Autonomous Systems Lab

From Passive Robot Learner to *Pro-Active Inter-Active* Robot Learner

The Role of Interaction in Robot Learning

Dongheui Lee

TU Wien, DLR

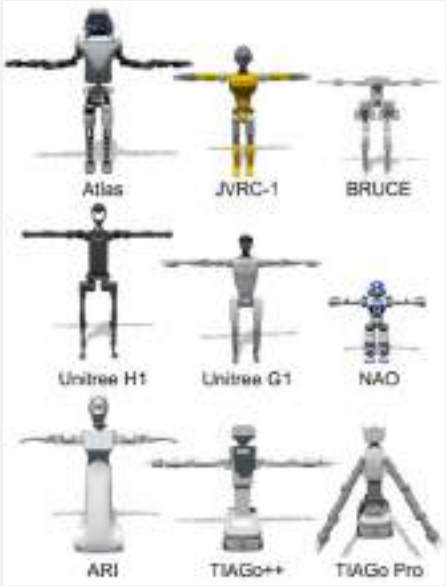
Imitation Learning

Why Imitation Learning from Humans?

Democratizing Robot Programming

Expressive Robot Motions

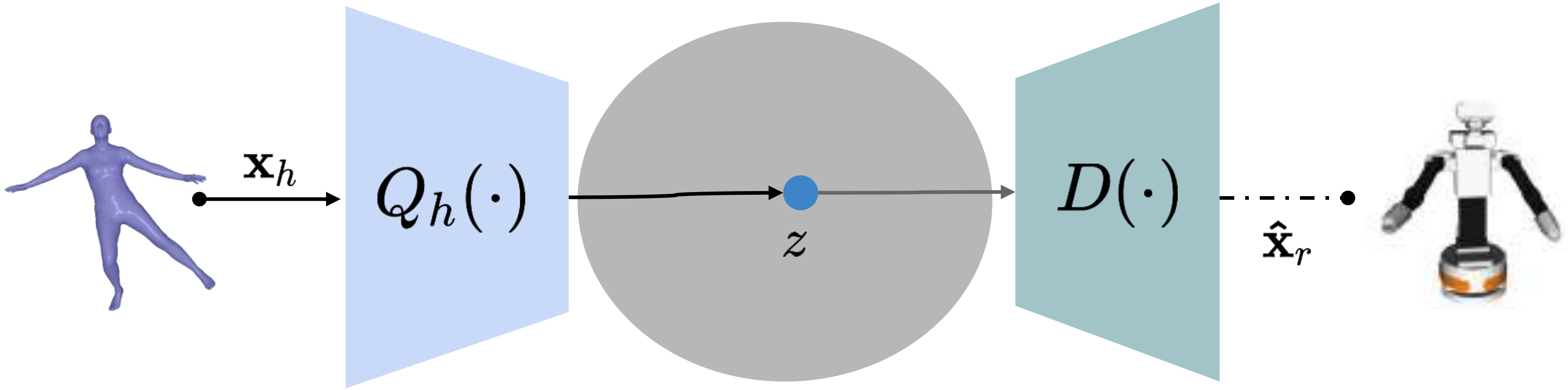
To Any Robots

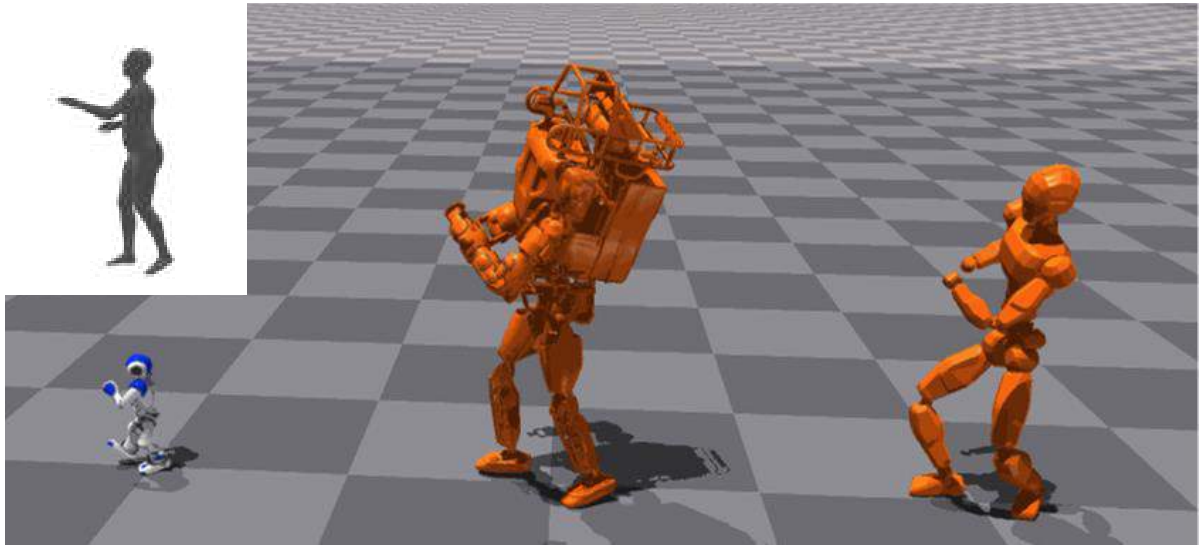


Fast Efficient Skill Learning

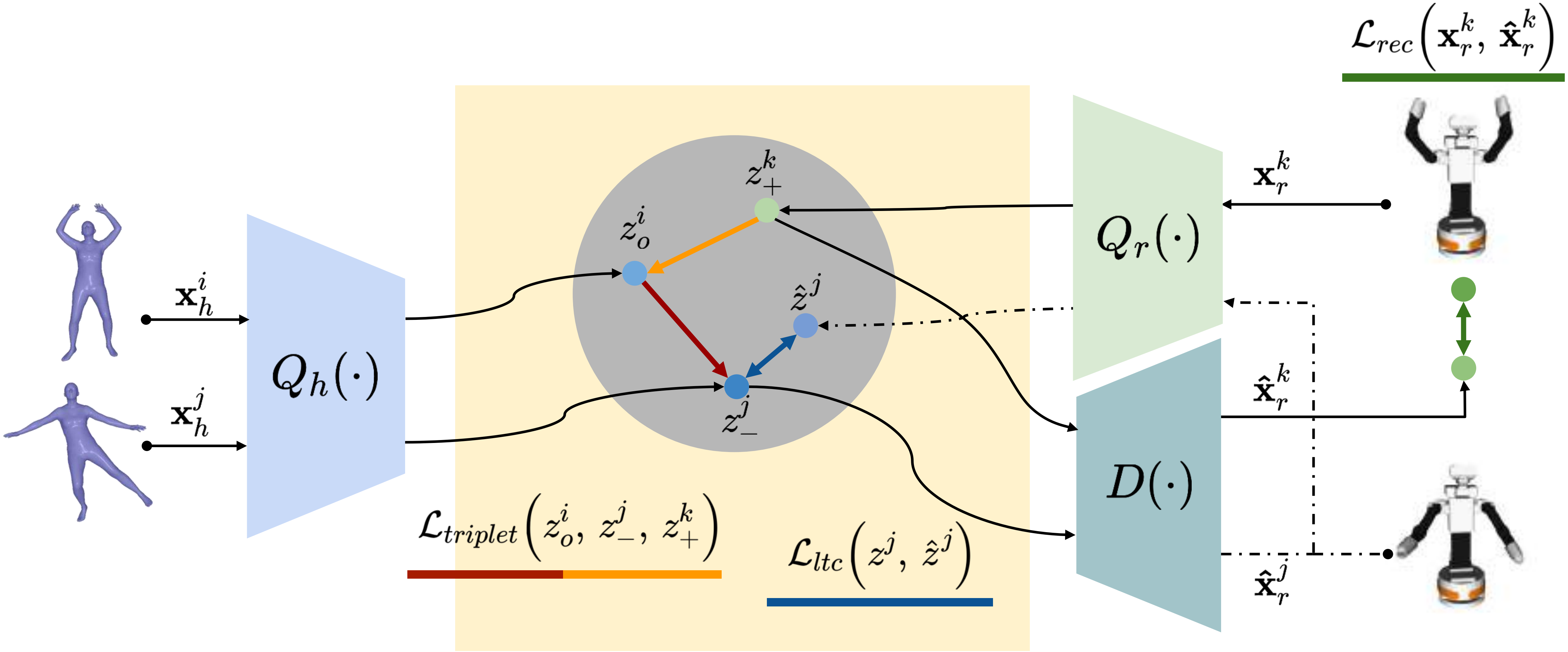
Natural Human-Robot Interaction

ImitationNet is an **unsupervised** DL method for human-to-robot retargeting via expressive shared latent space.

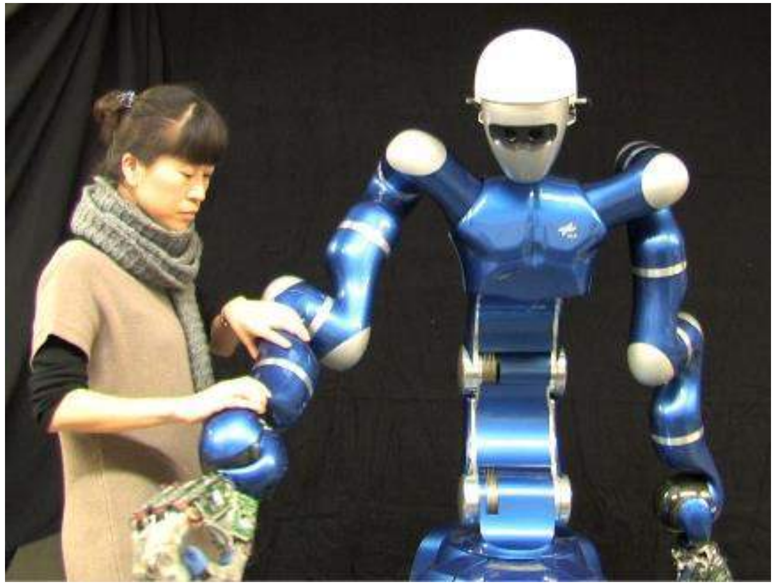


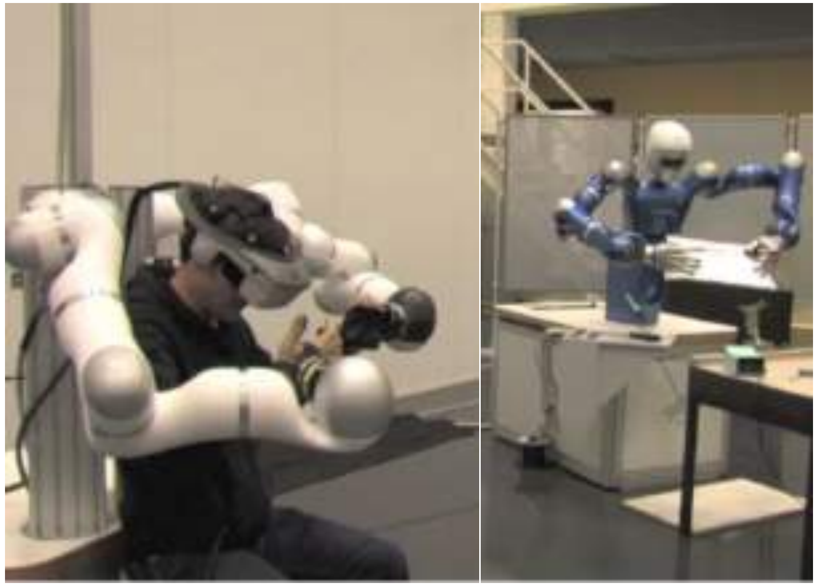


Shared latent space is built in unsupervised manner.



Imitation Learning from Humans





Motion Imitation

[Humanoids 2008, SYROCO2012, AT 2012, ICRA11, ICRA2014, etc]

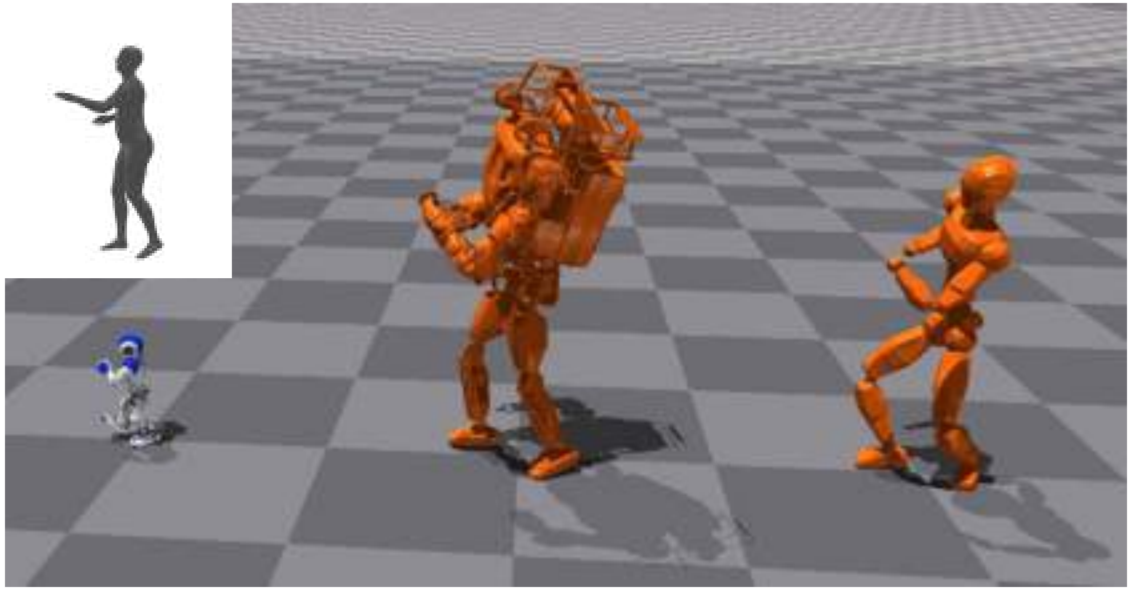
Kinesthetic teaching

[Autonomous Robots 2011, IROS 2010, ICRA 2015, etc]

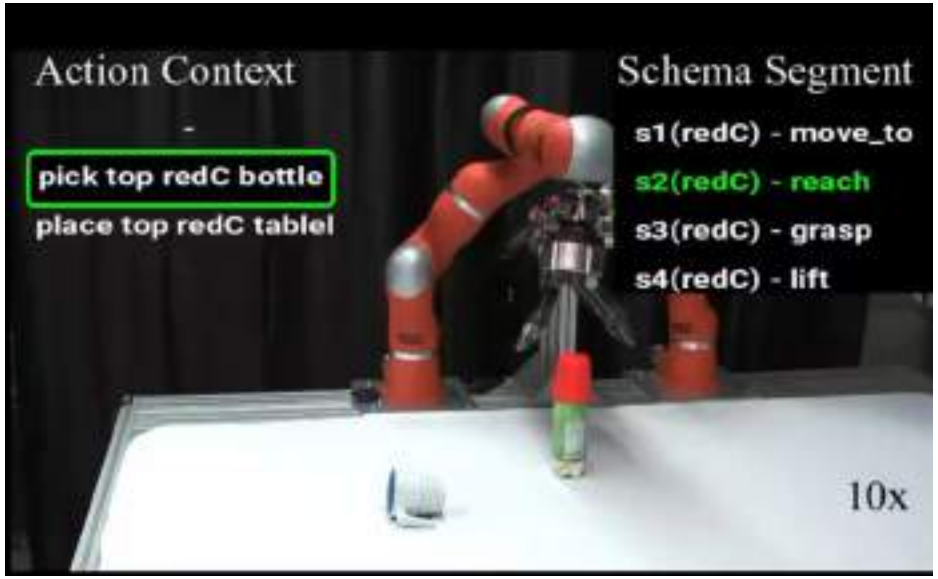
Teleoperation

[IROS 2011, WHC 2017, AURO2019, ICRA 2020, RAL 2021, TRO 2022, RAL 2023, RAL 2024, etc]

