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On the quest for robotic embodied intelligence

Robots that understand, adapt, and collaborate with us

Georgia Chalvatzaki

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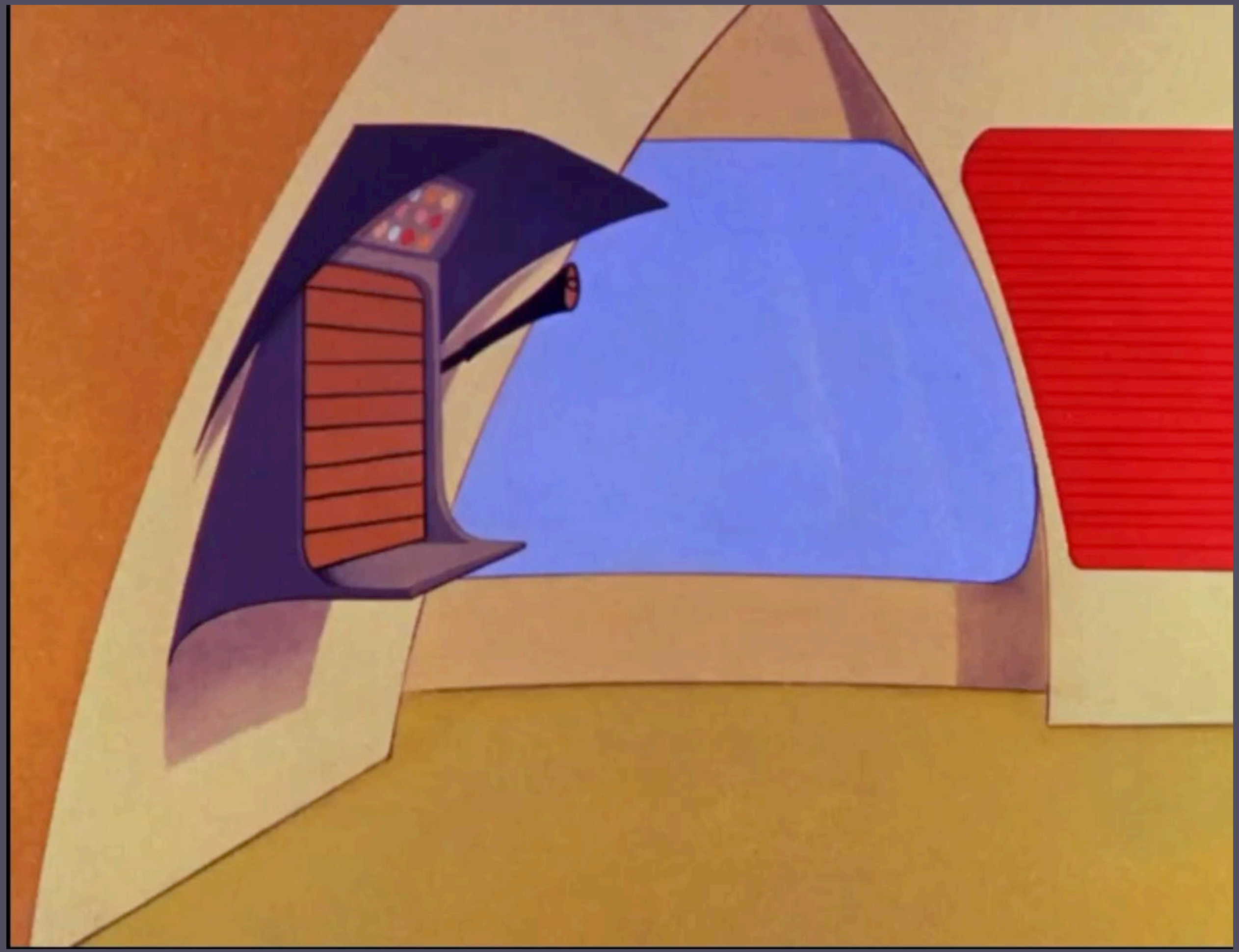
The dream of intelligent robotic assistants…



The Jetsons (1959)

How humans learn and adapt?

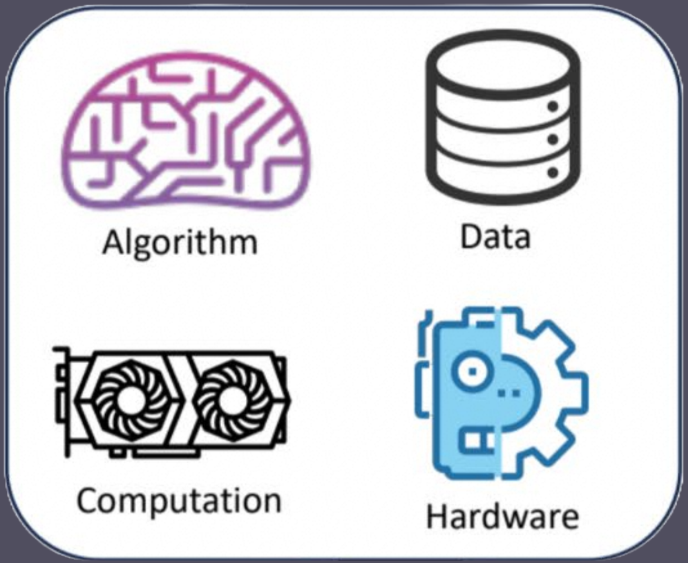
Perceive to act

Act to perceive

- Sensorimotor coordination
- Representation of the world
- Interactively explore and learn skills

Is Data all we need?

Robot Learning: the use of Machine Learning methods in robotics to allow robots to acquire skills through imitation and interaction with the environment => **learning from data**



How far are we?

Embodied AGI
in the physical world

Why is embodied intelligence so hard?

<u>Moravec's Paradox (1988)</u>

It is comparatively easy to make computers exhibit adult-level performance on intelligence tests, but difficult or impossible to give them the skills of a one-year-old.

How to endow robots with robust and adaptive behaviours around humans?

