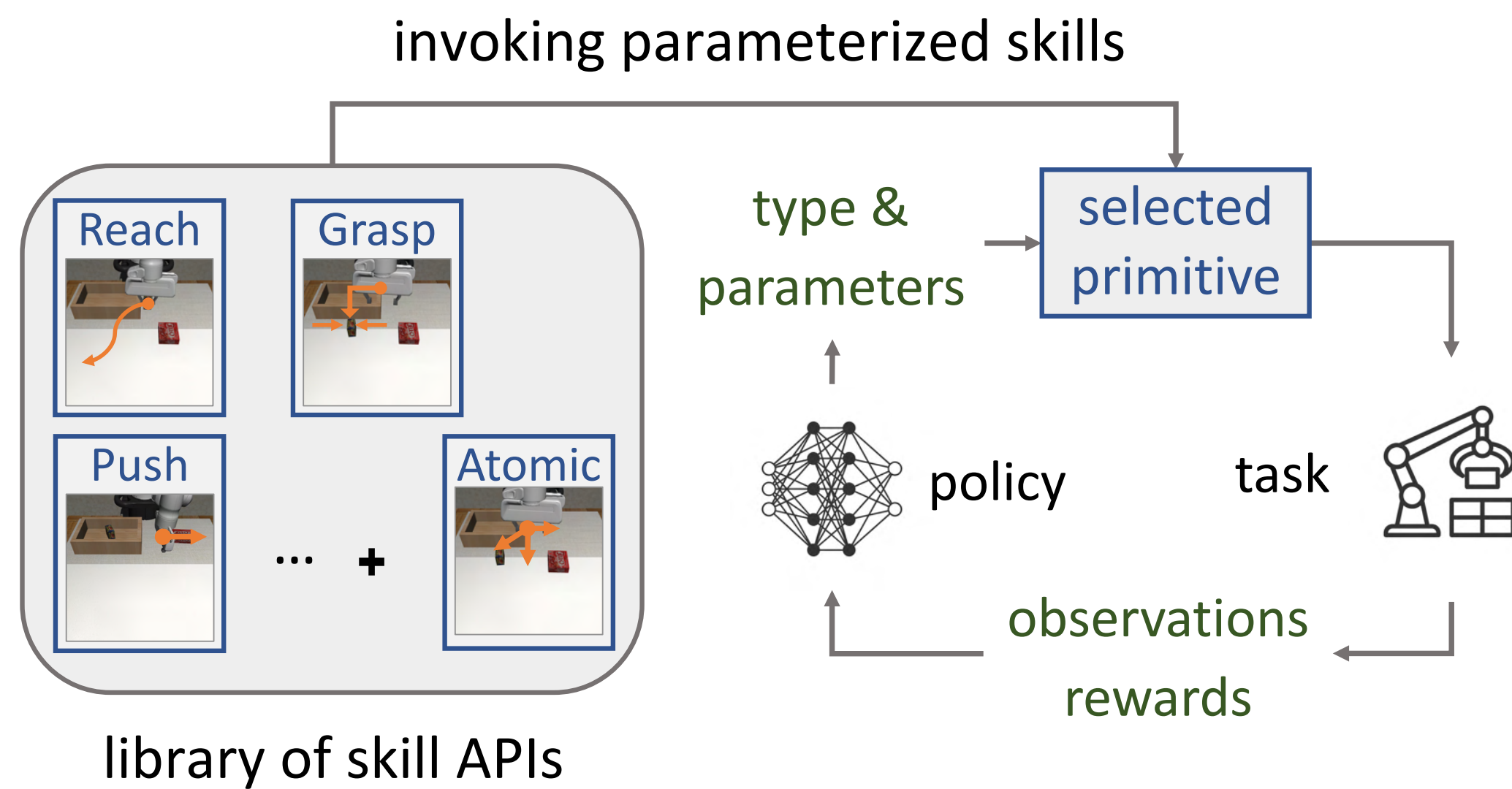
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Key Idea: Skills as APIs and Scaling Law



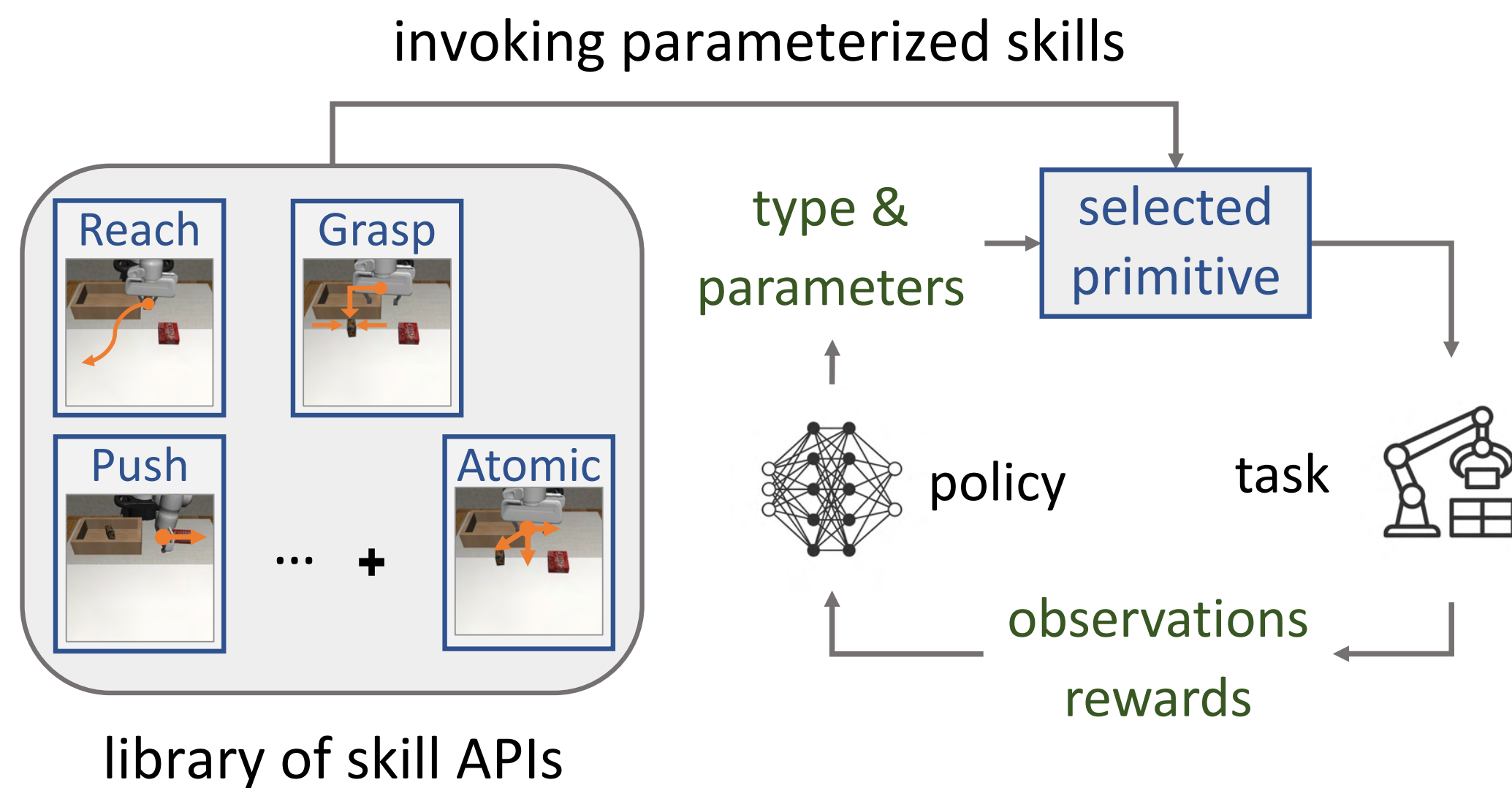
Skills as APIs

(Nasiriany et al. ICRA 2022)



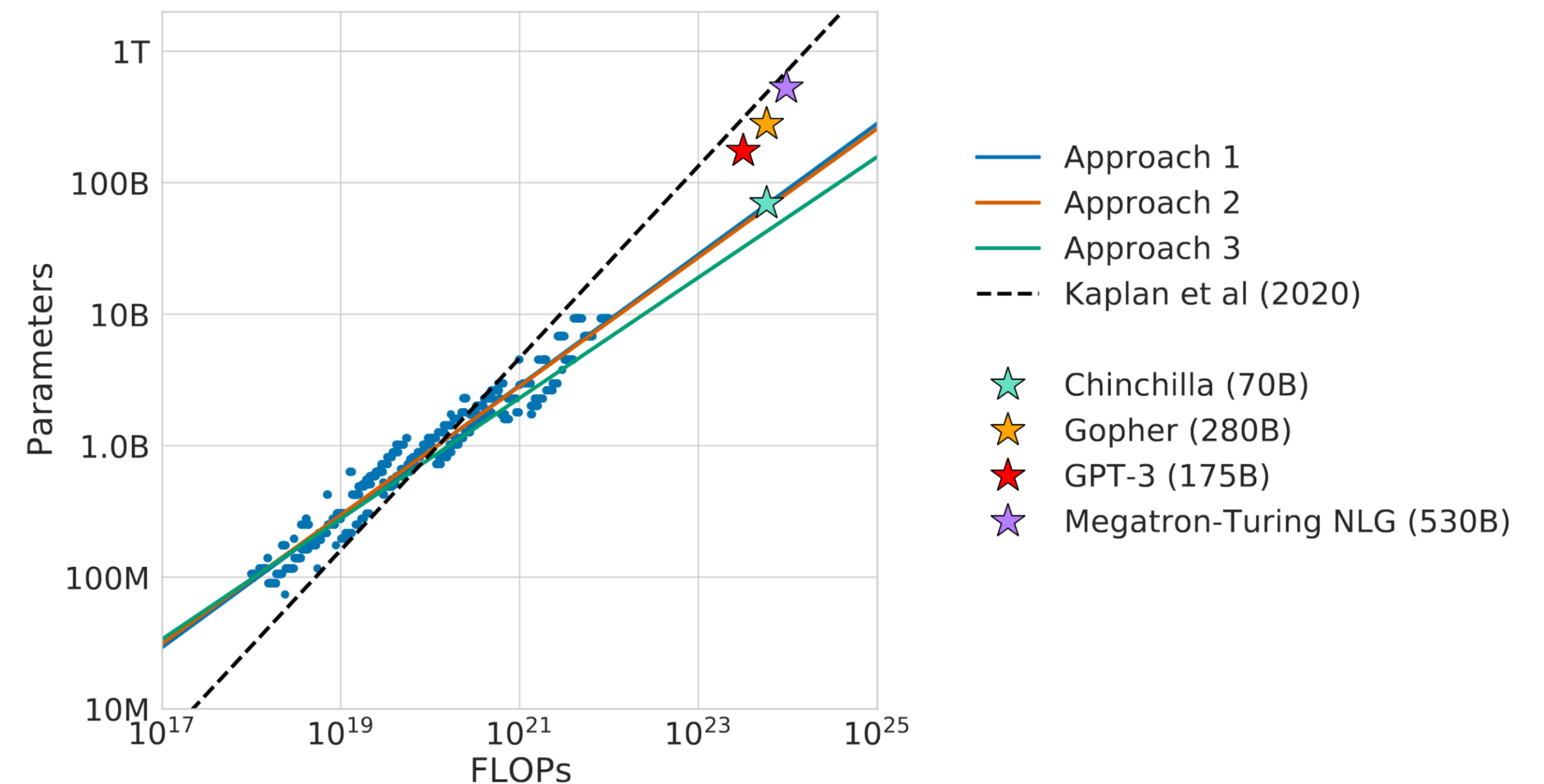
Soroush Nasiriany

Key Idea: Skills as APIs and Scaling Law



Skills as APIs

(Nasiriany et al. ICRA 2022)



Scaling Law for Language Models

(Kaplan et al. 2020; Hoffmann et al. 2022)

