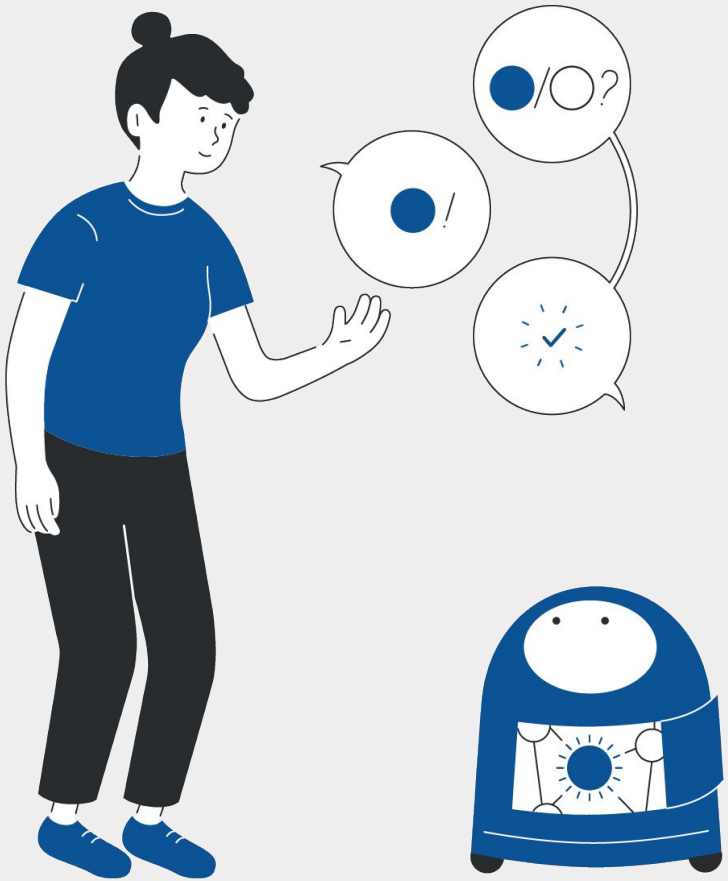


Teacher-Learner Interaction for Robot Active Learning

Mattia Racca

Lectio Praecursoria - 30/10/2020
The defence will start at 14.05 EET

Aalto University
School of Electrical
Engineering

ROBOTS: BEYOND INDUSTRIAL SETTINGS

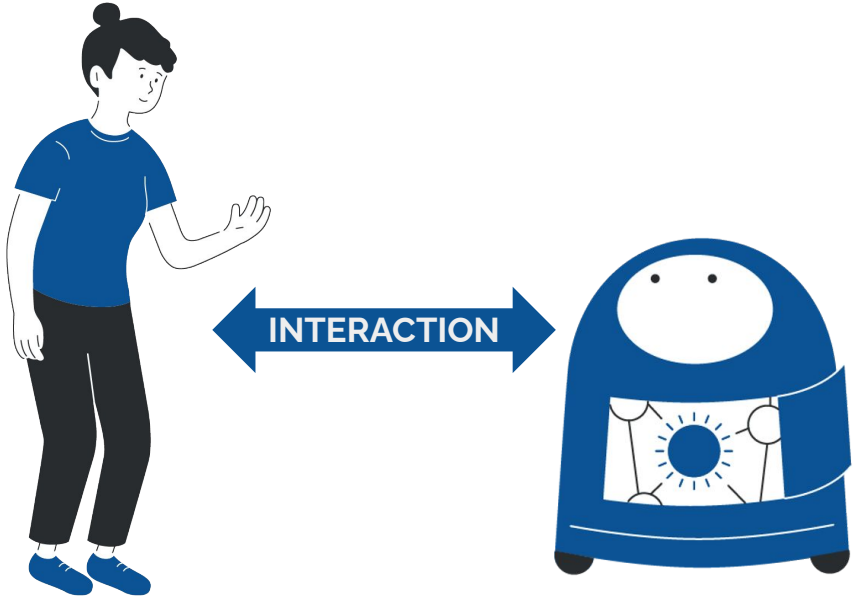
ROBOTS: BEYOND INDUSTRIAL SETTINGS

NEW USERS, NEW CHALLENGES

NEW USERS, NEW CHALLENGES

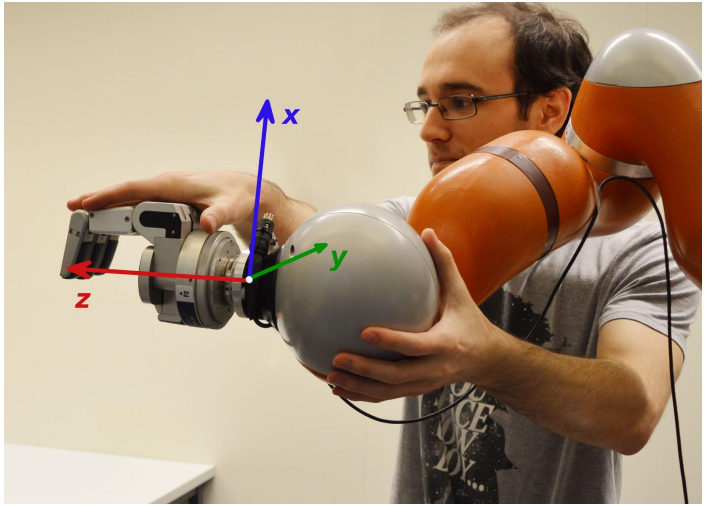
```python
#!/usr/bin/env python

import rospy
import copy
import panda_primitive as pp
import program_interpreter as interpreter
from panda_pbd.srv import EnableTeaching, EnableTeachingRequest
from panda_pbd.msg import UserSyncGoal, MoveToContactGoal, MoveToEEGoal
from panda_pbd.srv import MoveFingersRequest, ApplyForceFingersRequest
from sensor_msgs.msg import JointState


class PandaPBDInterface(object):
    def __init__(self):
        self.program = pp.PandaProgram('A Panda Program')

        self.last_pose = None
        self.last_gripper_width = None
        self.relaxed = False

        self.default_parameters = {'kinesthestic_ft_threshold': 5.0,
                                   'move_to_ee_default_position_speed': 0.07,
                                   'move_to_ee_default_rotation_speed': -1.0,
                                   'user_sync_default_force_threshold': 10.0,
                                   'apply_force_fingers_default_force': 20.0,
                                   'move_to_contact_default_force_threshold': 10.0,
                                   'move_to_contact_default_torque_threshold': 10.0,
                                   'move_to_contact_default_position_speed': 0.07,
                                   'move_to_contact_default_rotation_speed': -1.0}

        for parameter_name in self.default_parameters.keys():
            if not rospy.has_param('~' + parameter_name):
```

NEW USERS, NEW CHALLENGES

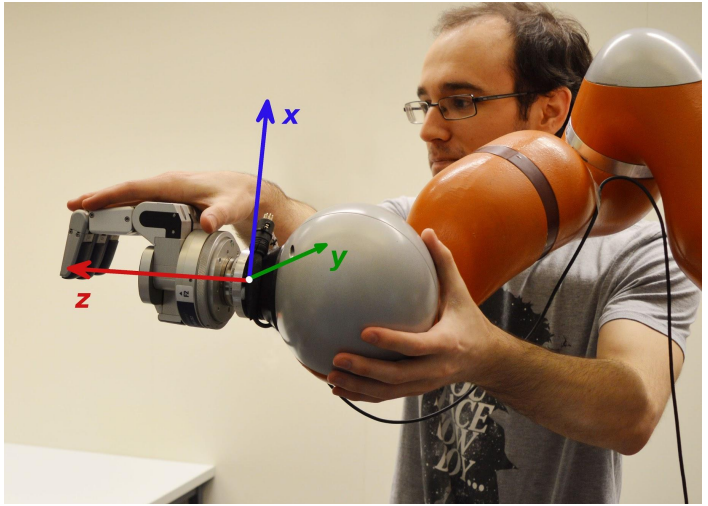


LEARNING FROM DEMONSTRATIONS

LEARNING FROM DEMONSTRATIONS

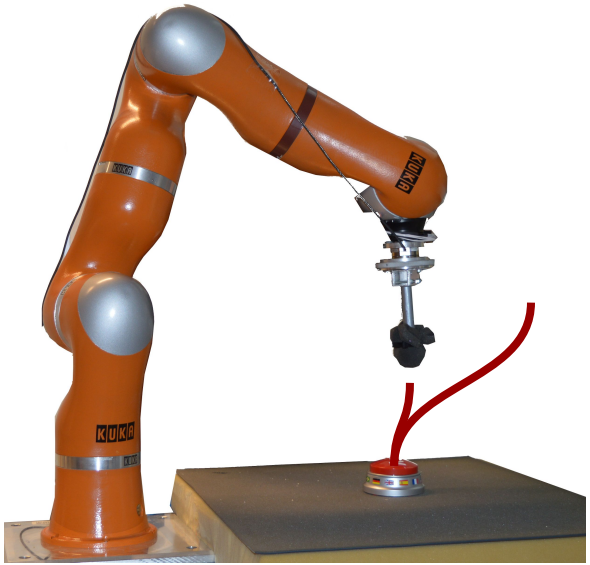


LEARNING FROM DEMONSTRATIONS

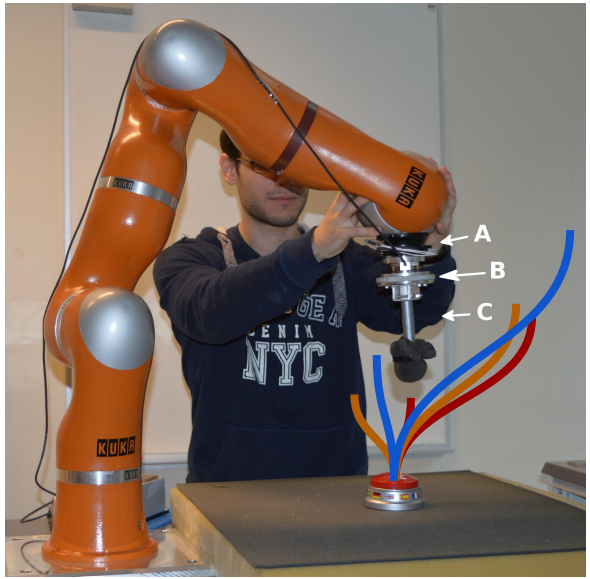


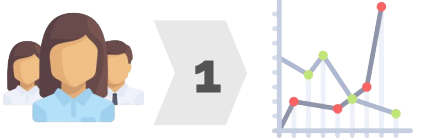
Effective teaching interface when the task is <u>difficult to encode in a declarative way</u>

LEARNING IN-CONTACT TASKS



LEARNING IN-CONTACT TASKS

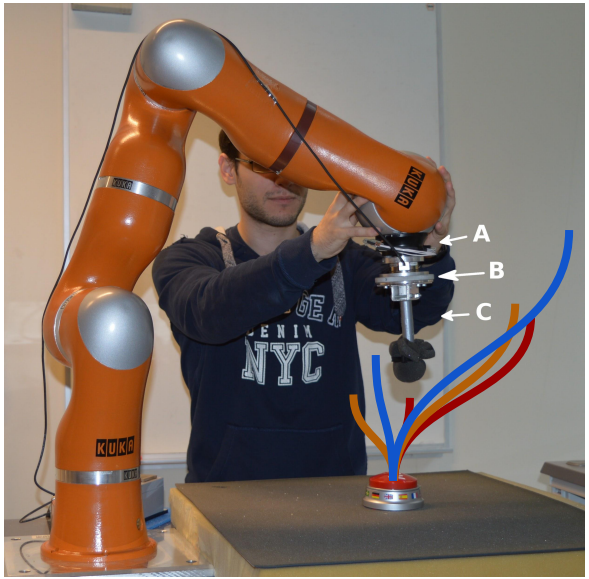


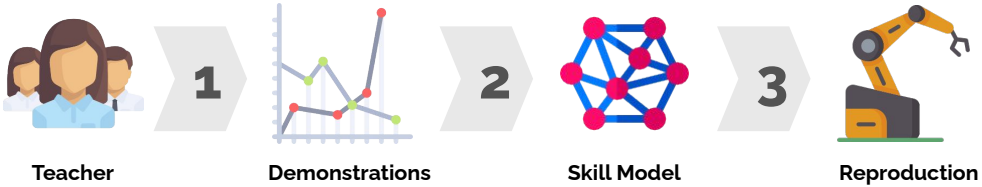


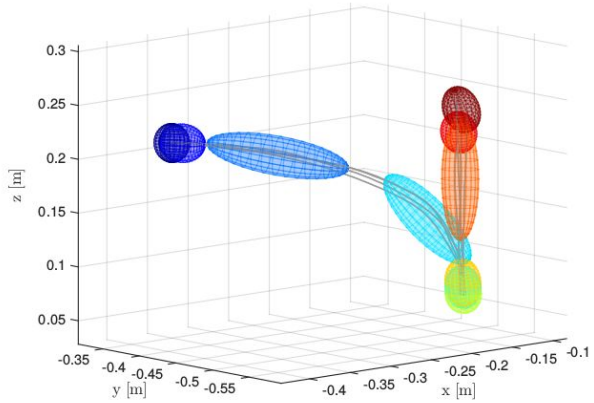
Teacher

Demonstrations

LEARNING IN-CONTACT TASKS





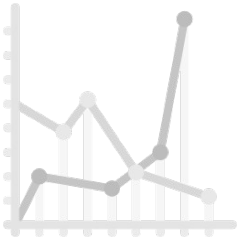


- Kinesthetic Teaching
- **Hidden Semi-Markov Models (HSMM)**
- Gaussian Mixture Regression (GMR)