From assistive robotics to embodied intelligence

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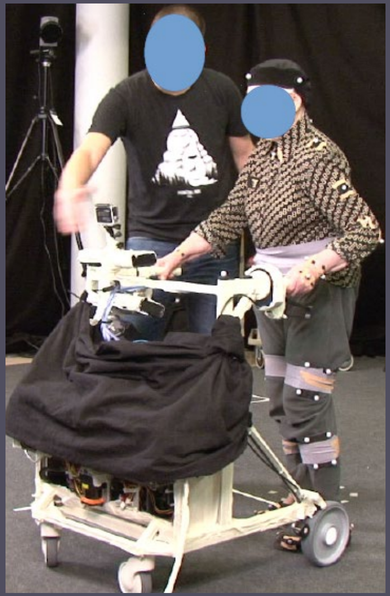
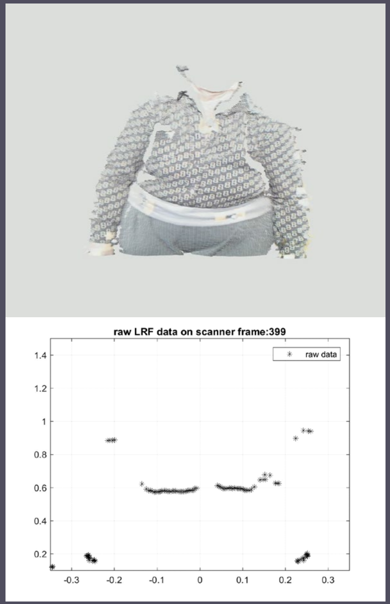
2019
PhD in Assistive Robotics
NTUA, Athens

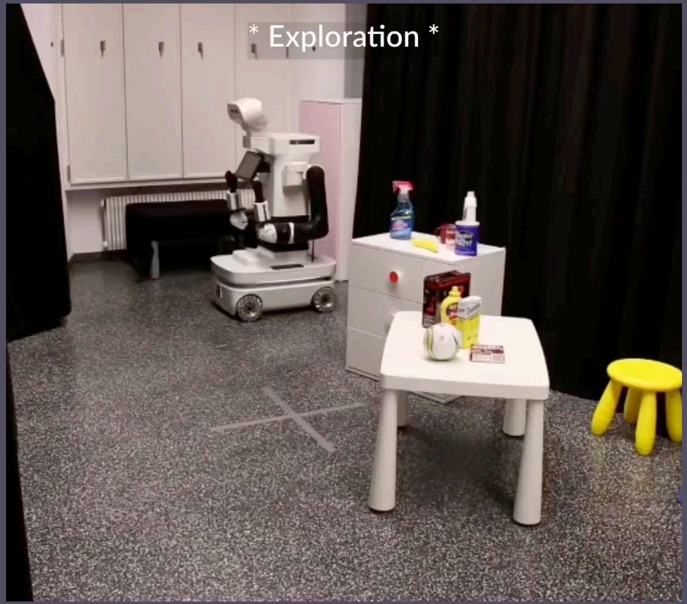
iROSA
2020
Emmy Noether DFG
iROSA, TU Darmstadt

SIREN
2024
PEARL Lab, ERC StG SIREN
W3 @ TU Darmstadt

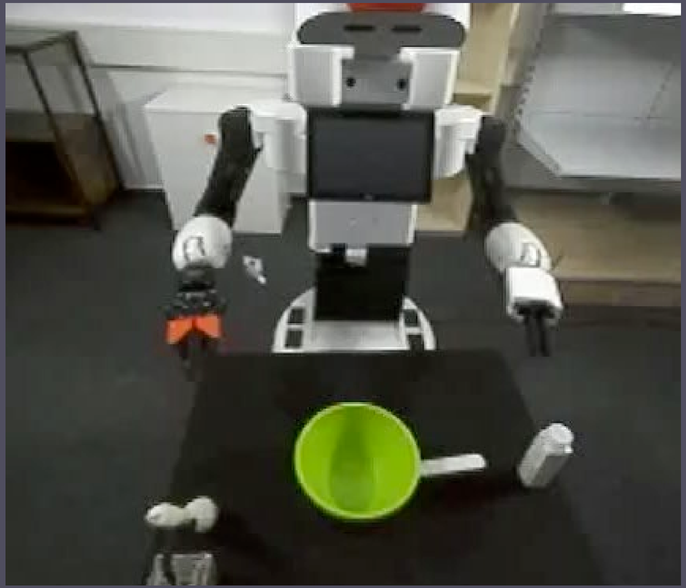




Human-centered modeling & motion prediction



Integrating perception & learning for mobile manipulation



Towards structured, embodied intelligence

Research focus: from understanding humans
→ to understanding how robots can learn to act among them

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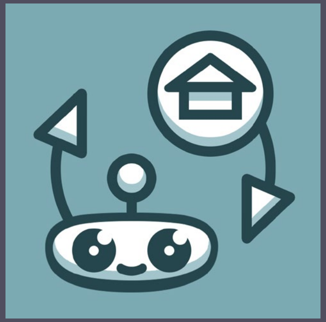
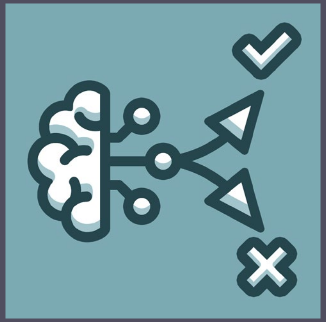
Our approach: Structured Robot Learning