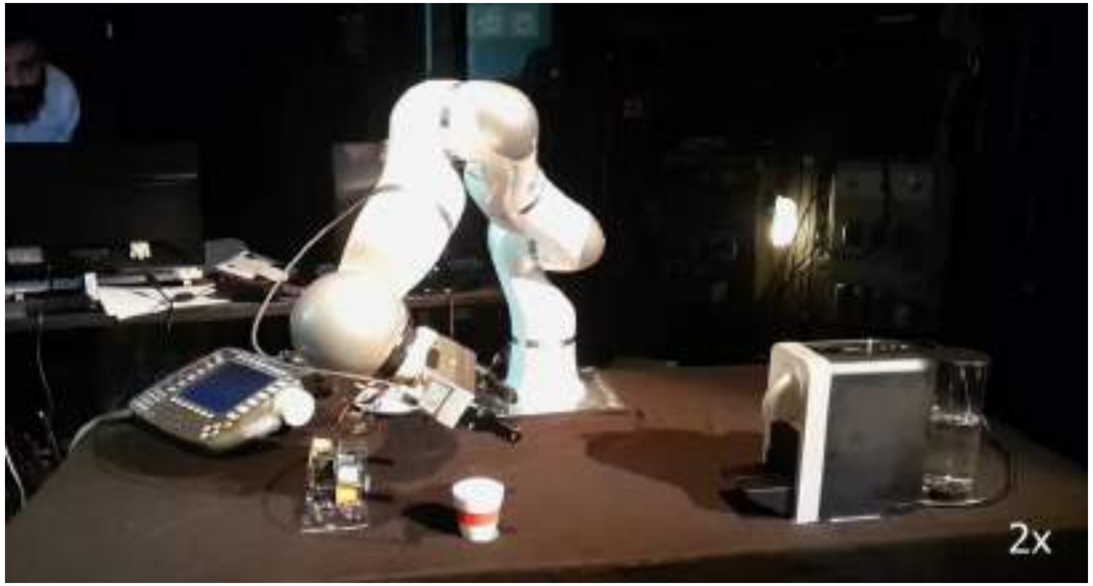
[Pervez and Lee, 2018]



[Yan+, 2023, 2025]

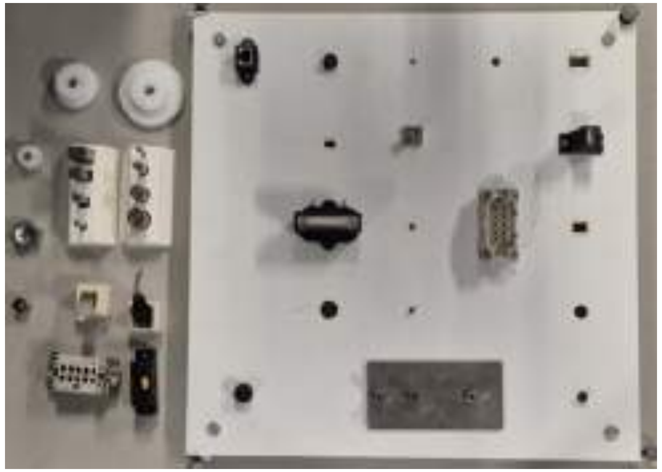


[Agostini+, RAL, 2020]



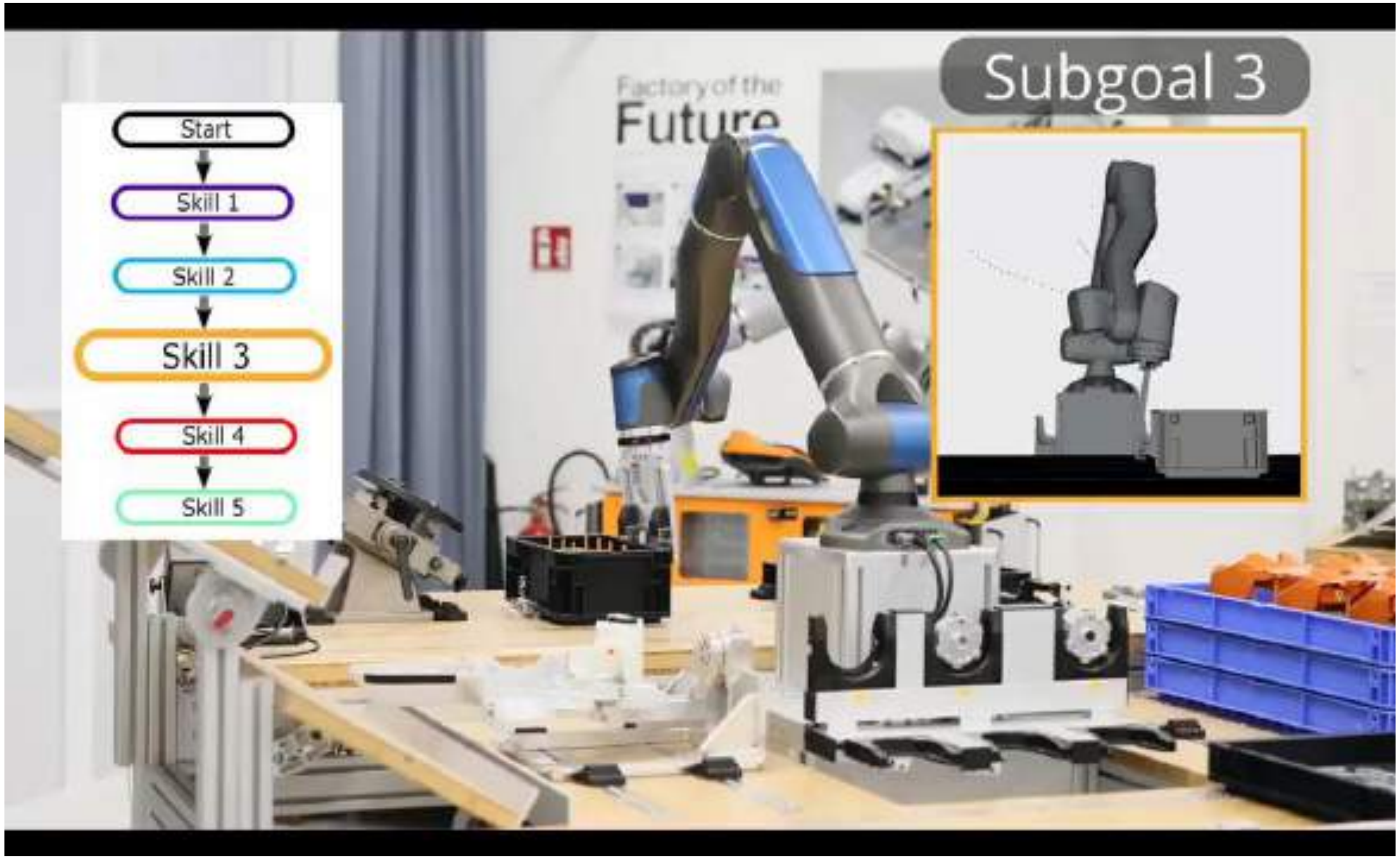
Bayerischer Rundfunk Zuendfunk Netzkongress, 2016

Embodied Intelligence: Contact-rich Manipulation



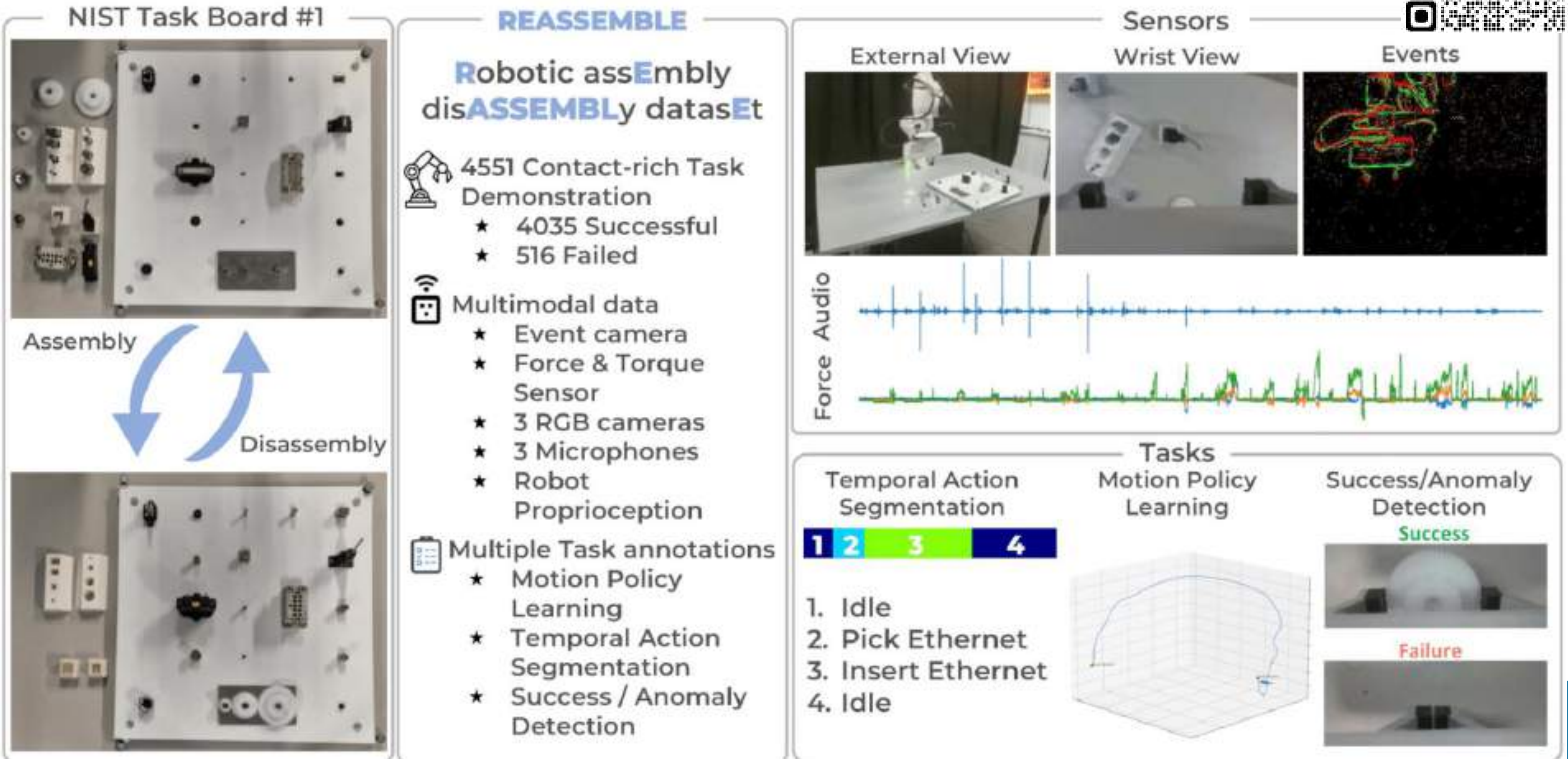
[Sliwowski+, REASSEMBLE, RSS 2025]

[Xue, RSS 2025]



[Willibald & Lee, IJRR 2025]

REASSEMBLE Dataset RSS 2025



REASSEMBLE Dataset

4 High-level Action

- Pick
- Insert
- Remove
- Place

9 low-level skills

- Grasp
- Lift
- Approac h
- Twist
- Push
- Align
- Release
- Pull
- Nudge

17 Objects

68 Unique action-object instances

121 Unique skill-object instances

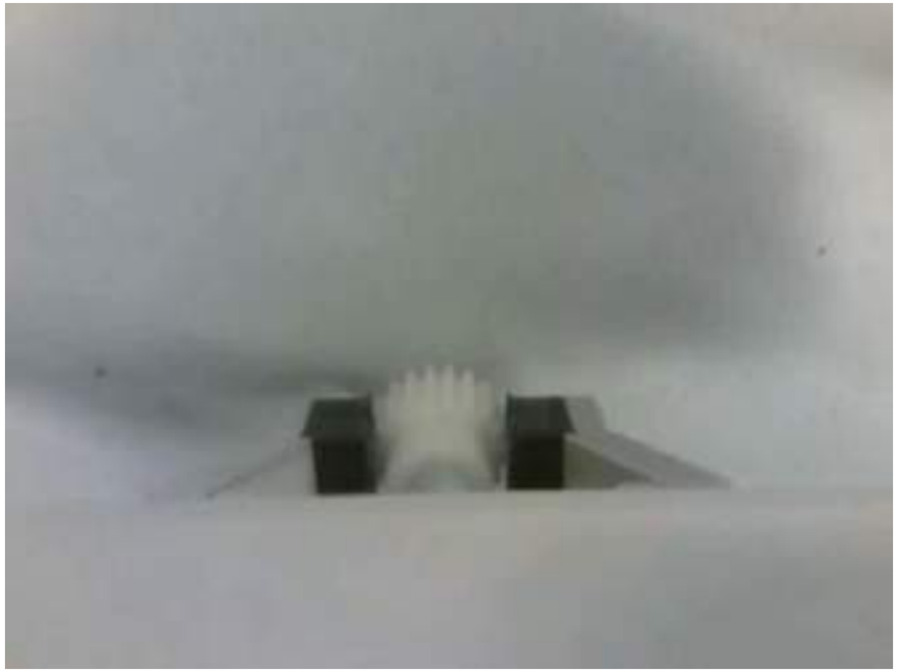
REASSEMBLE

Hierarchical skill execution

Assembly

Insert Small Gear ... Pick USB ...

