Institut de Robòtica
i Informàtica Industrial

CSIC

COHERENT:

COLLABORATIVE HIERARCHICAL ROBOTIC EXPLANATIONS

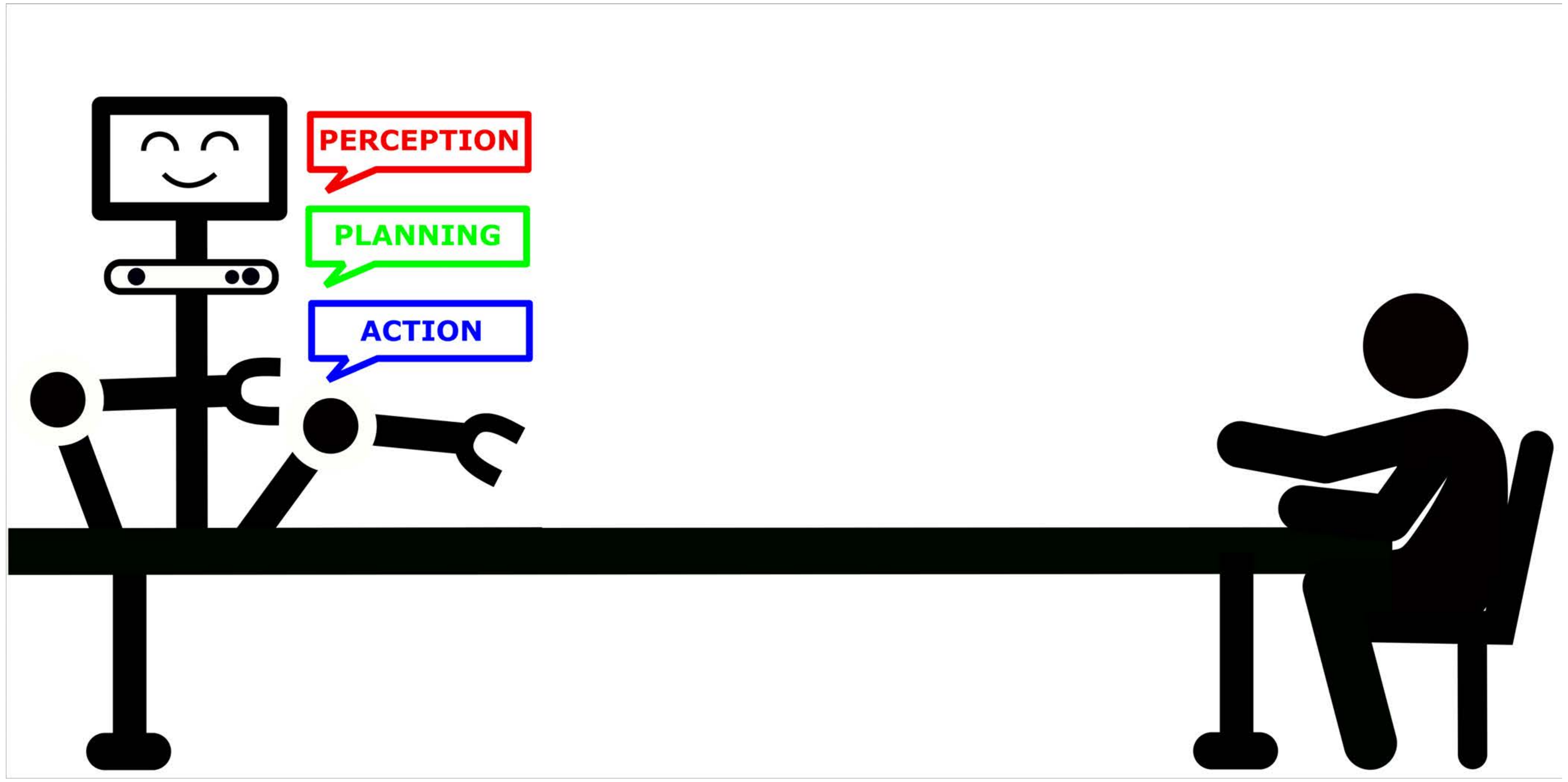
CSIC (Spain), KCL (UK) and UNINA (Italy)

Chistera Seminar 2022

OVERVIEW

- Robotic systems consist of several processes interacting with each other to accomplish a task.
- Relevant **explanations** may come from the such subsystems at **different layers**
  - Deep learning perception tools
  - Decision-making tools
  - Machine learning-based motions

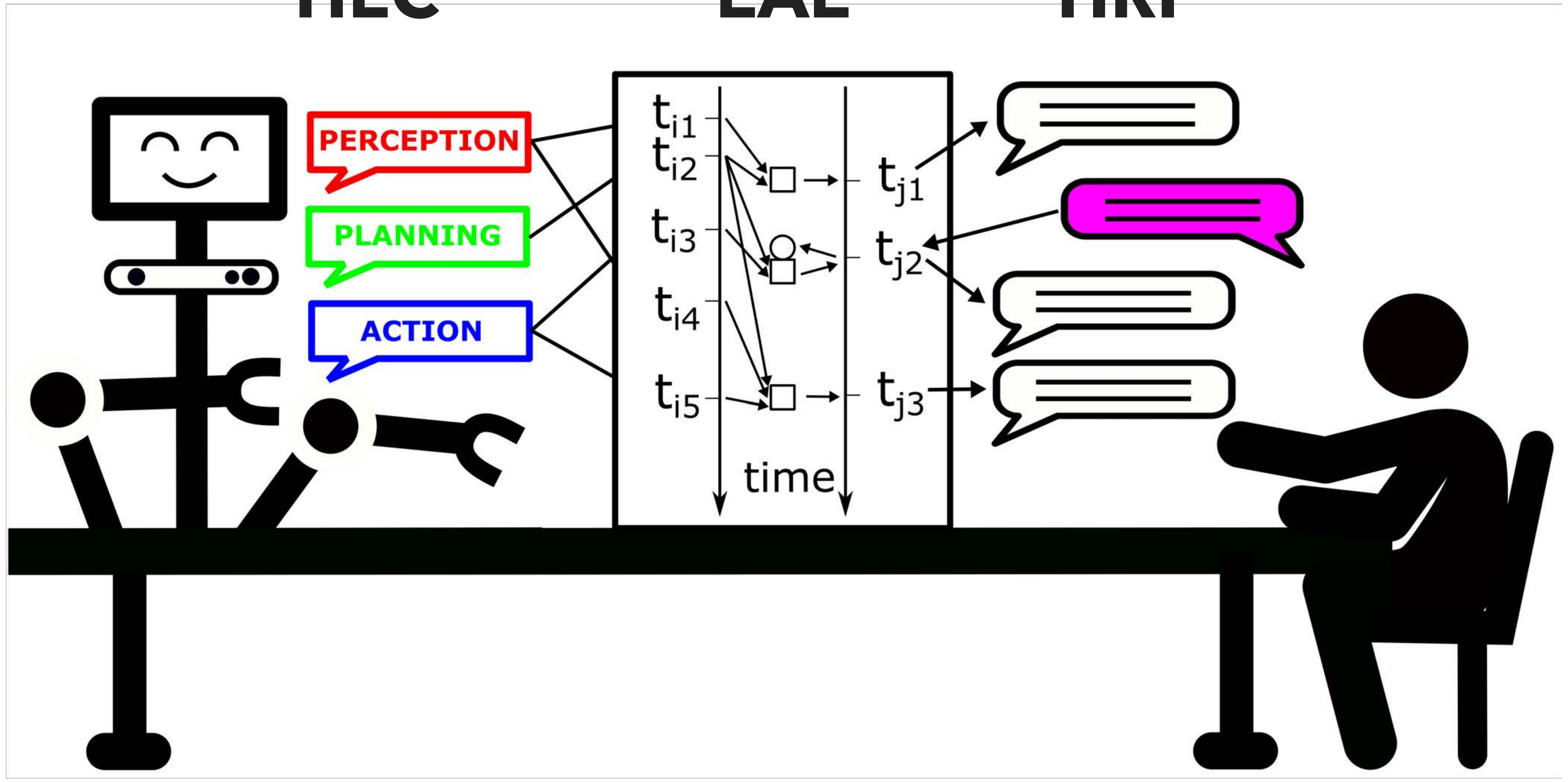
Combine into an **coherent** explanation