*Learning with **priors**, not just data.*



Structured representations from geometry and semantics

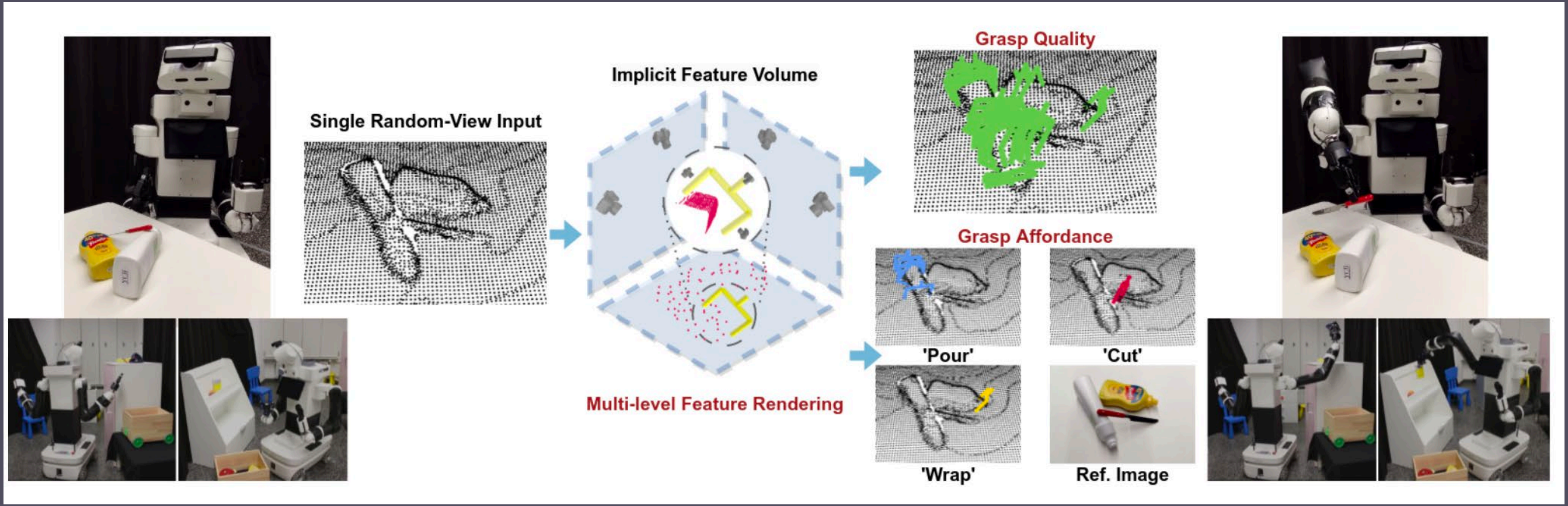


Robust and safe behavior under uncertainty

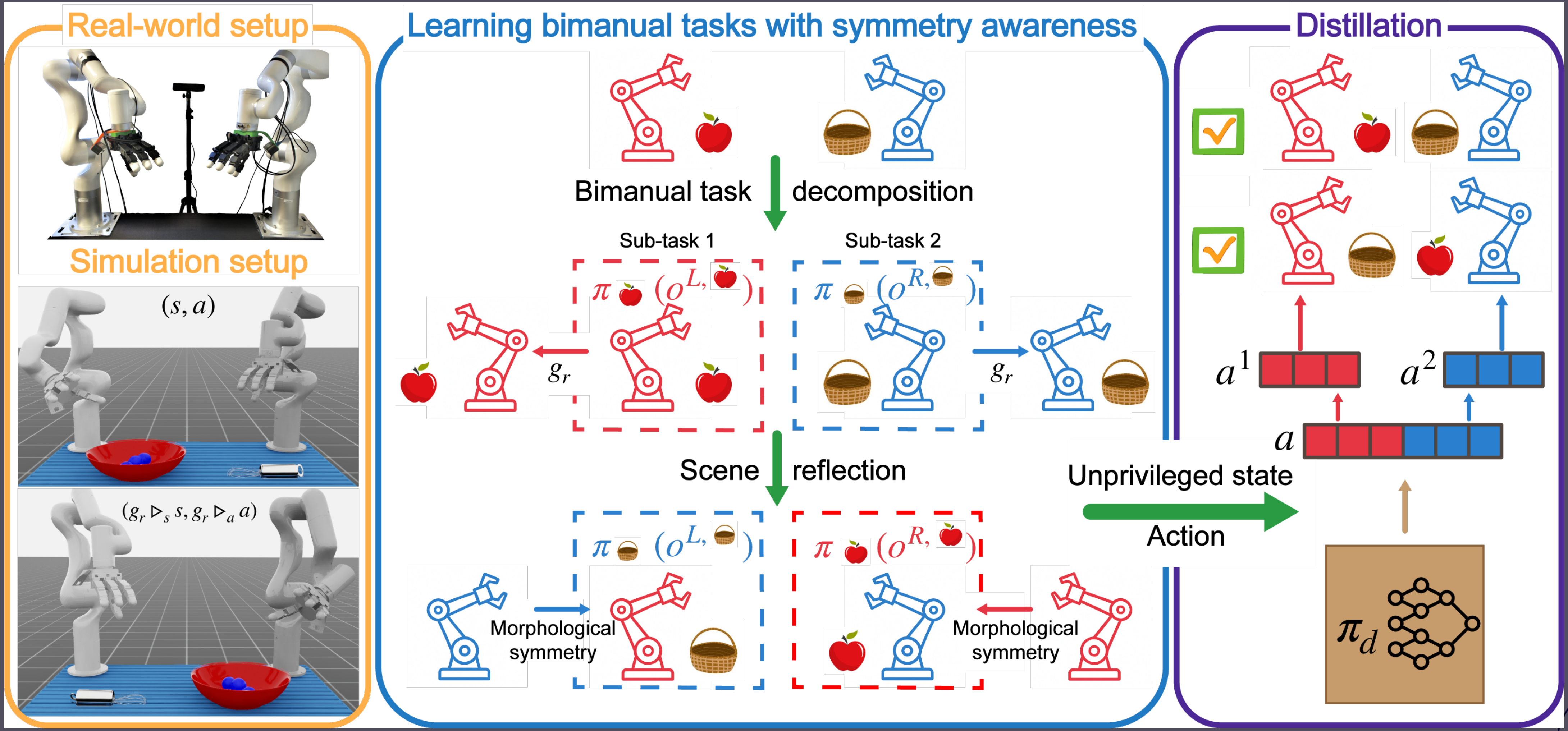
Physics-aware learning and reliable reasoning