Approach | Align | Push | Grasp | Lift



Insert Small Gear

Approach | Align | Push | Grasp | Align | Push

Imitation learning process is often designed as

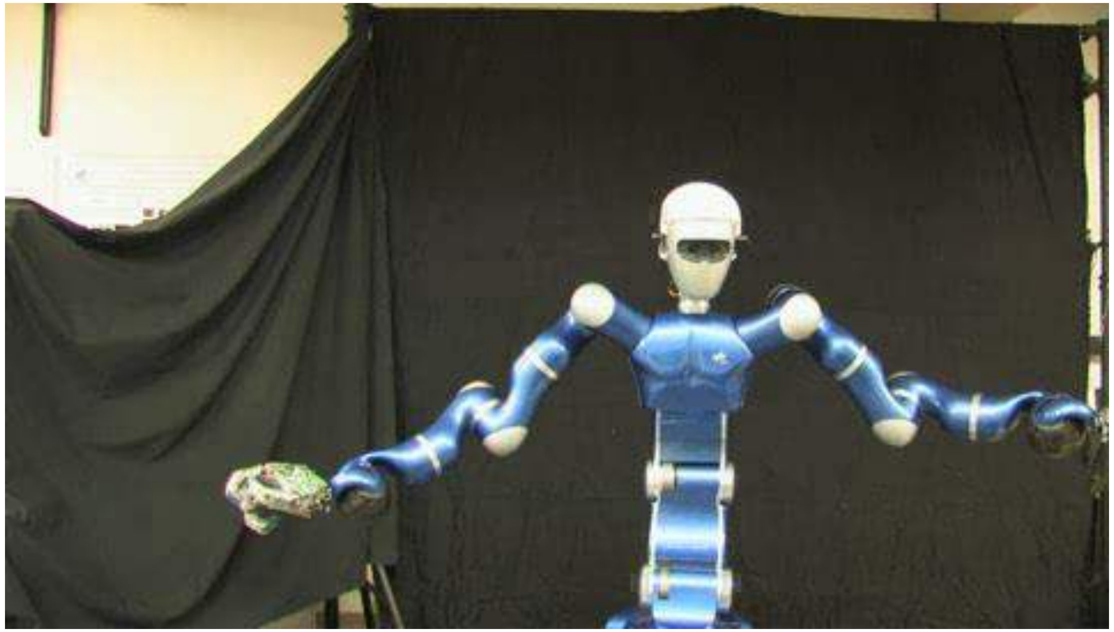
passive, ***unidirectional***, ***batch*** learning

Are we leveraging potential benefits of **HRI** in robot learning?

Part I

Interactive Robot Learning

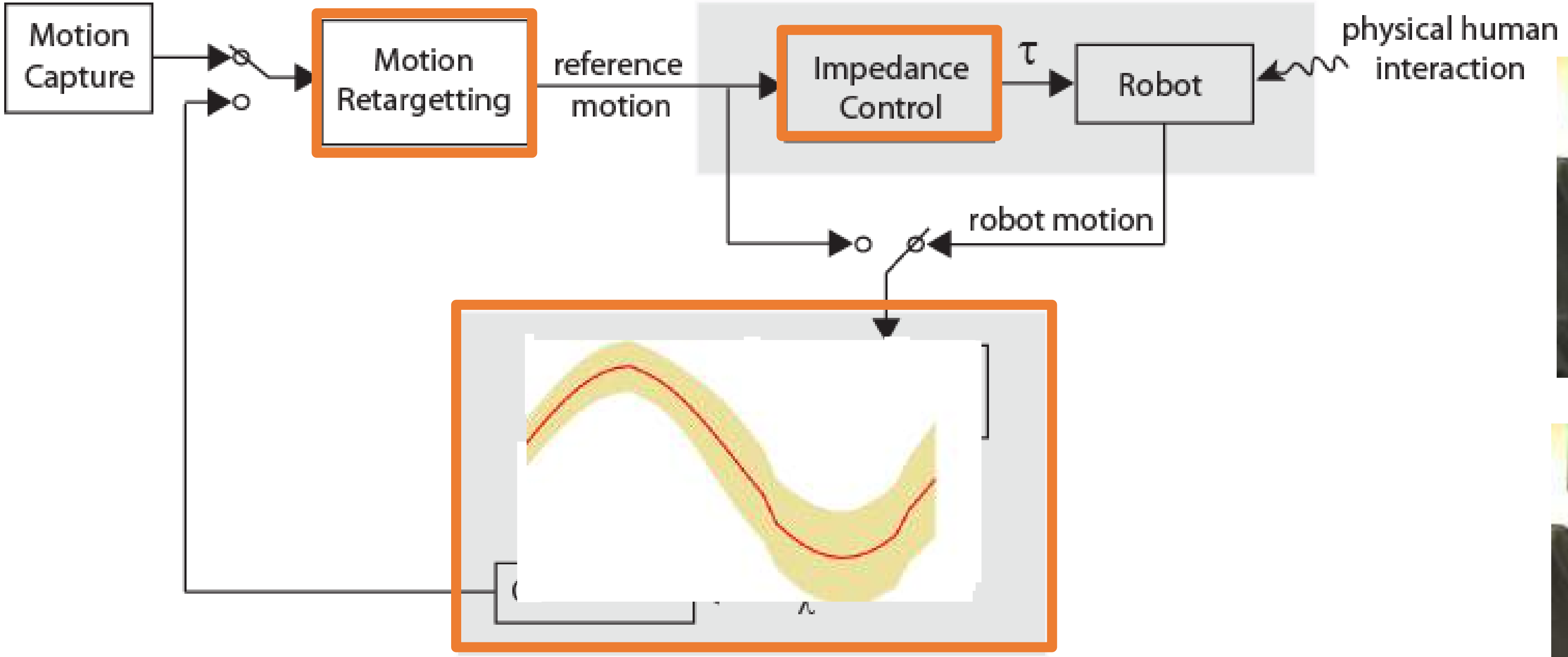
Teaching Pulp Fiction Twist Dance



The **demonstrator's intent** was not clearly conveyed to the robot.

Refine by kinesthetic teaching

$$\tau = g(q) + M(q)\ddot{q}_d + C(q,\dot{q})\dot{q}_d - D\dot{\tilde{q}} - s(\tilde{q})$$



[Autonomous Robots 2011, IROS 2010]

Interactive incremental learning
with heterogeneous teaching modalities
could communicate the demonstrator‘s intent better.

Current Biology

Report

Longitudinal evidence that infants develop their imitation abilities by being imitated

Samuel Essler,[1,2,5,*] Tamara Becher,[1] Carolina Pletti,[1,3] Burkhard Gniewosz,[4] and Markus Paulus[1]
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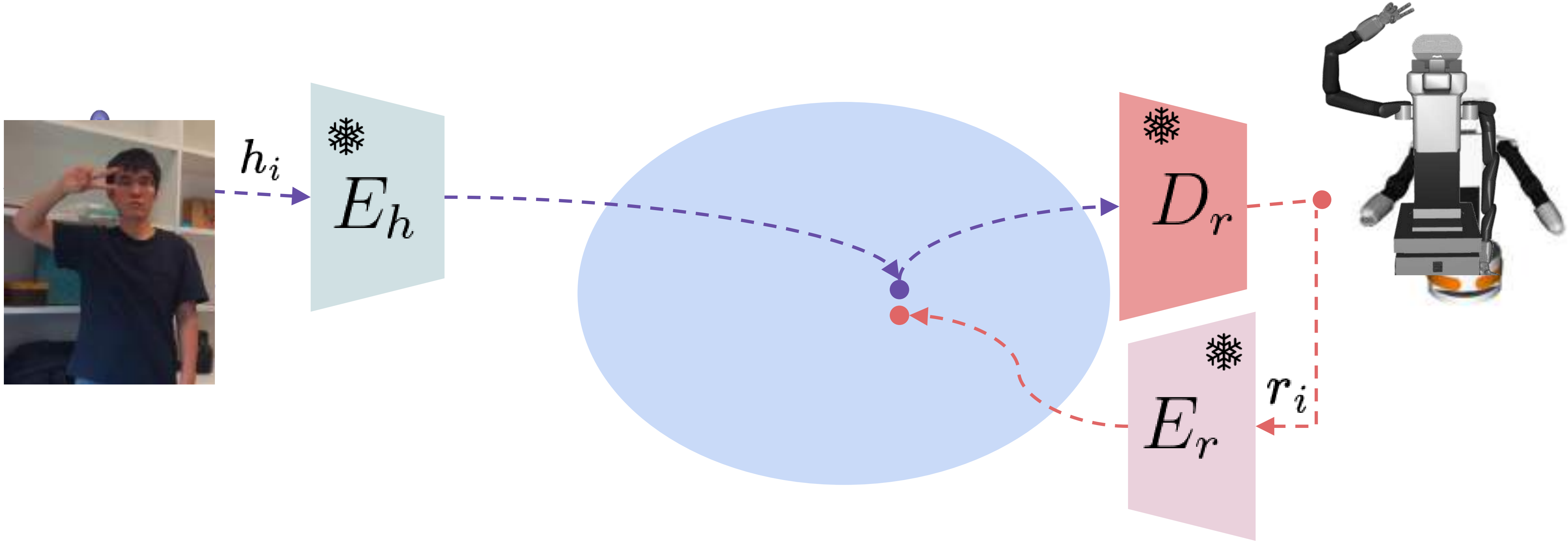
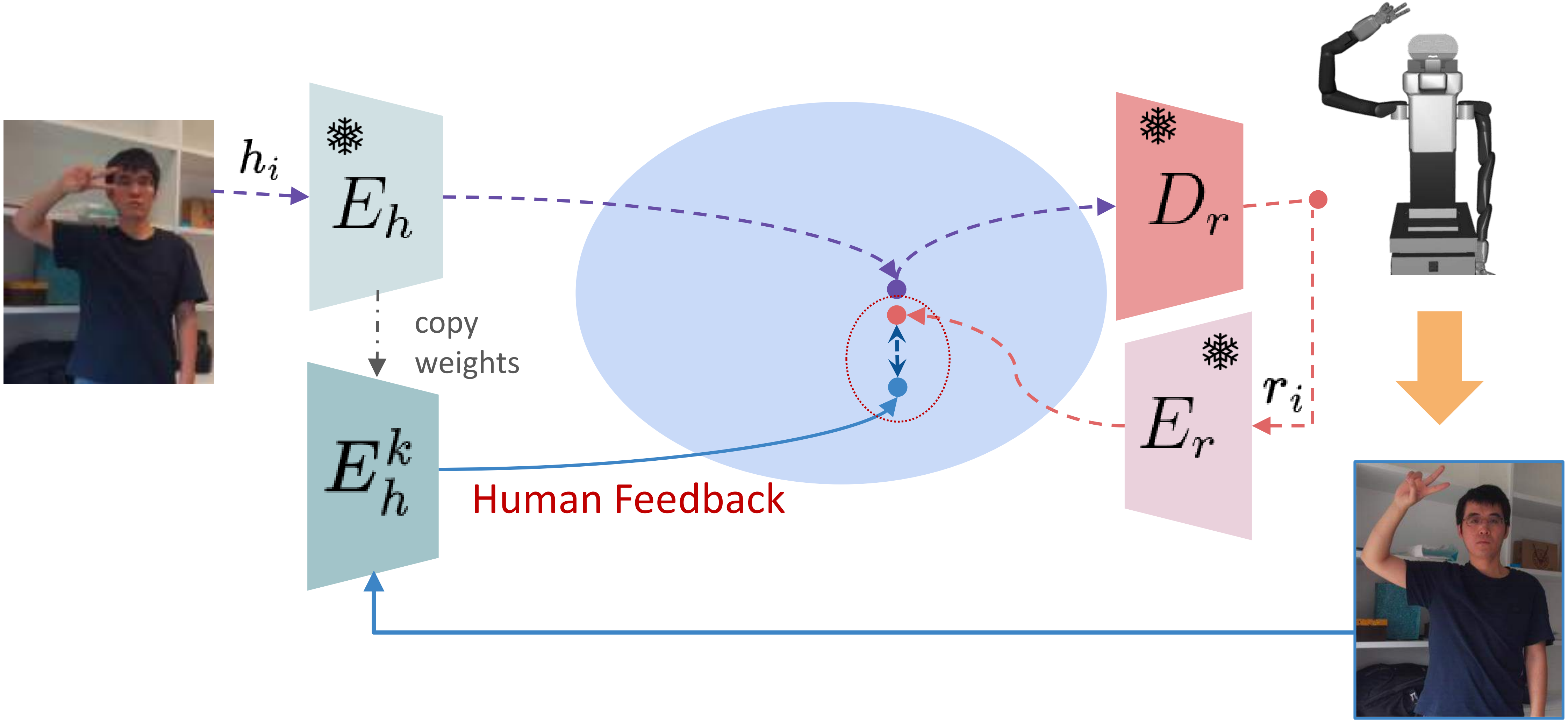
[2]FOM University of Applied Sciences, Leimkugelstraße 6, 45141 Essen, Germany
[3]University of Vienna, Universitätsring 1, 1010 Vienna, Austria
[4]Paris-Lodron-University, Kapitelgasse 4/6, 5020 Salzburg, Austria
[5]Lead contact
*Correspondence: samuel.essler@psy.lmu.de
https://doi.org/10.1016/j.cub.2023.08.084

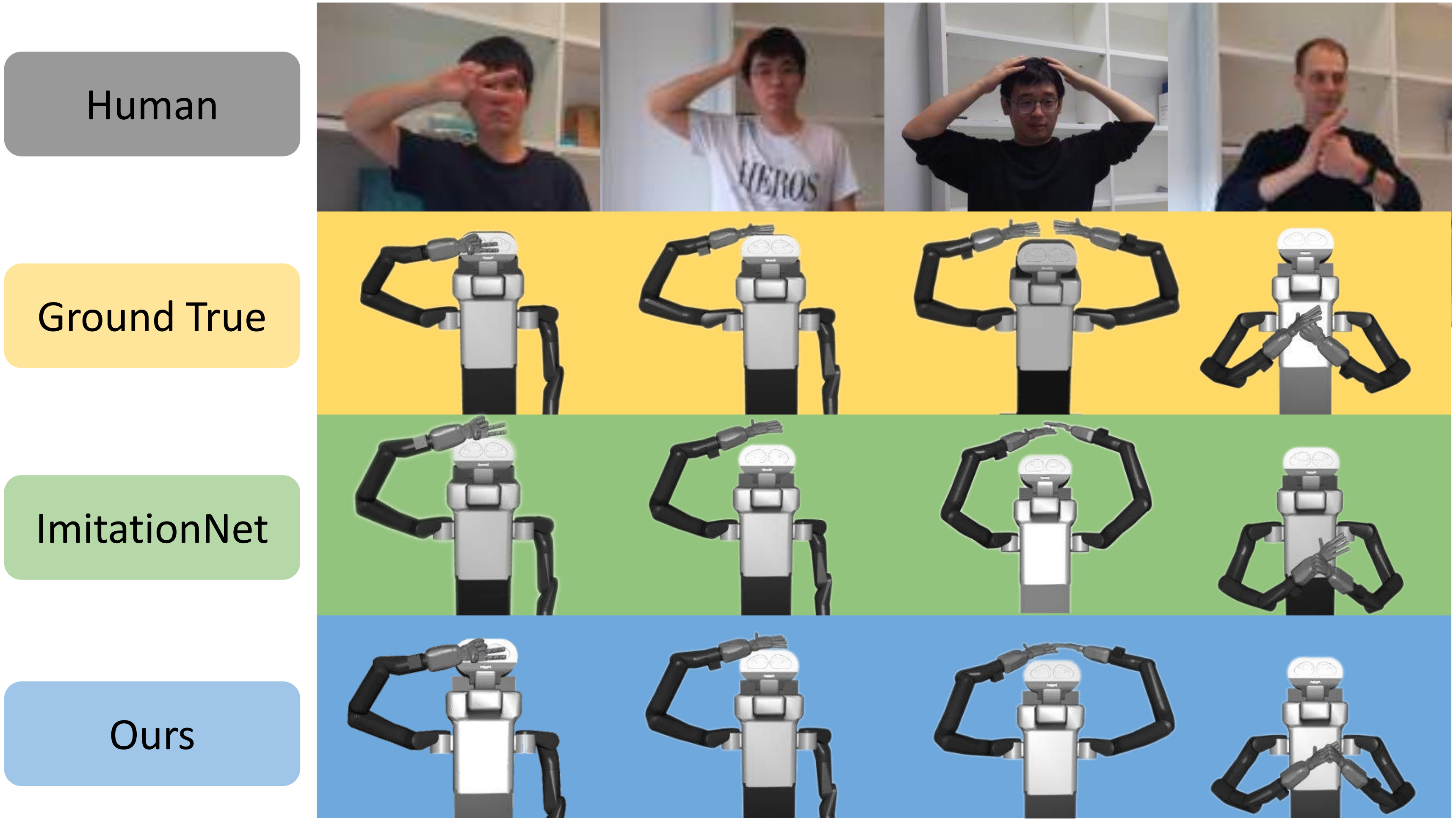
ImitationNet: Unsupervised Human Motion Retargetting



ImitationNet Finetuning using a few Human Feedback data



Performance of Personalized Motion Retargetting



[Yan et al, ICDL, 2025]

Human feedback

- reduces the gap between **robot‘s perception of human motion** and **human‘s perception of robot motion.**
- reinforces **the coactivation of visual and motor representations**

We saw ***Interactive robot learning*** *p*rocedure, but via **human‘s feedback**.