Data-Efficient Imitation Learning for Sensorimotor Skills

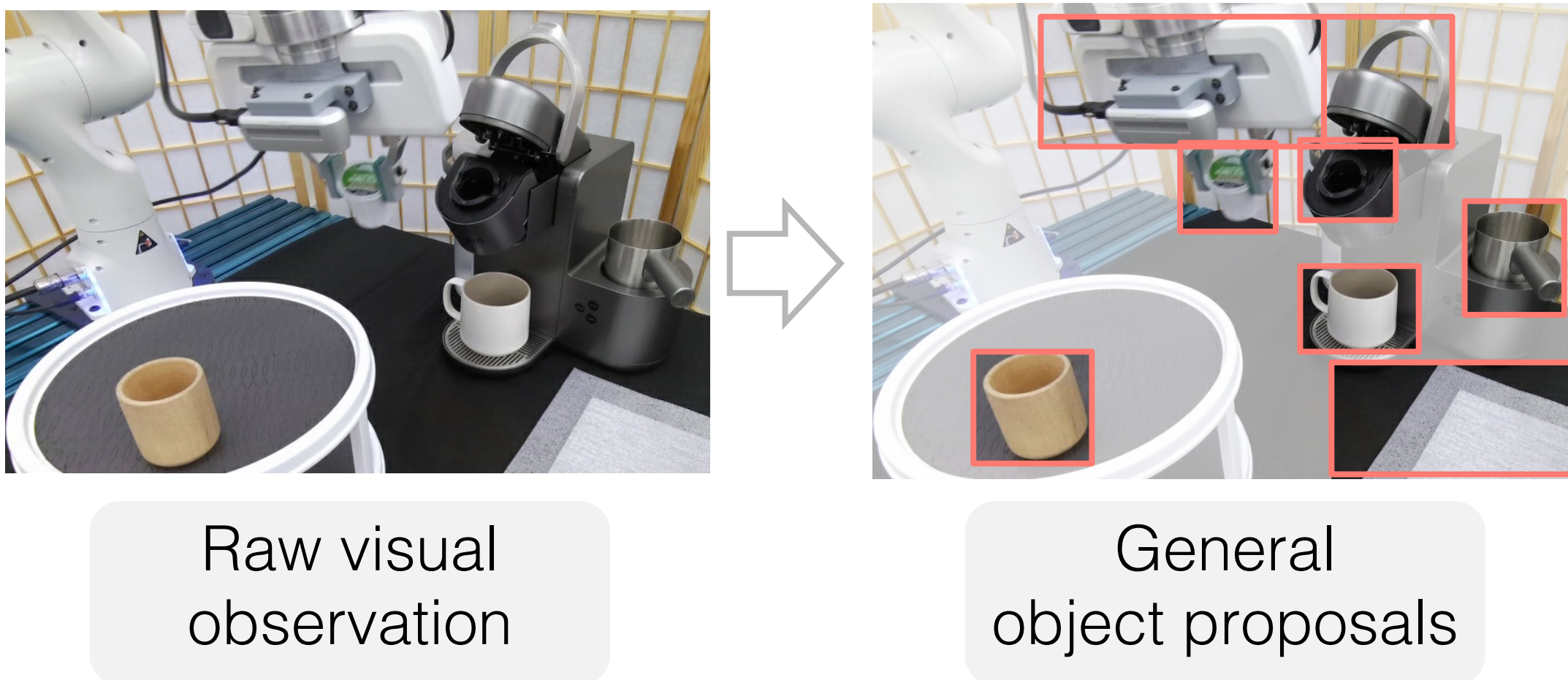


Raw visual
observation



Yifeng Zhu

Data-Efficient Imitation Learning for Sensorimotor Skills

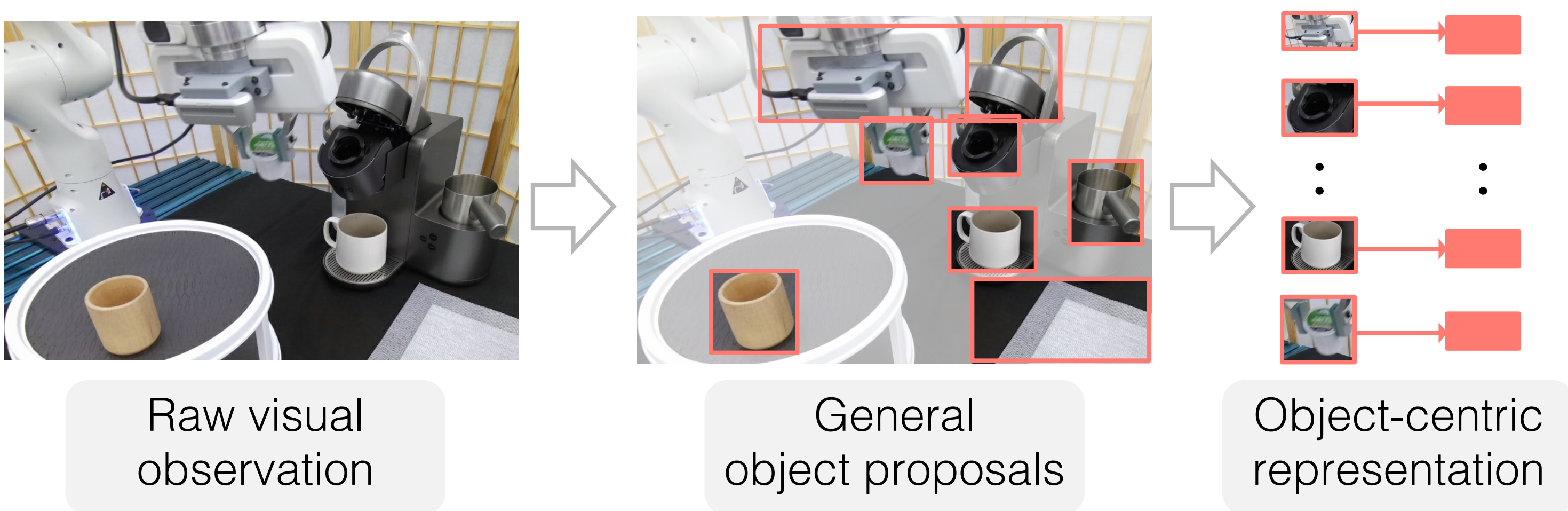


Yifeng Zhu



Large vision model trained on Internet-scale image datasets

Data-Efficient Imitation Learning for Sensorimotor Skills

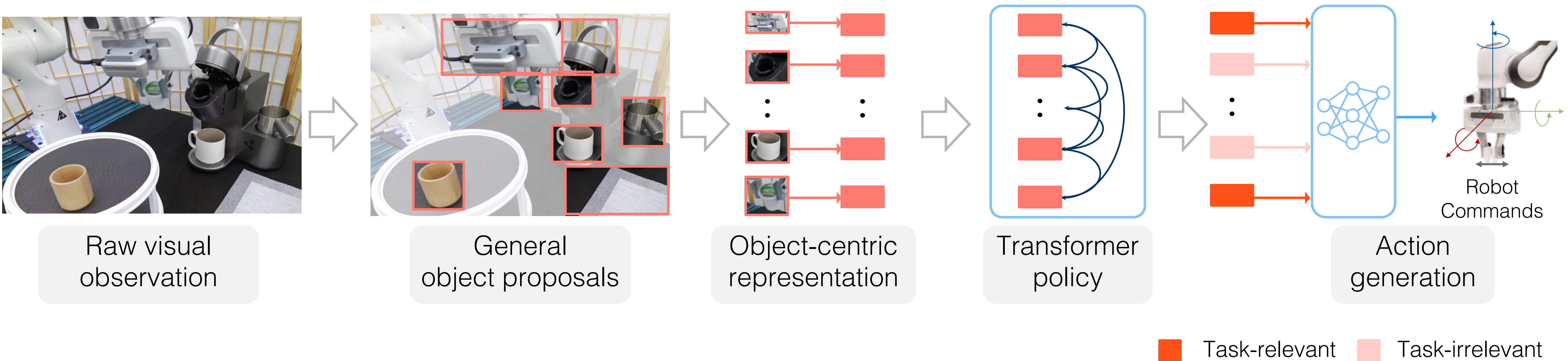


Encoding object **visual appearances**
and their **spatial locations**



Yifeng Zhu

Data-Efficient Imitation Learning for Sensorimotor Skills



Using transformers to select **task-relevant objects** and reason about **their relations**



Yifeng Zhu

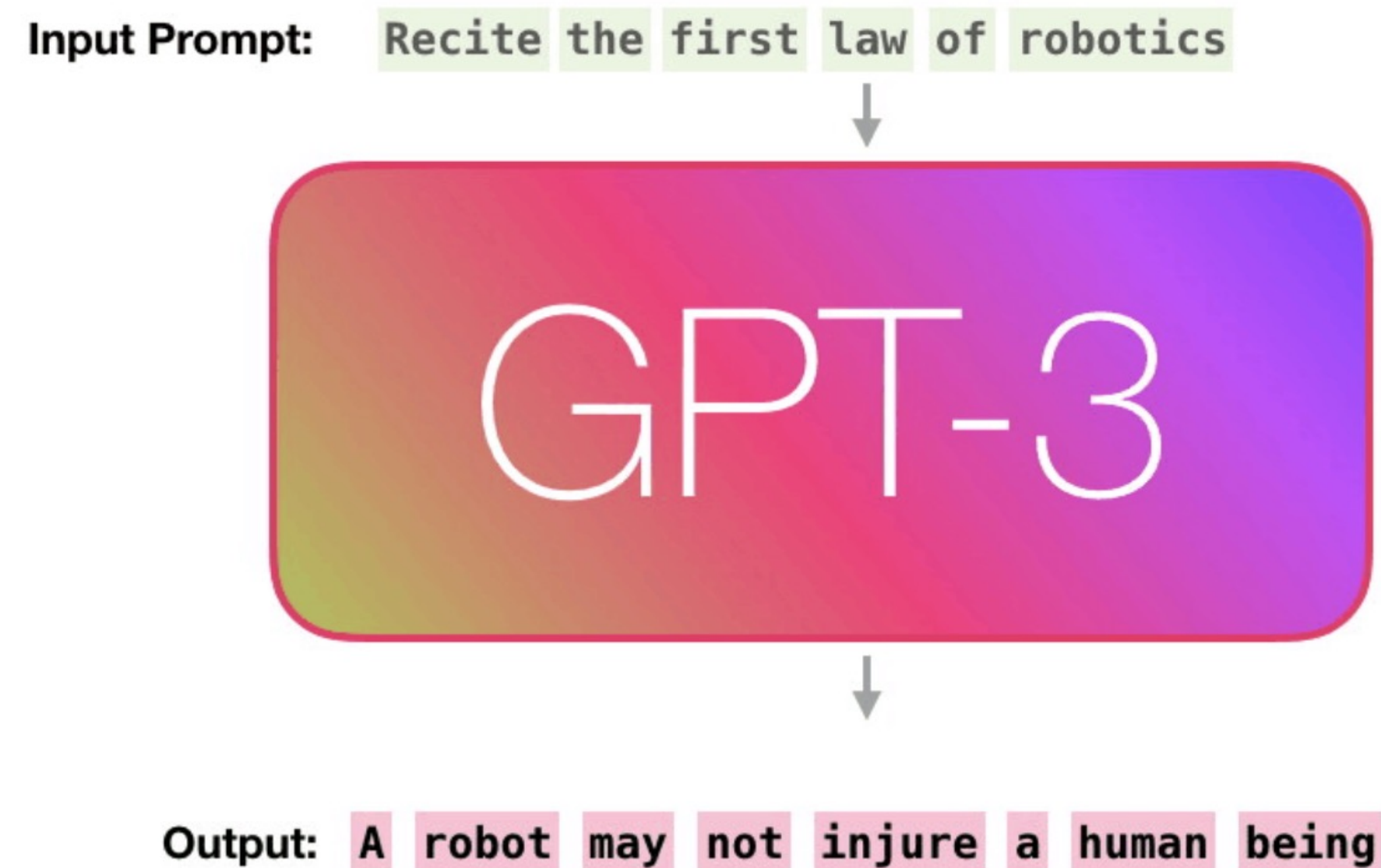


Policy Input

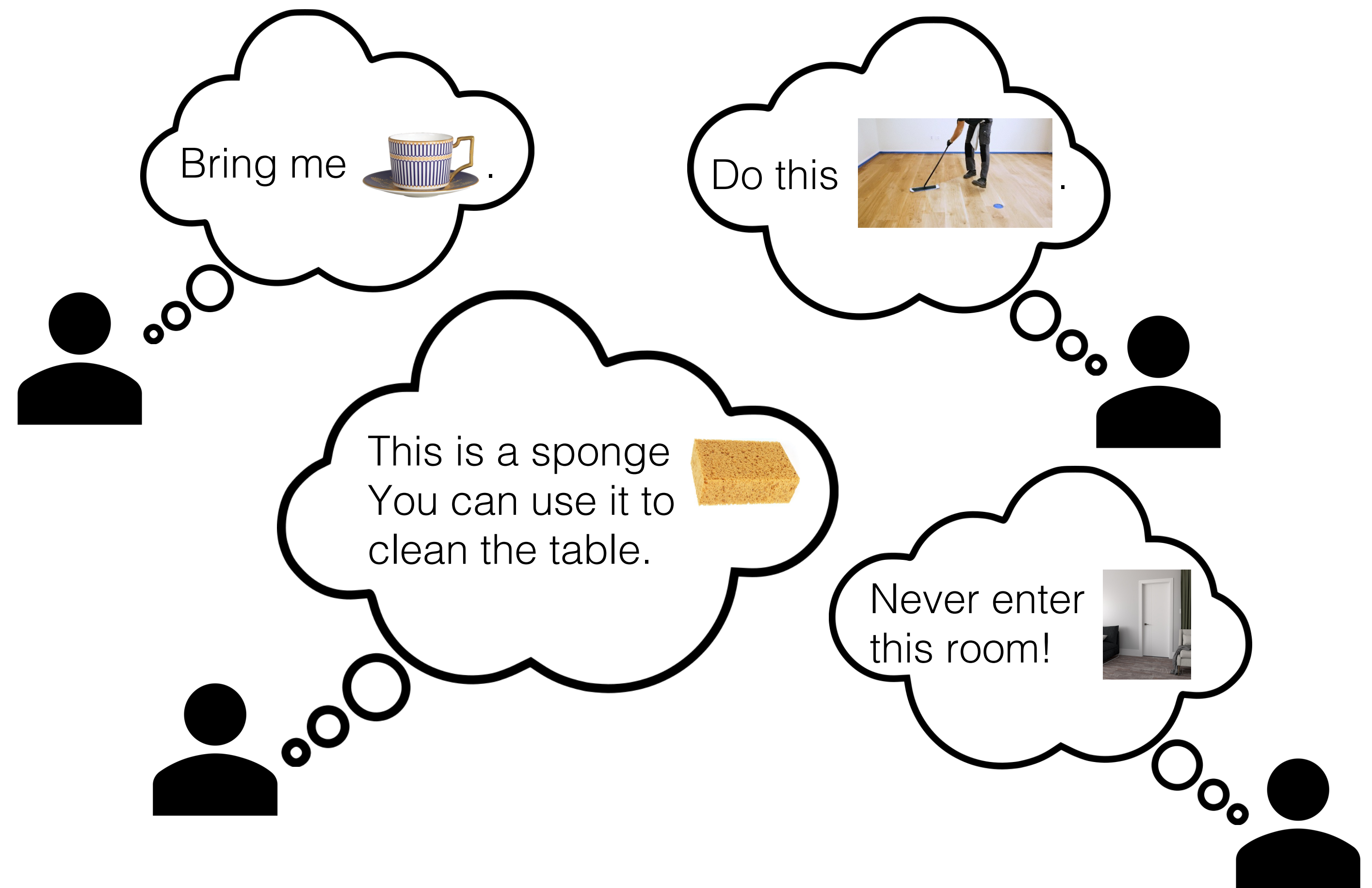
It learns to make coffee without additional annotations on human demonstrations.

Massively Multi-Task Robot Learning for Model Scaling

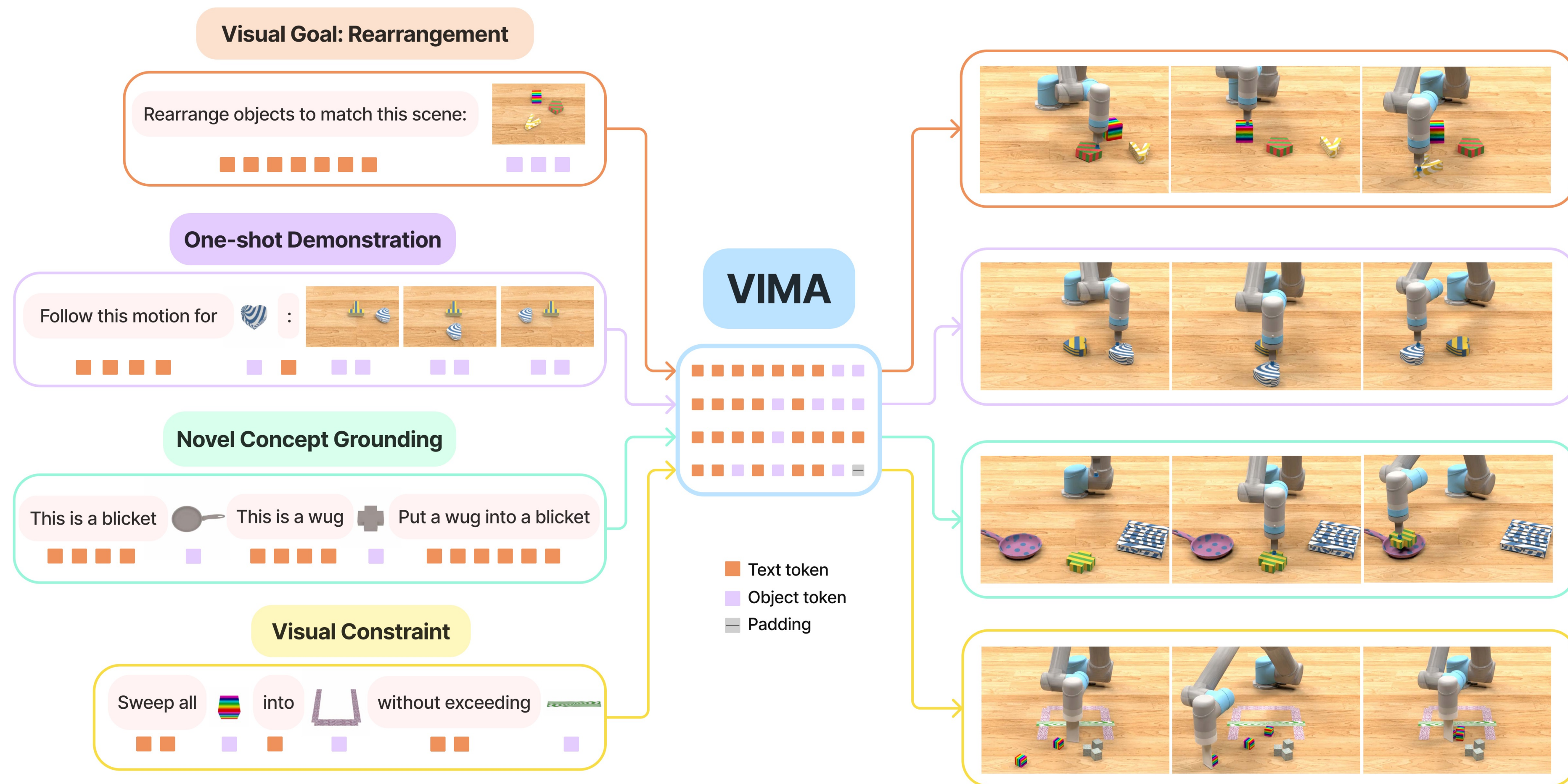
What if we can prompt a household robot to ...