Modular and composable skills and behaviors

Grasp anything anywhere with coarse-to-fine scene understanding

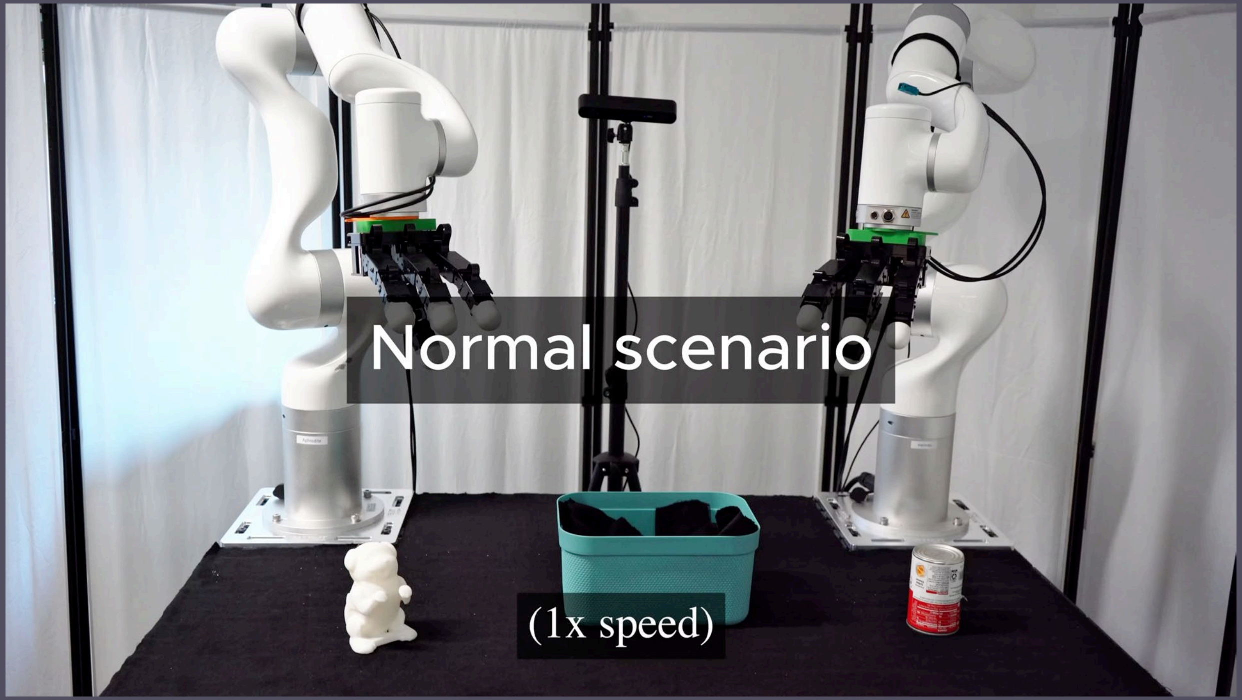


Morphological Symmetry as a Prior for Efficient Bimanual Manipulation

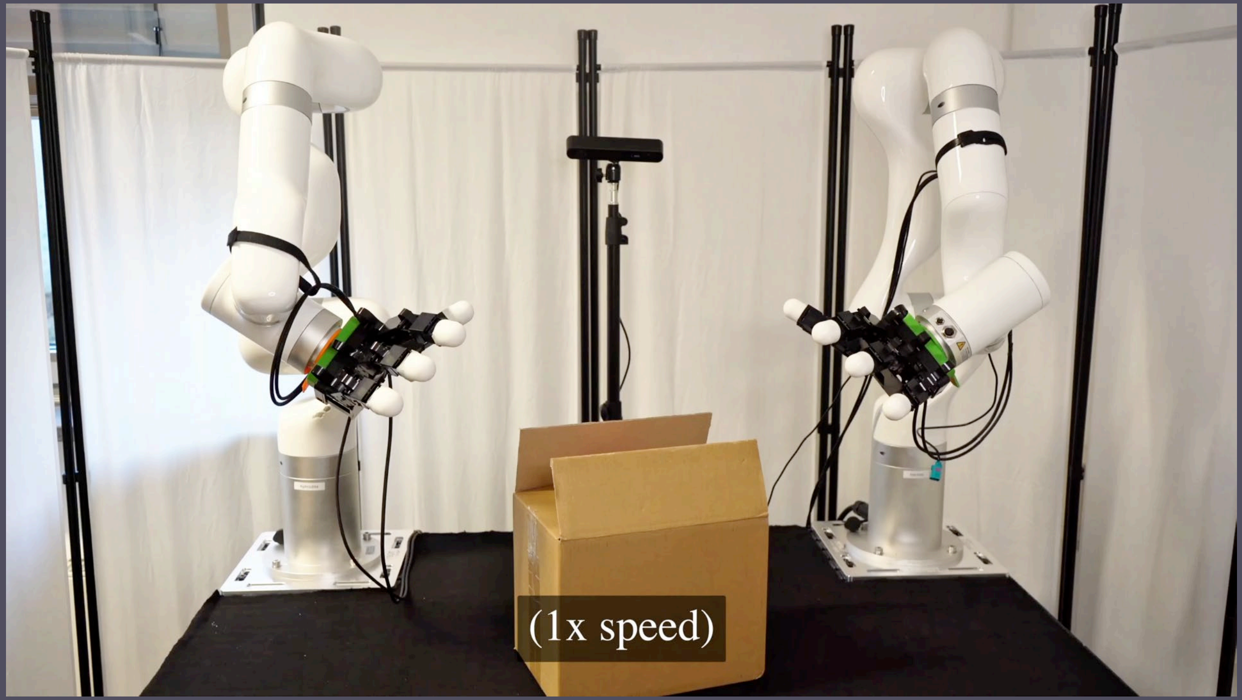


Morphological Symmetry as a Prior for Efficient Bimanual Manipulation

Put objects in box



Lift box



Semantic priors for generalizing bimanual manipulation

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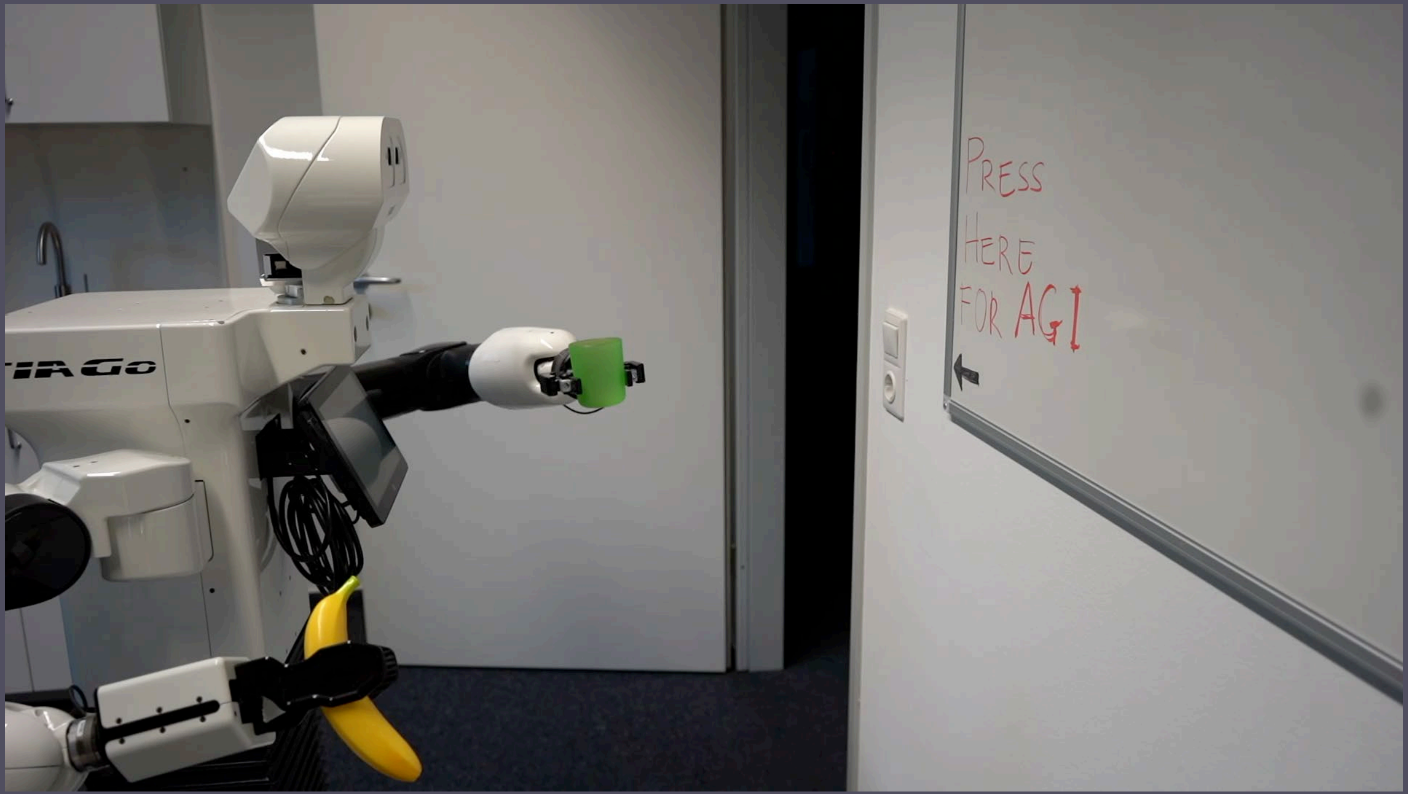