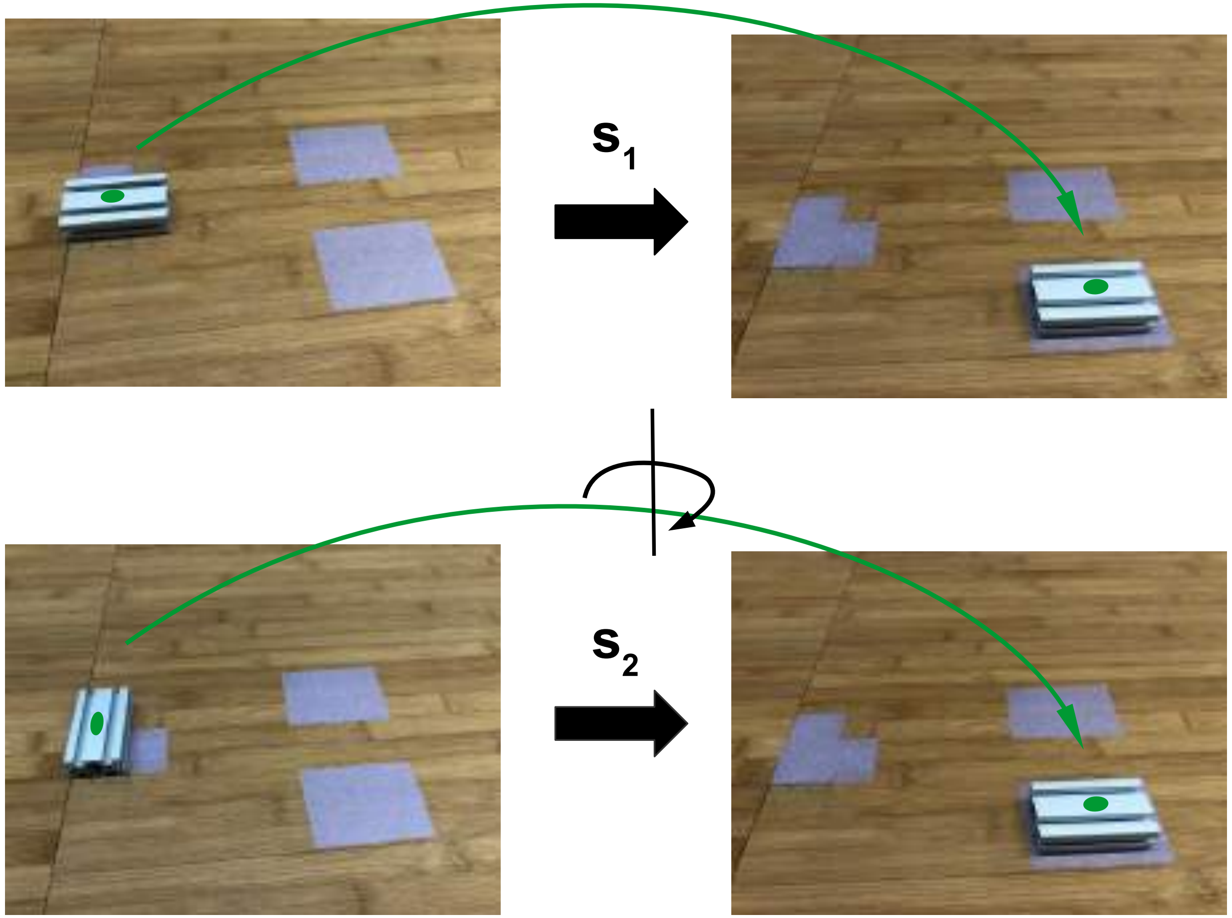
Robots remained *passive*.