WEAKNESSES of DEMONSTRATIONS

1

Teachers

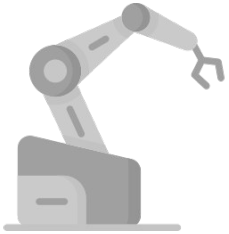


2

Demonstrations

3

Skill Model



Reproduction

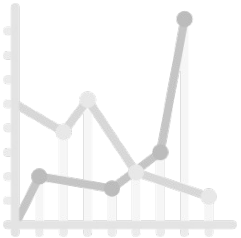
WEAKNESSES of DEMONSTRATIONS

Informative Demonstrations:

demonstrations that allow the robot to learn a reliable model of the taught task

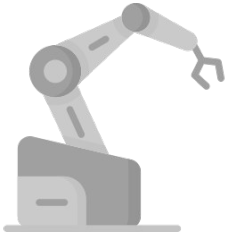
WEAKNESSES of DEMONSTRATIONS

1



2

3



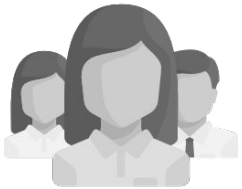
Teachers | Demonstrations | Skill Model | Reproduction

Informative Demonstrations:

demonstrations that allow the robot to learn a reliable model of the taught task

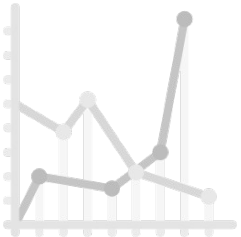
Require some understanding of the underlying Machine Learning process!

WEAKNESSES of DEMONSTRATIONS



1

Teachers

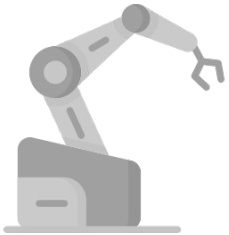


2

Demonstrations

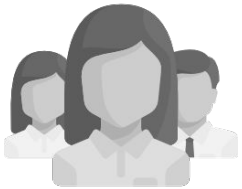
3

Skill Model



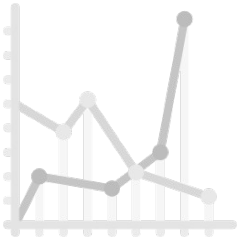
Reproduction

WEAKNESSES of DEMONSTRATIONS



1

Teachers

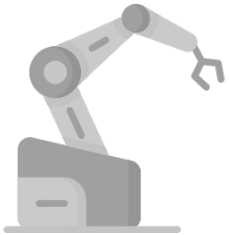


2

Demonstrations

3

Skill Model

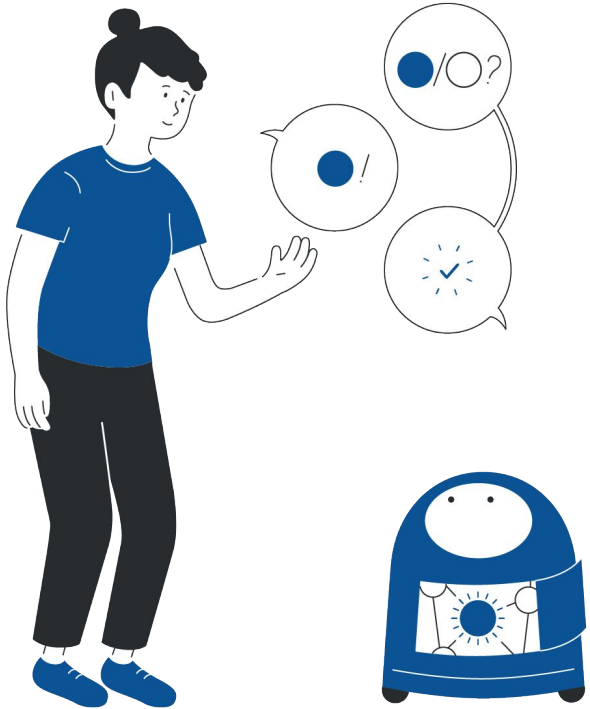


Reproduction

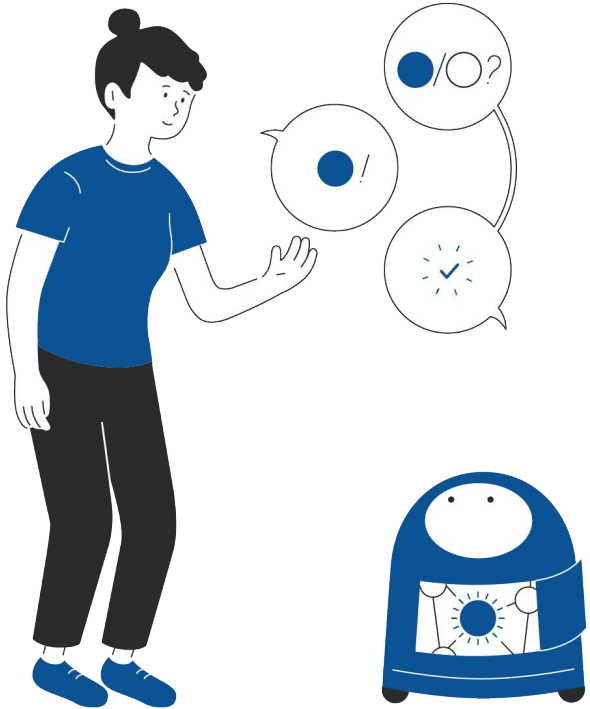
G.I.G.O.

Garbage in, Garbage out

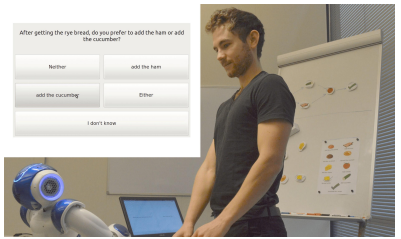
WEAKNESSES of DEMONSTRATIONS

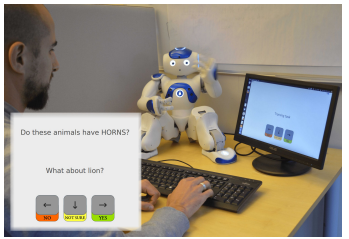


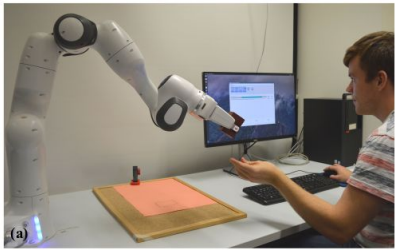
WEAKNESSES of DEMONSTRATIONS



ACTIVE LEARNING







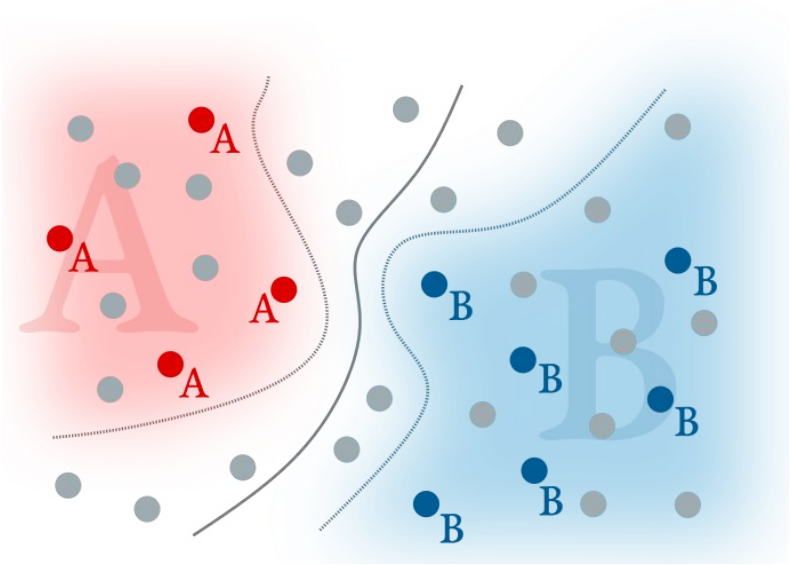
ACTIVE LEARNING FROM QUESTIONS

ACTIVE LEARNING FROM QUESTIONS

Queries:

requests of information aimed at **steering the training process** to cover the current **knowledge gaps** of the learner.

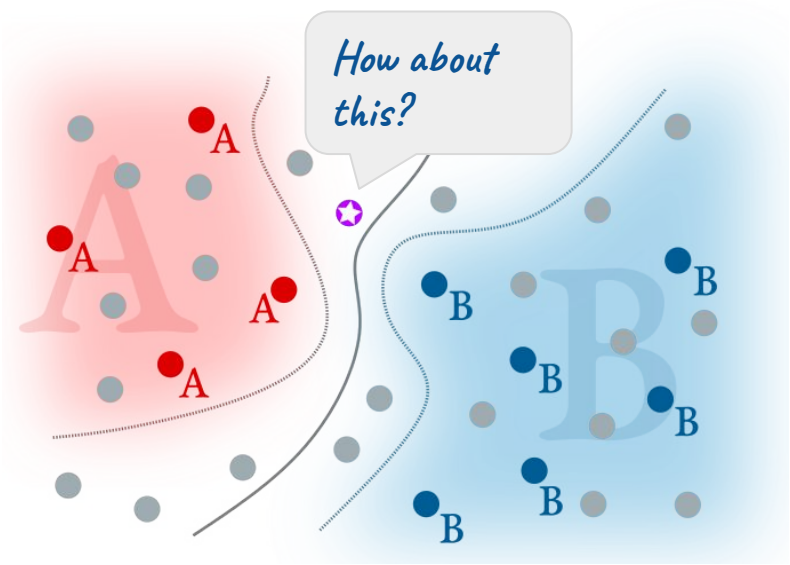
ACTIVE LEARNING 101



Queries:

requests of information aimed at **steering the training process** to cover the current **knowledge gaps** of the learner.

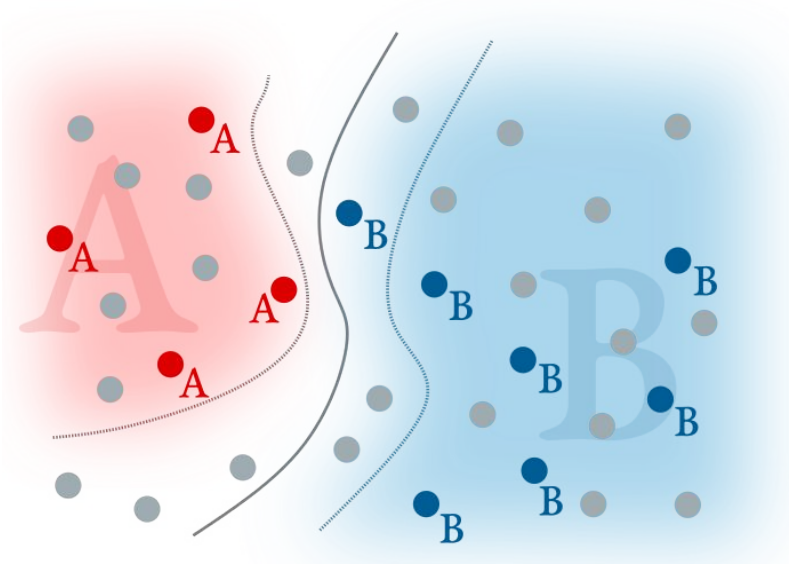
ACTIVE LEARNING 101



Queries:

requests of information aimed at **steering the training process** to cover the current **knowledge gaps** of the learner.