Leveraging whole-body interactions at the intersection of learning and control



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Learning object functionalities from human videos

Affordances for task: "Pour into bowl"

Typical manually-labeled affordances: ✗

Affordance extraction from interaction: ✓

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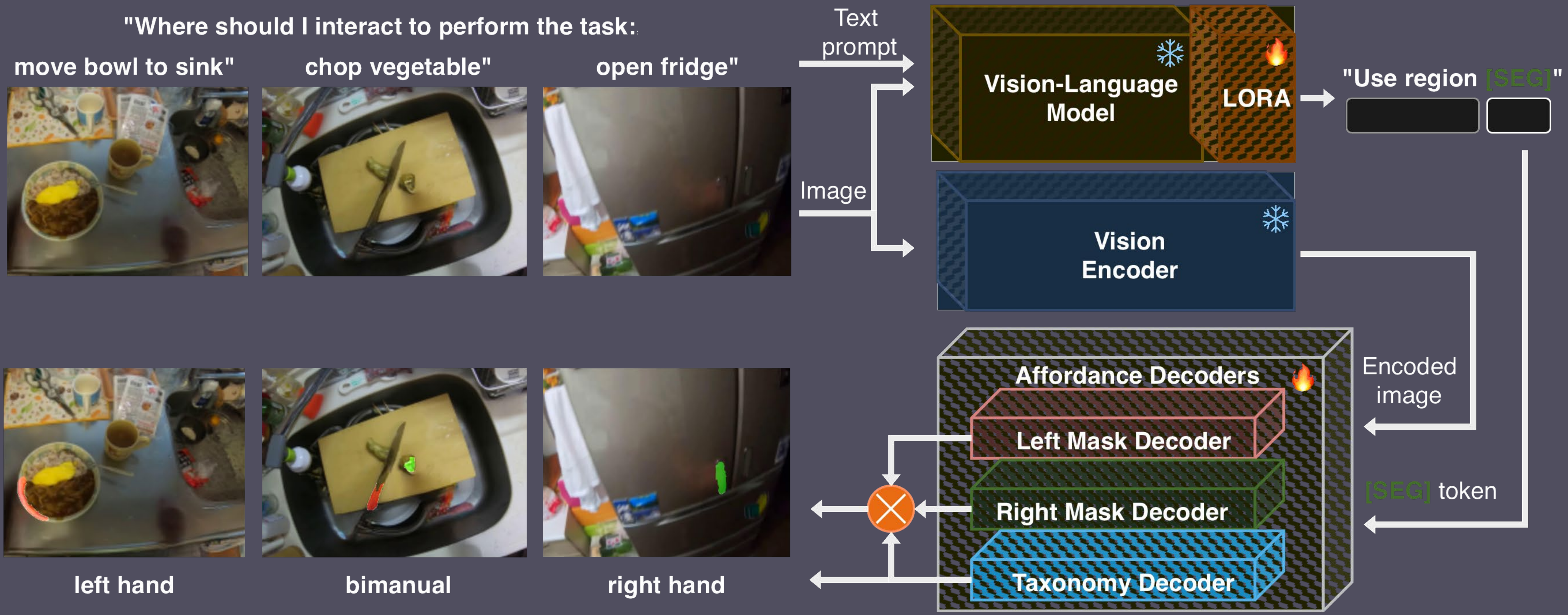
Learning object functionalities from human videos