OBJECTIVES

- O1: To develop a *standard framework* for Hierarchical Explanation Components (**HEC**): how to store and retrieve information.
- O2: Explainability along the execution (**EAE**): what to explain and when.
  - Two way communication: expl. under user request or when robot needs help
  - Consider user preferences
- O3: Benchmark for **HRI**: metrics for acceptance and effectiveness of explainations tailored for assistive robotic tasks

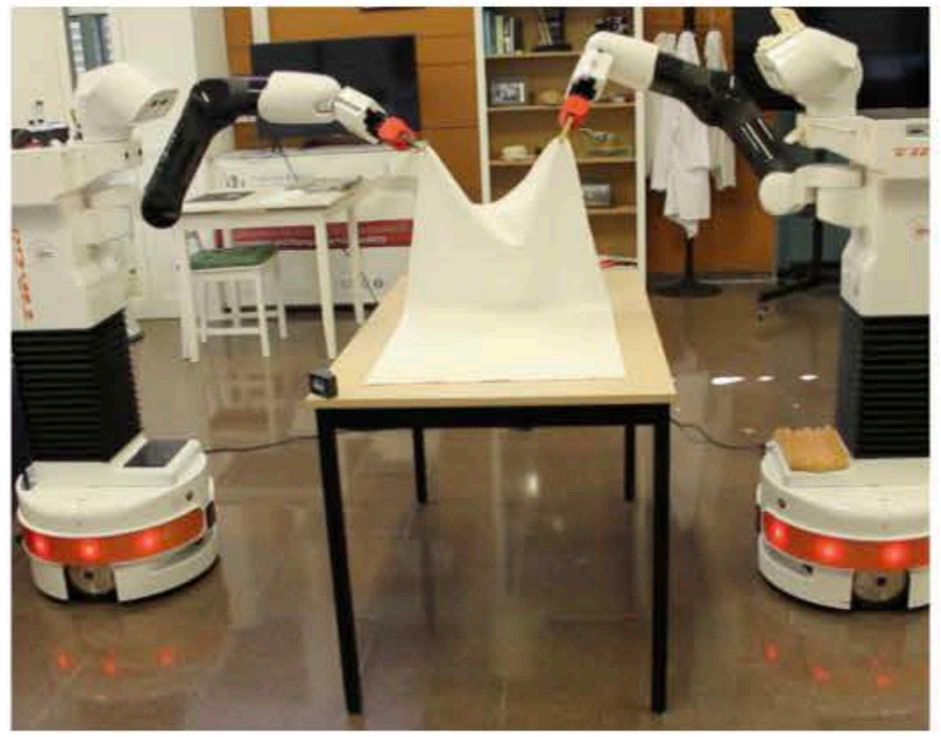
HEC EAE HRI

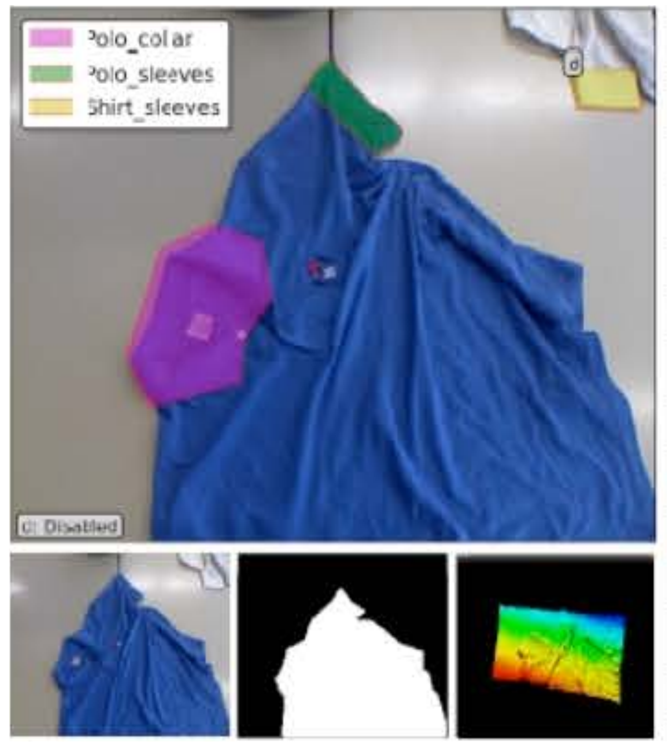


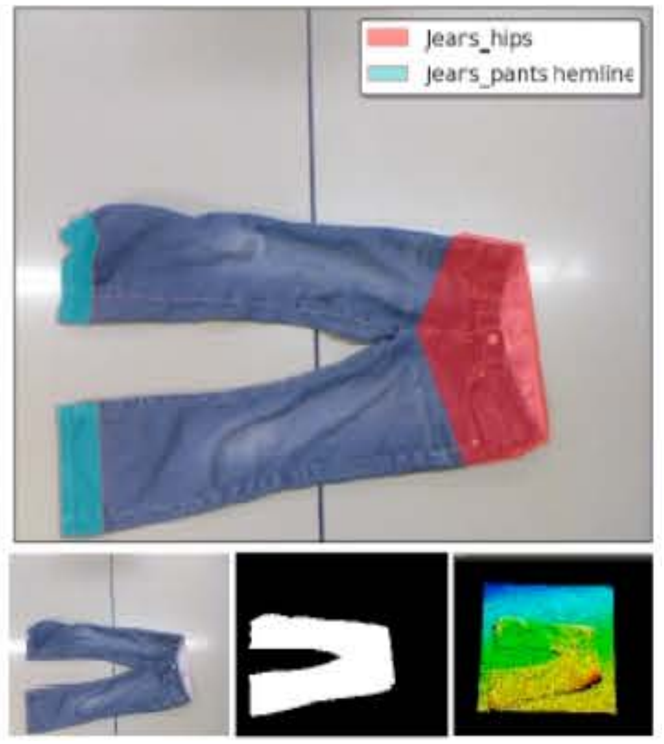
USE CASE: ASSISTIVE CLOTH MANIPULATION TASK

COHERENT

- Task with **impact in industry**
  - Clothing industry: inverse logistics and stores
  - Health care: logistics in hospitals and retirement homes.
  - Assistive robotics in general.
- Task with **enough complexity**
  - Bimanual grasps, envionmental constrains, several steps
  - Requires to **reason** about manipulation **decisions**
- Utilize CSIC previous experience on cloth manipulation