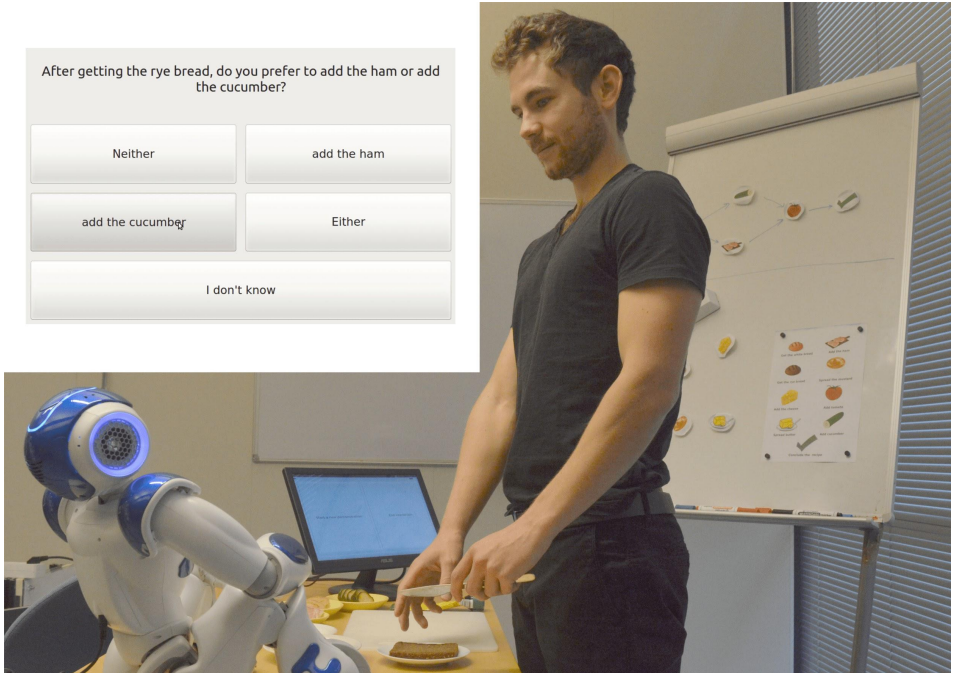
ACTIVE LEARNING 101



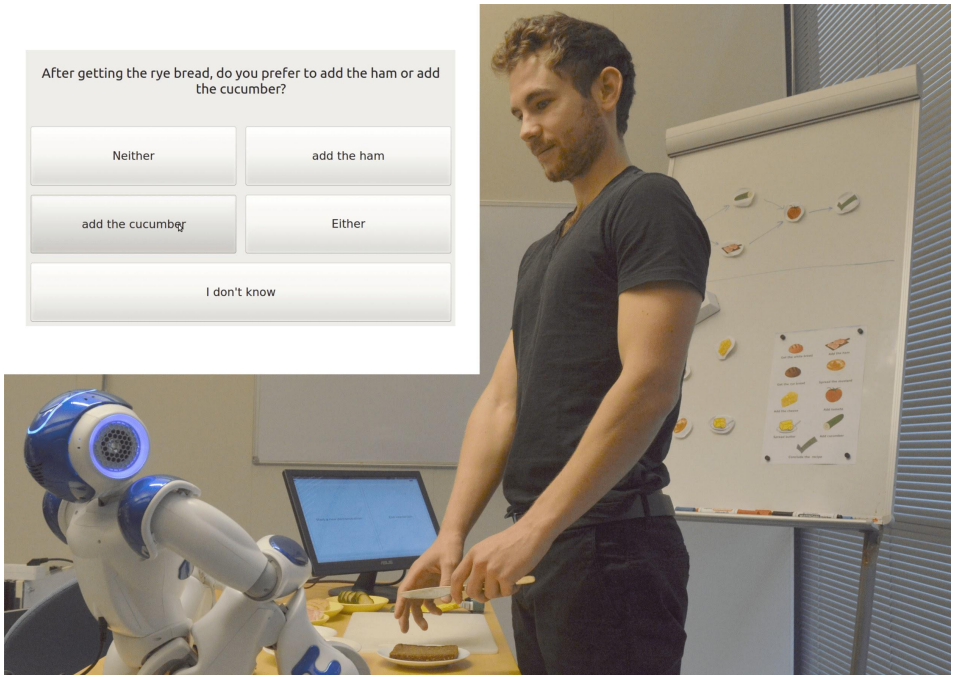
Queries:

requests of information aimed at **steering the training process** to cover the current **knowledge gaps** of the learner.

DEMONSTRATIONS and QUESTIONS

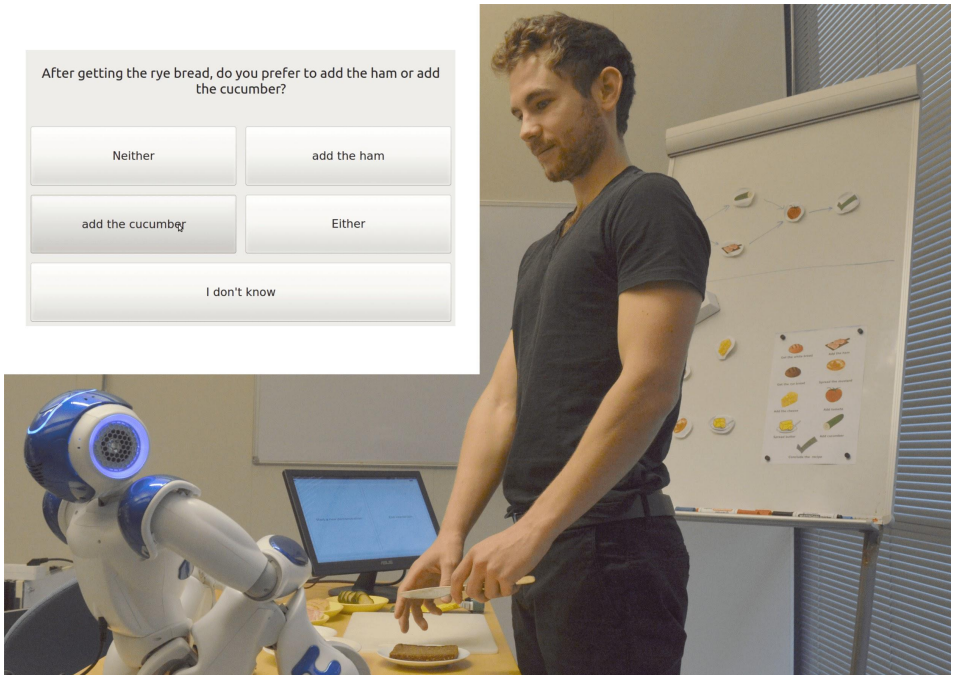


DEMONSTRATIONS and QUESTIONS



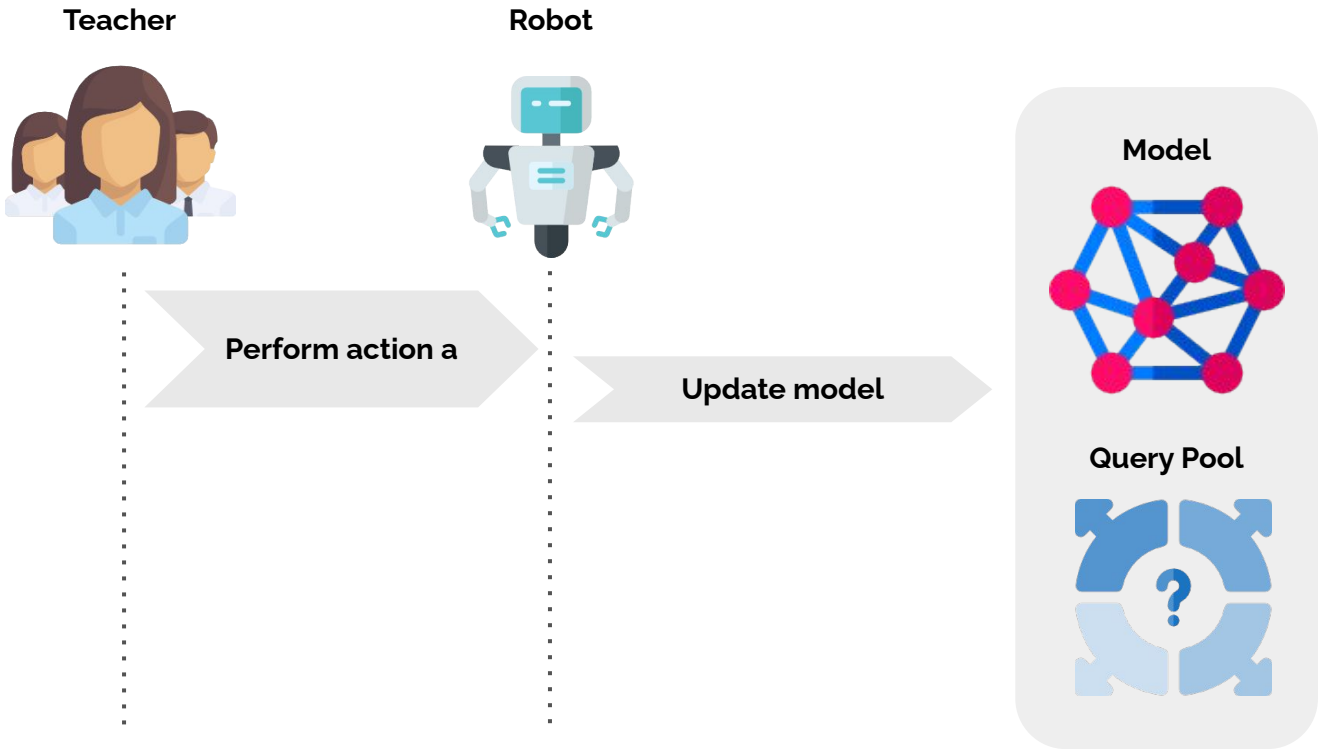
- **Demos + Queries:** the model must support both!

DEMONSTRATIONS and QUESTIONS

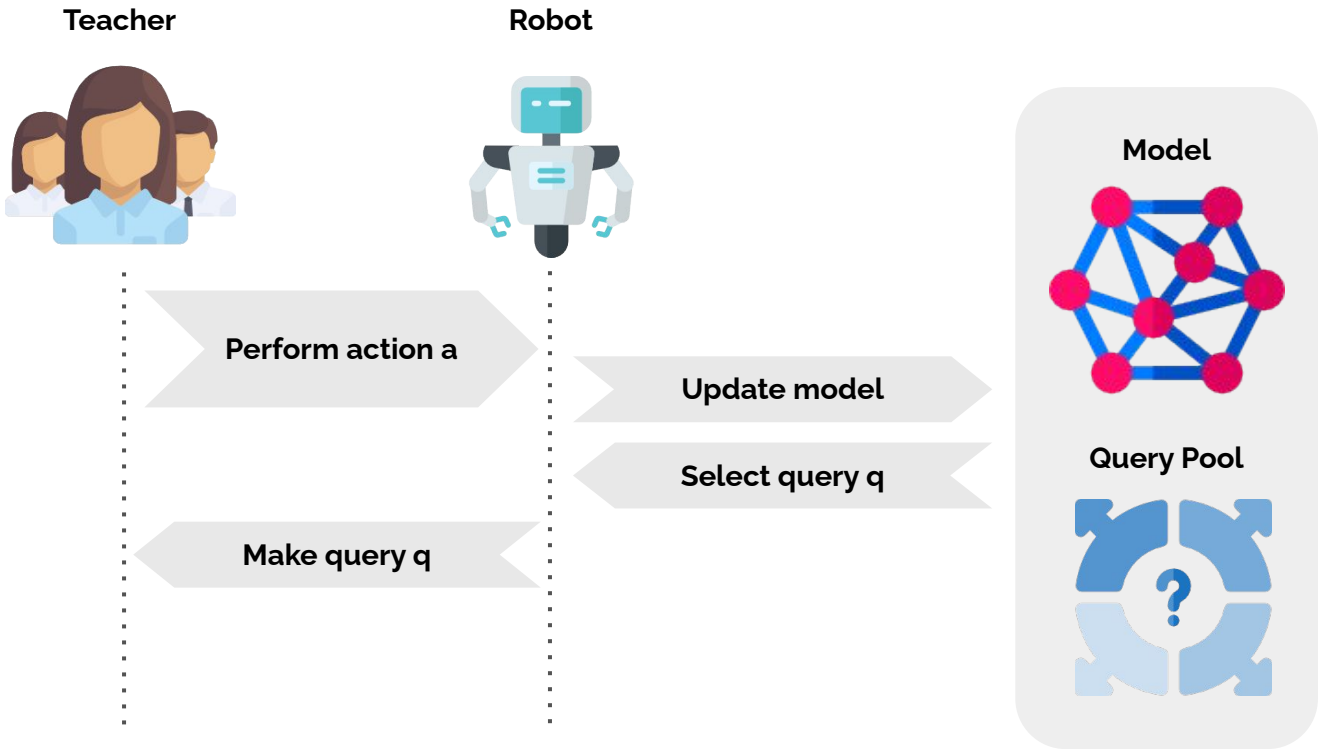


- **Demos + Queries:** the model must support both!
- **Temporal aspect:** careful design of queries