Part II

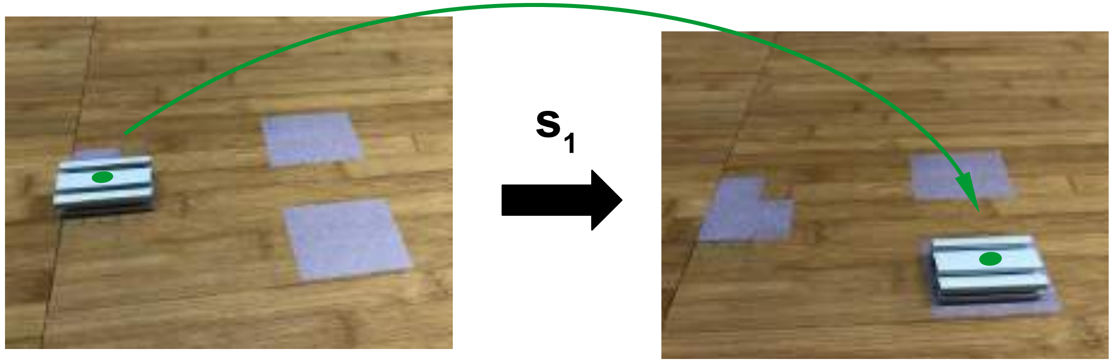
Pro-Active Robot Learning

Policy Learning by Noticing Anomalies

Proprioceptive Policy Learning without Vision

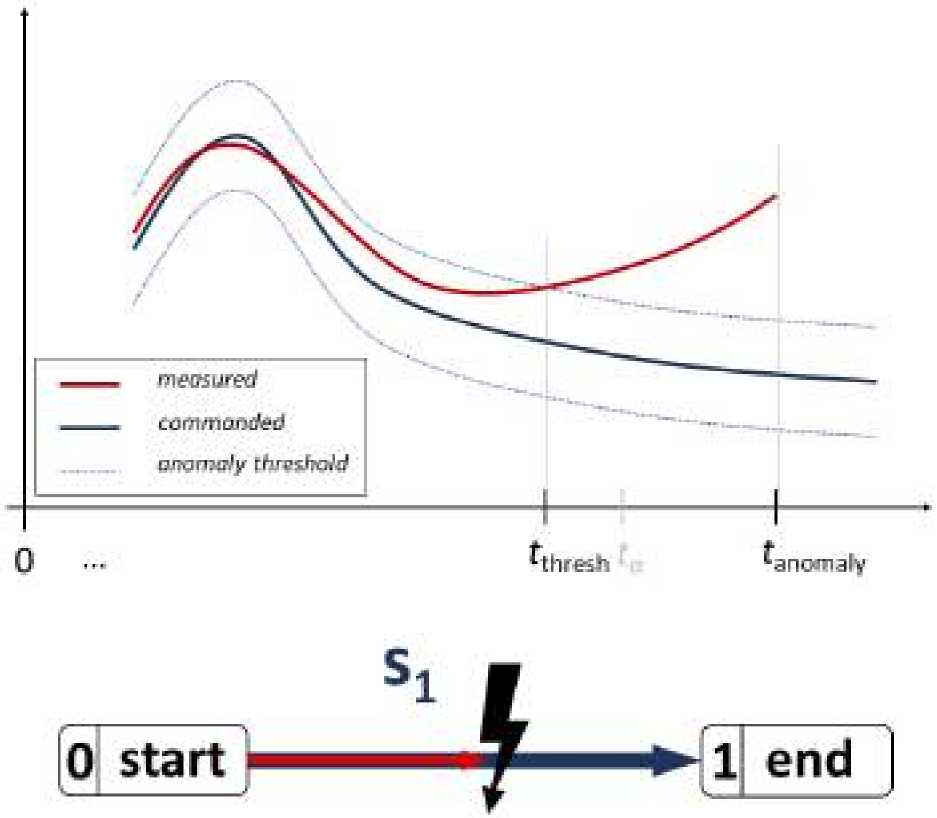


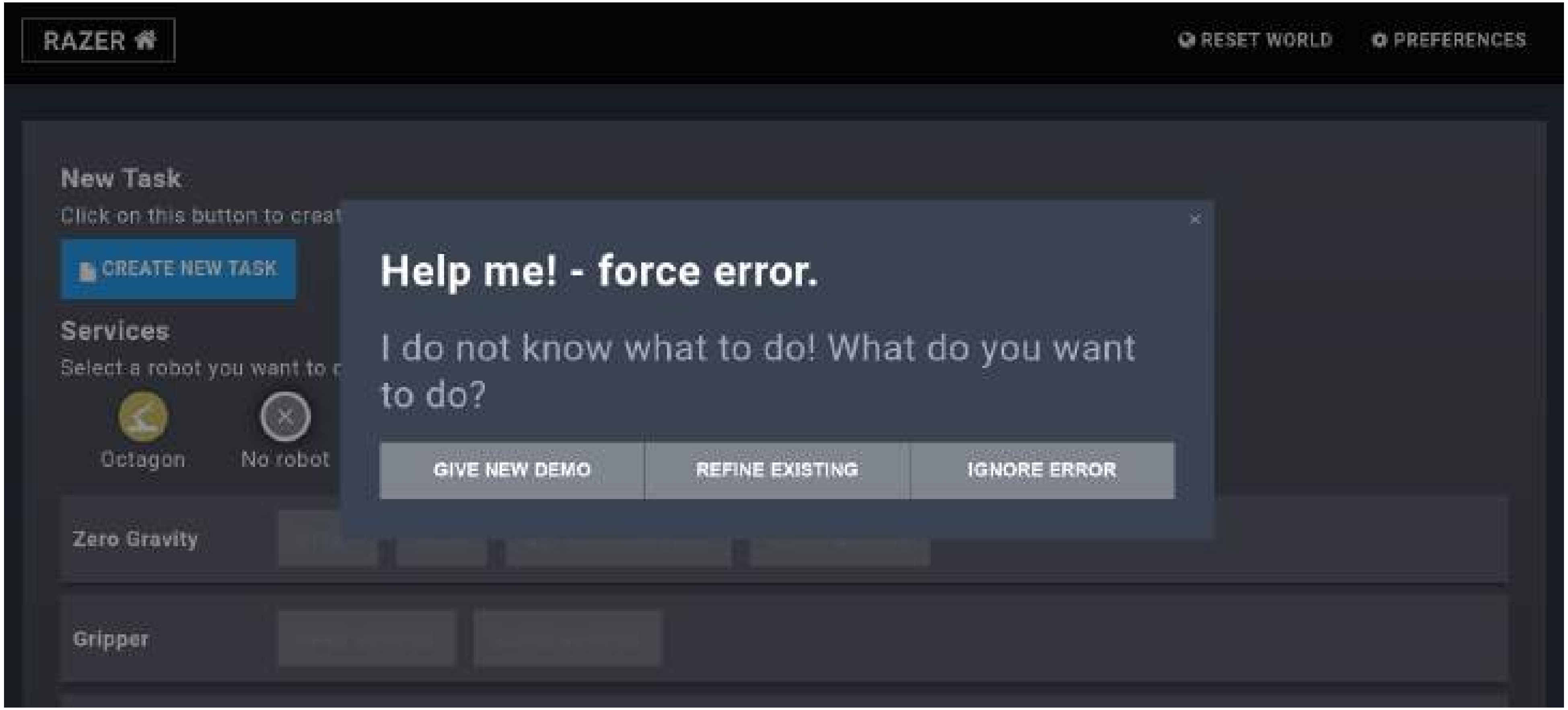
Initial Demonstration



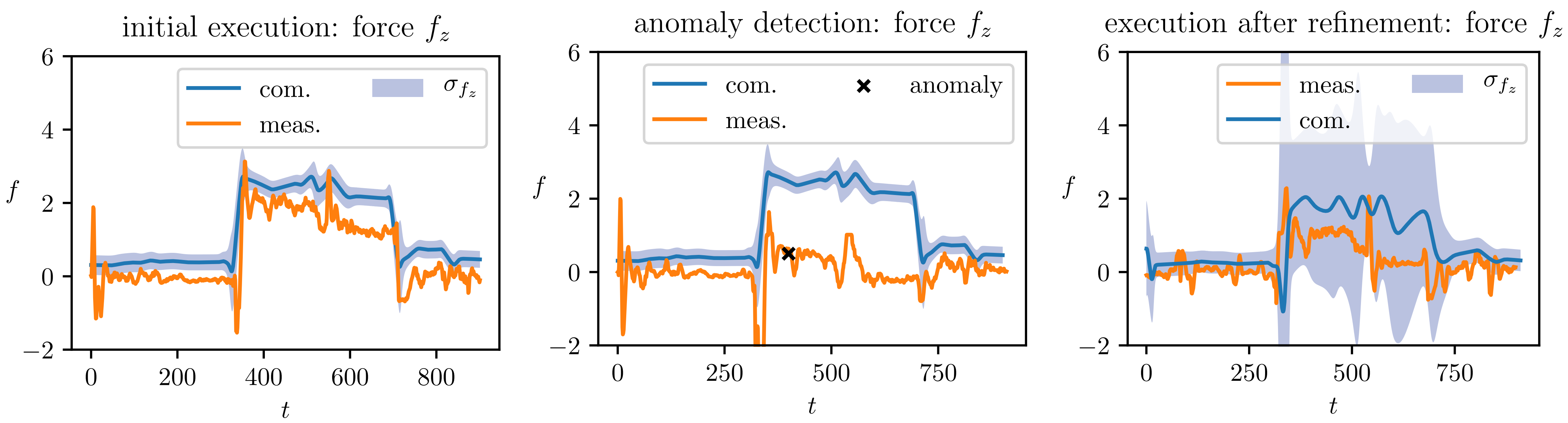
Task-Graph Generation

Monitored Execution: Anomaly Detection

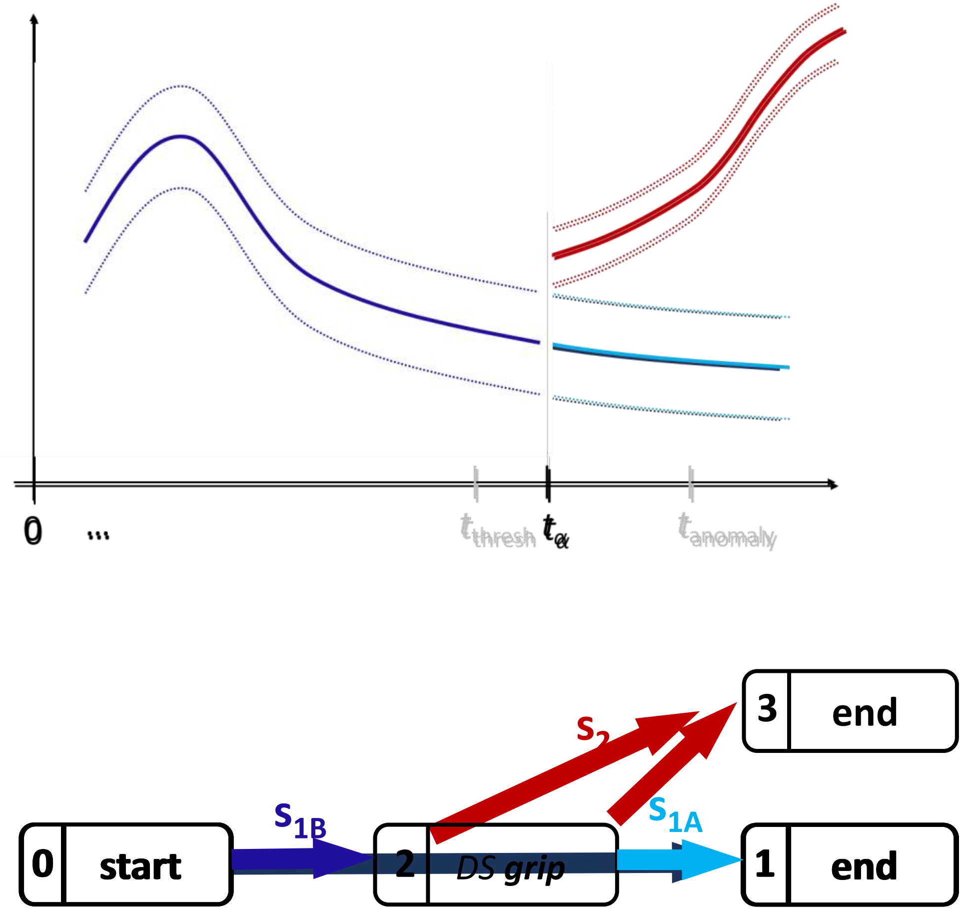



RAZER
RESET WORLD
PREFERENCES
New Task
CREATE NEW TASK
Services
Octagon
No robot
Help me! - force error.
I do not know what to do! What do you want to do?
GIVE NEW DEMO
REFINE EXISTING
IGNORE ERROR
Zero Gravity
Gripper

Skill Refinement



Add a New Skill to Task-Graph

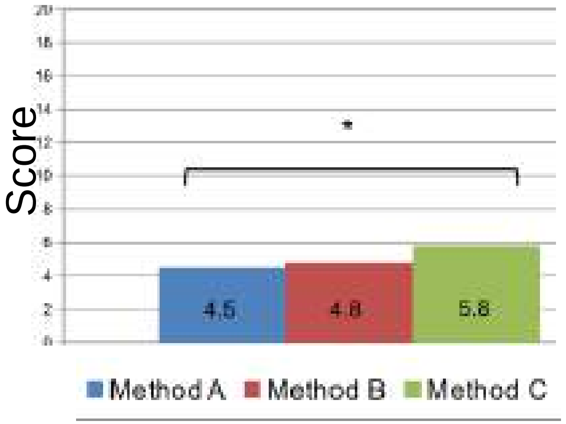


User Study on Interactive Programming and UI

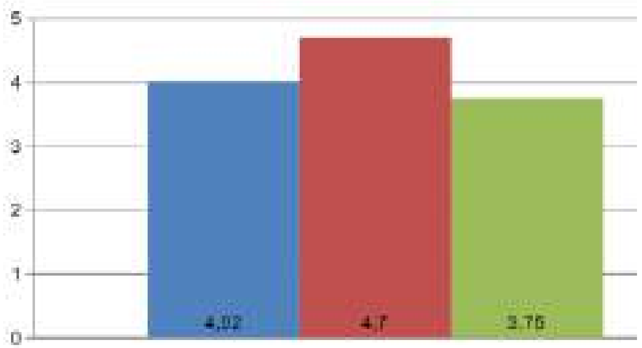
	Sequential Batch Programming (SBP)	**Collaborative Incremental** Programming (CIP)	**User-triggered Incremental** Programming (UIP)
Knowledge representation	sequential	sequential & **branching**	sequential & **branching**
Teaching Interaction	Unidirectional: **passive** data acquisition	Bidirectional: **active** data request	Unidirectional: **passive** data acquisition

21 participants

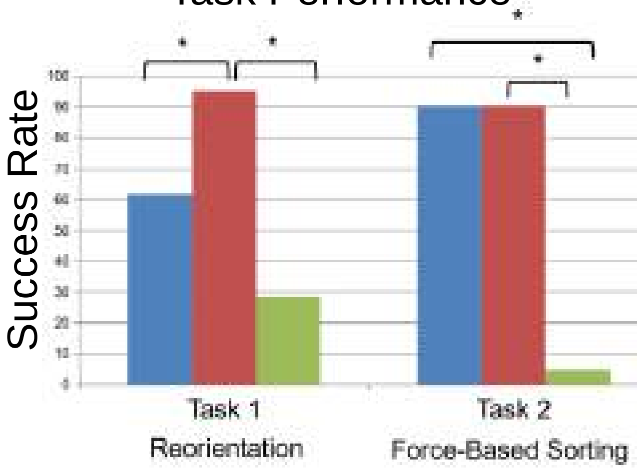
NASA-TLX



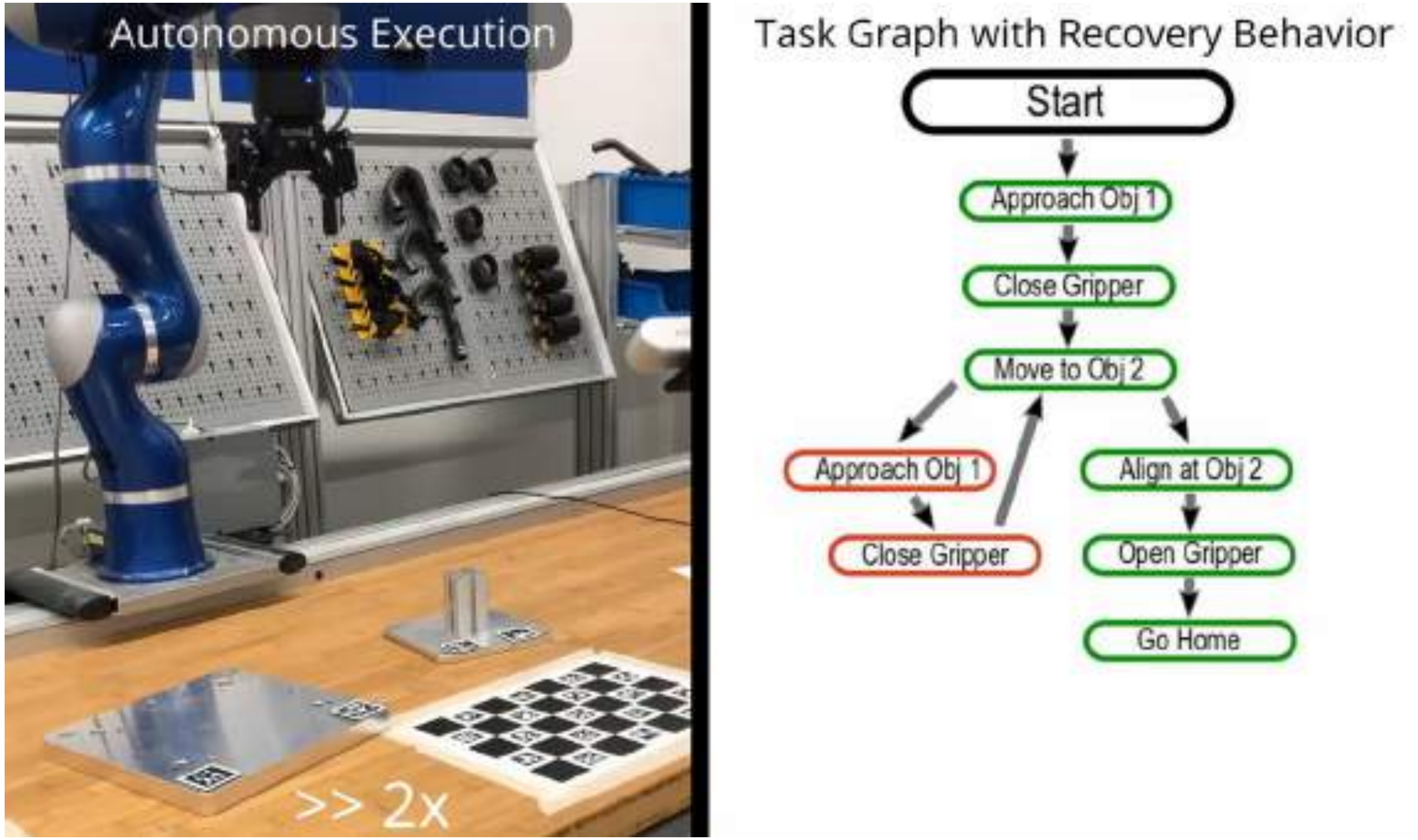
QUESI



Task Performance

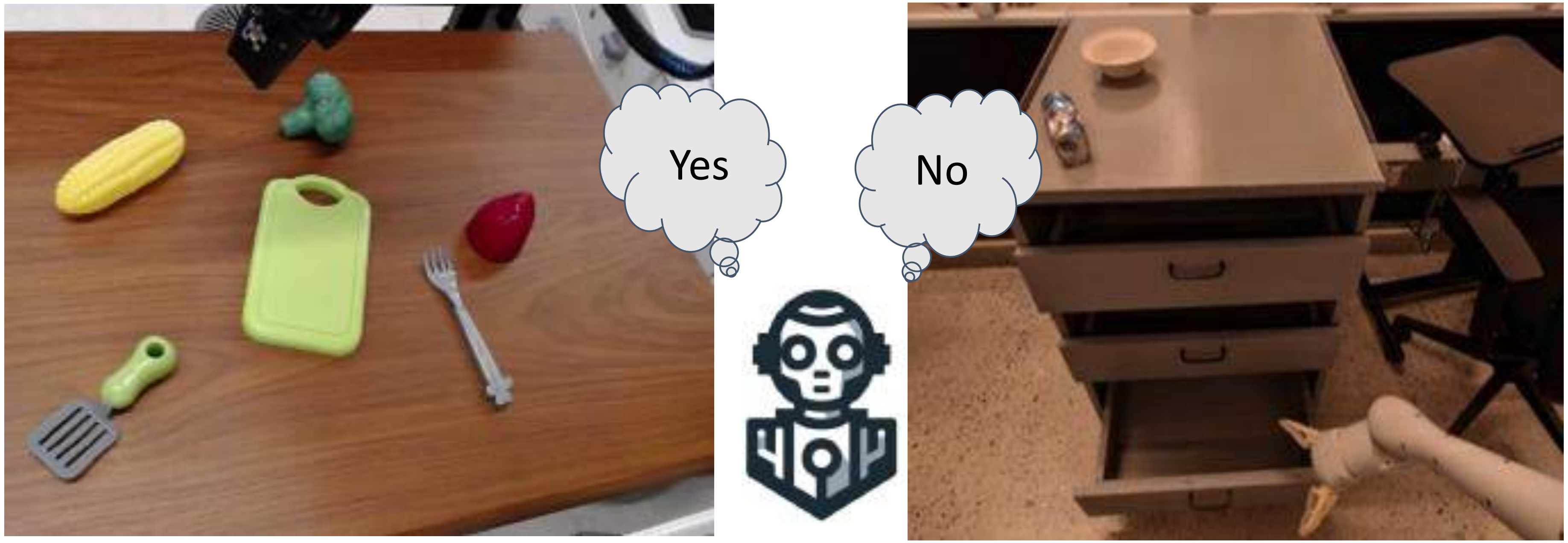


Online task programming: Segmentation and Anomalies



Can I put spatula on cutting board?

Did I open the top drawer?



Anomaly Detection based on Pre- and Post-condition Learning

ConditionNET

- Visual-language model for action preconditions and effects.
- Training for consistent action representation
- Real-time execution monitoring.