European Research Council
Established by the European Commission

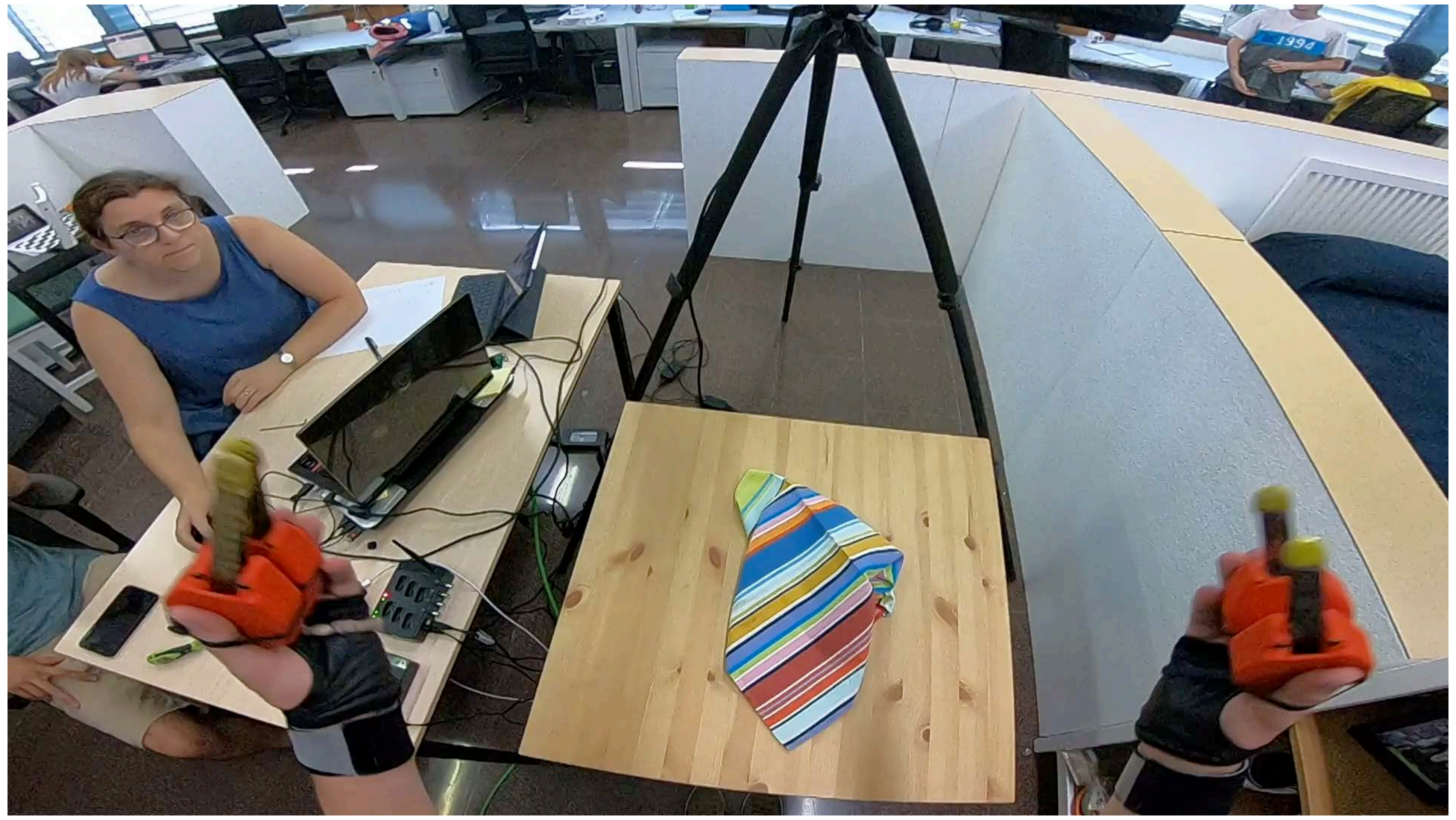
CLOTHILDE project

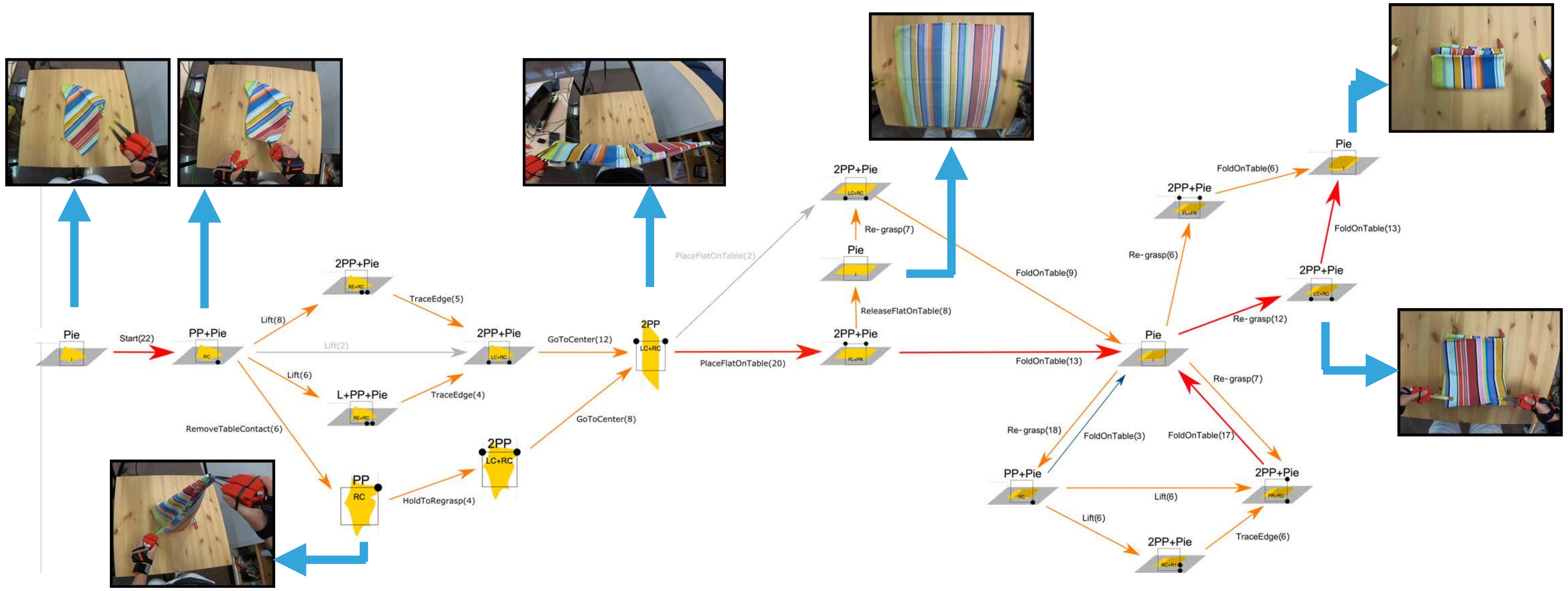
Júlia Borràs, project coordinator.

CSIC

HIERARCHICAL EXPLANATION FRAMEWORK

- Novel representation of a task as a graph of **transitions** between **scene states**.
- Common representation to drive each layer explanation, facilitating the **cohesion** and the **assembly of a coherent message**.