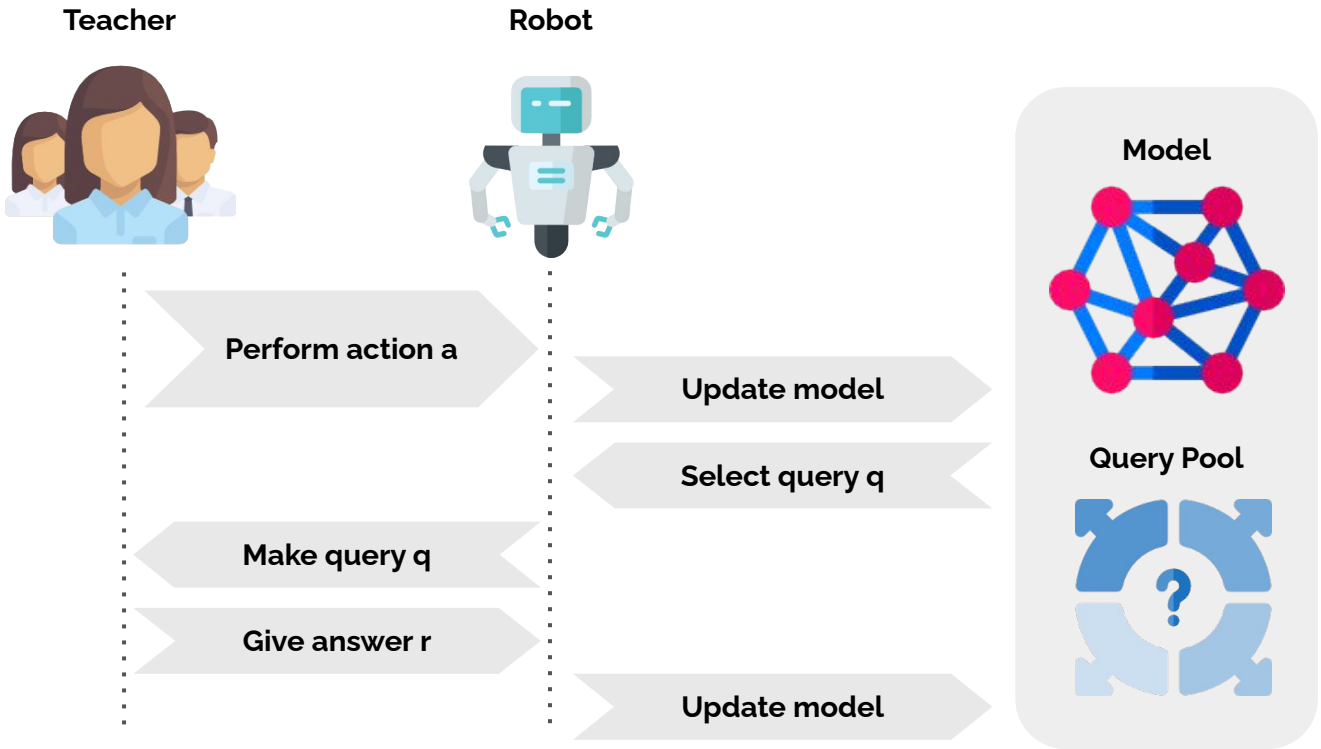
DEMONSTRATIONS and QUESTIONS



DEMONSTRATIONS and QUESTIONS



DEMONSTRATIONS and QUESTIONS



QUERY DESIGN

QUERY DESIGN

“With what probability you do action A after action B?”

“Do you do action A after action B with probability 0.3?”

QUERY DESIGN

"With what probability you do action A after action B?"

"Do you do action A after action B with probability 0.3?"

Frequency Queries

"Do you **always /often/never** do action A after B?"

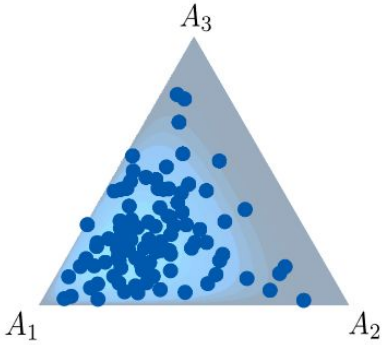
Disambiguation Queries

"After action B, **do you prefer** to do action A or C?"

Model Friendly  **User Friendly**

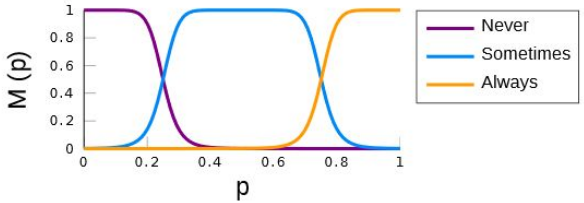
MODEL UPDATE

Question q



1. Sample the pre-query Dirichlet

Answer a

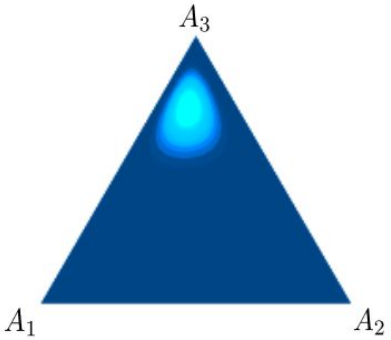


$$w_s(q^*, r^*) = \begin{cases} M_f(s(a_{post})) & \text{if } r^* = \text{'yes'} \\ 1 - M_f(s(a_{post})) & \text{if } r^* = \text{'no'} \end{cases}$$

$$w_s(q^*, r^*) = M_{r^*}(s(a_1), s(a_2))$$

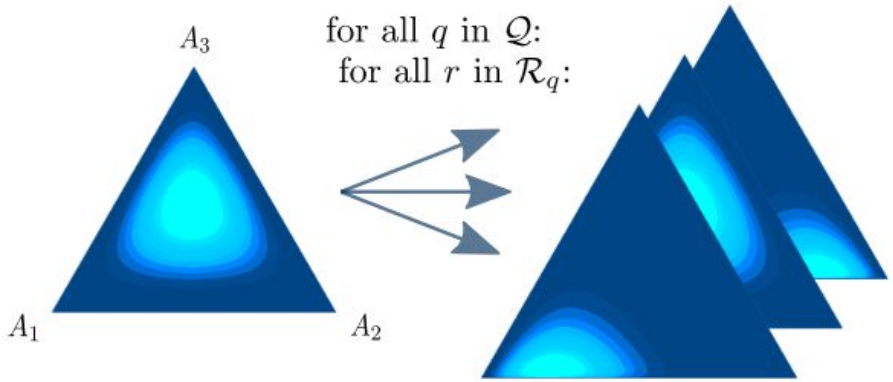
2. Filter/Weight samples based on answer

Updated model



3. Fit the post-query Dirichlet

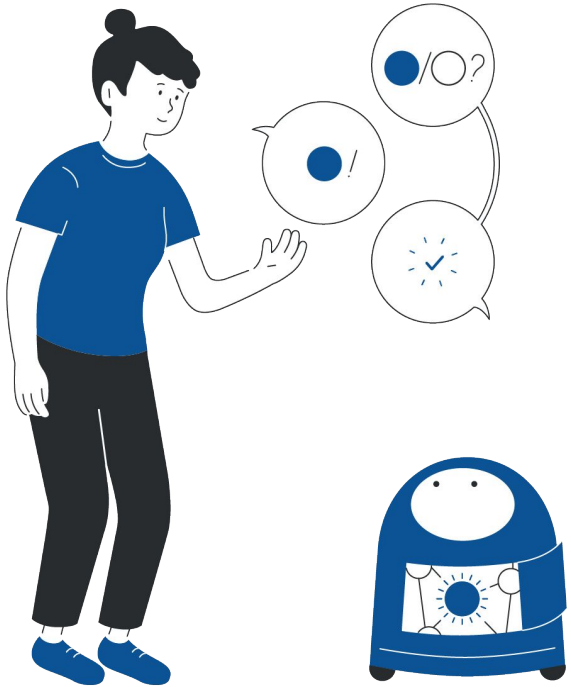
QUERY SELECTION



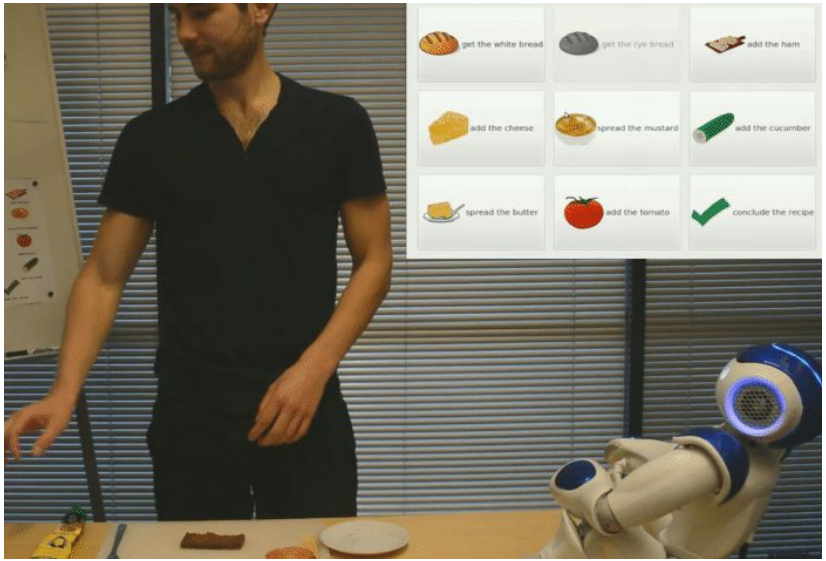
$$\Delta\mathbb{H}_q = \overbrace{\mathop{\mathbb{E}}_{r}[\mathbb{H}(\mathrm{Dir}(\cdot|\boldsymbol{\alpha}, q, r))]}^{\text{post-query}} - \overbrace{\mathbb{H}(\mathrm{Dir}(\cdot|\boldsymbol{\alpha}))}^{\text{pre-query}}$$

$$= \sum_r p(r|q)\mathbb{H}(\mathrm{Dir}(\cdot|\boldsymbol{\alpha}, q, r)) - \mathbb{H}(\mathrm{Dir}(\cdot|\boldsymbol{\alpha})),$$

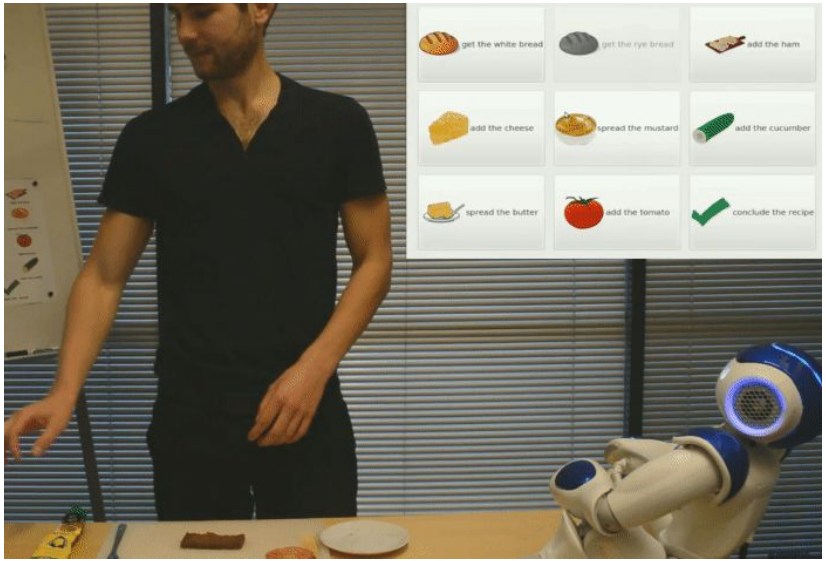
INTERACTING with an ACTIVE LEARNING ROBOT



INTERACTING with an ACTIVE LEARNING ROBOT



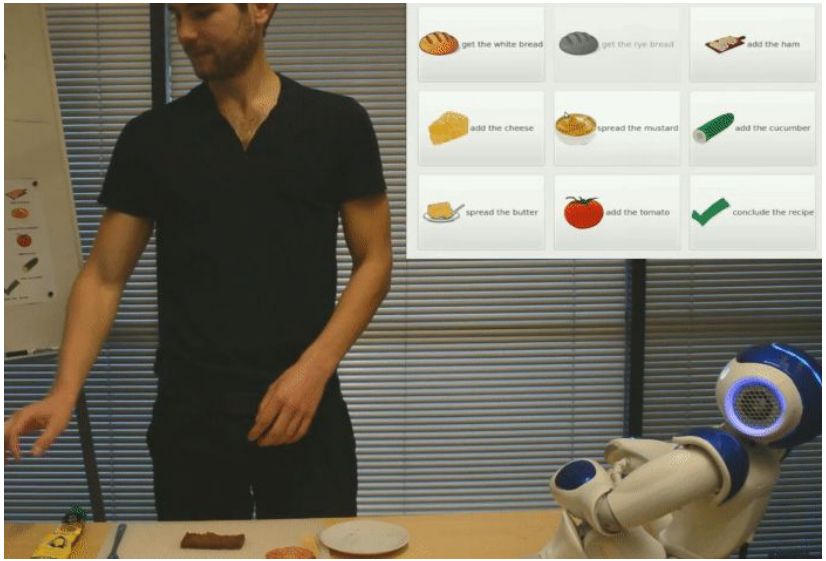
INTERACTING with an ACTIVE LEARNING ROBOT



User study:

- **perception** of robots using different selection strategies and **effects on the teacher**

INTERACTING with an ACTIVE LEARNING ROBOT

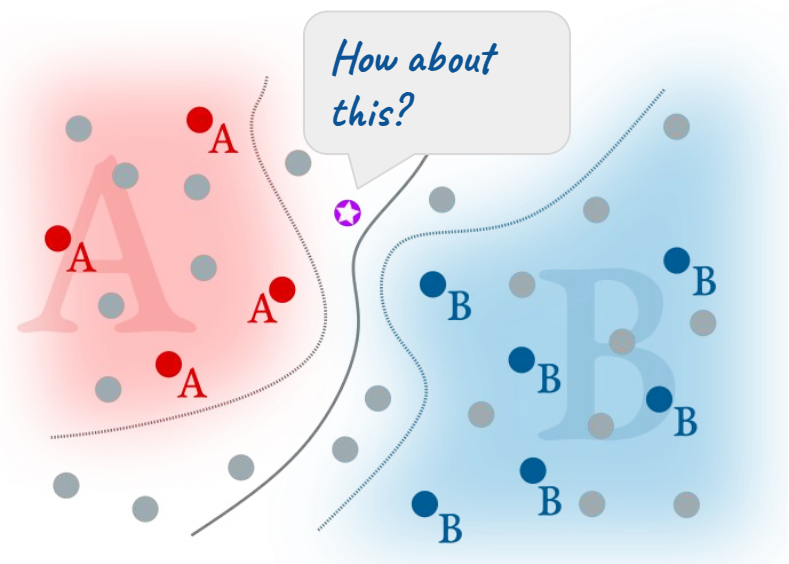


User study:

- **perception** of robots using different selection strategies and **effects on the teacher**

- **interpretation of learning** behaviours, with frequent mismatches!