ConditionNET

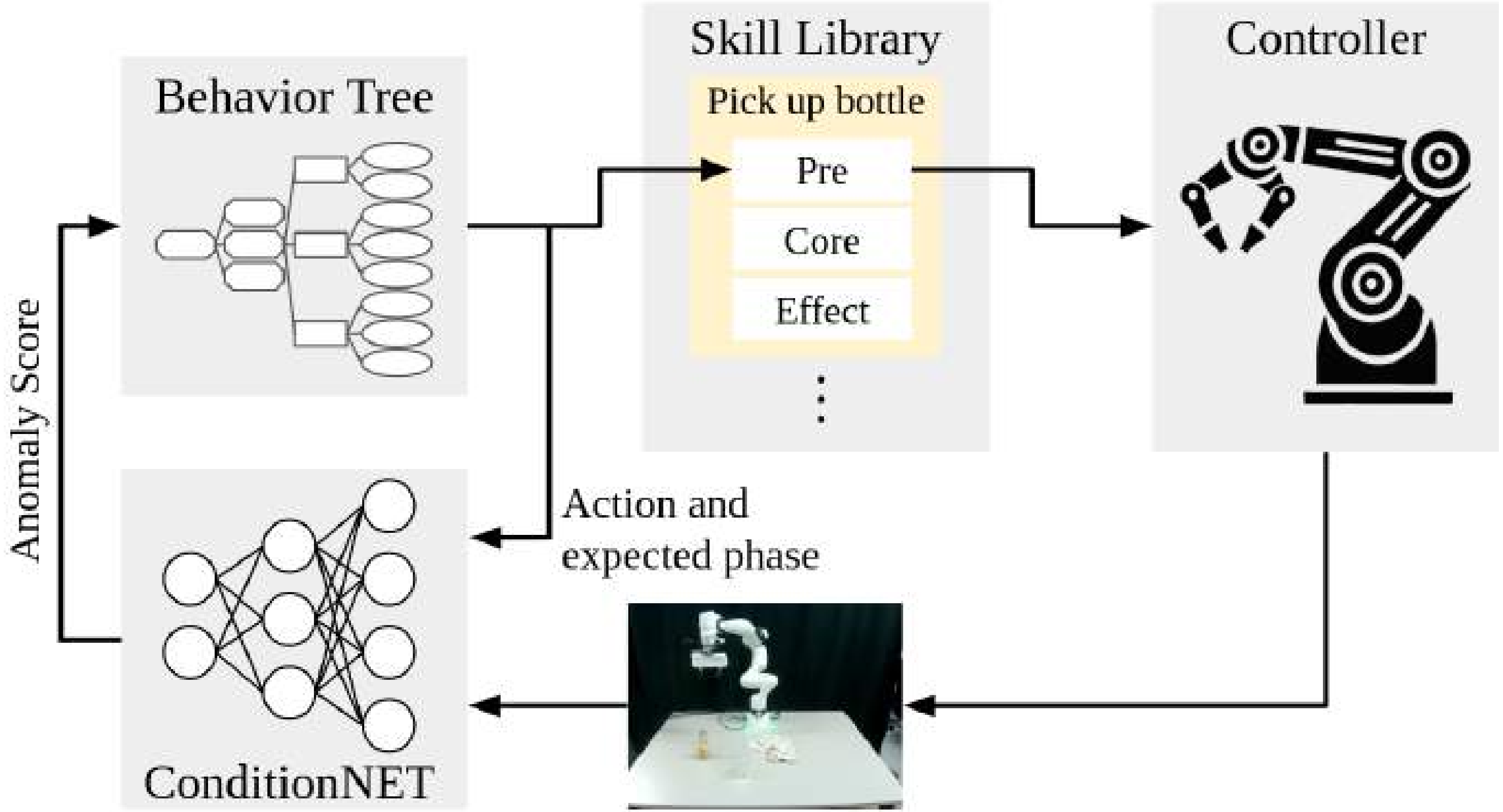
(30M Parameters)

Precondition
Postcondition
Unsatisfied

Planner

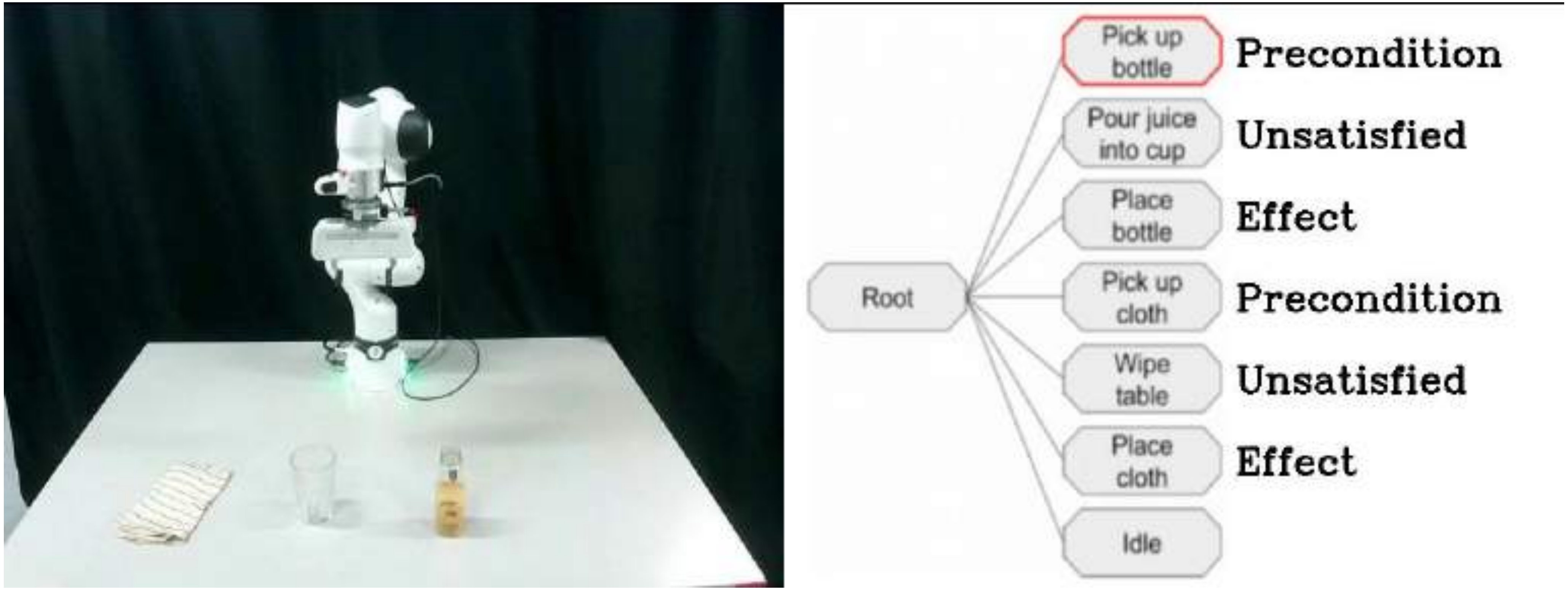
Pick up bottle

Planning, Execution, and Monitoring



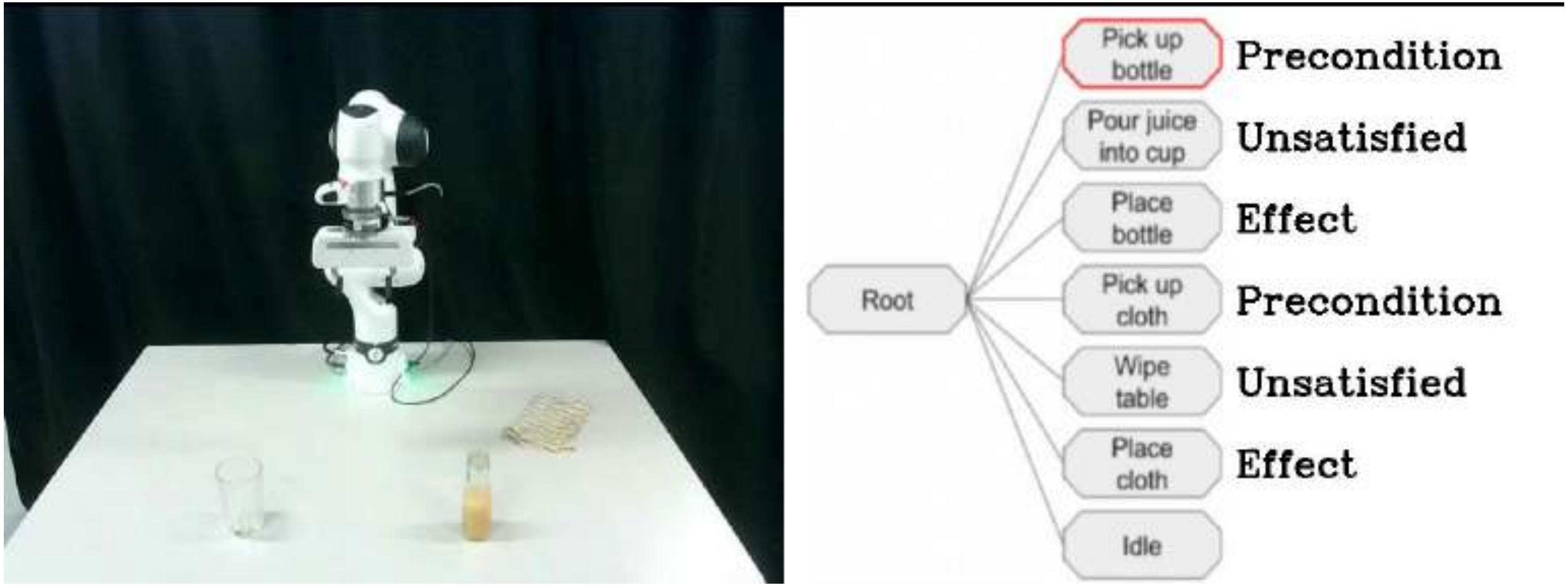
Monitoring Pre-/Post- Condition of Actions

Human perturbation – taking away items



Monitoring Pre-/Post- Condition of Actions

Human perturbation – spilling and taking away items

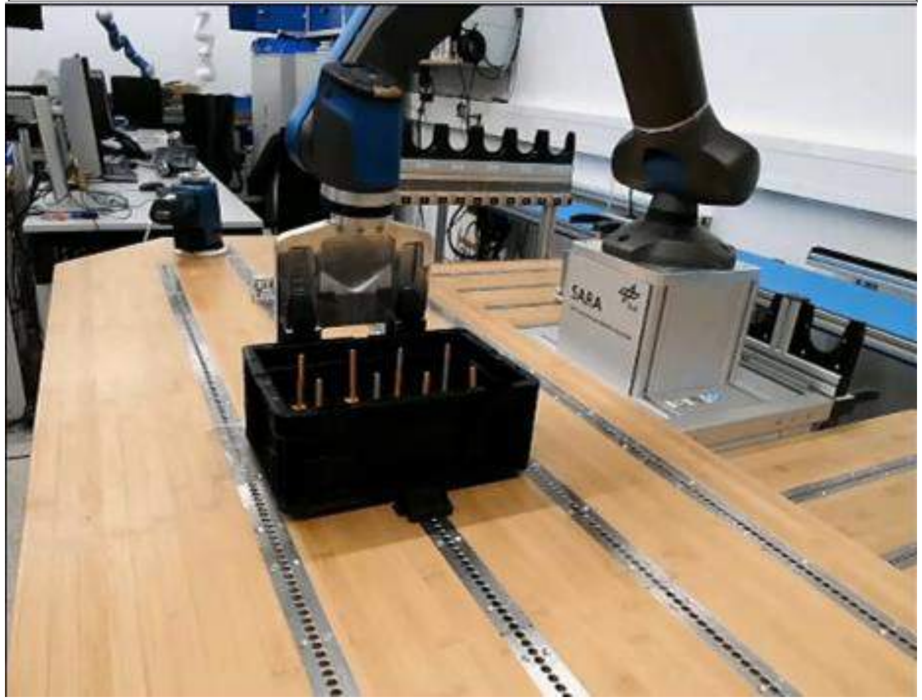


ConditionNET Evaluation on two datasets

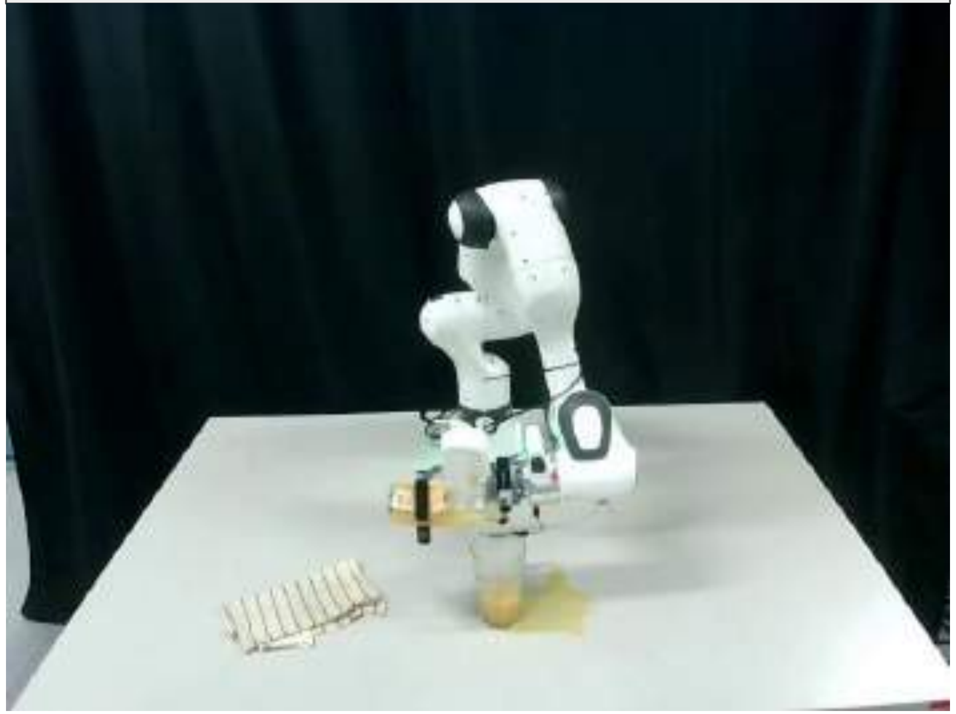
TABLE I: Quantitative evaluation.

Model	Anomaly Detection				Condition Learning			
	Acc	Pre	Rec	F1	Acc	Pre	Rec	F1
FAILURE [19]								
CLIP+MLP	0.81	0.81	0.81	0.81	0.8	0.77	0.71	0.74
DINO+MLP	0.82	0.82	0.84	0.8	0.78	0.72	0.67	0.69
FinoNET [19]	0.79	0.79	0.79	0.79	-	-	-	-
TP-VQA [2]	0.62	0.67	0.82	0.73	0.44	0.75	0.24	0.37
ConditionNET	**0.89**	**0.91**	**0.89**	**0.88**	**0.88**	**0.85**	**0.79**	**0.82**
(Im)PerfectPour								
CLIP+MLP	0.86	0.91	0.86	0.87	0.93	0.79	0.77	0.78
DINO+MLP	0.72	0.88	0.72	0.74	0.85	0.74	0.7	0.72
FinoNET [19]	0.74	0.80	0.74	0.74	-	-	-	-
TP-VQA [2]	0.76	0.81	0.9	0.85	0.44	0.74	0.17	0.27
ConditionNET	**0.97**	**0.97**	**0.97**	**0.97**	**0.99**	**0.98**	**0.97**	**0.97**