THE COHESION GRAPH

PROJECT PLAN AND ORGANIZATION

- 3 partners

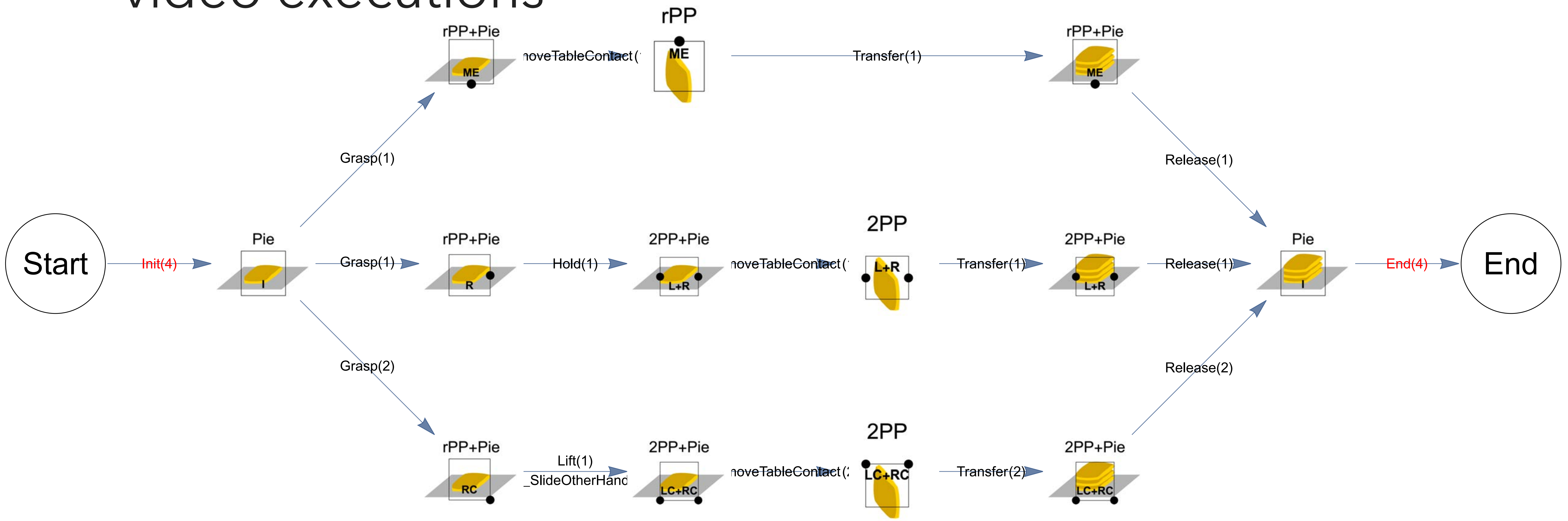
CSIC - Spain	KCL - UK	UNINA - Italy
PI & Coord.: Júlia Borràs	PI: Andrew Coles	PI: Silvia Rossi

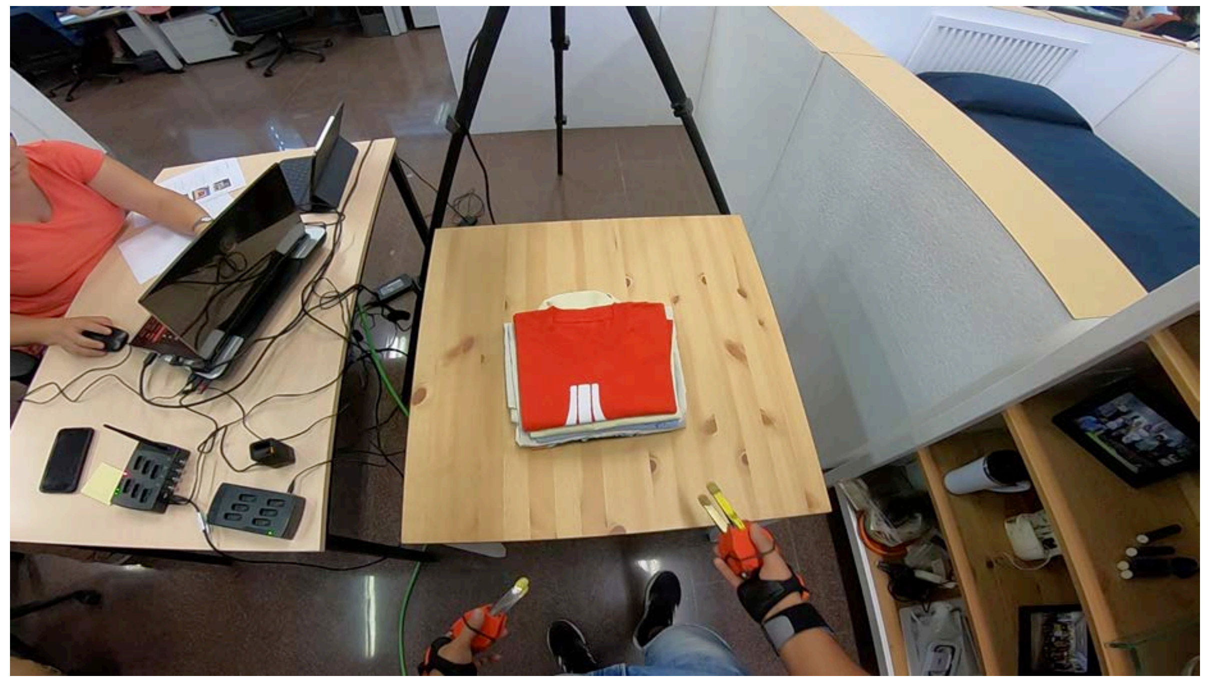
- Started Arpil 1st, 2021 - 3 year project

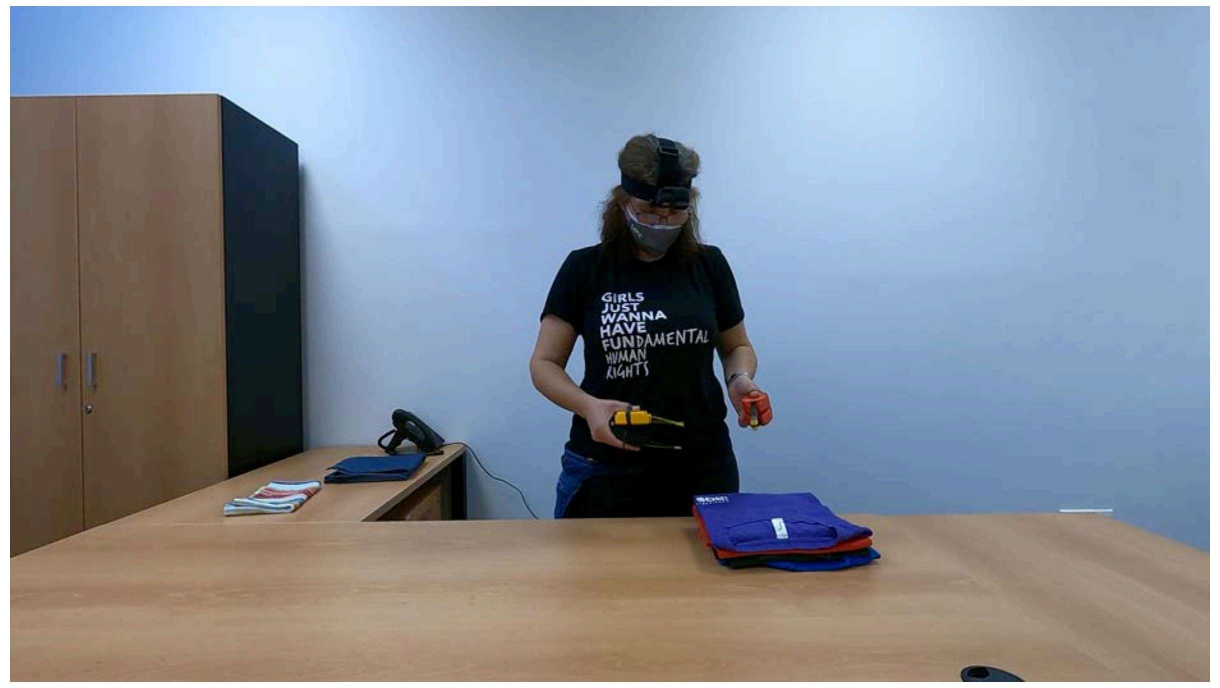
Cohesion graph → **Timing, synthsis, communication, metrics…** → **Pilot study**

KNOWLEDGE REPRESENTATION

- Specification of the use case: pick and pile folded clothes
  - Learning the COHESION graph from video executions