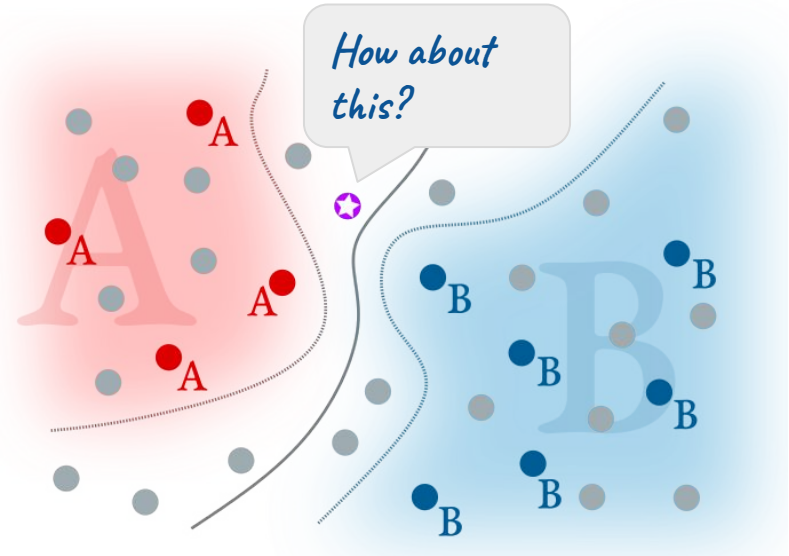
ROBOT QUERIES and REAL TEACHERS



Sample Efficiency:

- **learning faster** and/or with **less data**

ROBOT QUERIES and REAL TEACHERS



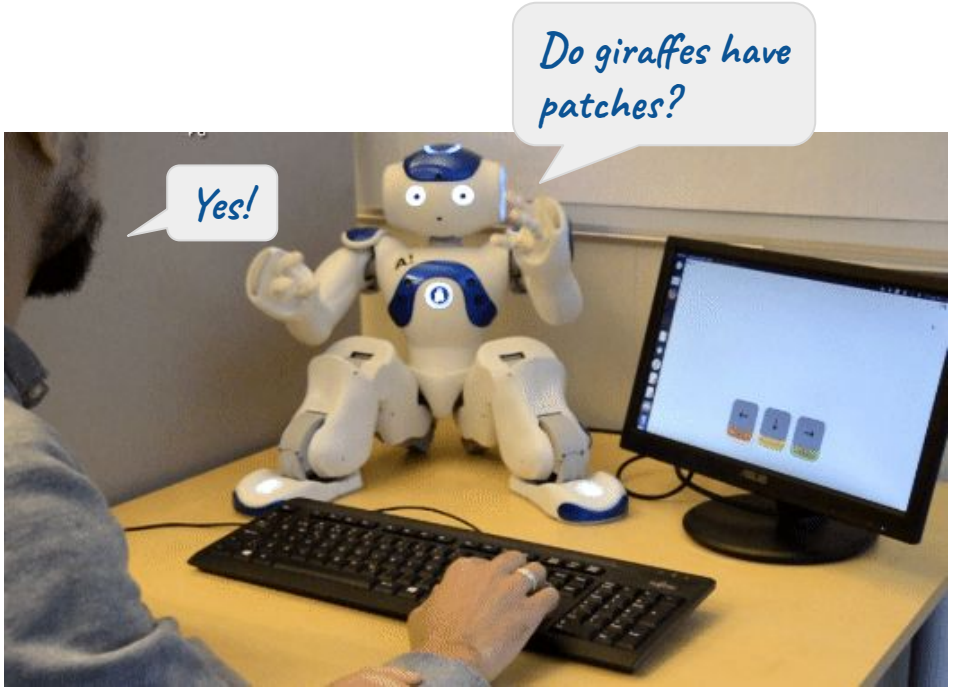
Sample Efficiency:

- **learning faster** and/or with **less data**

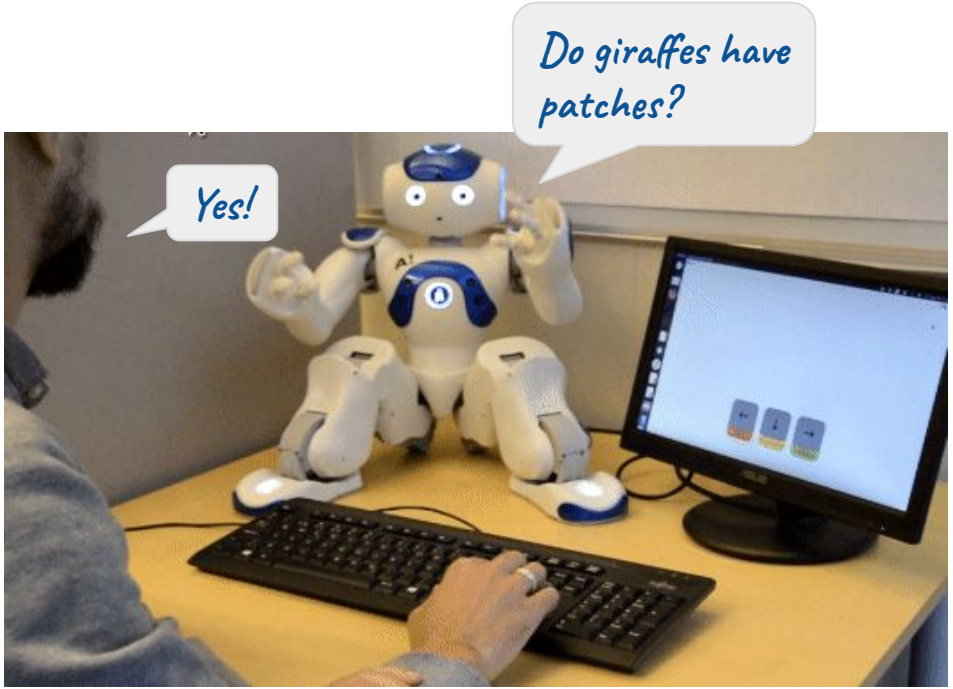
What if the efficient query selection is not the best for the teacher?

- cause **errors** and **delays**

ROBOT QUERIES and REAL TEACHERS

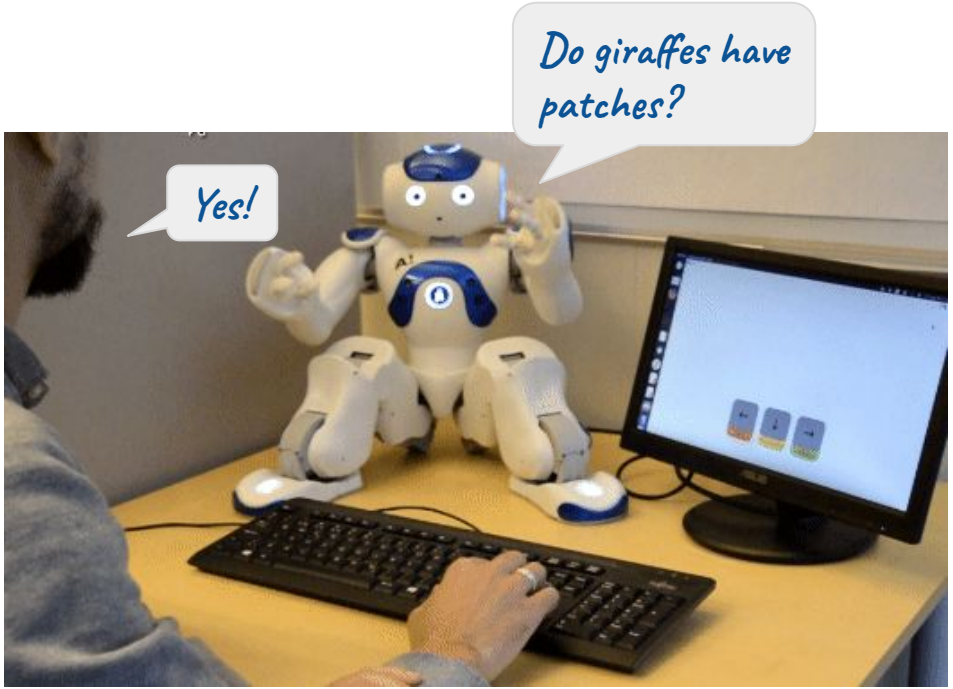


ROBOT QUERIES and REAL TEACHERS



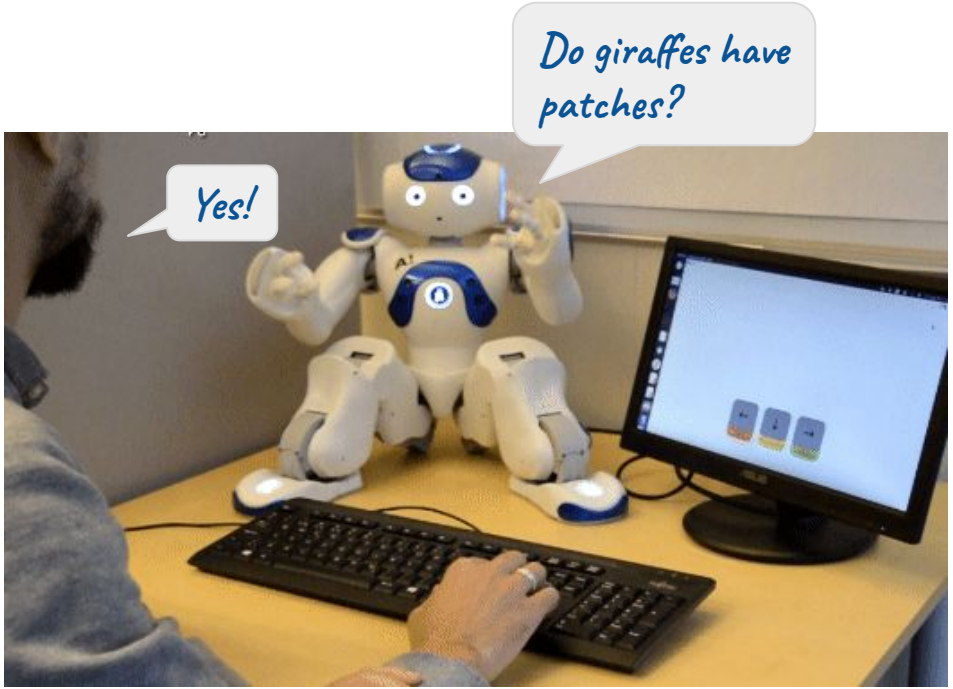
- **ACTIVE LEARNING STRATEGY**

ROBOT QUERIES and REAL TEACHERS



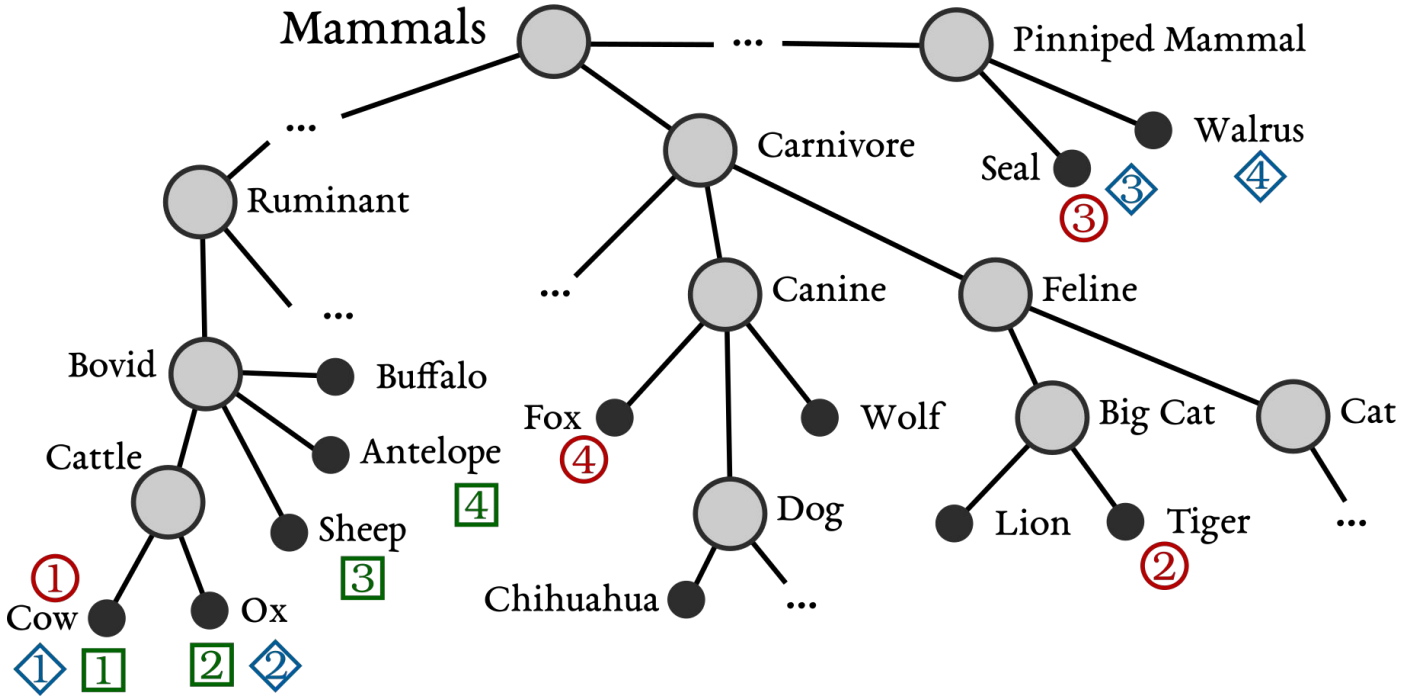
- **ACTIVE LEARNING STRATEGY**
- **MEMORY-AWARE STRATEGY**