Jamming Gripper

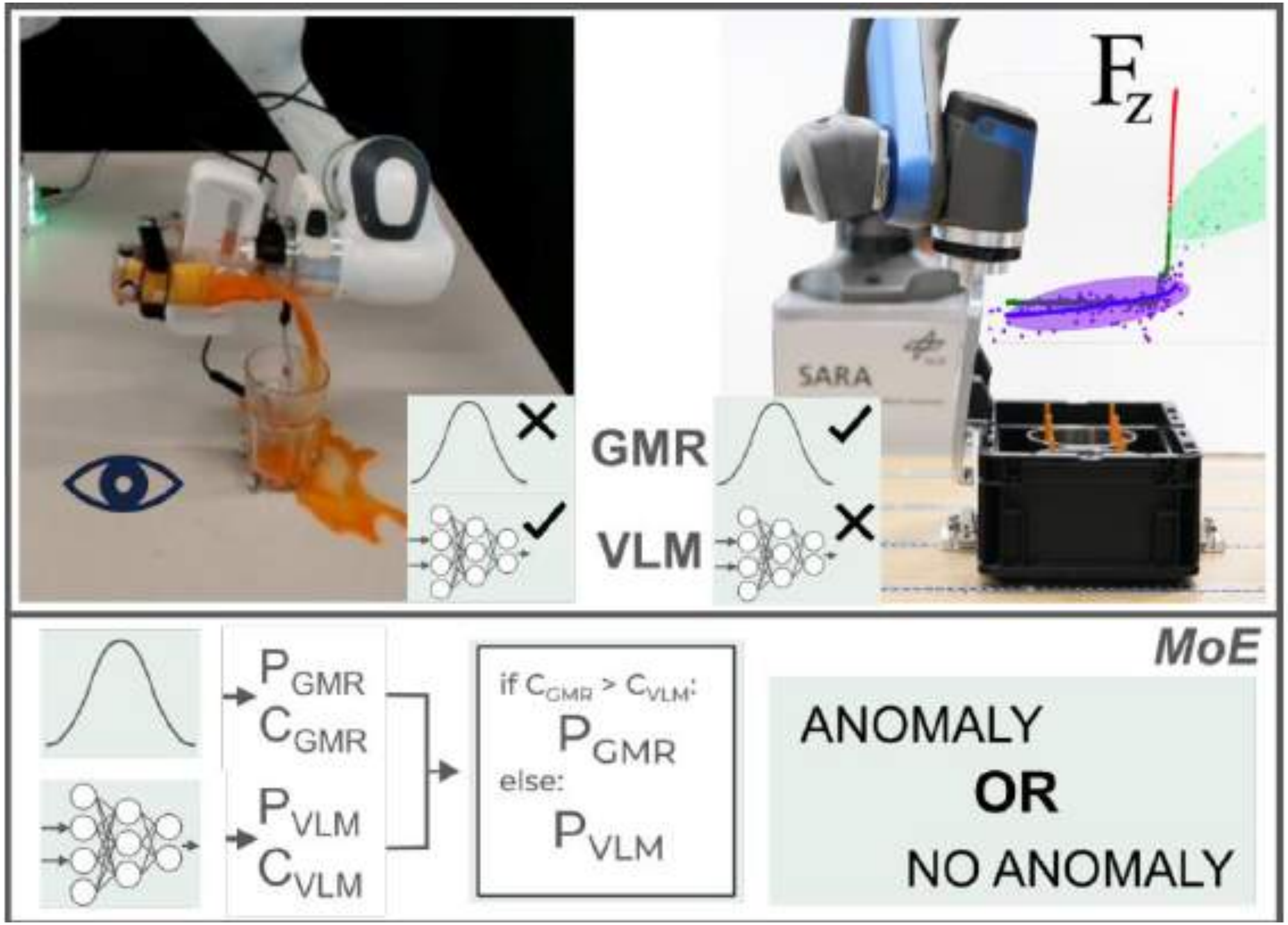


Spill Drink



Mixture of Expertise: Proprioception and Exteroception

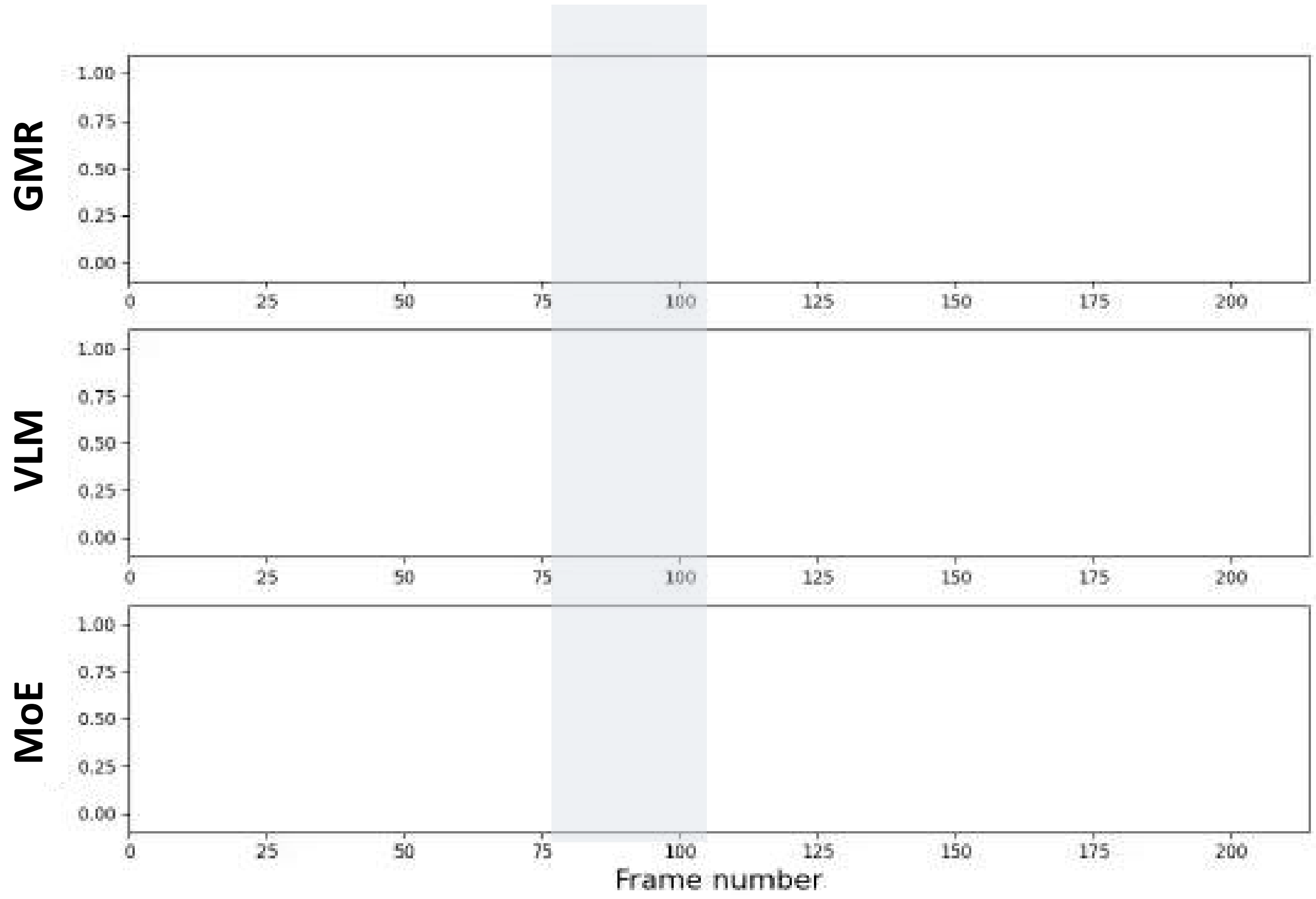
Multimodal anomaly detection

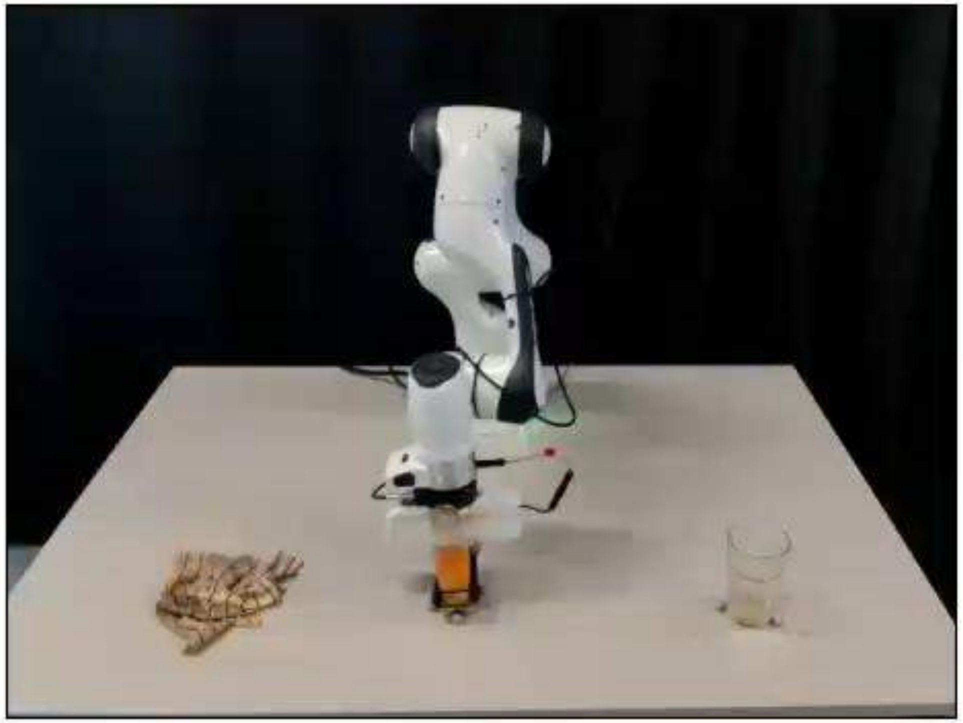


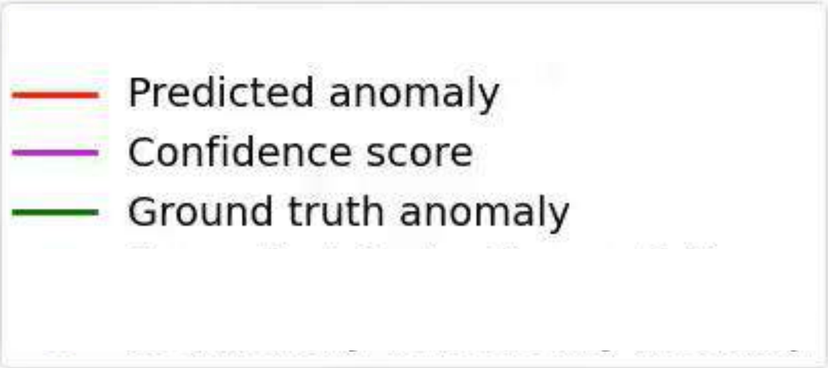
Willibald+. "Multimodal Anomaly Detection with a Mixture-of-Experts." IROS (2025)

Push while Pouring

Propriocept expert detects push.



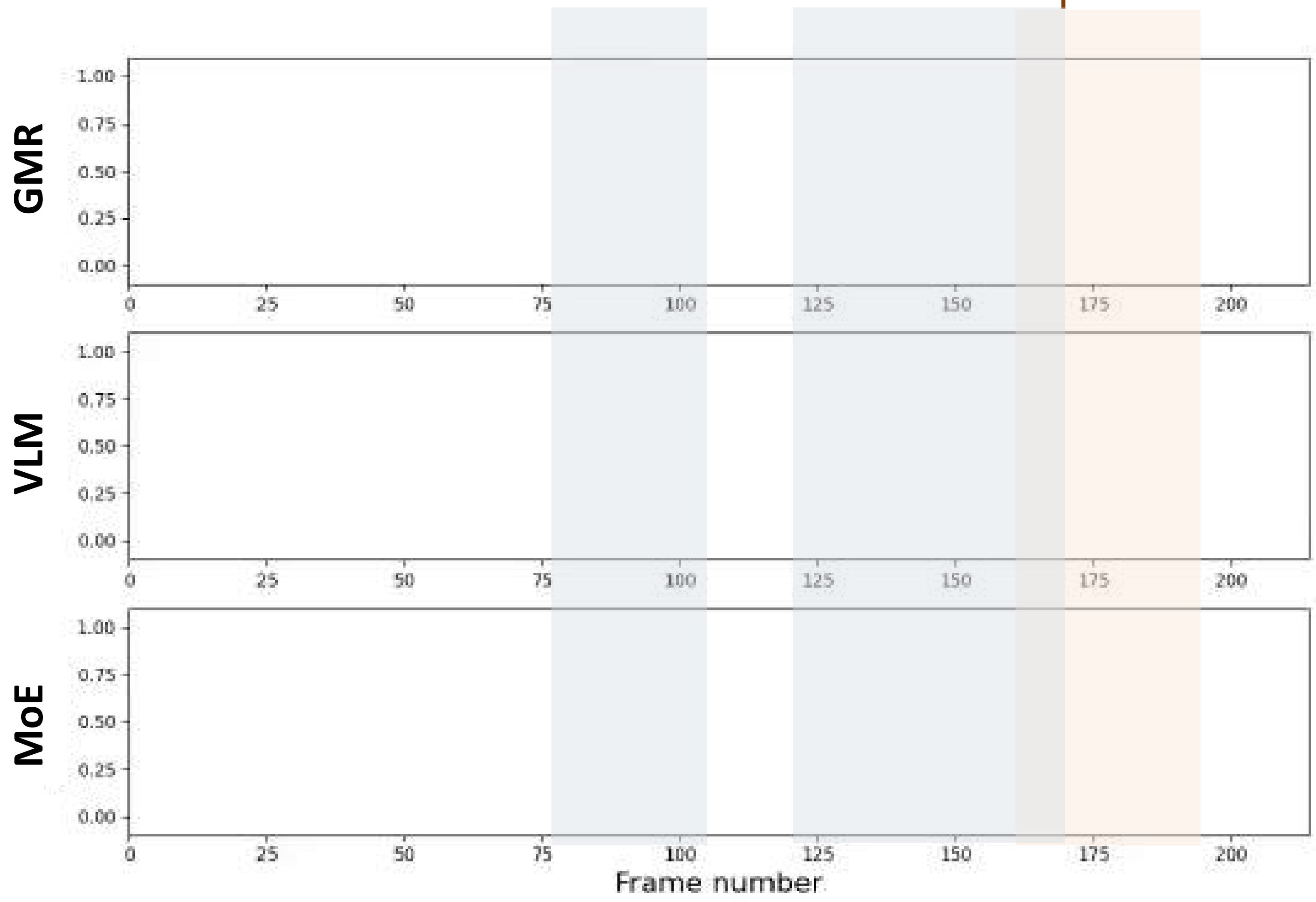


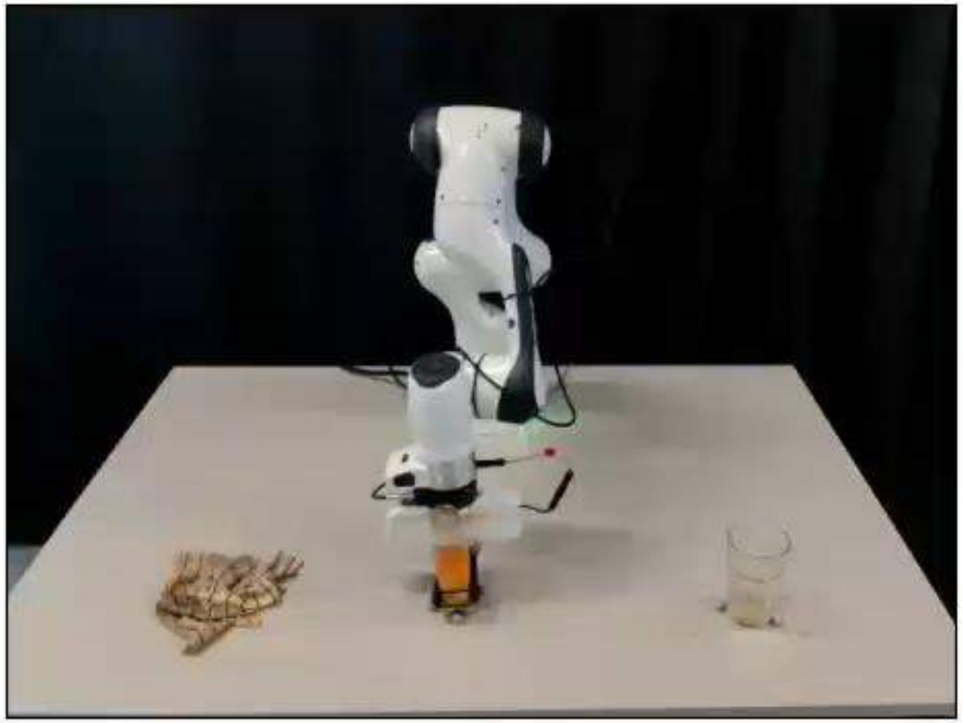


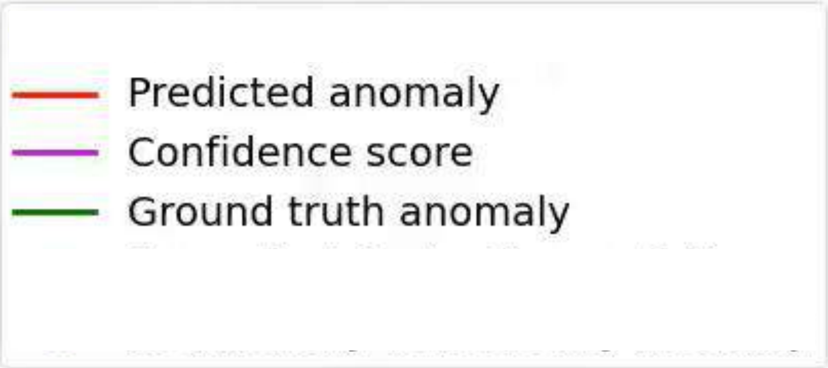
Push while Pouring

Propriocept expert detects push.