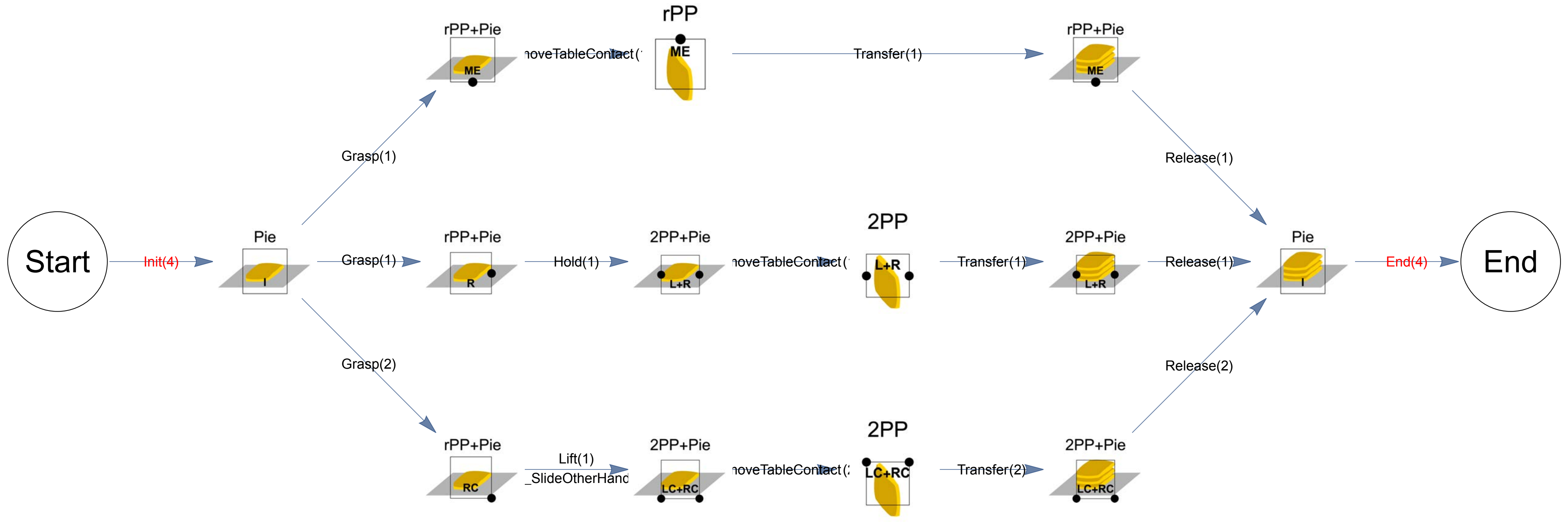


- We can translate it easily to PDDL plans [1] but we need additional information to execute it.

[1] Irene Garcia-Camacho, Júlia Borràs and Guillem Alenyà, **Knowledge representation to enable high-level planning in cloth manipulation tasks**, submitted.

USE CASE SPECIFICATION AND IMPLEMENTATION

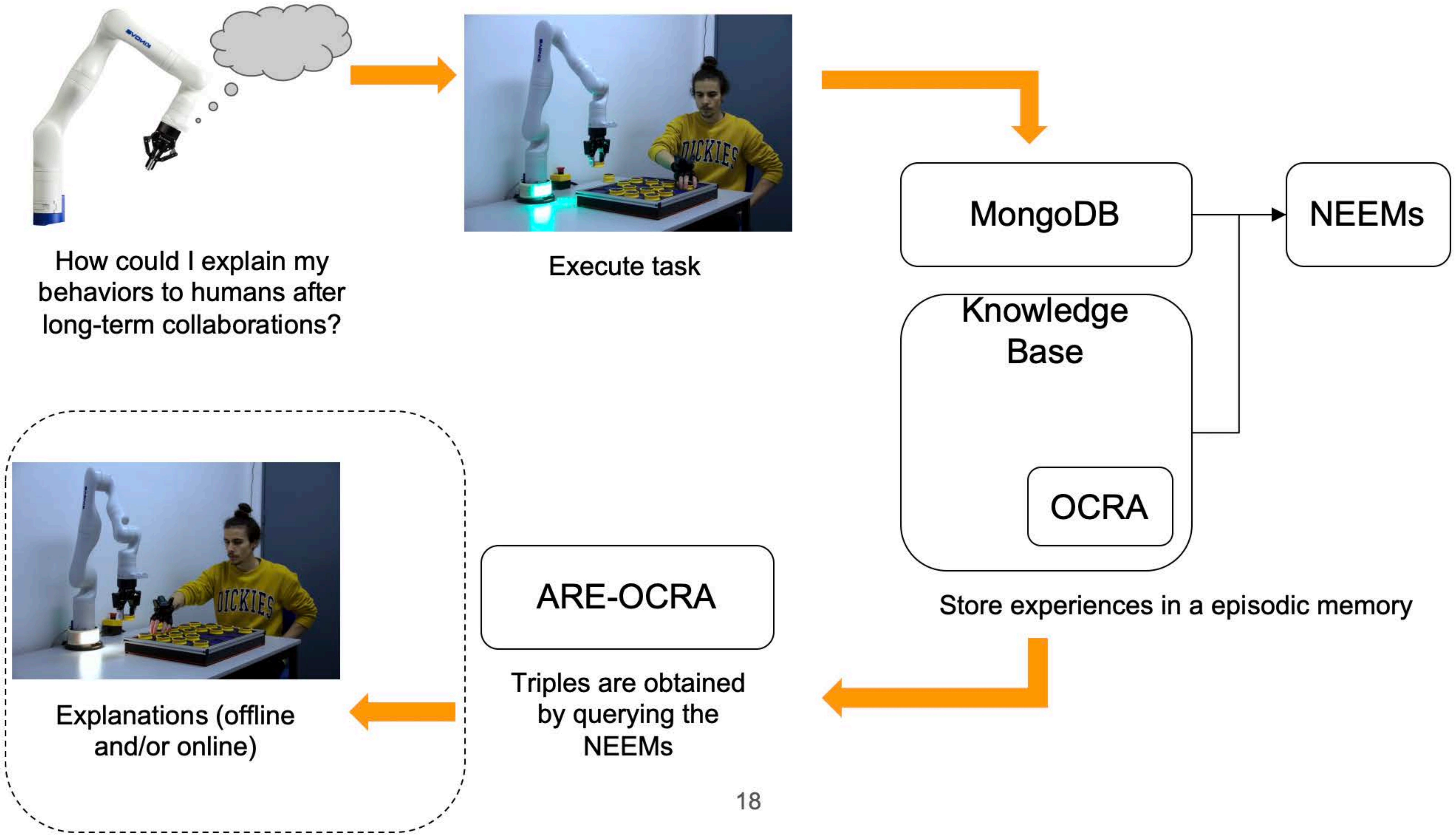
- Specification of the use case: pick and pile folded clothes
  - Learning the COHESION graph from video executions
  - Development of basic skills to pick and place folded clothes
  - Recognition of semantic states to monitor [1]
  - Cloth deformation after grasping depends on cloth properties and number of folds



- Proposal: use ontologies to represent prior-knowledge on cloth properties that are relevant for decision-making

[1] G. Tzelepis, E.E. Aksoy, J. Borràs & G. Alenyà (2022). **Semantic State Estimation in Cloth Manipulation Tasks**. arXiv preprint arXiv:2203.11647 (submitted to IROS2022).