[Credit: Jay Alammam]



Massively Multi-Task Robot Learning for Model Scaling



generalist robot agent for multi-task learning and zero-shot generalization

Massively Multi-Task Robot Learning for Model Scaling

VIMA: Visuo-Motor Attention model

- Transformer **encoder-decoder**;
- Encodes **multimodal prompts** with a frozen language model;
- **Object-centric** representations for visual observations
- Predicts **skill APIs** given the prompt and interaction history.



VIMA

Massively Multi-Task Robot Learning for Model Scaling

Data scalability from 0.1% to full dataset

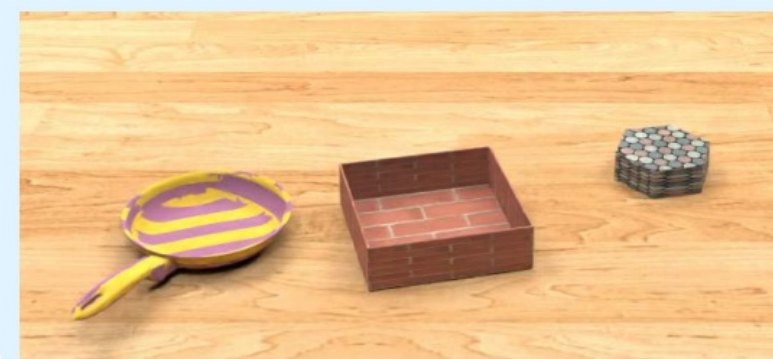
Level 1 Object Placement

Put the  into the 



Level 2 Novel Combination

Put the  into the 



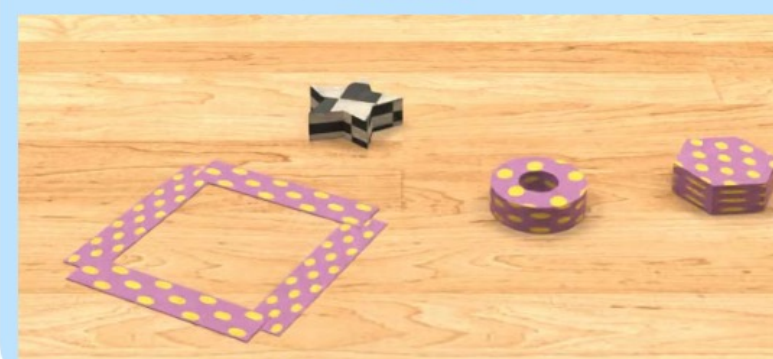
Level 3 Novel Object

Put the  into the 

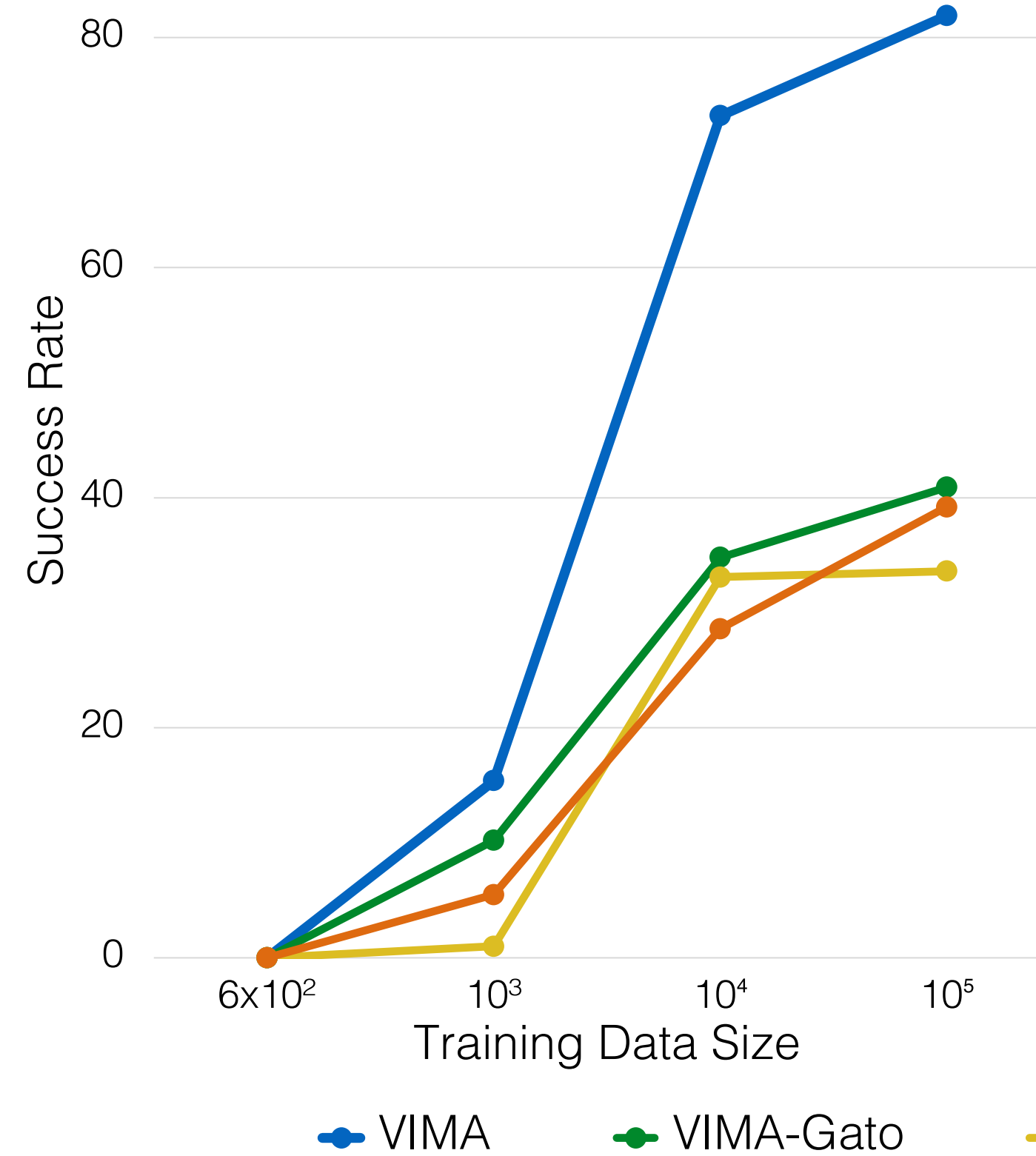


Level 4 Novel Task

Put all objects with the same texture as  into it

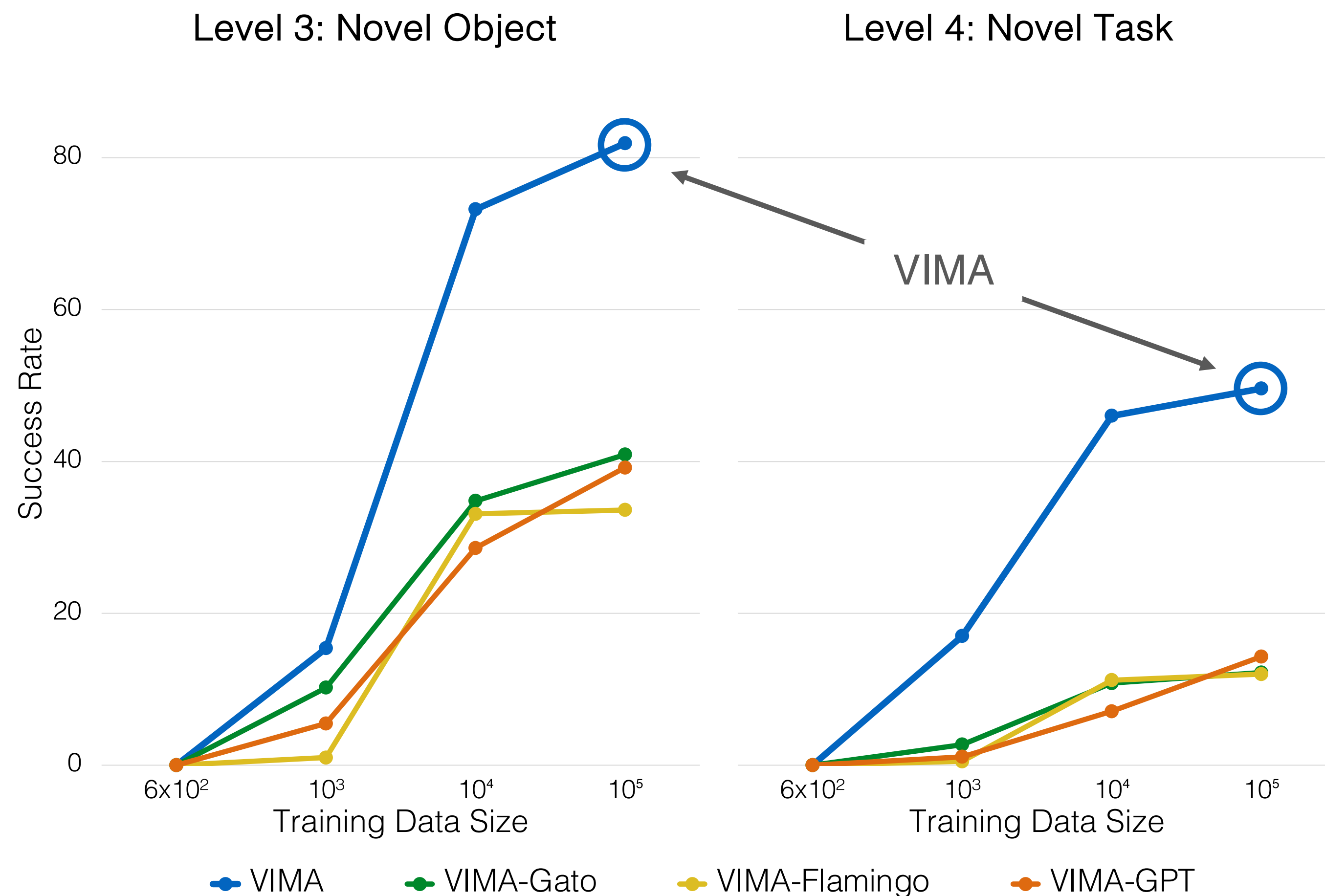
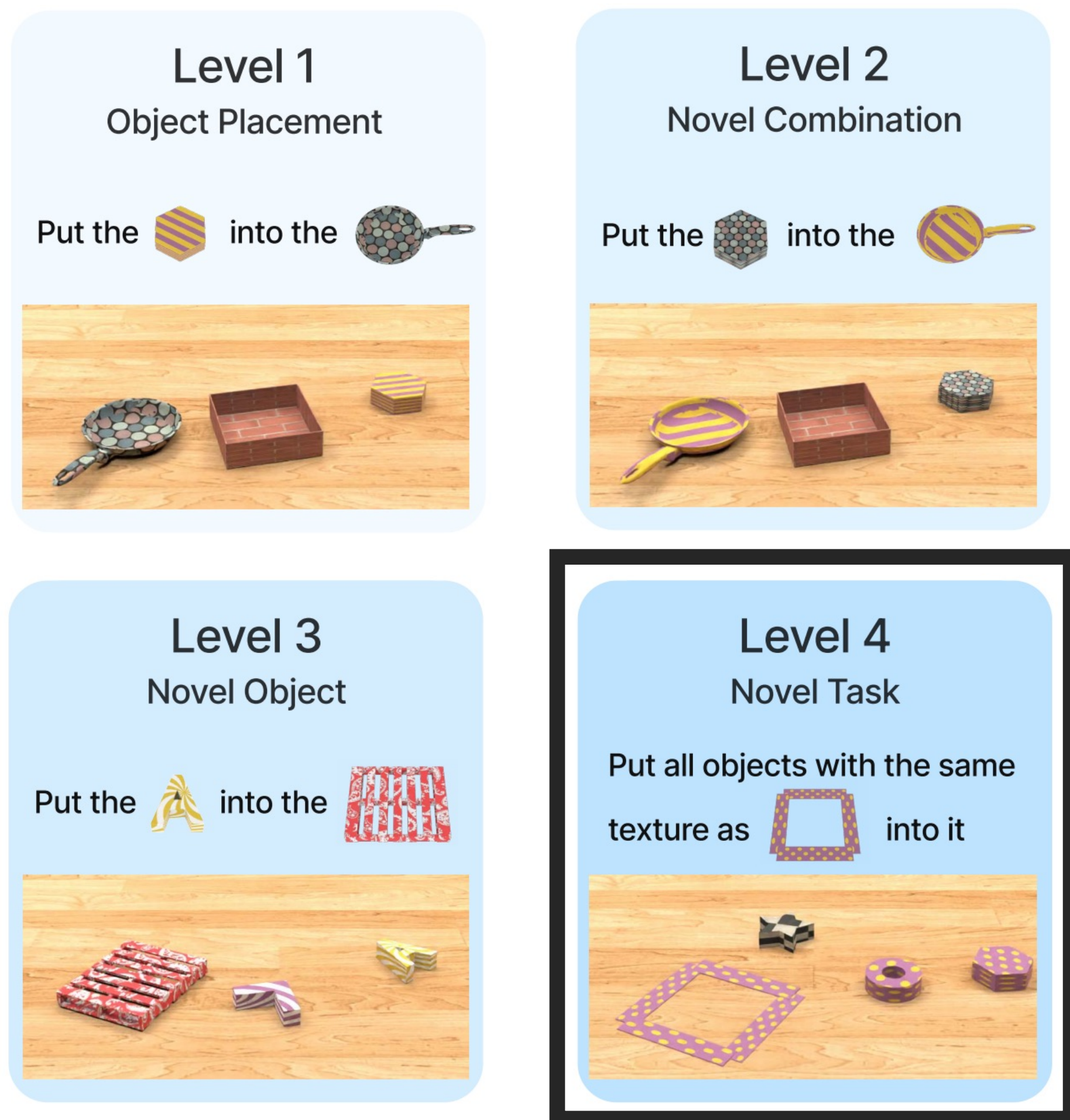