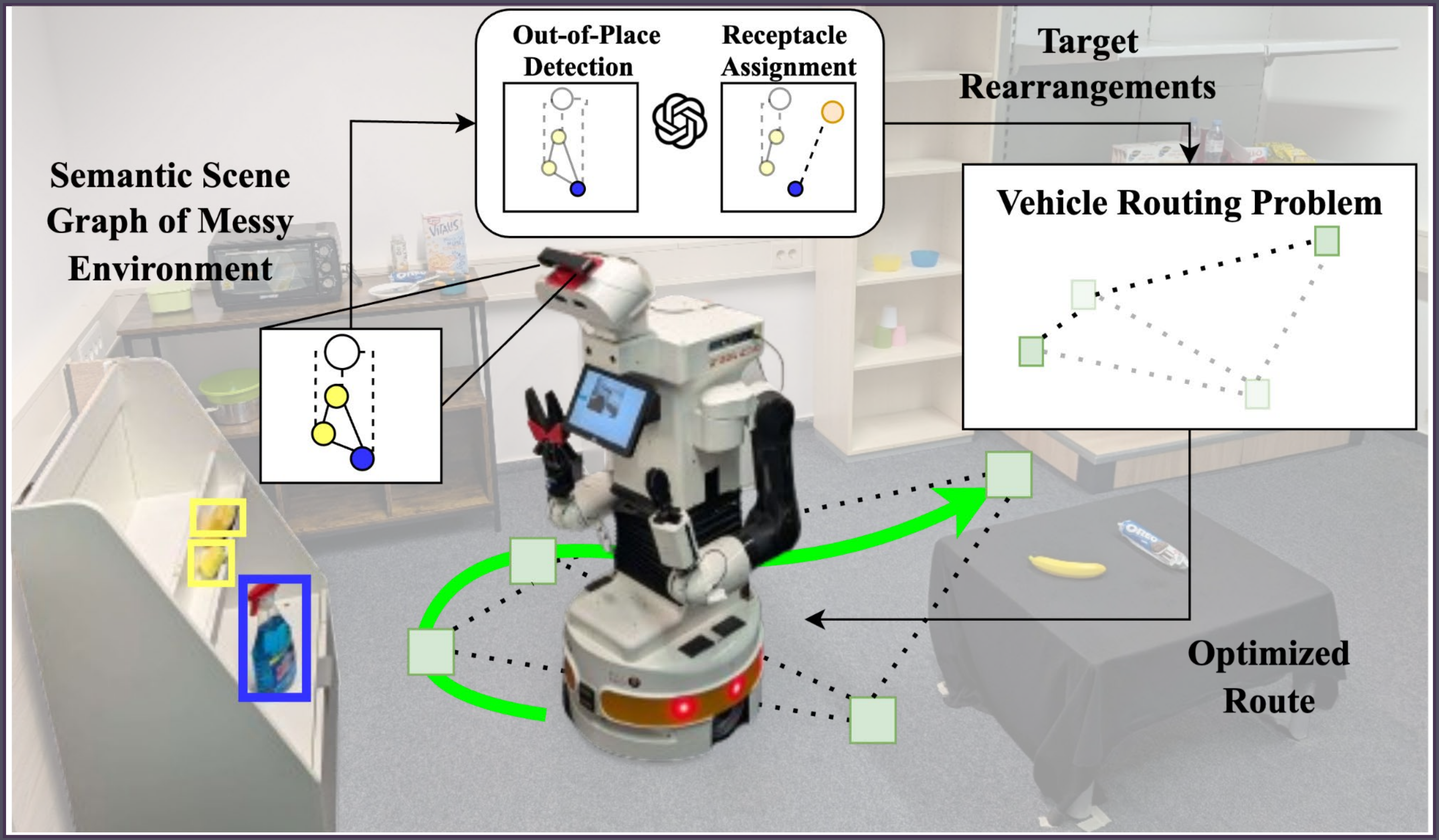


Learning object functionalities from human videos

Open the bottle

Stir the vegetables

Scene-graph grounding with LLM suggestions for efficient room tidying



Scene-graph grounding with LLM suggestions for efficient room tidying