ROBOT QUERIES and REAL TEACHERS



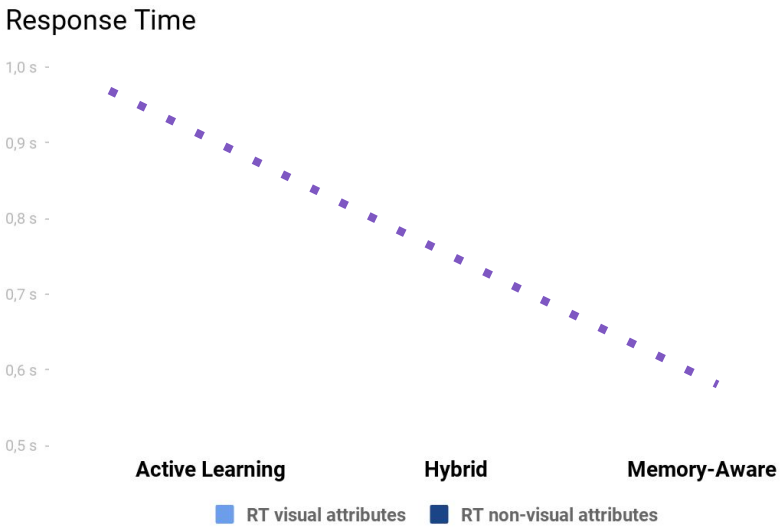
- ACTIVE LEARNING STRATEGY
- MEMORY-AWARE STRATEGY
- HYBRID STRATEGY

ROBOT QUERIES and REAL TEACHERS

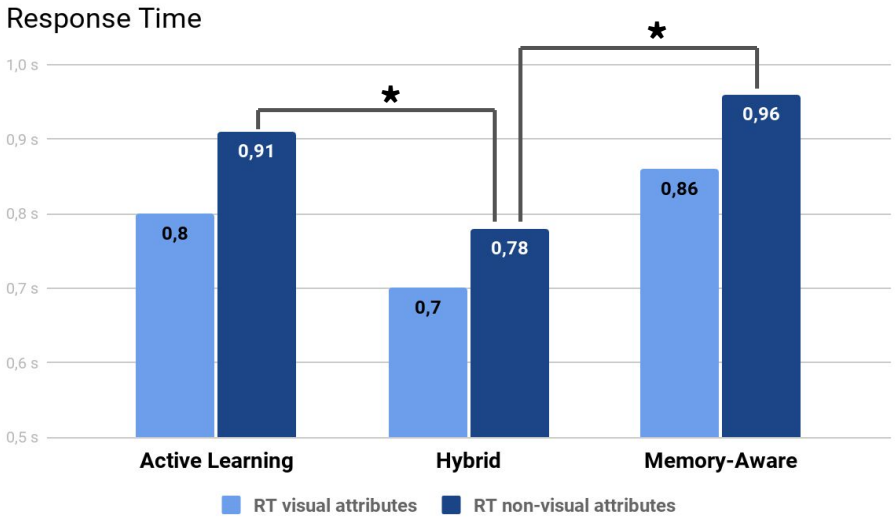


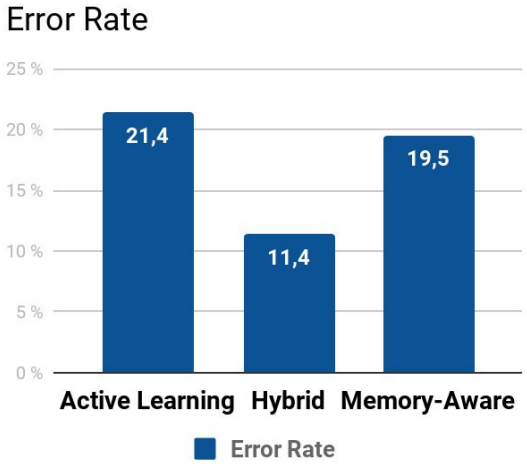
ACTIVE LEARNING MEMORY-AWARE HYBRID

HYPOTHESES

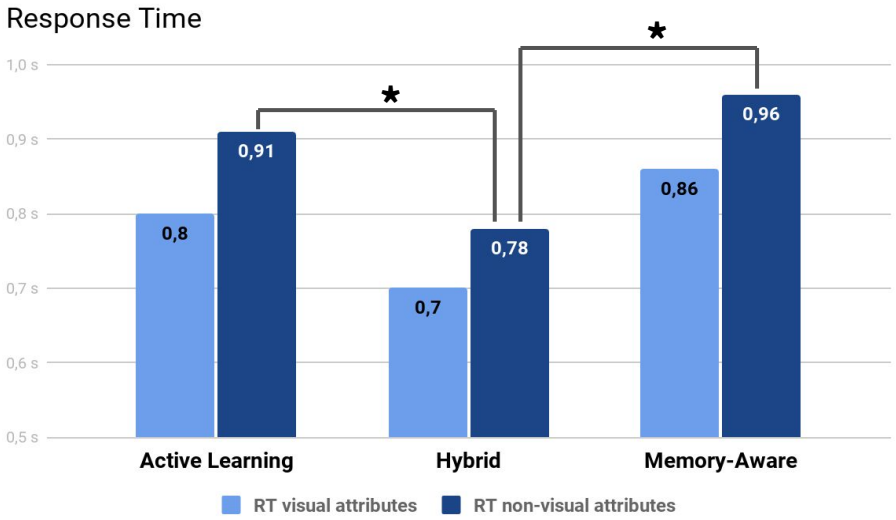

Response Time
1,0 s
0,9 s
0,8 s
0,7 s
0,6 s
0,5 s
Active Learning
Hybrid
Memory-Aware
RT visual attributes
RT non-visual attributes

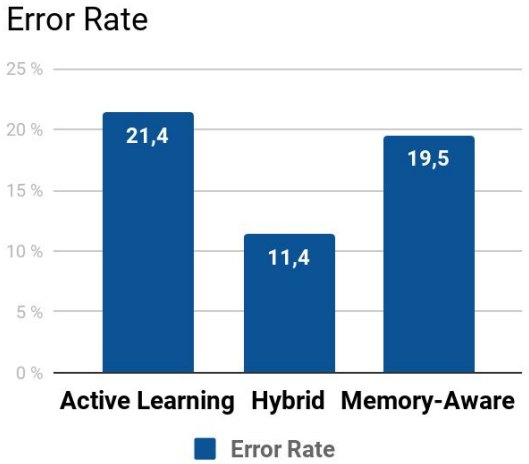
UNEXPECTED RESULTS





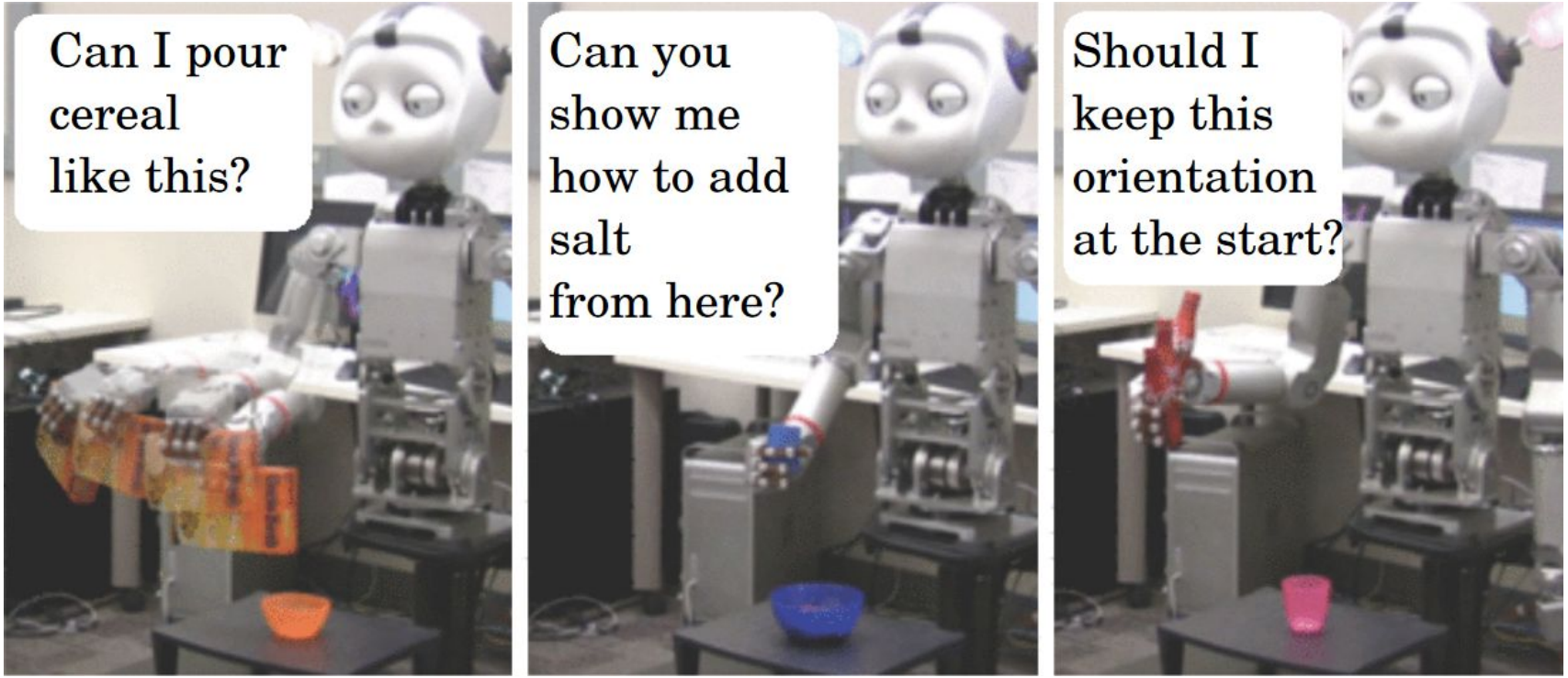
UNEXPECTED RESULTS



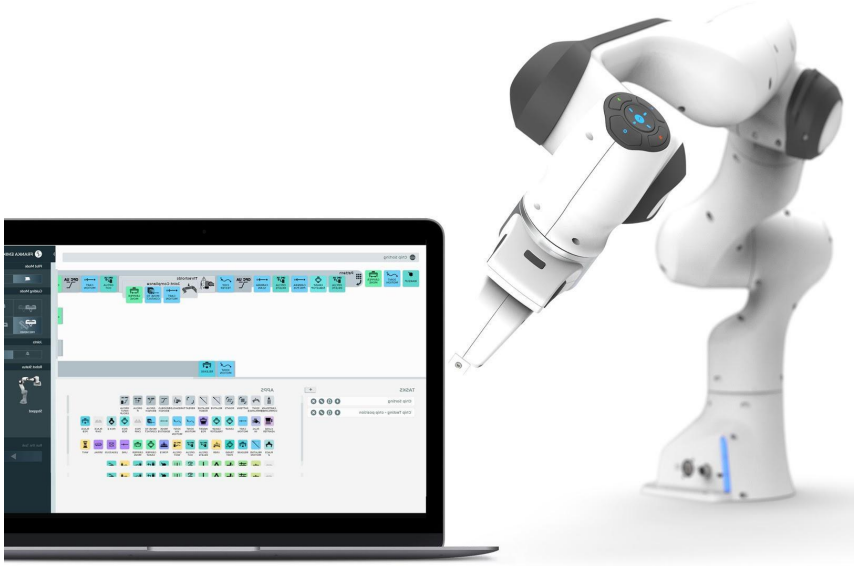


Different strategies drastically impact the human teacher!