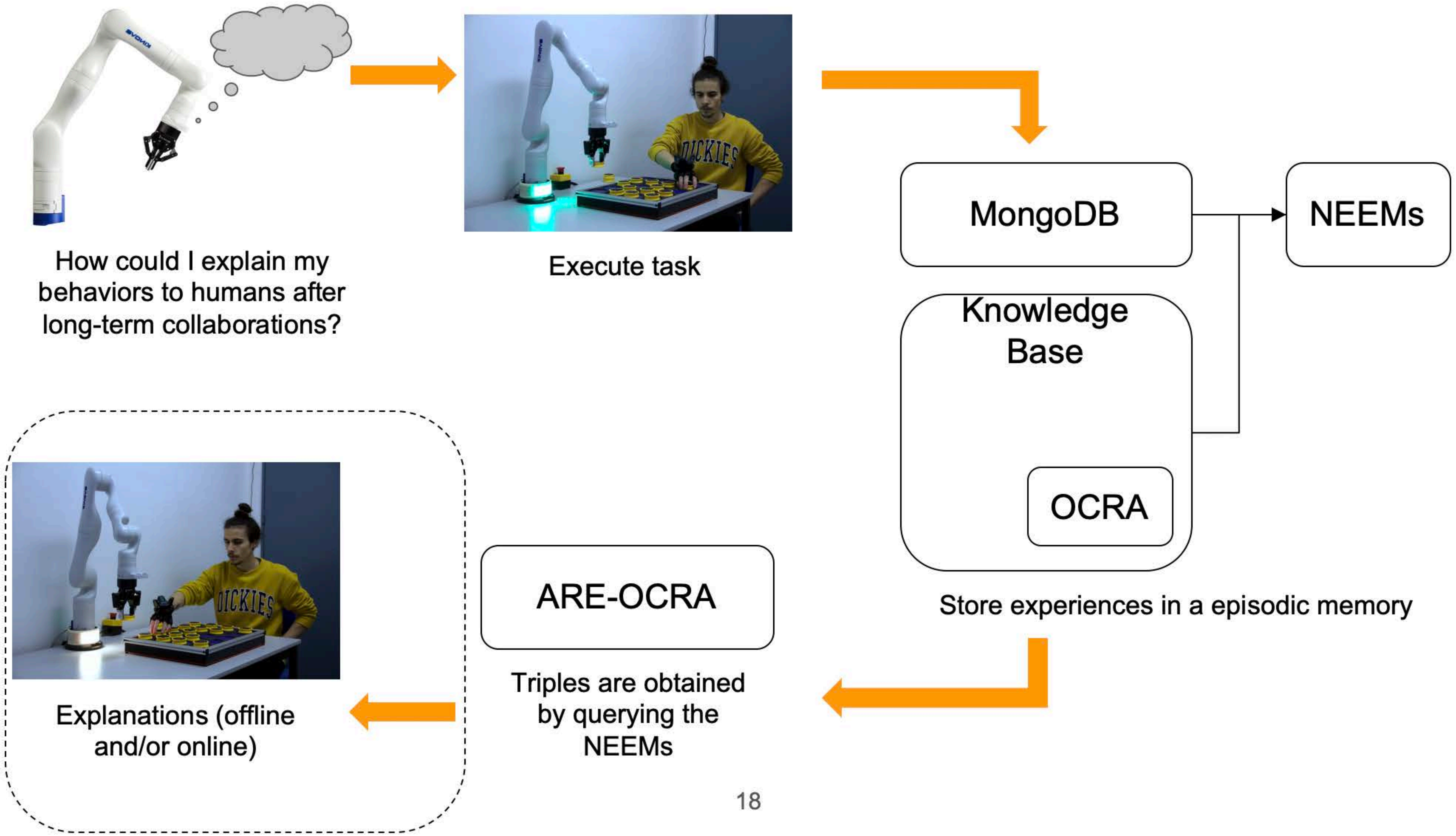
ONTOLOGIES TO EXPLAIN COLLABORATIVE TASKS



- OCRA: Definitions and formalization of collaborative robotic tasks.

A. Olivares-Alarcos, S. Foix, S. Borgo and G. Alenyà. **OCRA – An ontology for collaborative robotics and adaptation**. Computers in Industry, 132: 103627, 2022.

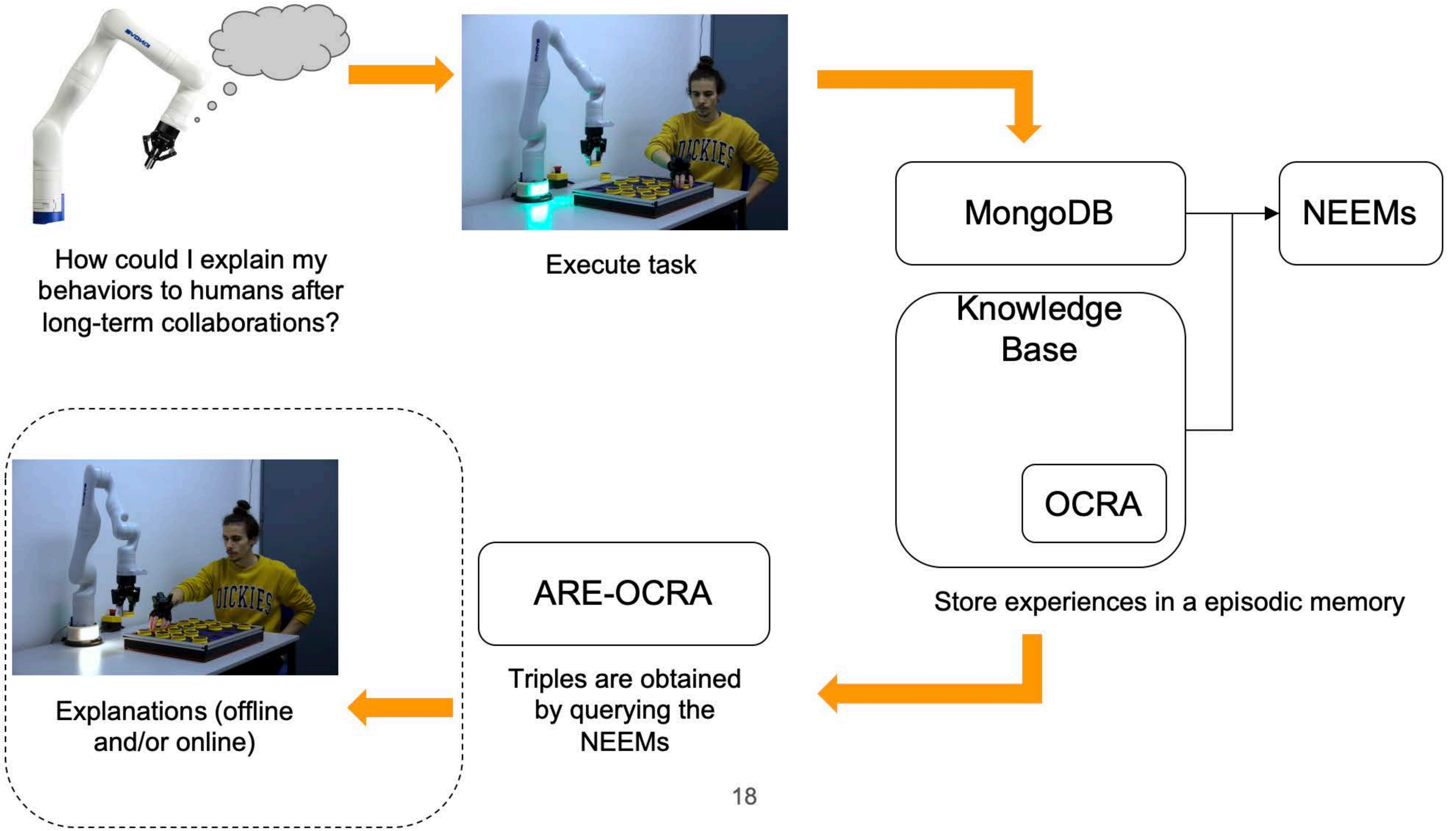
ONTOLOGIES TO EXPLAIN COLLABORATIVE TASKS



- NEEMs: narrative-enabled episodic memories
- They store the interactions the robot has done, with the knowledge structure given by OCRA

A. Olivares-Alarcos, S. Foix and G. Alenyà. **Knowledge Representation for Explainability in Collaborative Robotics and Adaptation**, 3rd International Workshop on Data meets Applied Ontologies, 2021, Bratislava, Slovakia (Virtual), pp. 1-8.