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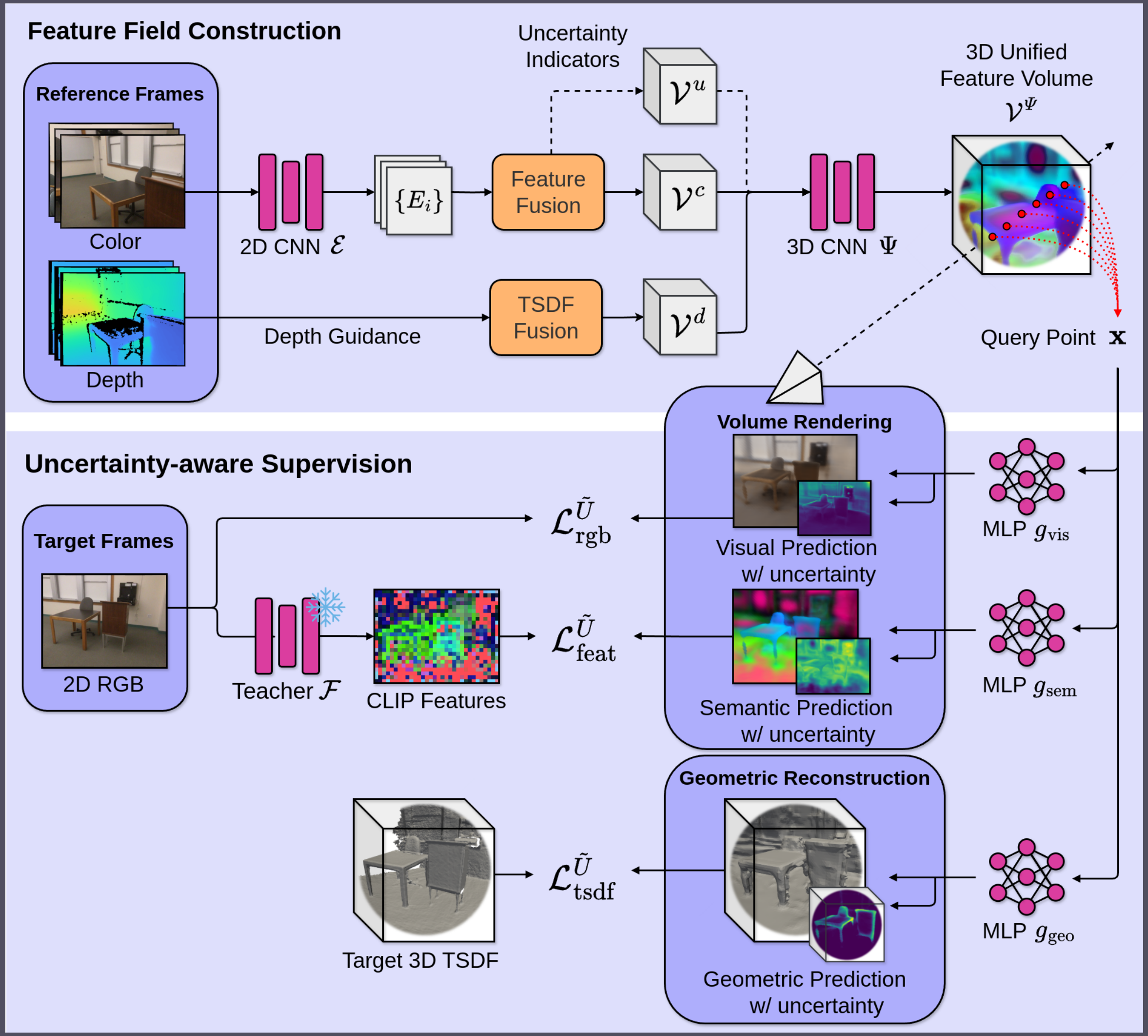
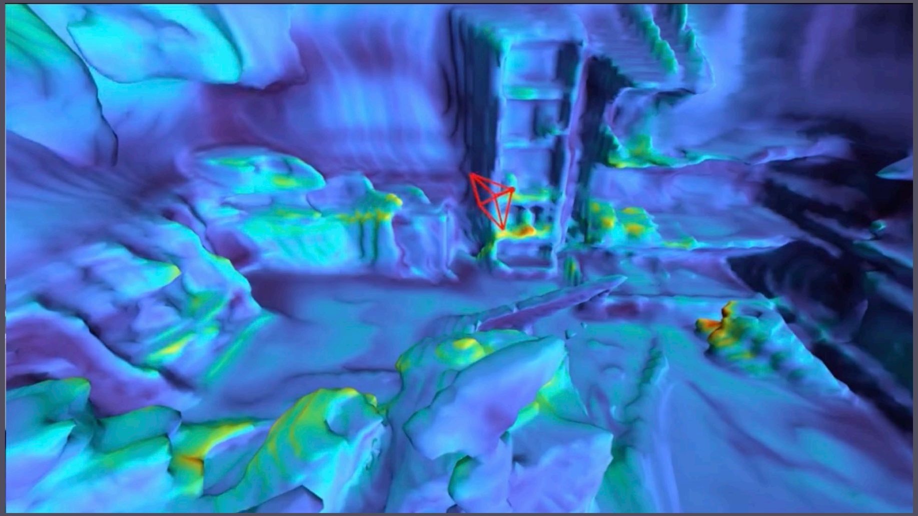
Microwave Oven 0.95
Stovetop 0.85
Cleaning Solution 0.88
Paper Towel Roll 0.97
ZED image