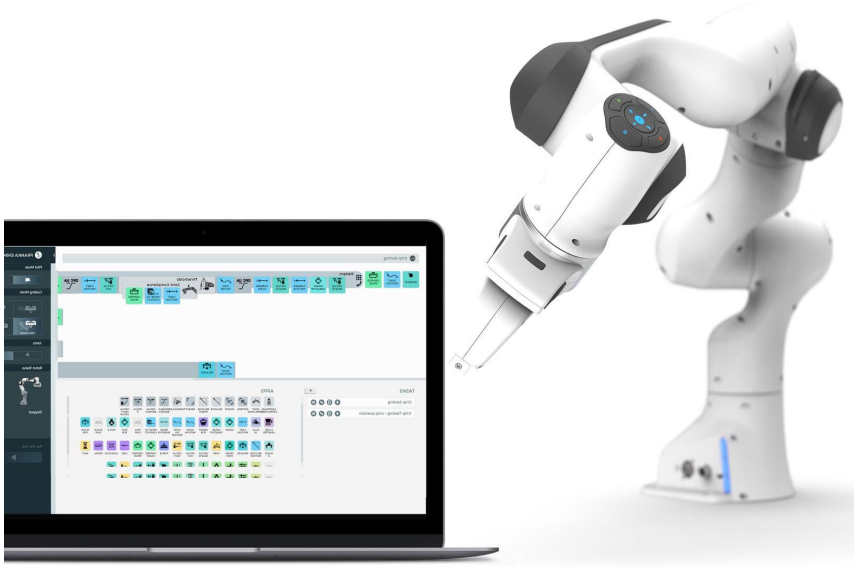
EMBODIED QUESTIONS



EMBODIED QUESTIONS for ROBOT PROGRAMMING



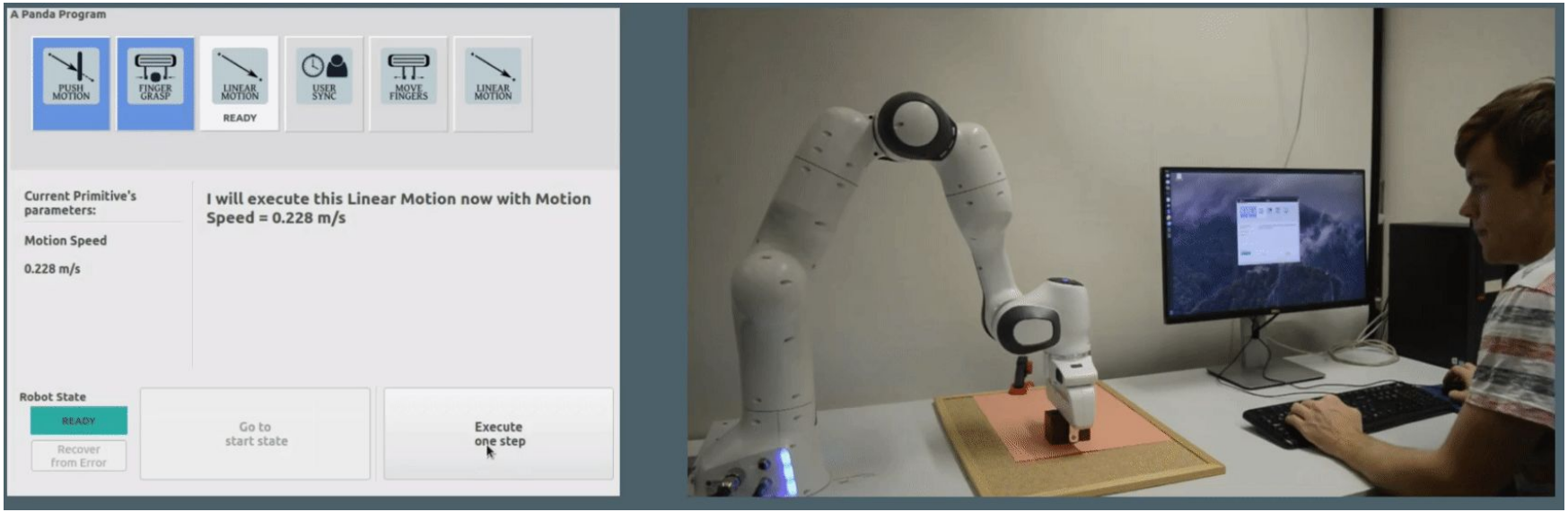
EMBODIED QUESTIONS for ROBOT PROGRAMMING



PARAMETERS

- Goal Pose
- Translational Speed
- Collision Threshold (move until you sense a contact)

TUNING ROBOT PROGRAMS



TUNING ROBOT PROGRAMS

User study:

- tune parameters faster and closer to how experts would tune them

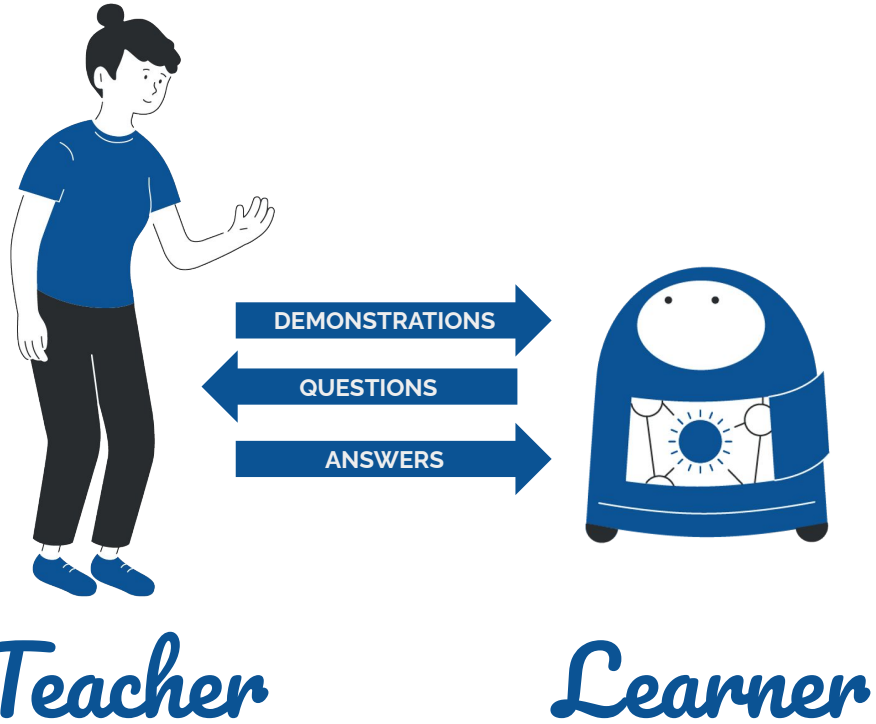
TUNING ROBOT PROGRAMS

User study:

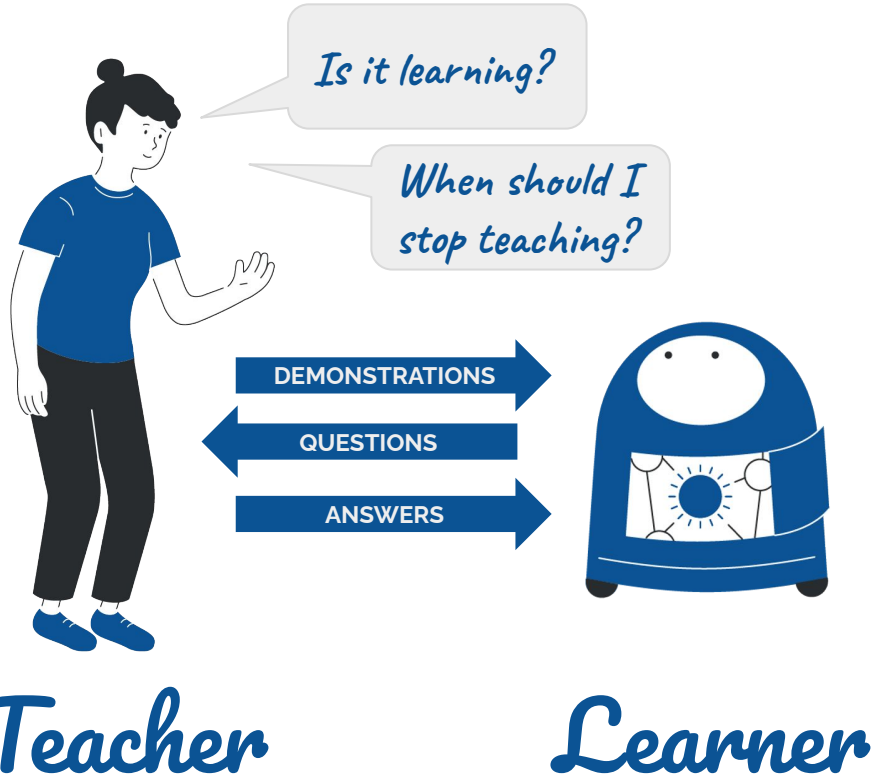
- **tune parameters faster and closer to how experts would tune them**

- **integration** of **Active Learning** in **commercially available robot programming interface**

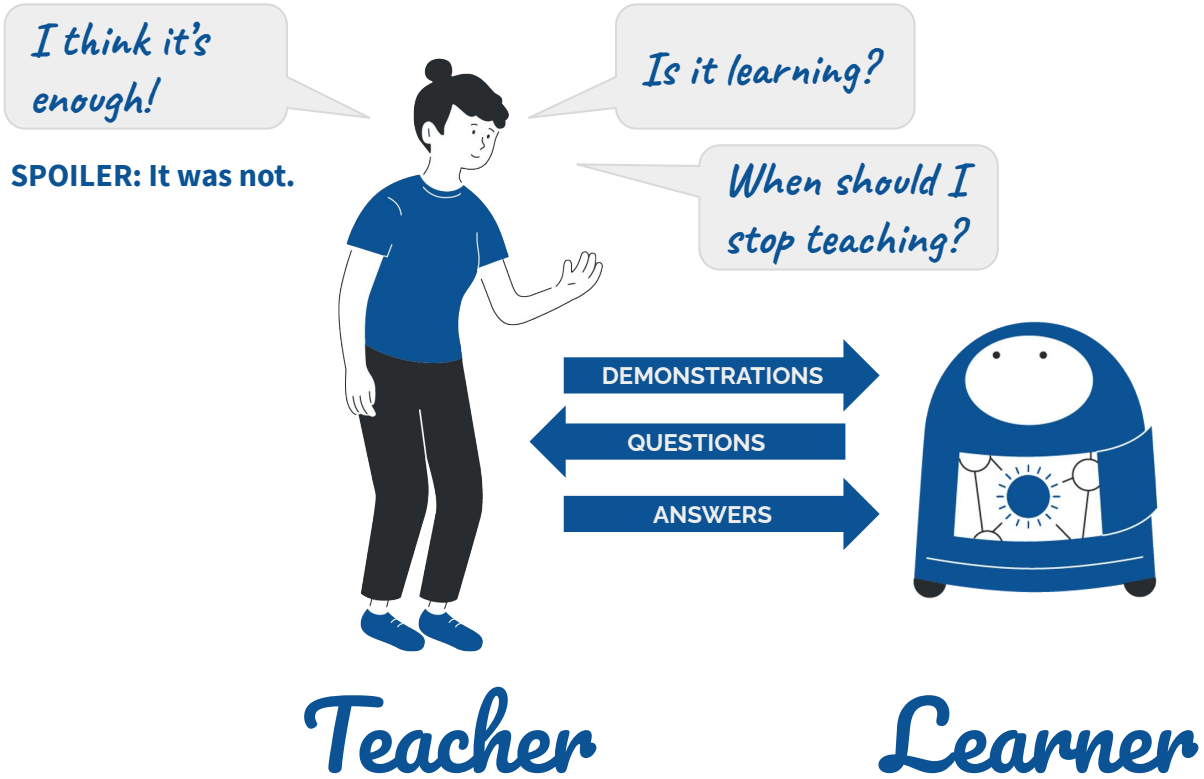
TEACHER-LEARNER TRANSPARENCY



TEACHER-LEARNER TRANSPARENCY



TEACHER-LEARNER TRANSPARENCY



TEACHER-LEARNER TRANSPARENCY

I think it's enough!

SPOILER: It was not.

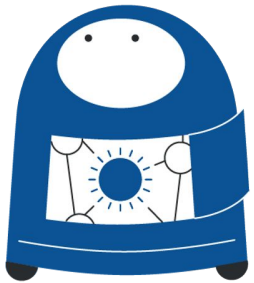
Is it learning?

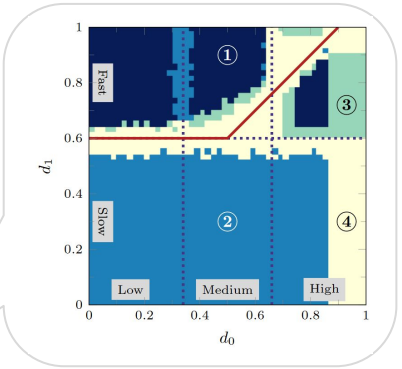
When should I stop teaching?