Level 3: Novel Object

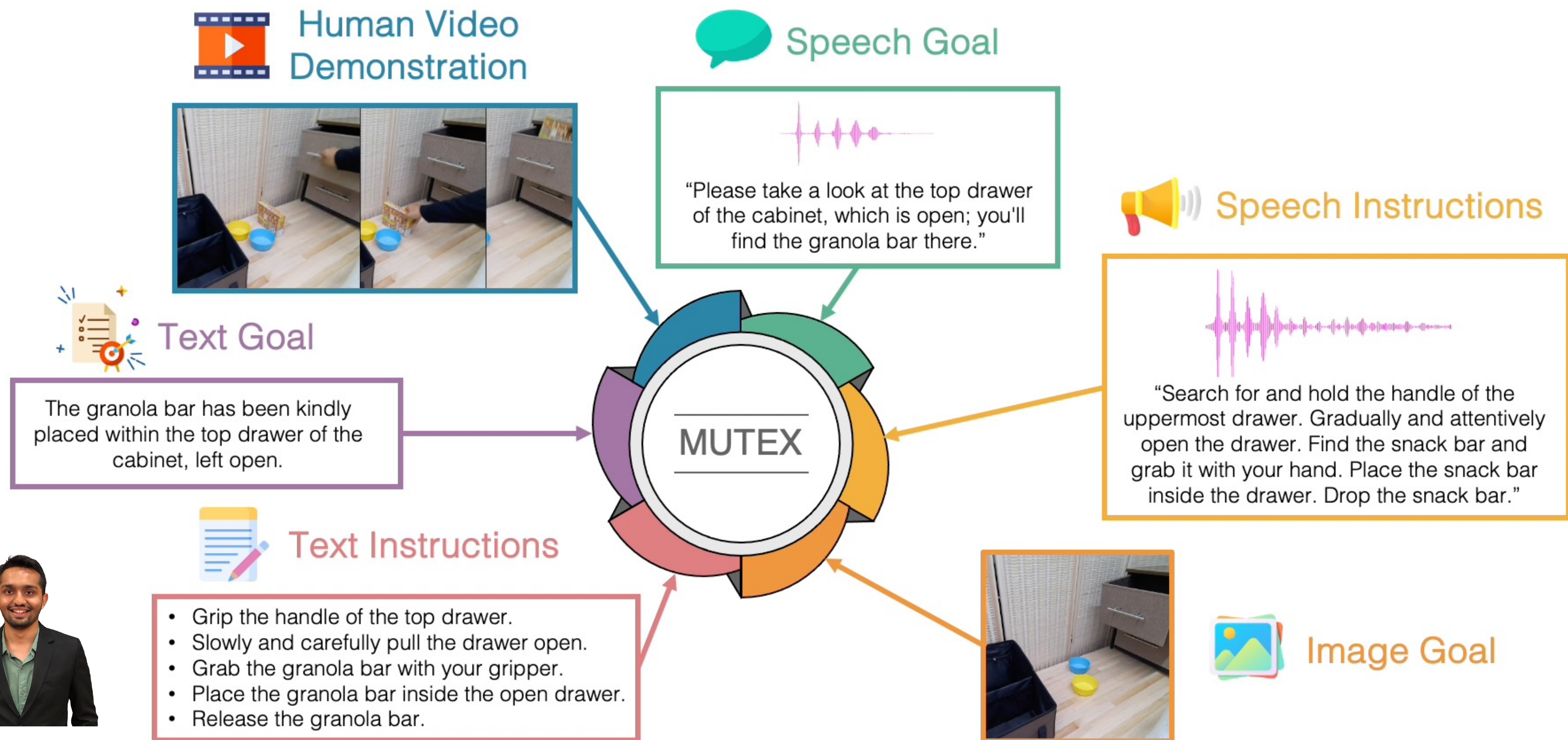


Massively Multi-Task Robot Learning for Model Scaling

Data scalability from 0.1% to full dataset



Massively Multi-Task Robot Learning for Model Scaling

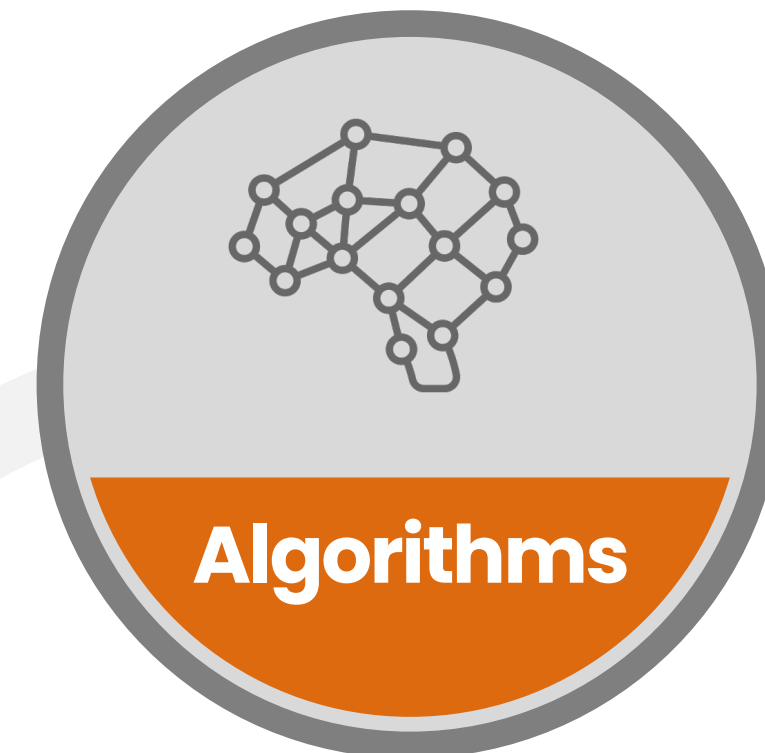


Rutav Shah

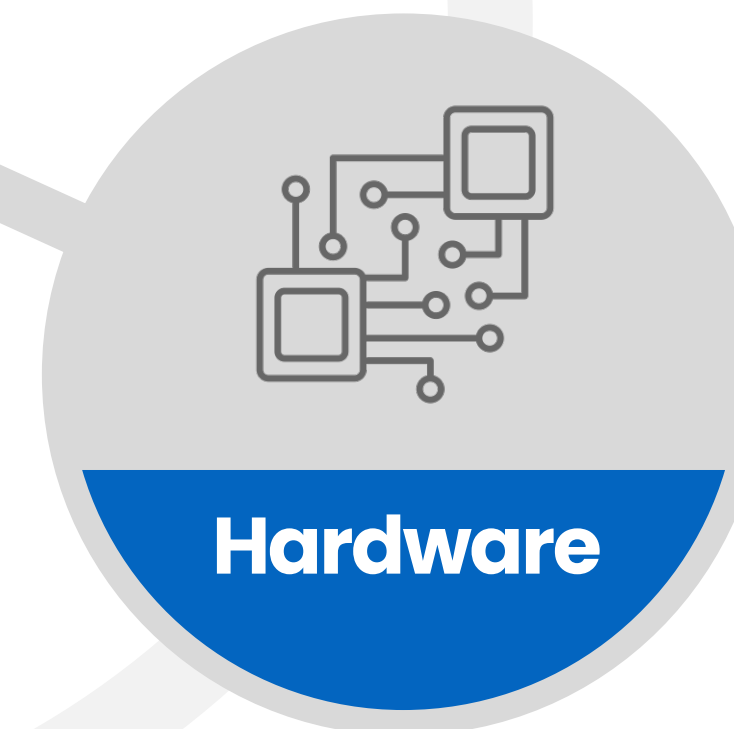
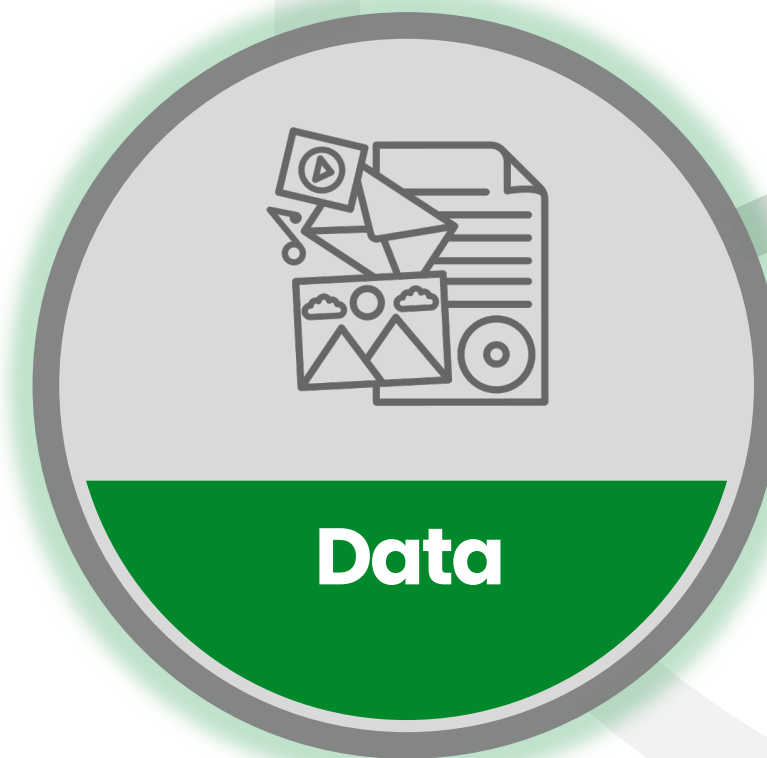
Recipe for Building Generalist Robot Models

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**Generalist
Robot Model**



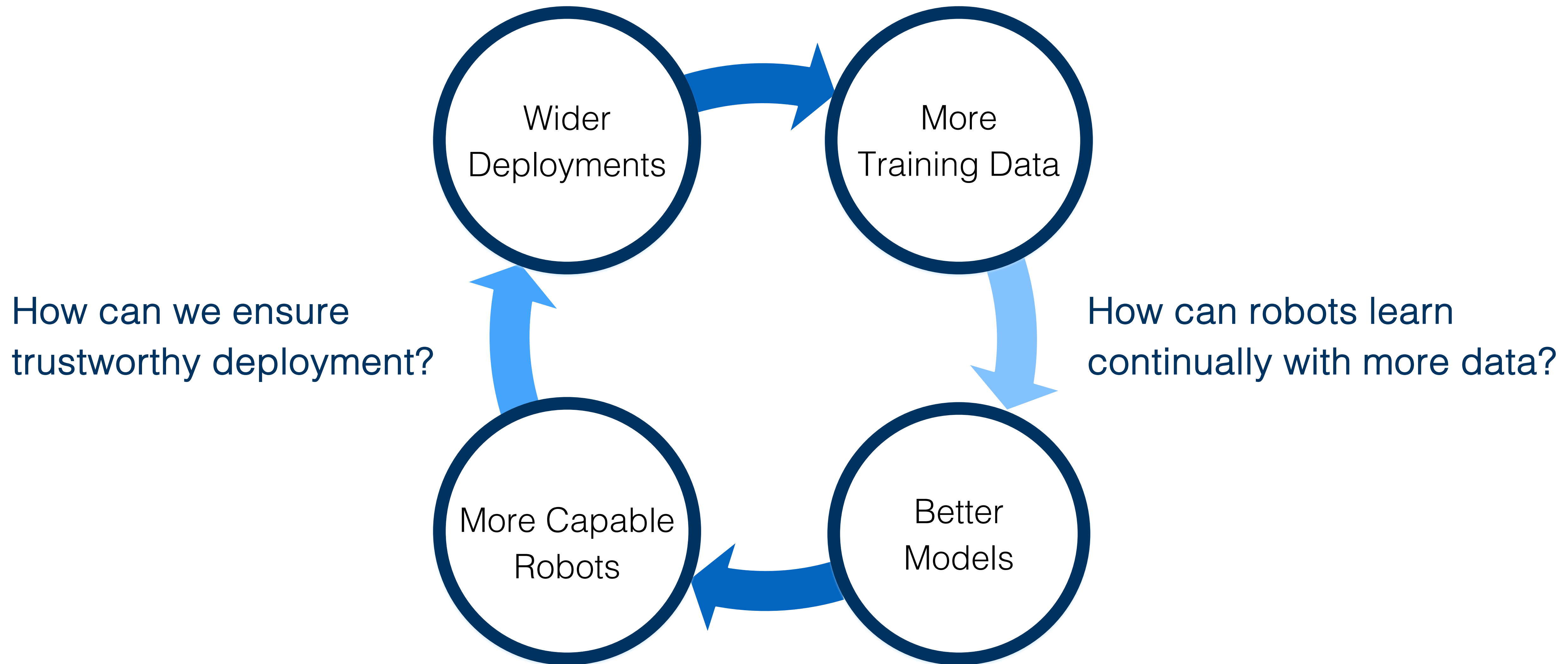
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Humanoid robot platform for
broad applications

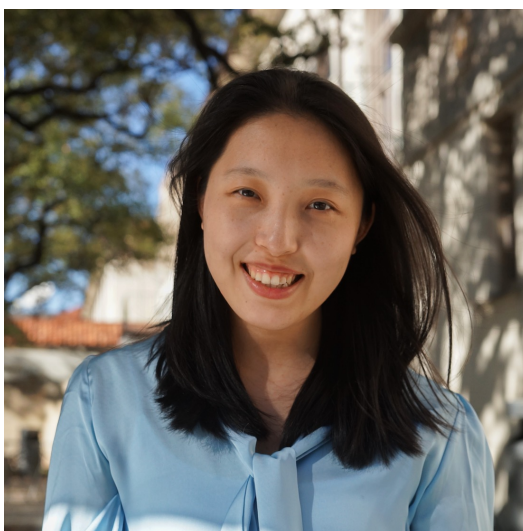
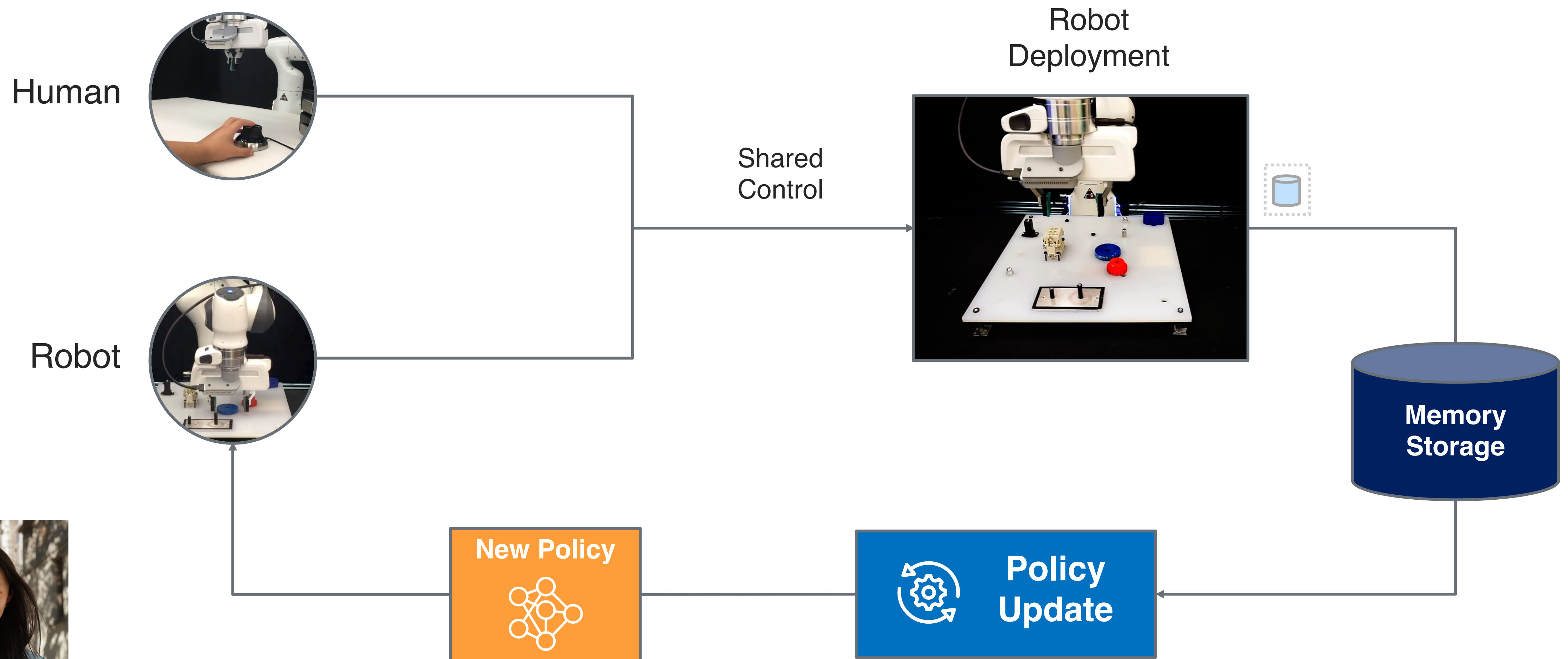
Data Flywheel