ONTOLOGIES TO EXPLAIN COLLABORATIVE TASKS



- ARE-OCRA: Algorithm for Robot Explanation with an Ontology for Collaborative Robotics and Adaptation

A. Olivares-Alarcos, S. Foix and G. Alenyà. **Knowledge Representation for Explainability in Collaborative Robotics and Adaptation**, 3rd International Workshop on Data meets Applied Ontologies, 2021, Bratislava, Slovakia (Virtual), pp. 1-8.

PLANNING WITH AN ONTOLOGY

- Planners do not know **why** the model is the way it is
- **Lack of knowledge** limits explainations that can be given.
- Hence, we look at planning with **explicit visibility of an ontology** that captures this missing knowledge, to find plans that are better for the user
- Challenges:
  - 1: Being sensitive to the ontoloty
  - 2: Explaining alongside the execution
  - 3: When things go wrong
    - 3b: When to explain

CHALLENGE 1: BEING SENSITIVE TO THE ONTOLOGY

- The ontology provides new ways of defining **costs** or **durations** for planning.
  - If the cloth bends a lot, releasing will be more difficult.
- To do this we need improved heuristics and search algorithms:
  - Heuristics that provide guidance to solution plans that are good according to the ontology
  - Search algorithms that intelligently explore the trade-off between plan quality criteria (e.g. plan execution time vs user preference)

Gerard Canal, Carme Torras, and Guillem Alenyà, "**Are Preferences Useful for Better Assistance?: A Physically Assistive Robotics User Study**", ACM Transactions on Human-Robot Interaction (THRI), vol. 10, no. 4, pp. 1–19, 2021

CHALLENGE 2: EXPLAINING ALONGSIDE EXECUTION

- To **verbalise the plan:** takes time and needs to **be planned for**.
- Treat explanations as first-class citizens: the plan has actions to "give explanations".
  - Could be before execution, during execution, or both
- **This fundamentally affects what makes a good plan**:
  - a plan that is efficent but hard to explain is less valuable
  - than one which is a bit less efficient, but needs less explanation time.

Gerard Canal, Carme Torras, and Guillem Alenyà, "**Generating Predicate Suggestions based on the Space of Plans. An Example of Planning with Preferences**", User Modeling and User-Adapted Interaction, 2022. In press

CHALLENGE 3: WHEN THINGS GO WRONG

- Execution failures are common and lead to **re-planning**. In the worst case, we need an entirely new plan.
- A completely different new plan is a barrier for the **user understanding**.
  - We need to explain: **why was a new plan needed**?
- With explanations as first-class citizens (actions that are part of the plan)
  - Definition of a good (re-)plan is influenced by how it needs to be explained.

S. Izquierdo, G. Canal, C. Rizzo, and G. Alenyà, "**Improved Task Planning through Failure Anticipation in Human-Robot Collaboration**," in IEEE International Conference on Robotics and Automation, 2022.

CHALLENGE 3B: WHEN TO EXPLAIN

- Refine the model of **when explanations are needed to:**
  - **improve efficiency** without compromising **user trust**
- By **monitoring the user** (for instance, through eye gaze) we can **model user confusion**
  - To detecting situations where the user needs an explanation
- What needs to be explained is reflected in the ontology
  - So, it influences the plans found.

Lennart Wachowiak*, Peter Tisnikar*, Gerard Canal, Andrew Coles, Matteo Leonetti, and Oya Celiktutan, "**Analysing Eye Gaze Patterns during Confusion and Errors in Human-Agent Collaborations**". Submitted.

EXPLANATION EVALUATION: SCIENTIFIC BACKGROUND

- Existing work on “explanation evaluation” usually breaks down the problem into the evaluation of narrower aspects of an explanation
  - Intelligibility, accuracy, precision, completeness, and consistency
  - Context-dependent and hard to assess in a general way
  - Do not consider characteristics linked to an embedded system, e.g., legibility, safety

KEY CHALLENGES AND POTENTIAL IMPACT

- Humans in the XAI evaluation loop
  - Trust has impact on the motivations and intentions to use the systems
  - Trust is linked to the perception of a system
  - Hard to assess

- Definition of metrics and measurement
  - Independent from
    - The type of explanation provided (verbal, behavioral, multi-modal)
    - The robotic/HRI task