DEMONSTRATIONS

QUESTIONS

ANSWERS

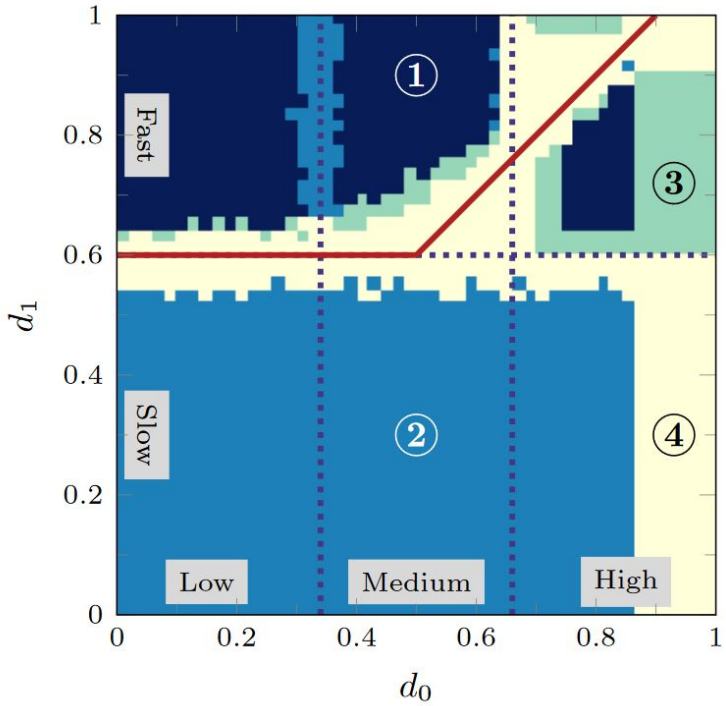


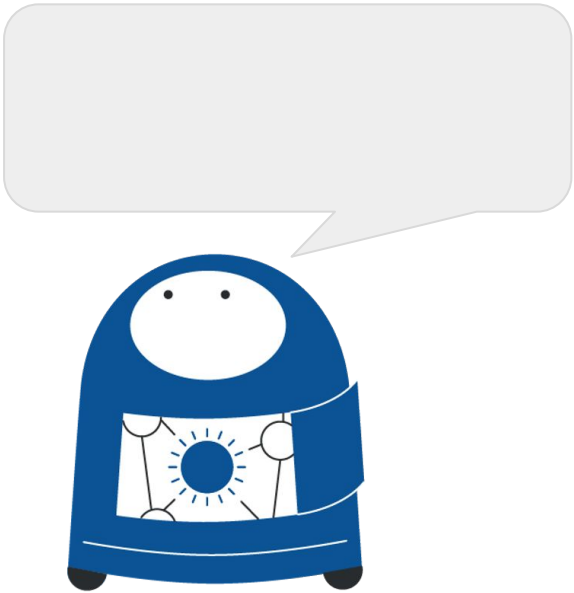


Teacher

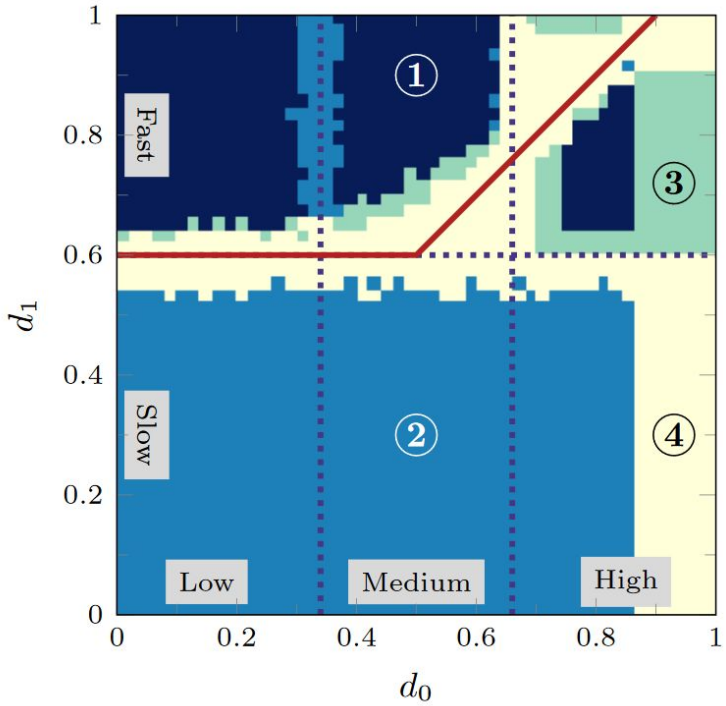
Learner

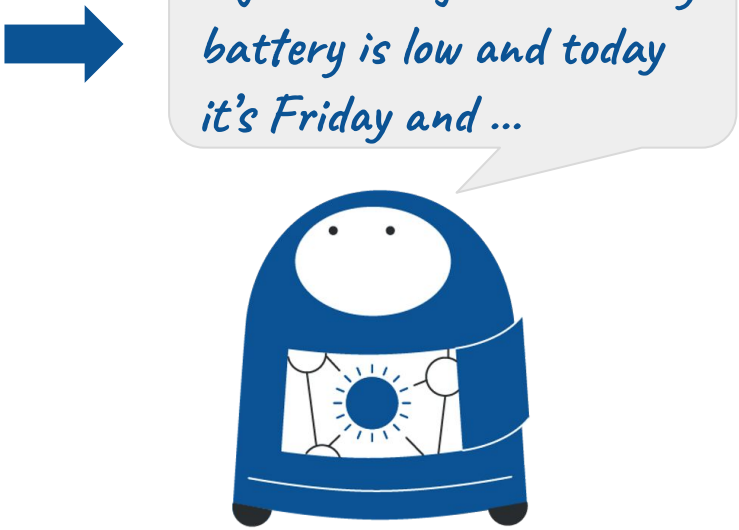
POLICY EXPLANATION



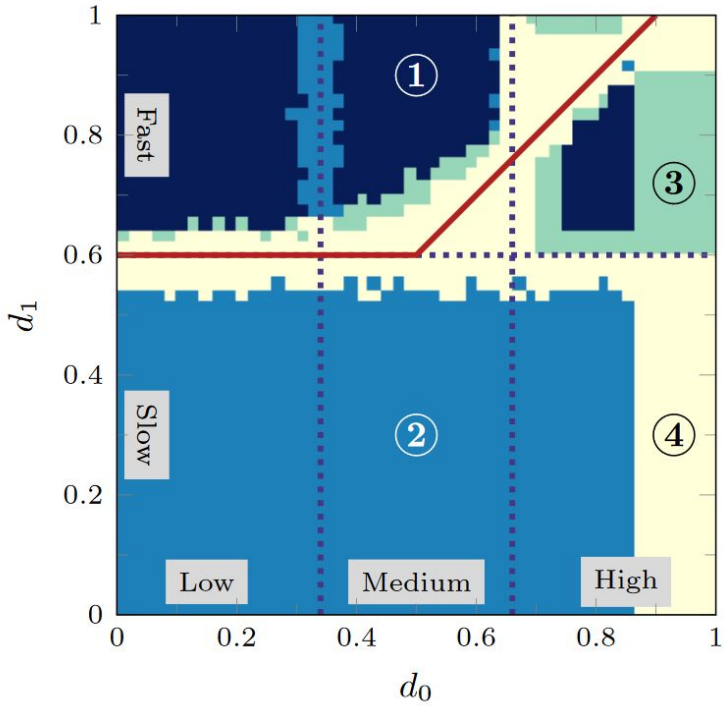


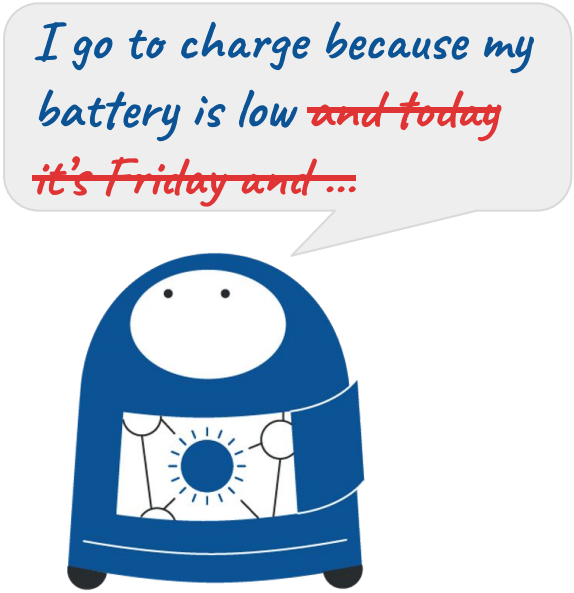
POLICY EXPLANATION





FOCUSED POLICY EXPLANATION





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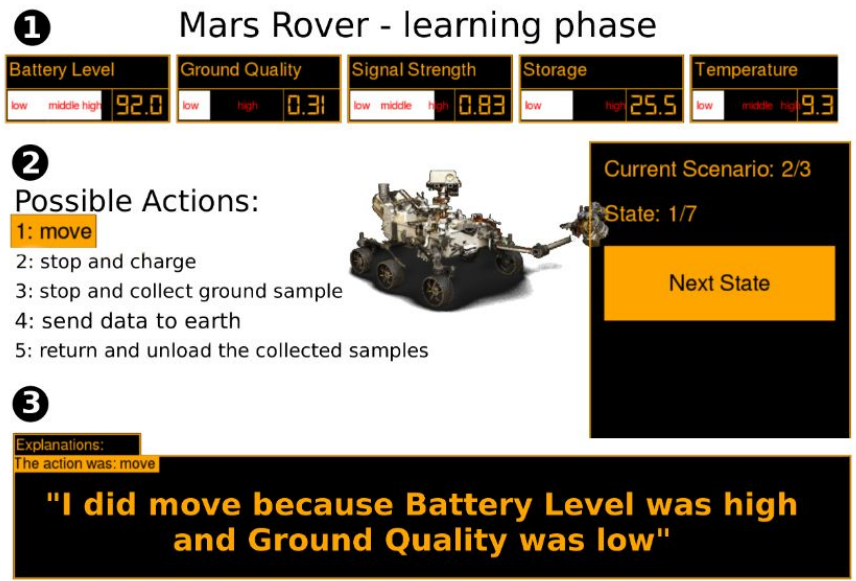

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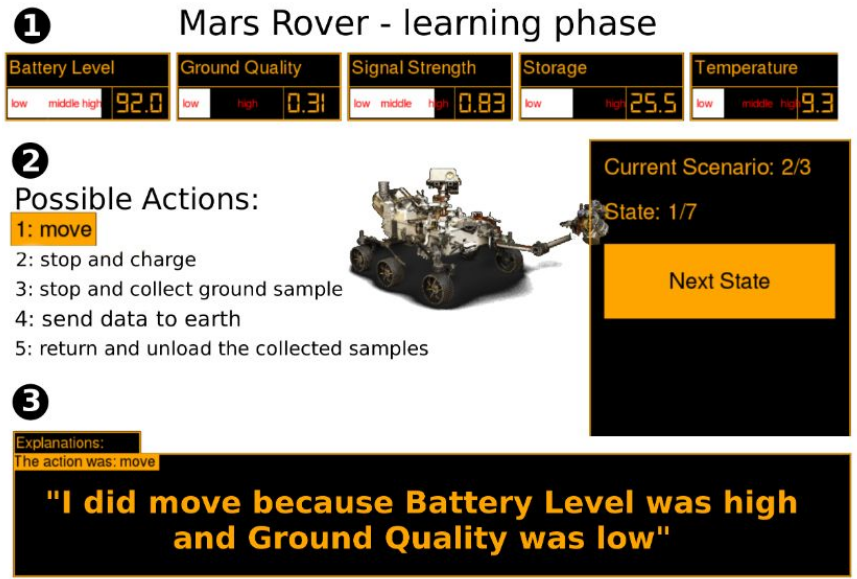


Better understanding of robot policies!

but we have a long way to go before we have **Interpretable Machine Learning**!

Interactive Robot Learning with human-in-the-loop

Interactive Robot Learning with human-in-the-loop

Active Learning

Learning from Demonstration

Interactive Robot Learning with human-in-the-loop

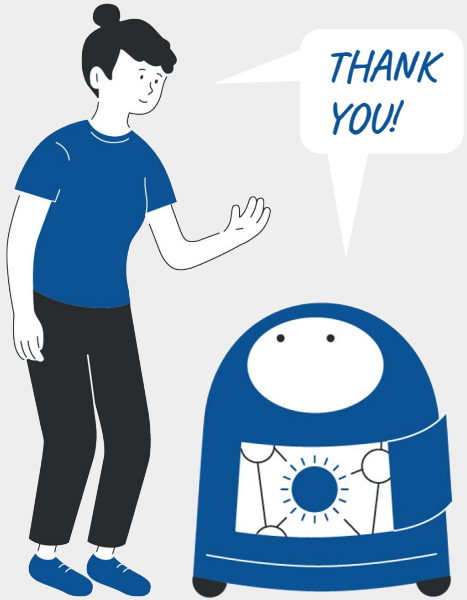
Active Learning

Learning from Demonstration

Focus on the Human-Robot Interaction

Lectio Praecursoria - 30/10/2020

Teacher-Learner Interaction for Robot Active Learning



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