New mechanism to collect
massive training data

Key Idea: Robot Learning **Data Flywheel**



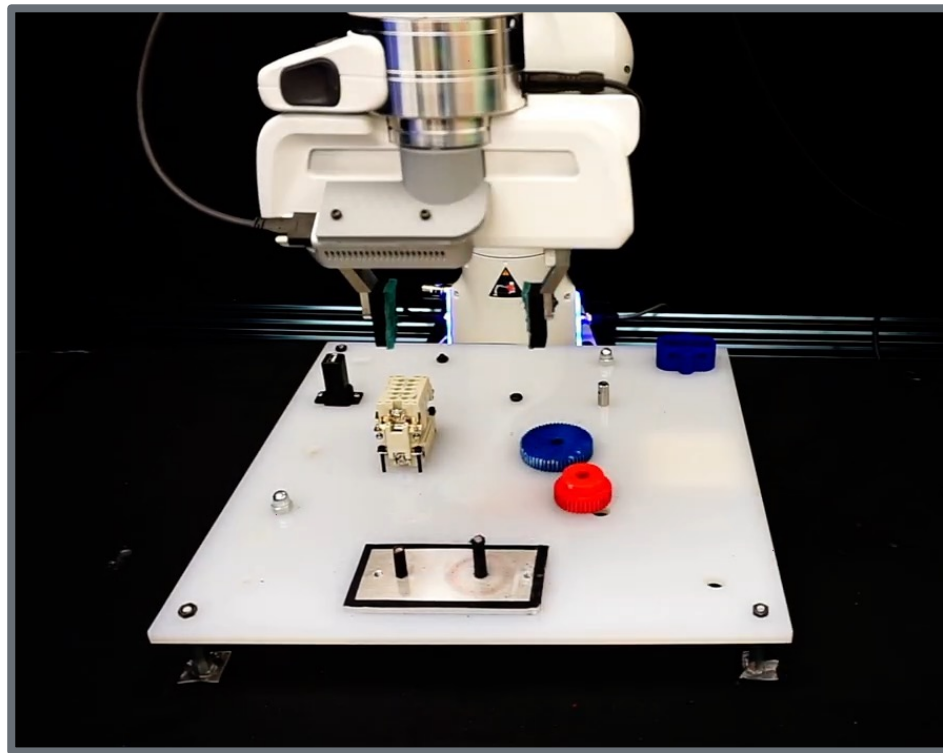
Robot Learning on the Job: Building the Data Flywheel