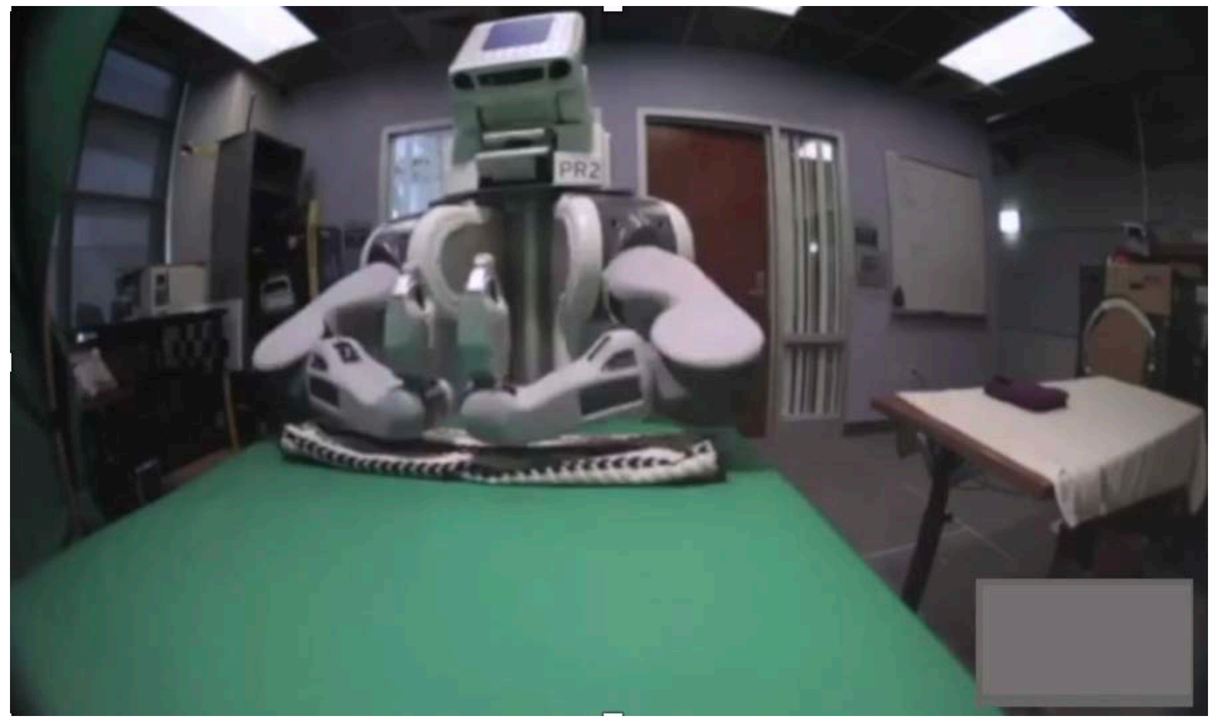
MEASURING MENTAL MODELS

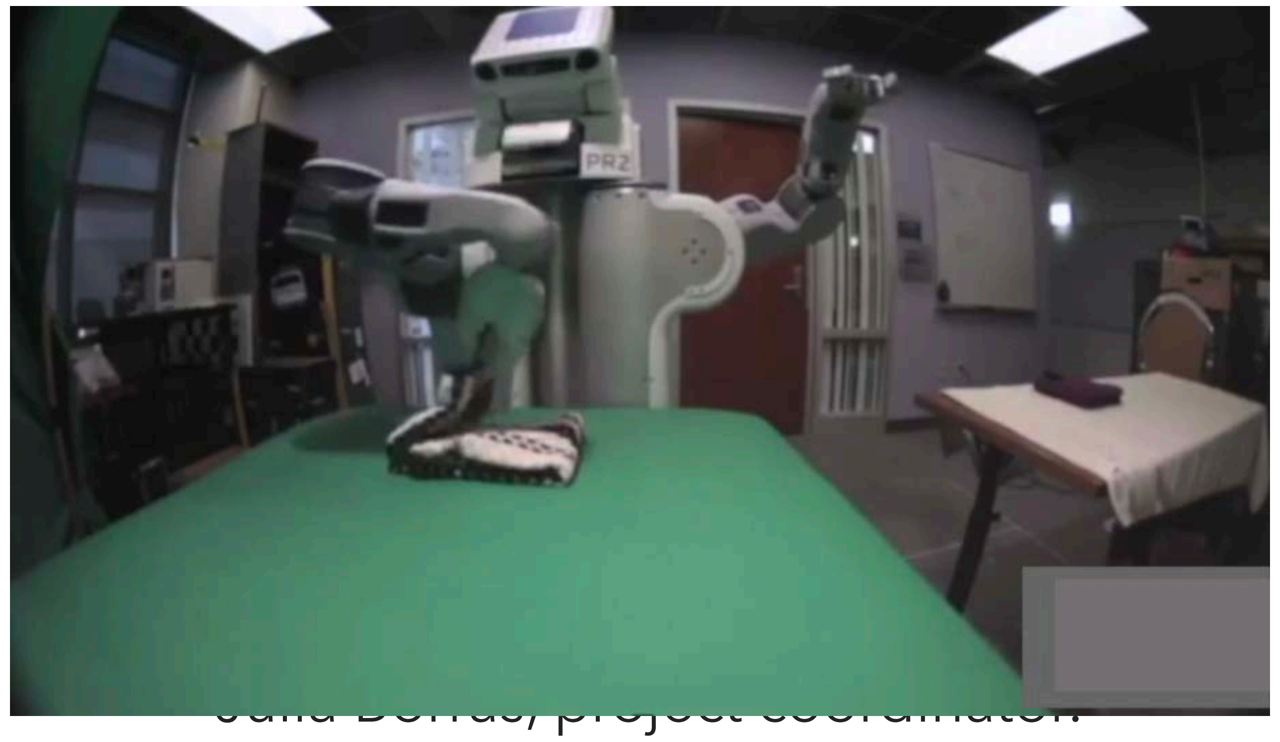
- Theory of Mind (ToM) is a natural and fundamental ability that allows to infer others' intentions and behaviours, and regulates our own behaviours accordingly
  - How do we endow a robot with the ability of ToM?
  - Do people recognize that a robot has a ToM?

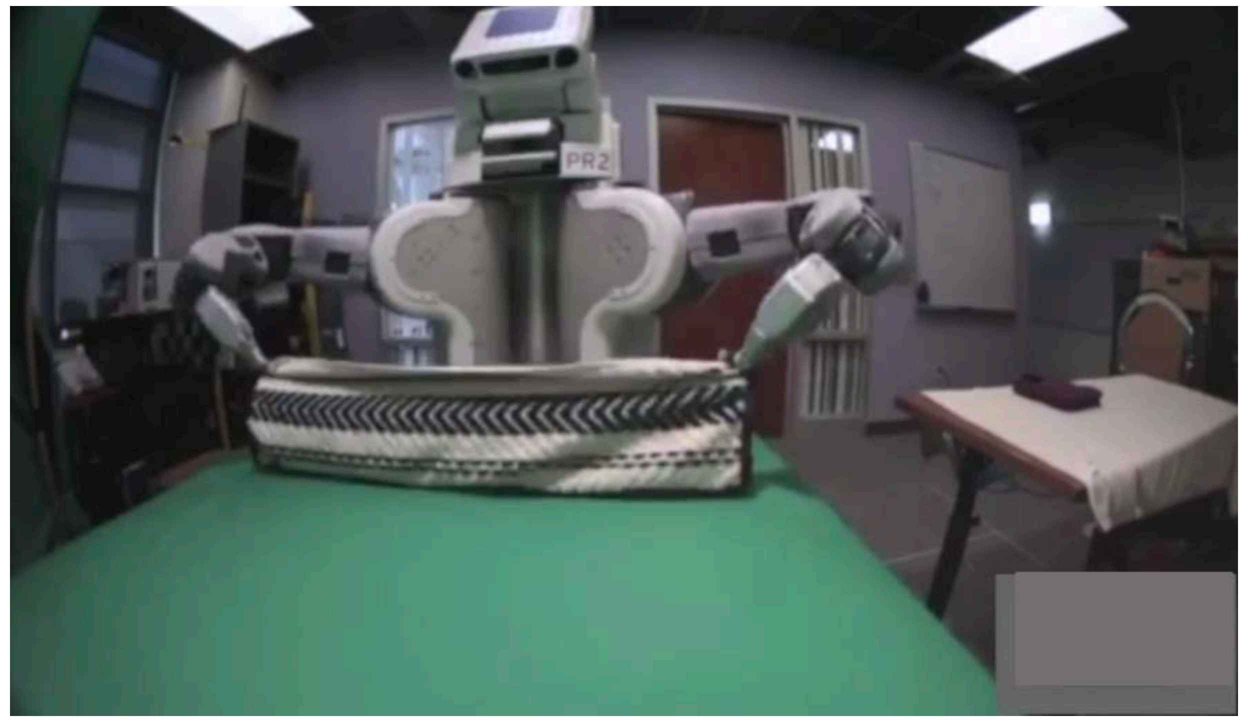
AIMS

Create a valid measurement tool that aims to assess the ability of humans to attribute mental states to robots, whether they are humanoid or non-humanoid;

People tend to attribute intentionality to both robotic agents that interact with humans and robotic agents that perform actions on their own.







MAIN SCIENTIFIC RESULTS AND OTHER OUTPUT

Rossi, A., Scheunemann, M.M., L'Arco, G., Rossi, S. (2021). **Evaluation of a Humanoid Robot's Emotional Gestures for Transparent Interaction**. In: , *et al.* Social Robotics. ICSR 2021

→ Emotional Feedback for Transparent Behaviours

Cucciniello, I., Sangiovanni, S., Maggi, G. and Rossi, S. (2022). **Mind Perception in HRI: Exploring Users' Attribution of Mental and Emotional States to Robots with Different Personalities**. International Journal of Social Robotics, Springer - submitted

→ Manipulation of robot's personalities (Friendly, Neutral and Authoritarian) for modeling people's mental models and perception of robots' capabilities

Rossi, A., Andriella A., Rossi S., Torras, C. and Alenyà, G. (2022). **Evaluating the Effect of Theory of Mind on People's Trust in a Faulty Robot**. In: IEEE International Conference on Robot & Human Interactive Communication (RO-MAN 2022) – submitted

→ Theory of Mind for providing copying mechanism after robots' errors

CONCLUSIONS AND WORK FOR THE NEXT YEARS

- Bring together the development of planning, knowledge representation, and evaluation into the project robotic demonstration use case
  - Use the COHESION graph as a knowledge graph to store explanations comming from different levels
    - Perception / Planning / Execution / Ontology of domain knowledge
- Design the pilot study with subjects with the metrics developed by UNINA
  - First as evaluation of videos of robot demonstrations
  - Towards the end of the project, with subjects interacting with the robot

https://coherent.csic.es/