VLM detects spill.

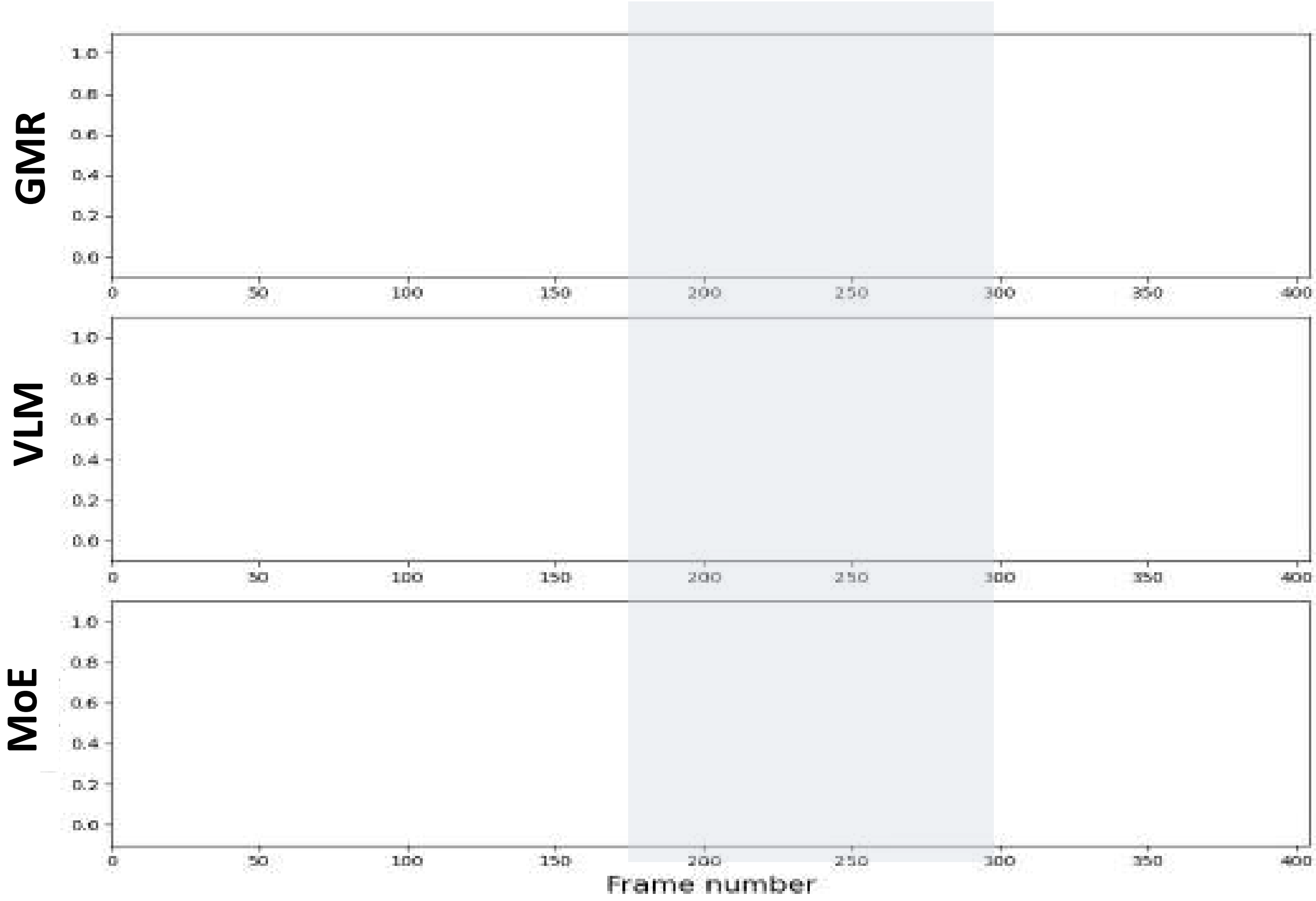


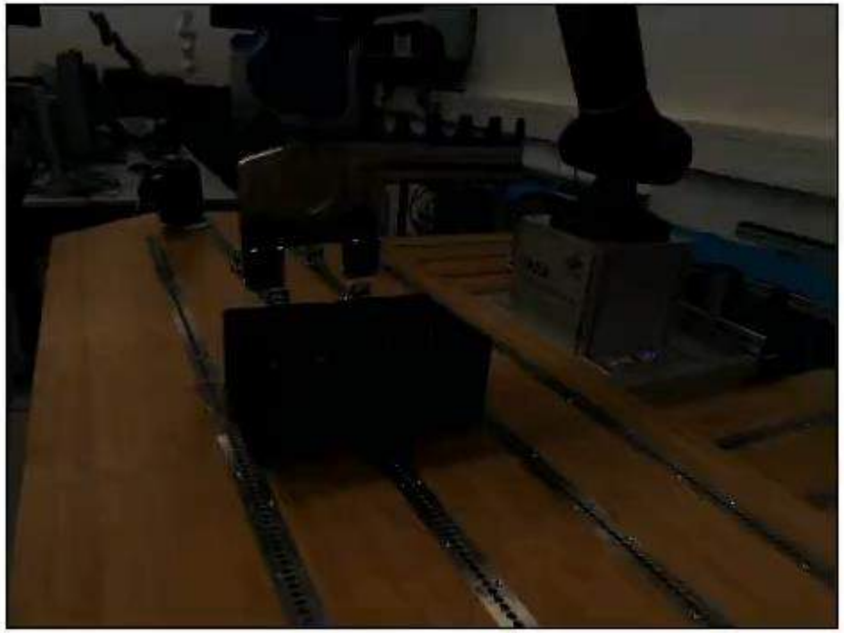


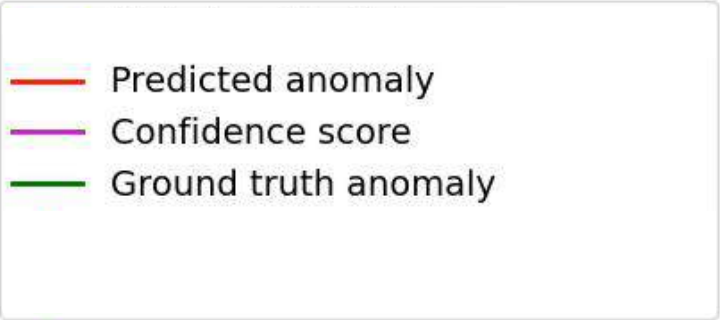


Hardware Failure

Propriocept expert
detectsed jamming.



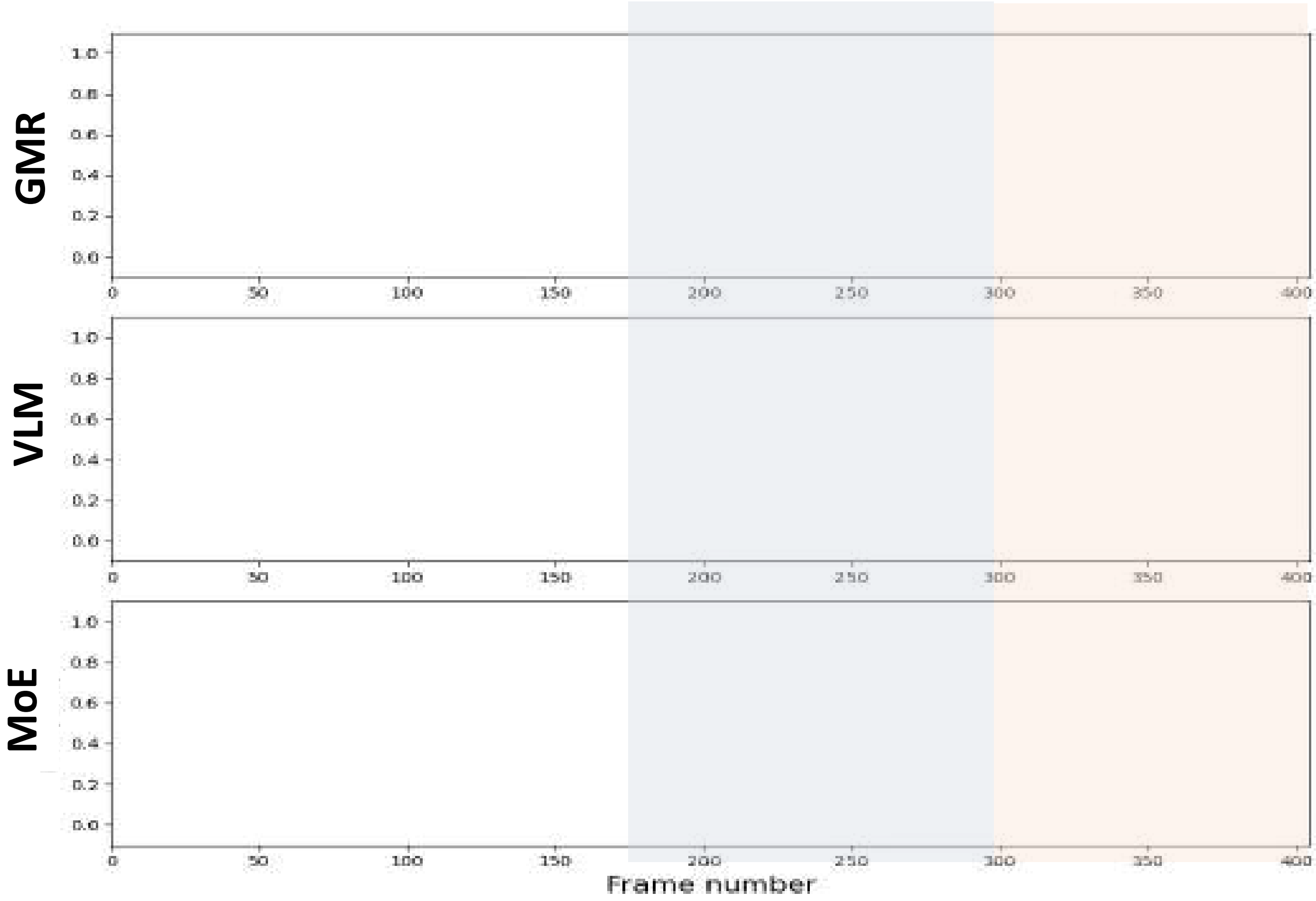


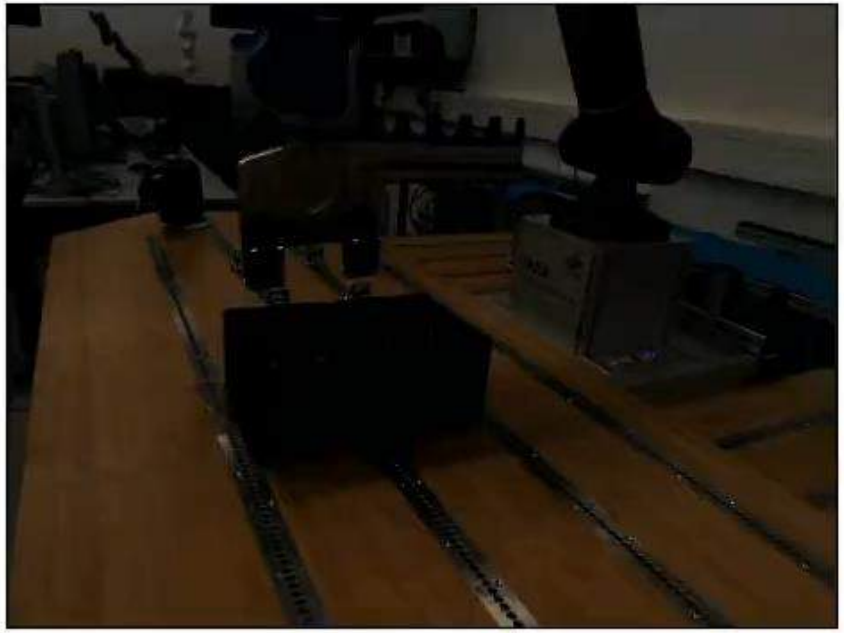


Hardware Failure

Propriocept expert detectsed jamming.

VLM detected it later.





MoE improves Performance of individual Detectors

Method	Box-grasping Acc	Pre	Rec	F1	F1@50	Del
MoE (our)	88.1	96.6	**82.6**	**88.3**	**86.4**	**0.47**
GMR	**88.8**	**100**	81.7	87.4	78.9	1.20
CondNET	79.8	95.9	73.2	81.6	75.0	1.23

Method	Pouring Acc	Pre	Rec	F1	F1@50	Del
MoE (our)	**88.7**	**88.7**	**88.1**	**87.2**	**84.7**	-0.3
GMR	84.5	86.9	81.0	83.3	76.7	**-0.4**
CondNET	75.8	88.0	67.2	70.2	69.3	0.4

Summary

- Go beyond ***Passive Unidirectional Batch*** Learning
- ***Interactive Continual*** **Learning** clarifies the teacher's intended goal of the task.
- ***Proactive Interactive Continual*** **Learning**: Self-Awareness can lead to Proactive Learner and leap at learning speed and task performance.

What’s the holy grail in robot learning?

Proactive Interactive continual learning

Foundation VLA model pretrained with web-scale data

For embodied intelligence, tactile and priprioception is essential.

22nd IEEE International Conference on Advanced Robotics and its Social Impact (ARSO 2026)

Vienna, Austria **10th – 12th June 2026**

IEEE Robotics & Automation Society

Organized Session proposals
9zh December 2025

Full Paper submission
22nd January 2026

Notification of acceptance
22nd March 2026

Final paper submission
23rd April 2026

venue & access in the middle of Europe

General Co-Chairs

Dongheui Lee

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TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Thank you for your attention

Thanks to team members and collaborators