Huihan Liu

Robot Learning on the Job: Building the Data Flywheel

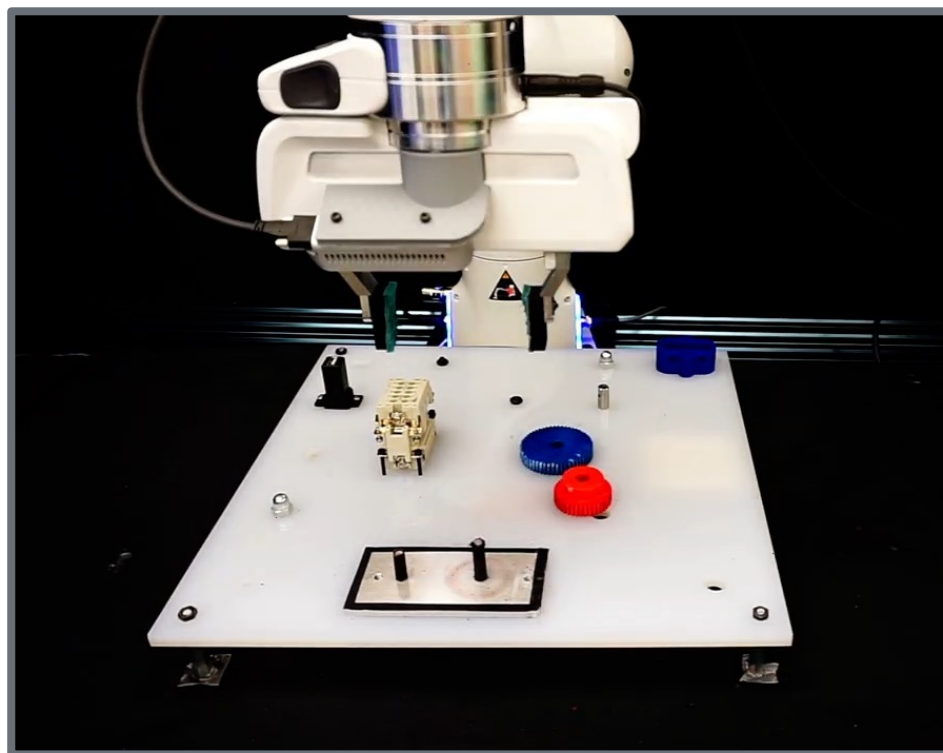
Robot
Deployment



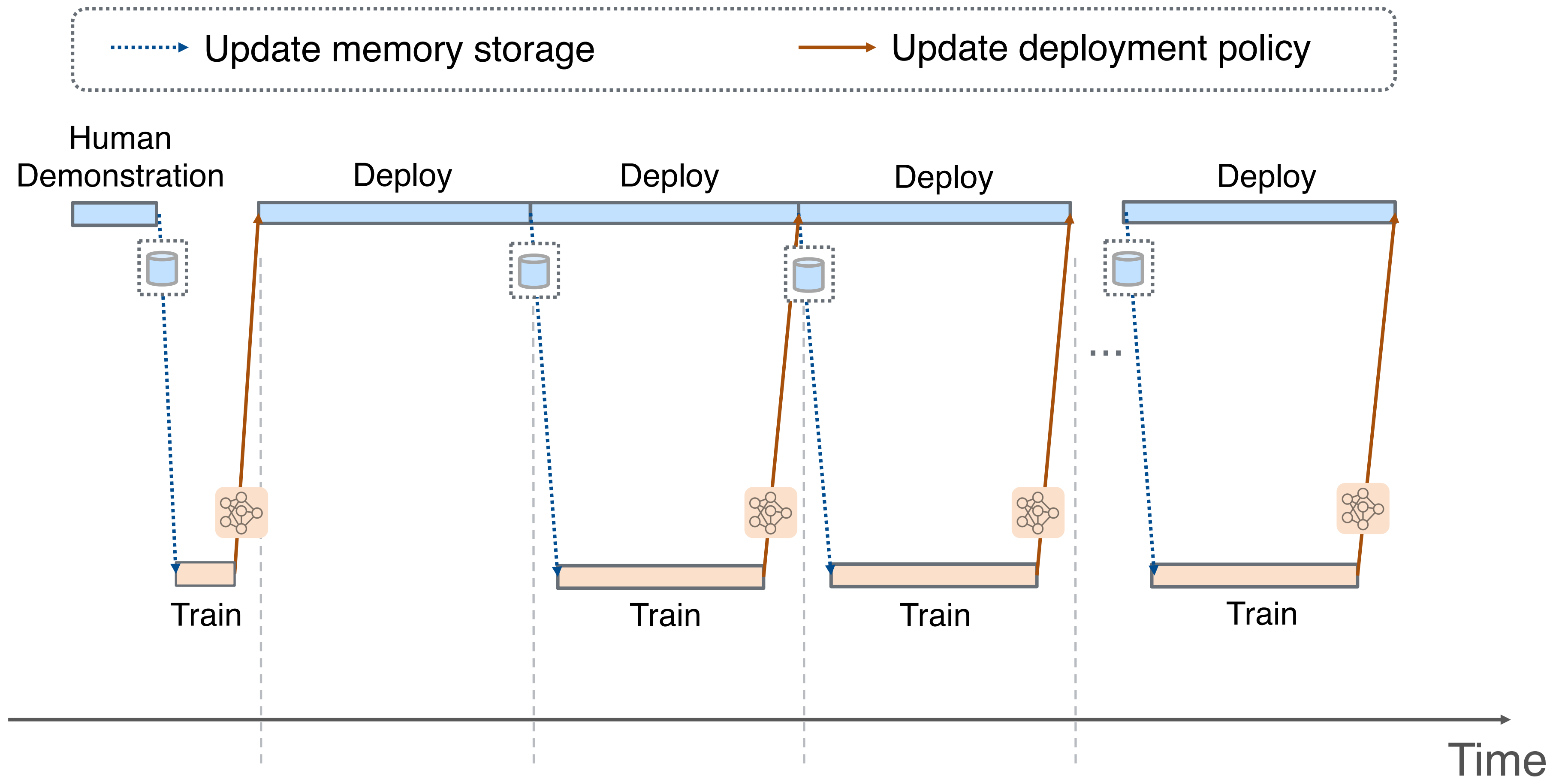
**Policy
Update**

Robot Learning on the Job: Building the Data Flywheel

Robot
Deployment



Policy
Update

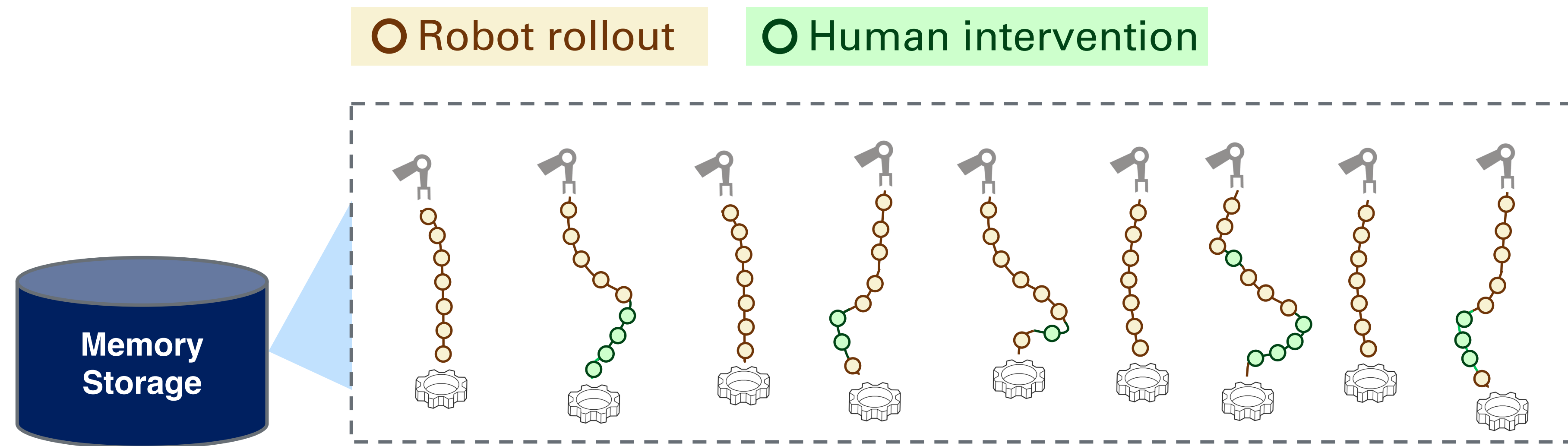


2x

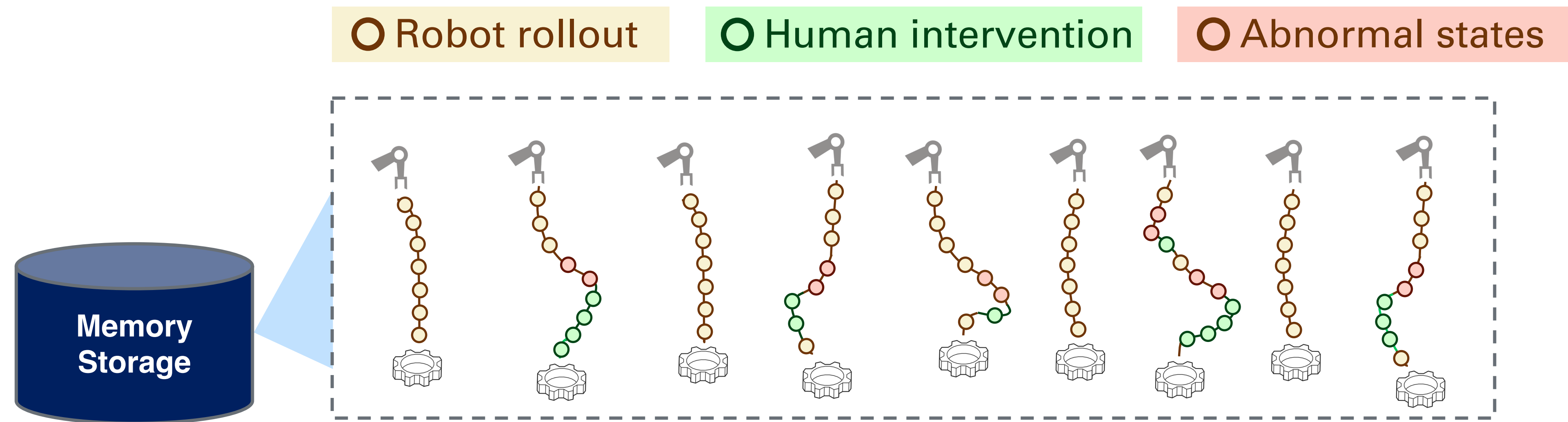
Robot takes
control again

Human provides
an intervention

Robot Learning on the Job: Building the Data Flywheel

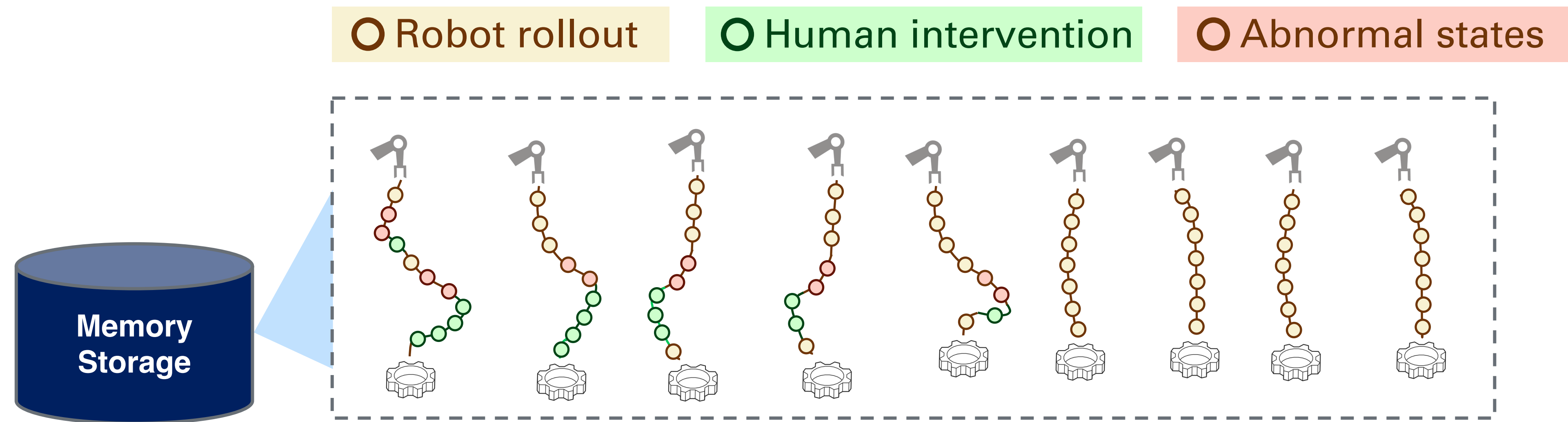


Robot Learning on the Job: Building the Data Flywheel



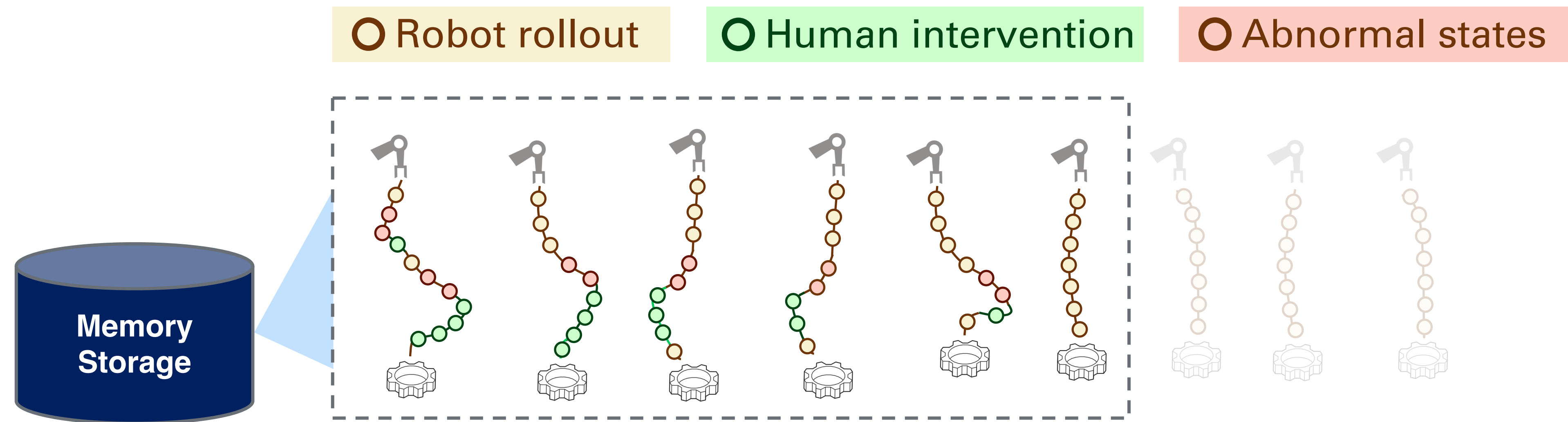
Relabel **abnormal states** before interventions

Robot Learning on the Job: Building the Data Flywheel



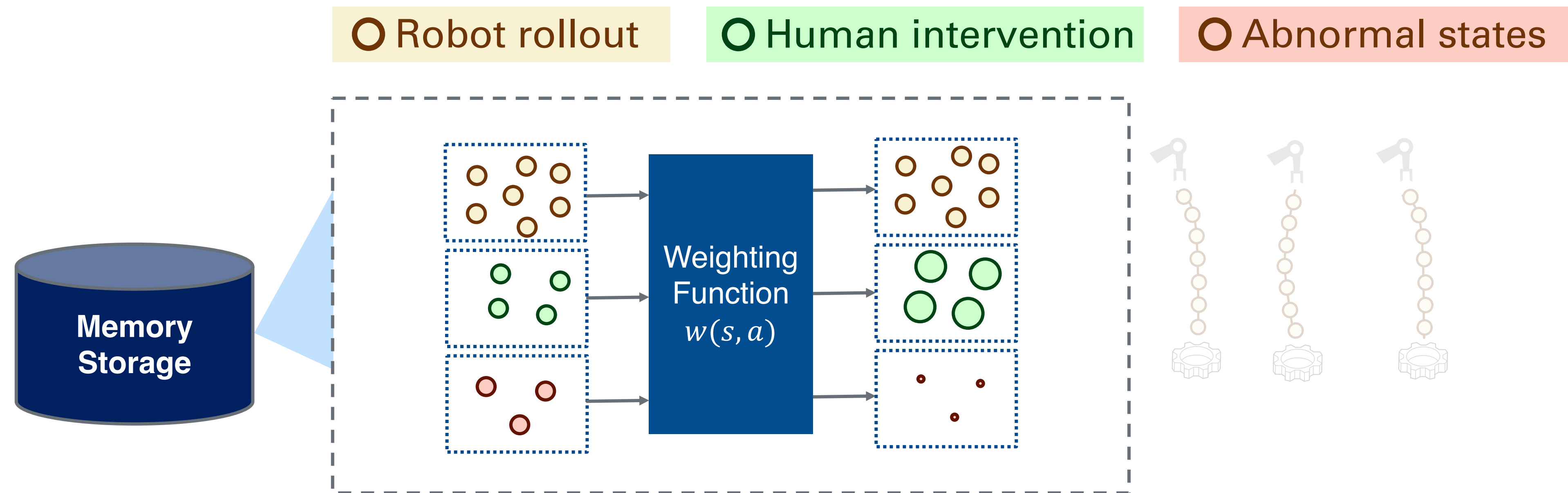
Sort by a **dataset curation** strategy

Robot Learning on the Job: Building the Data Flywheel



Reduce memory to a **fixed size**

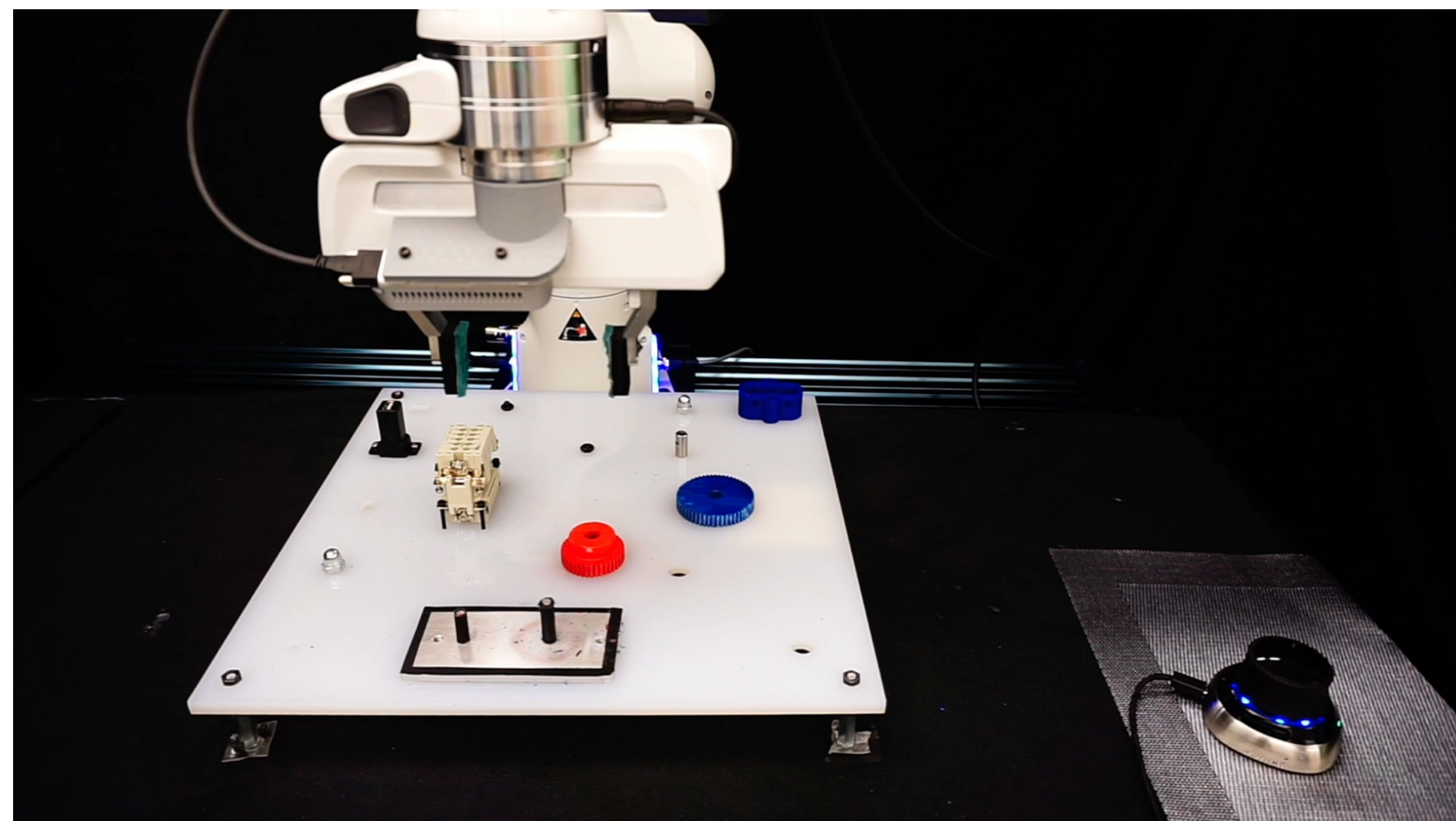
Robot Learning on the Job: Building the Data Flywheel



Reweight samples for imitation learning

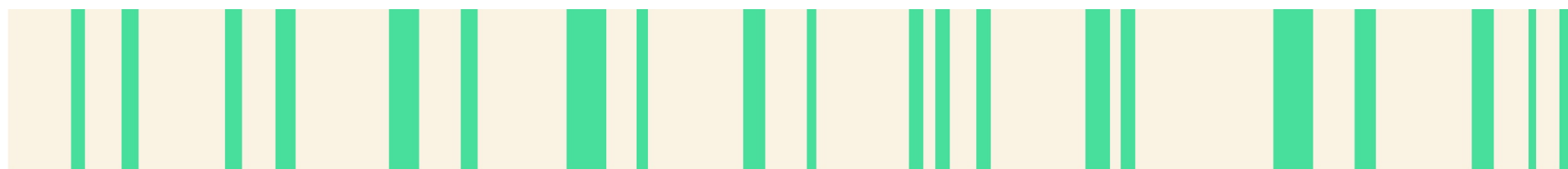
Robot Learning on the Job: Building the Data Flywheel

Round 1 Deployment

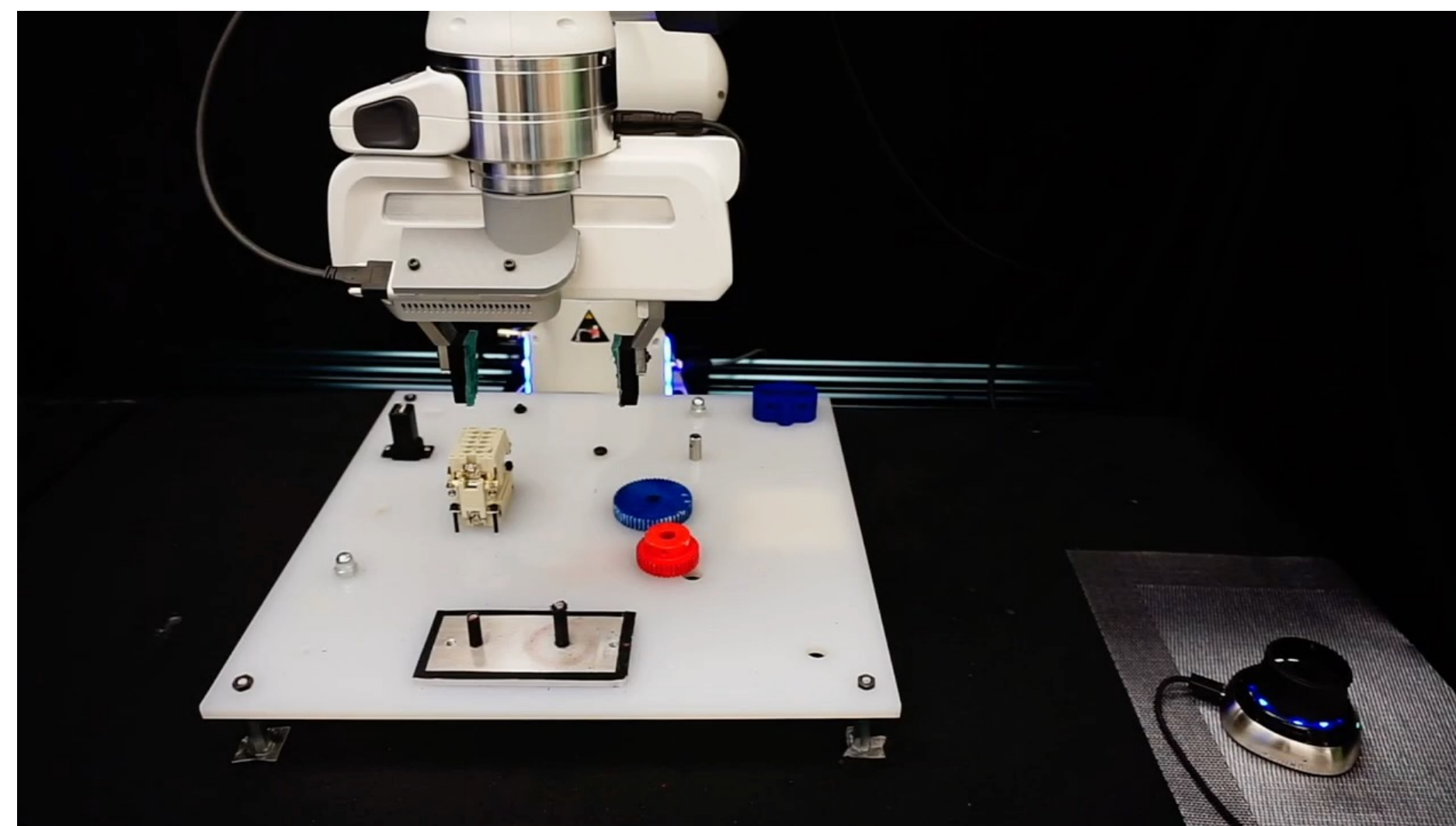


† Green masks indicate human intervention.