Reasoning about uncertainties for efficient exploration and interaction





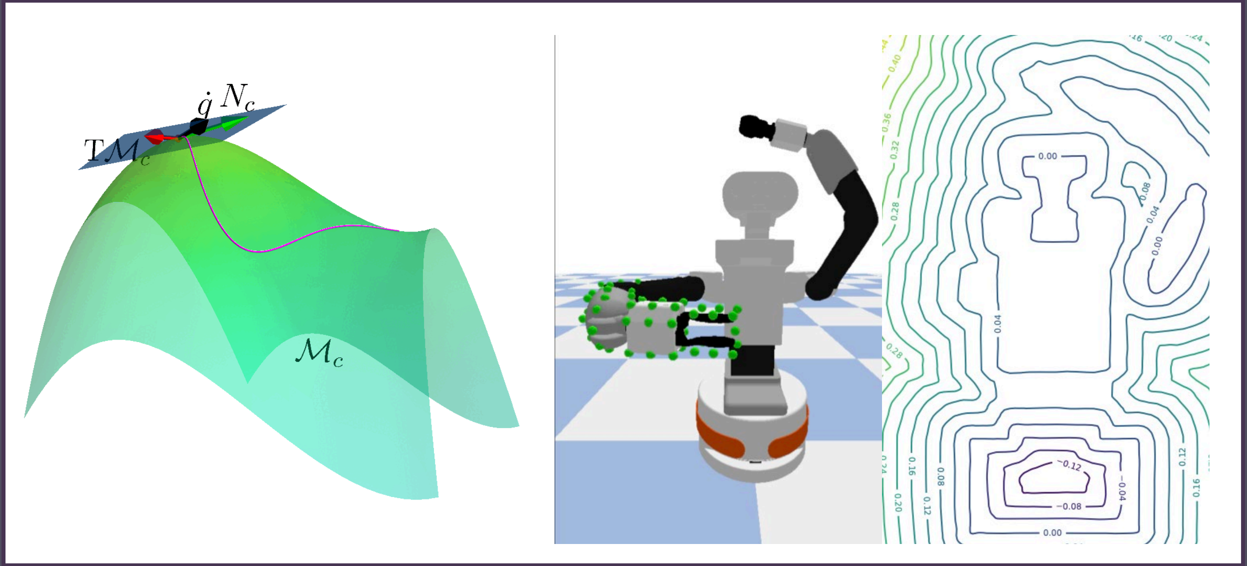

OREO

Safe human-robot interaction leveraging constraints

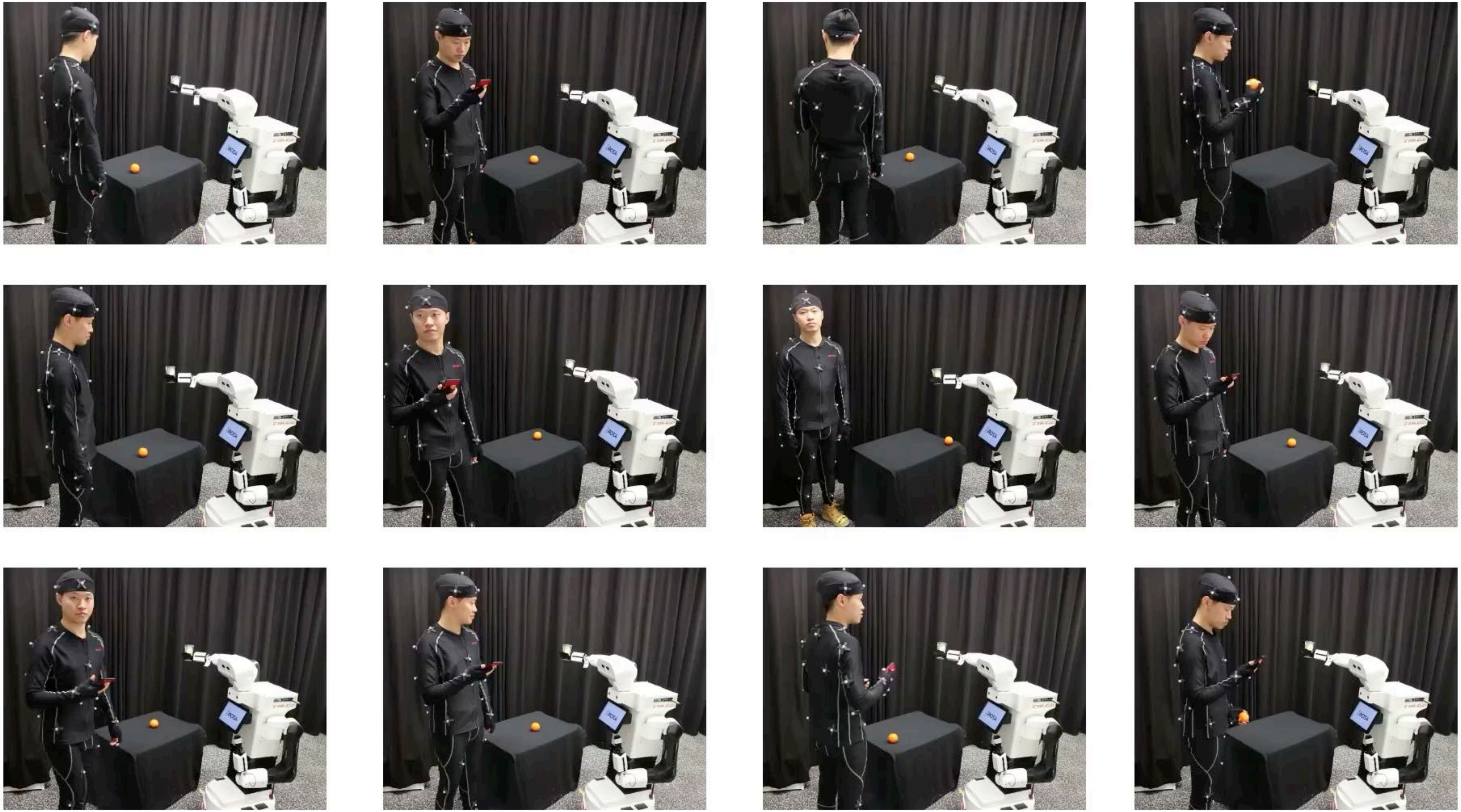
Exploit the "topology" of the constraints

Transform the robotic actions to always be tangent to the manifold

Locally safe behaviors through the active action transformation



Exploit the Topology of the Constraints



Takeaway

Geometry · Physics · Humans · Semantics · Representations

Generalization · Grounding · Reasoning · Robustness · Adaptation

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Impact: Foundations for **continuous** robot learning systems

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Thank you!

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MANiBOT

ARISE

Funded by the European Union

erc
European Research Council
Established by the European Commission

Emmy Noether-Programm
DFG Deutsche Forschungsgemeinschaft

RAI
REASONABLE AI

The adaptive Mind

PEARL

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Max, Franziska, Sophie and Sohan

Ask TIAGo to take a Selfie!