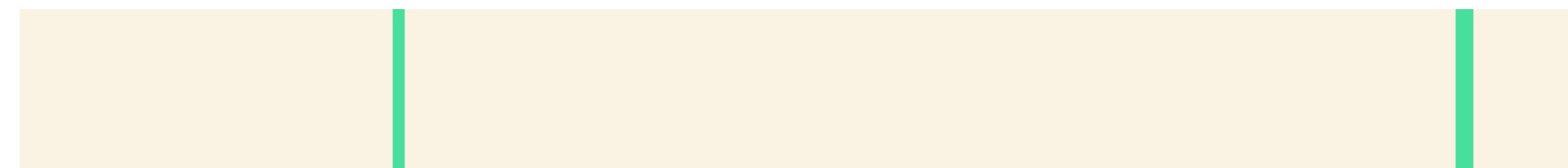
Intervention Distribution



Round 3 Deployment



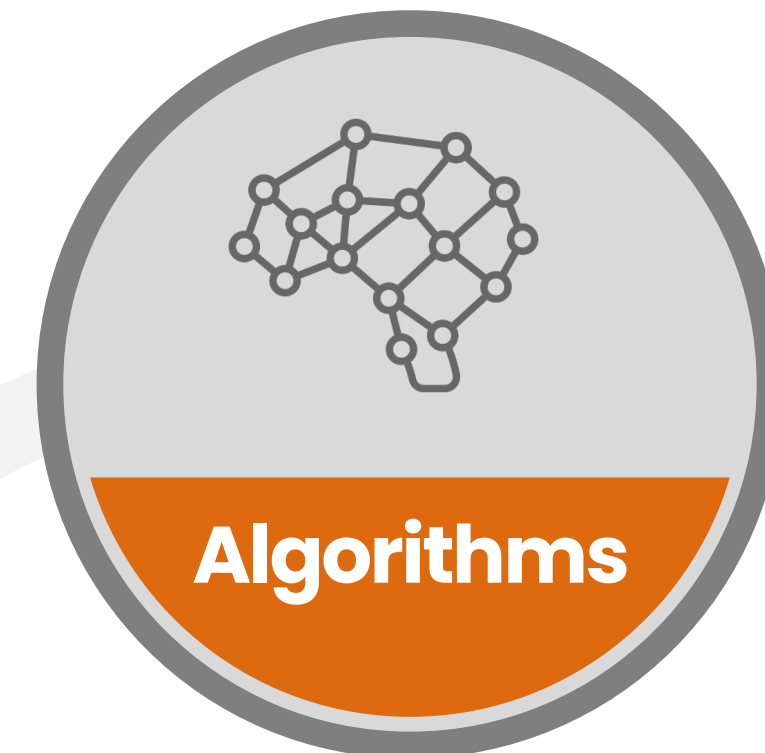
Intervention Distribution



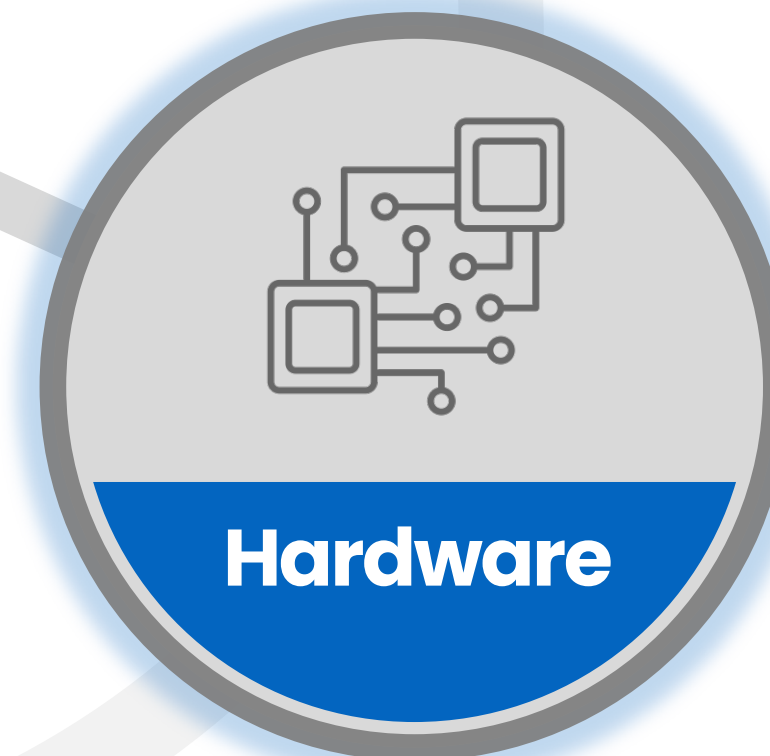
Recipe for Building Generalist Robot Models

Scaling Law

Powerful robot learning models
that scale with data and compute



**Generalist
Robot Model**



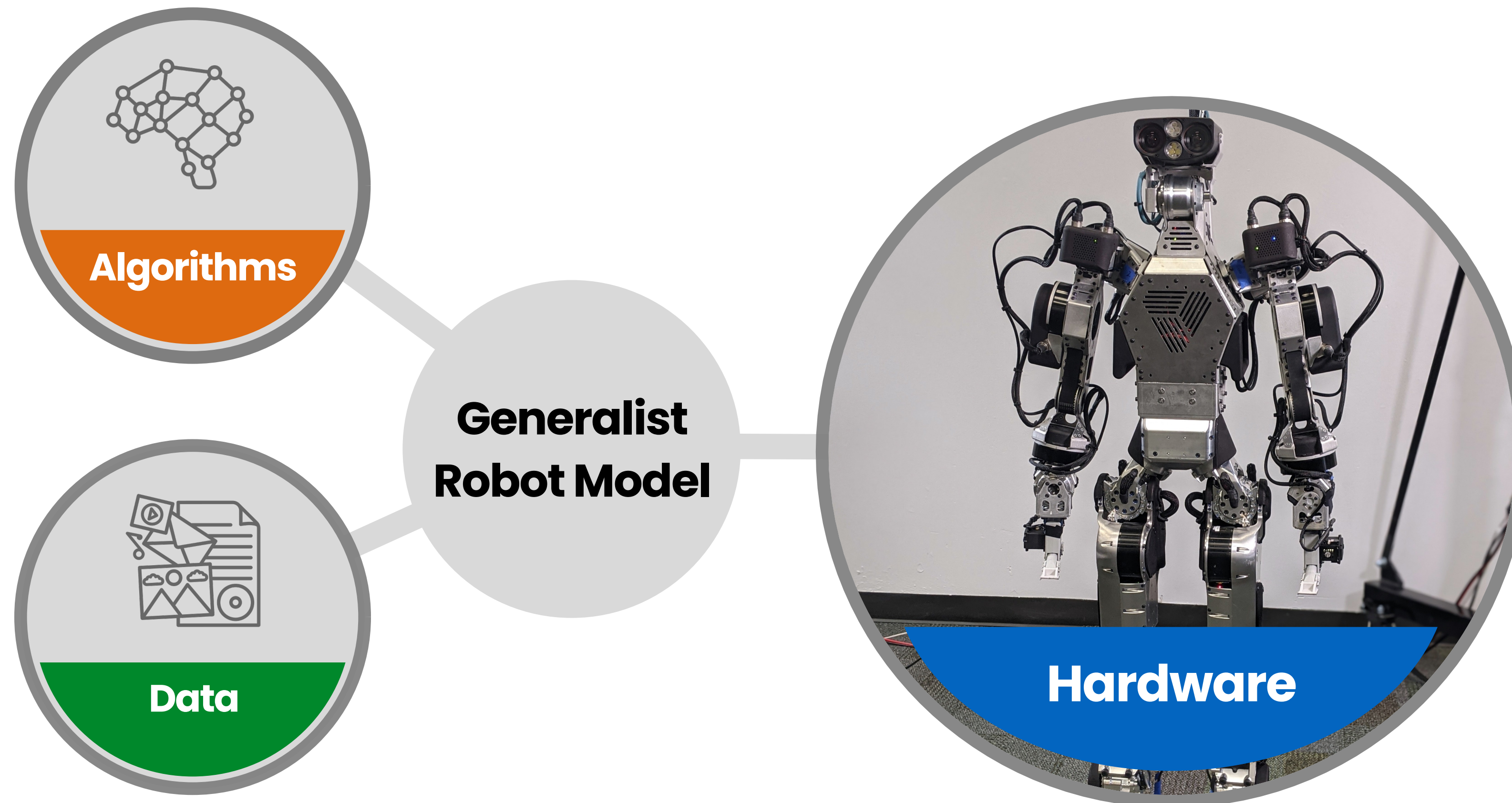
Humanlike Embodiment

Humanoid robot platform for
broad applications

Data Flywheel

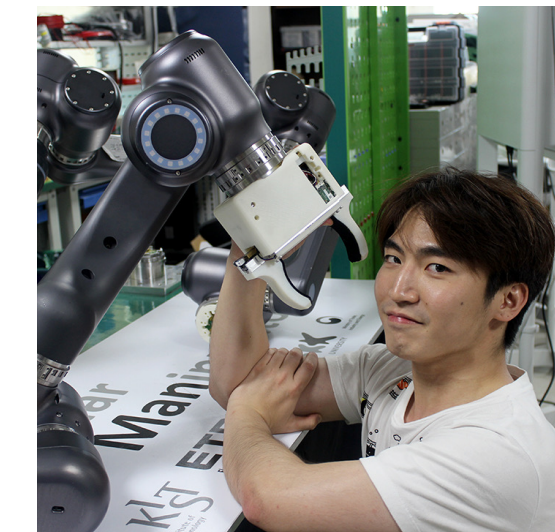
New mechanism to collect
massive training data

Humanlike Embodiment: Generalist Humanoid Robot



Draco3 Humanoid

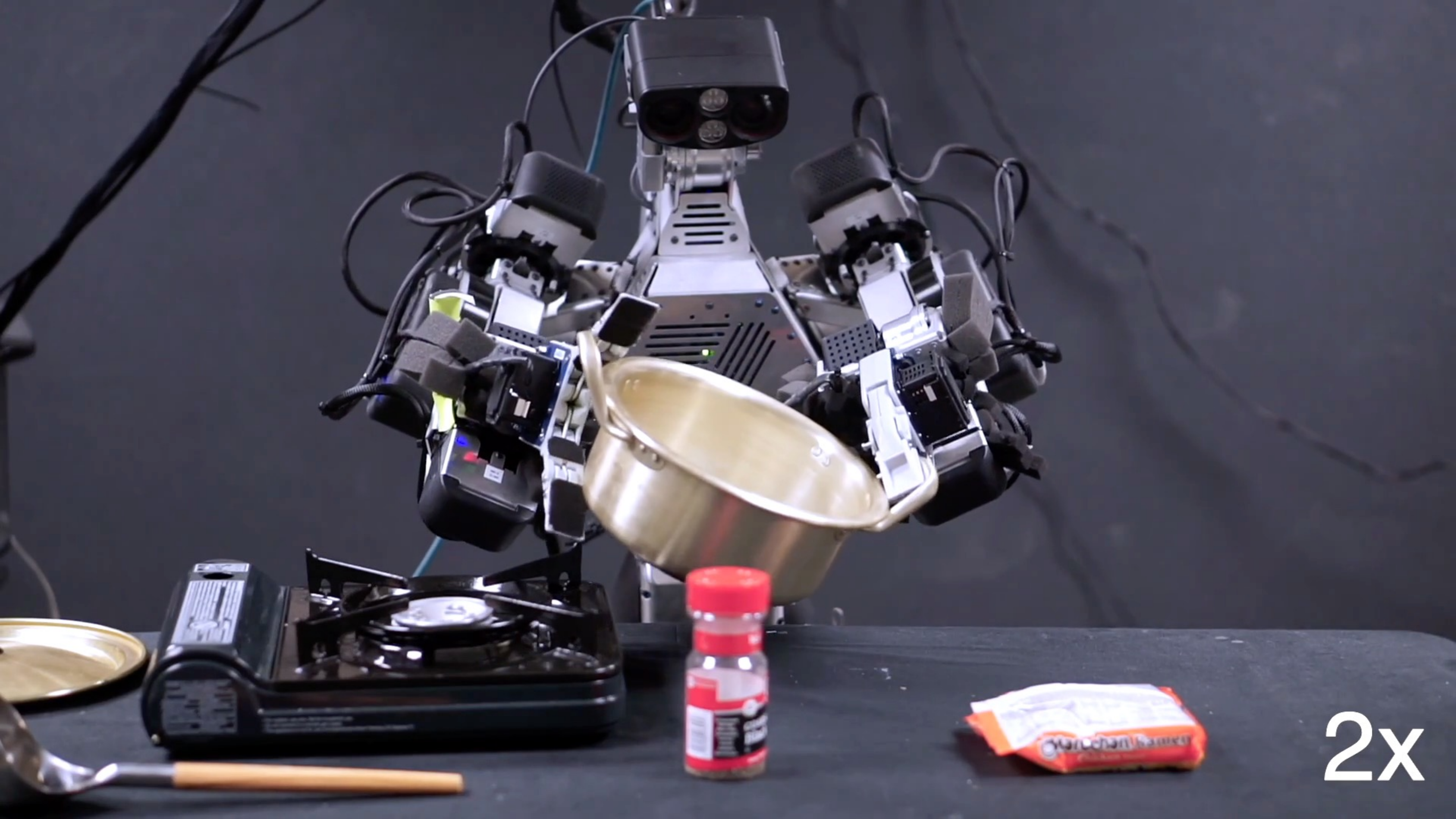
Team



Mingyo Seo

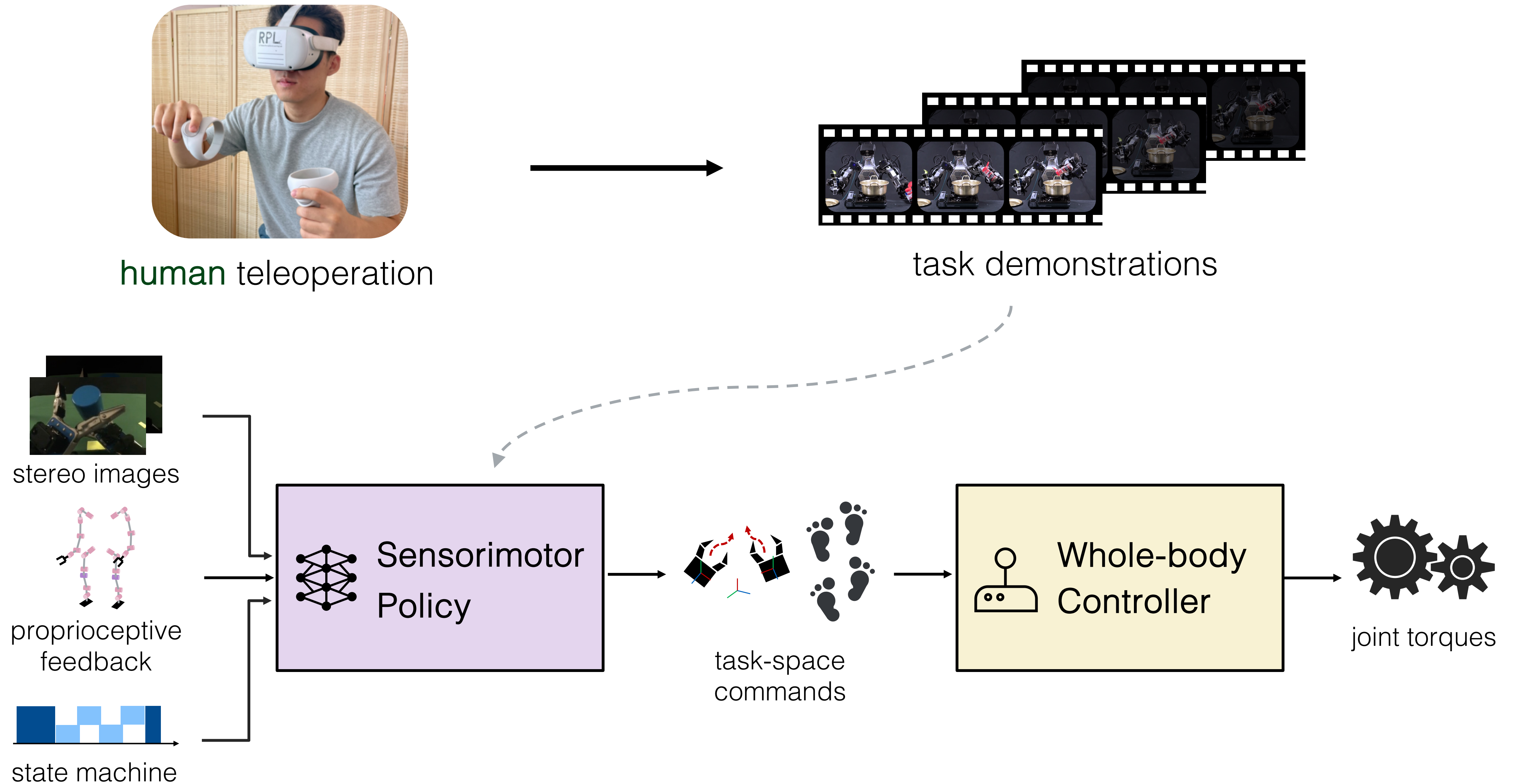


Luis Sentis



2x

Humanlike Embodiment: Generalist Humanoid Robot

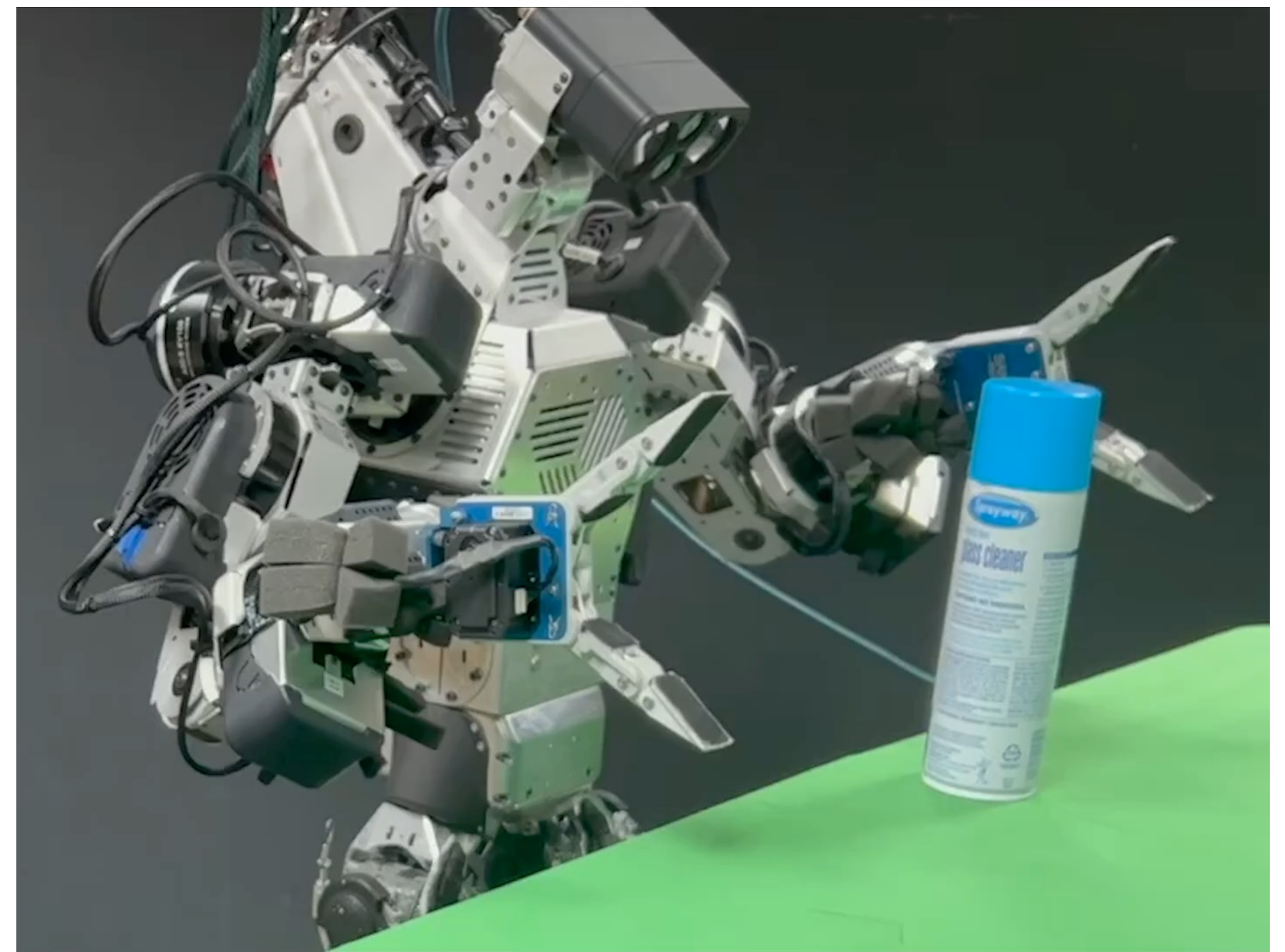


Humanlike Embodiment: Generalist Humanoid Robot

Policy deployments in simulation and real world



Loco-manipulation (sim): 92% success rate

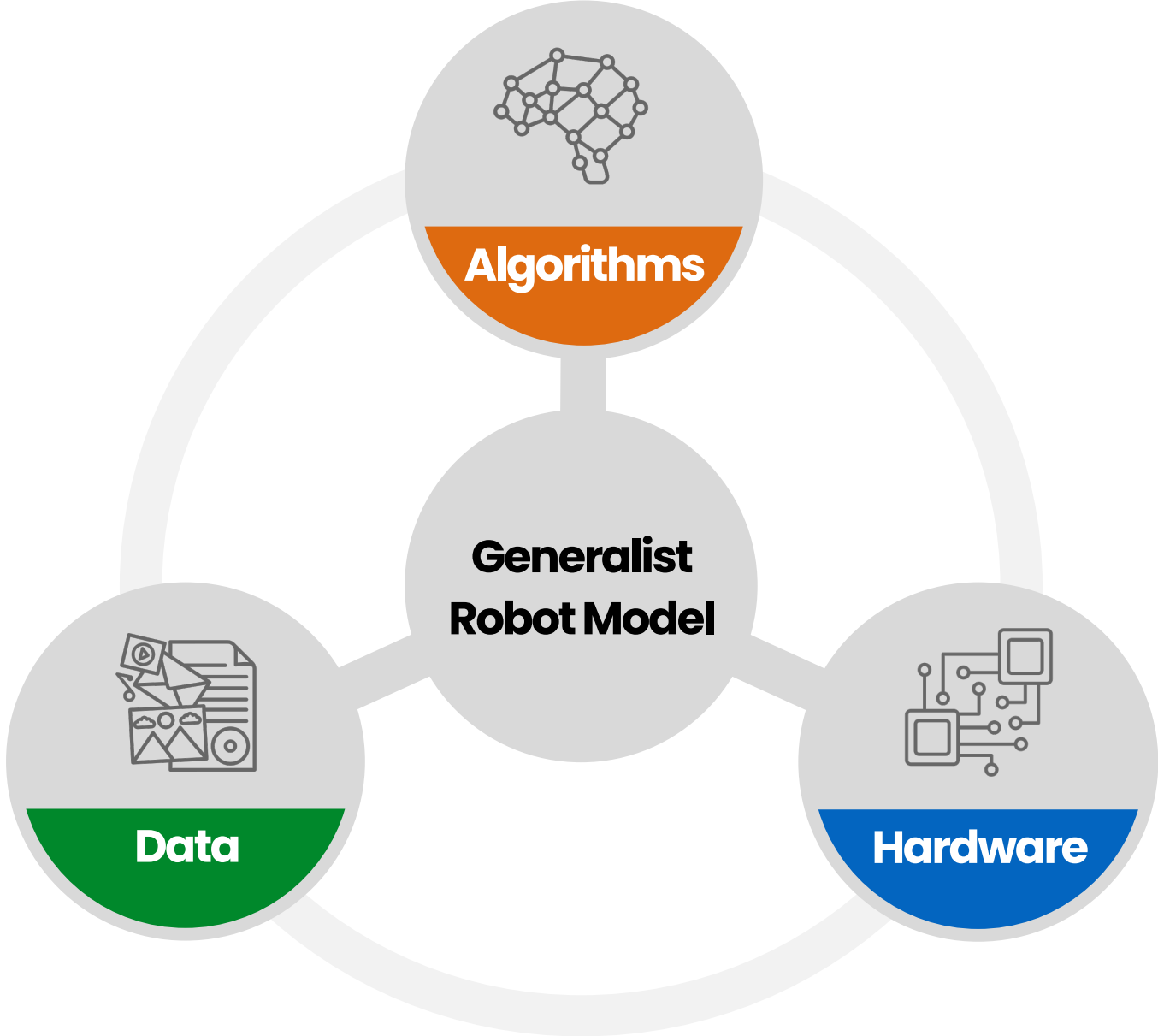


Bimanual manipulation (real): 90% success rate

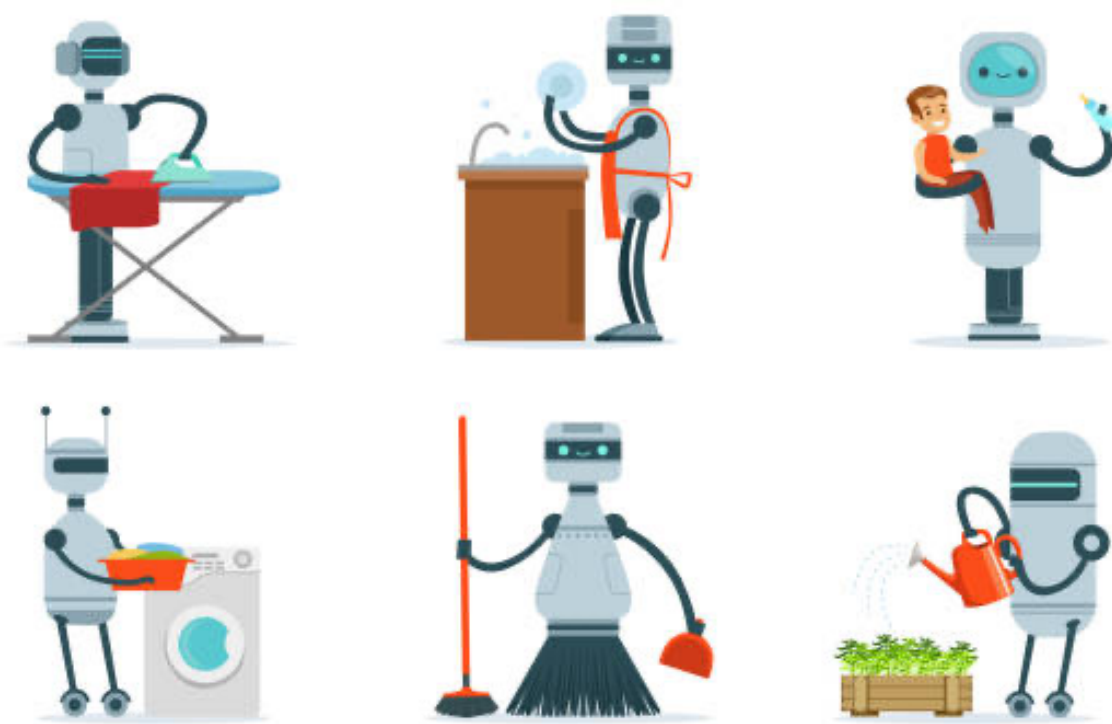
Pathway to Generalist Robots



Specialist Robots



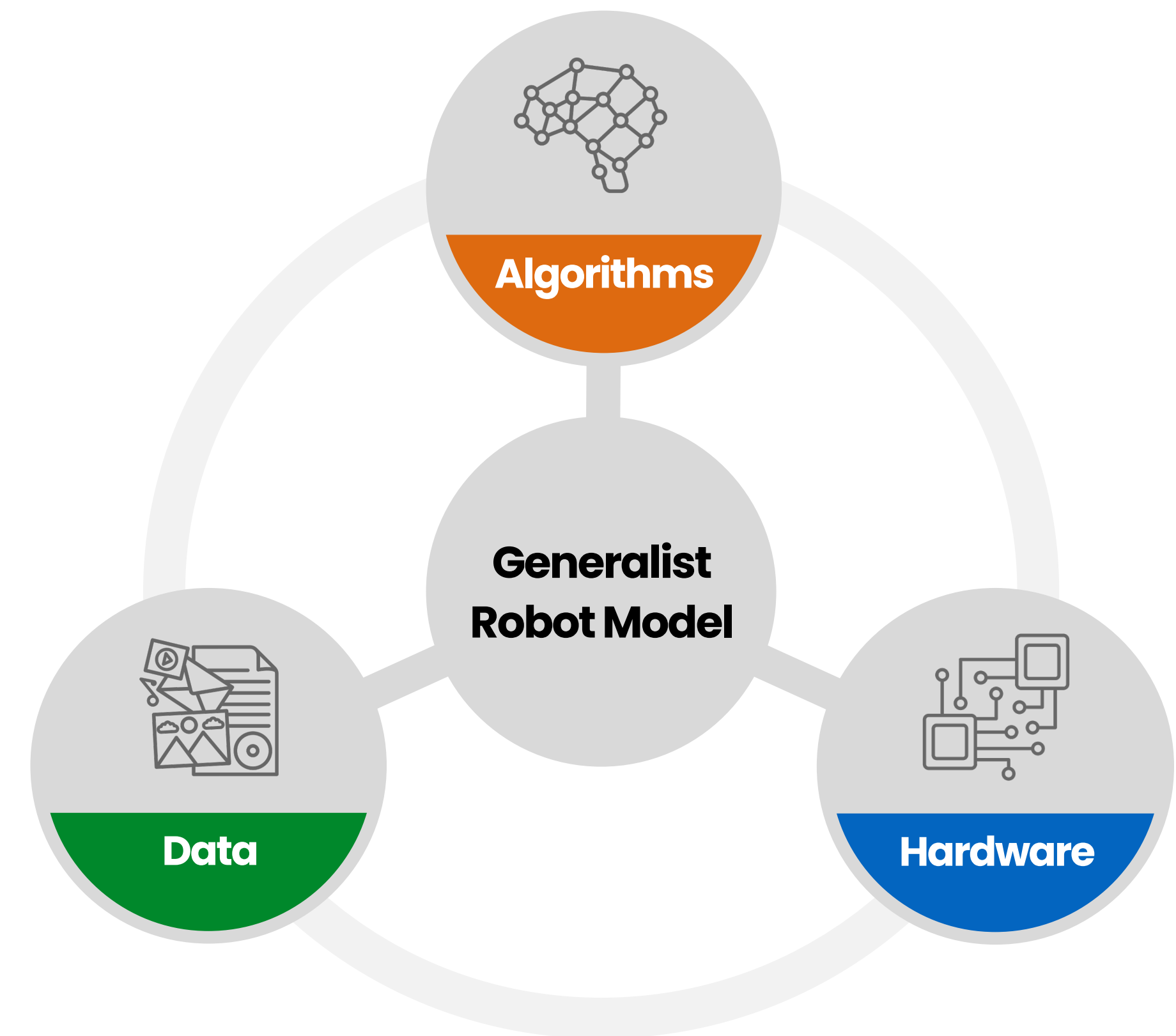
Generalist Robot Models



Specializing Generalist Robots

Pathway to Generalist Robots

- **Algorithms:** Scaling up robot learning models with skill APIs and massively multi-task training
- **Data:** Building a data flywheel in real-world deployments through human-in-the-loop robot autonomy
- **Hardware:** Humanoid robots as a generalist robot platform to develop human-level physical intelligence



UT Robot Perception & Learning Lab

Mission statement: building general-purpose robot autonomy in the wild

