Foundations of ontology-based explainable robots

A tale of human-robot interaction, ontological modeling and explanatory narratives

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beginning..

What if we could study the use of **ontologies** as an **integrative** framework for the construction of robot **explanations**, particularly within **interactive** settings involving **humans**?

Review and ontological scope [1]

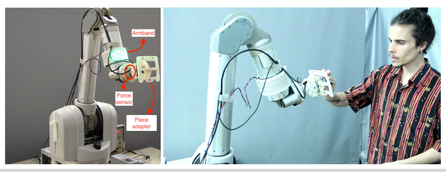
Minority of works on ontological modeling **industrial** human-robot interaction and **collaboration**

Lack of ontological **models** for some essential **cognitive** capabilities of robots: **recognition and categorization**, **decision making and choice**, and **remembering, reflection and learning**.

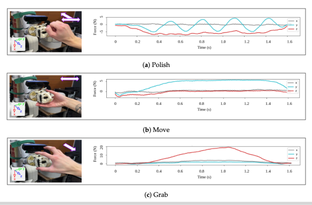
Ontologies might help providing a common **representation** and **reasoning** tool for them.

Hands-on experience in robot perception for recognition and decision-making in collaborative robotic tasks [2,3]

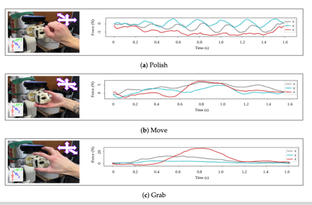
Human intention inference for (trustworthy) decision making



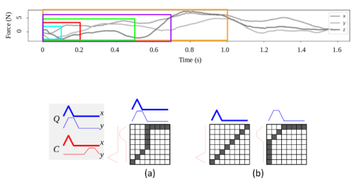
Mechanical set



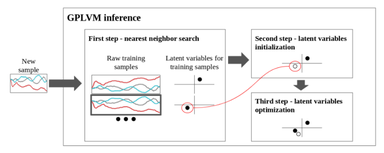
Natural set



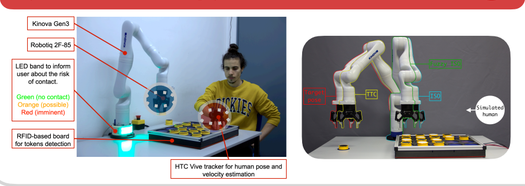
kNN+DTW



GPLVM+SVM



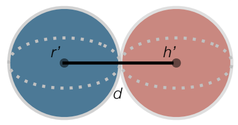
Collision risk monitoring for (trustworthy) decision making



3D TTC formulation

at the moment of contact..

$$d = ||(r'_x, r'_y, r'_z) - (h'_x, h'_y, h'_z)||$$

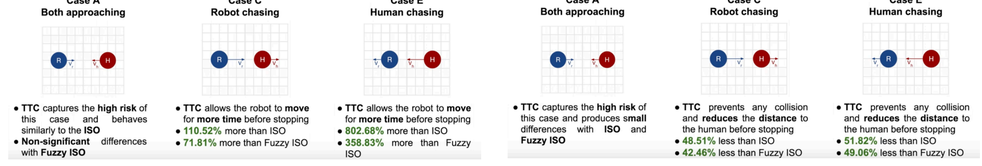


$$rad_r + rad_h = \sqrt{(r'_x - h'_x)^2 + (r'_y - h'_y)^2 + (r'_z - h'_z)^2}$$

$$\vec{r}' = \vec{r} + \vec{v}_r ttc$$

$$\vec{h}' = \vec{h} + \vec{v}_h ttc$$

TTC boosts tasks' efficiency while still being safe



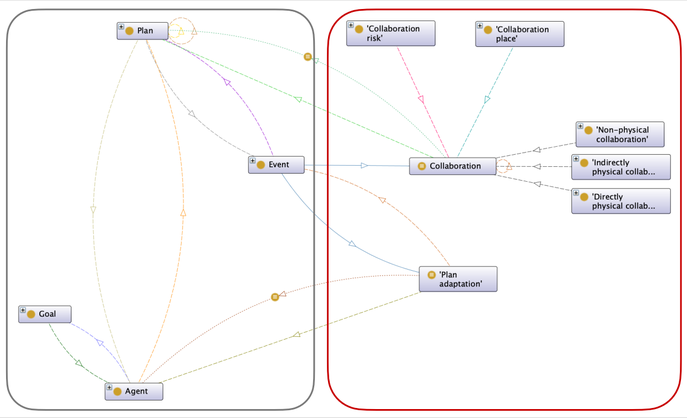
Ontological analysis and conceptual modeling in collaborative and adaptive tasks [4]

Representation of the domain knowledge for robot reasoning

Ontology for **C**ollaborative **R**obotics and **A**daptation

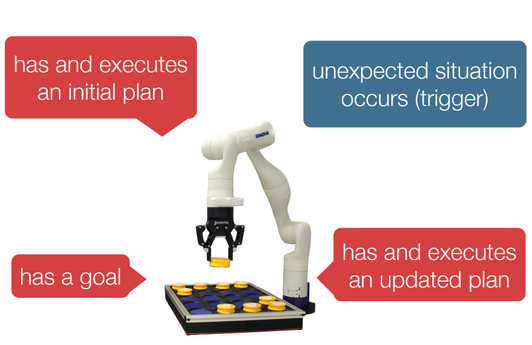
FOL

OWL



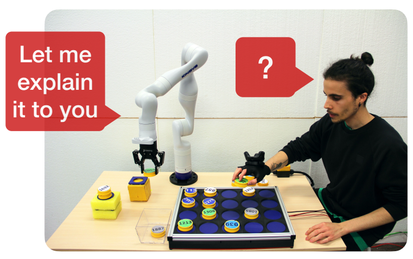
Collaboration

Plan Adaptation

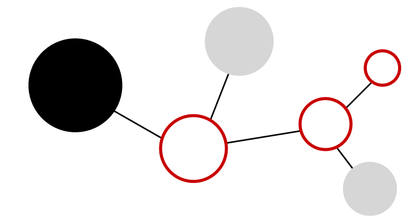


Ontology-based explainable robots [5,6]

Memory (remembering and reflection) of robots' knowledge and decisions (adaptations) for explanatory narration to humans



During interactive tasks..



Generate **knowledge** of finished **events** (e.g., collaborations and plan's adaptations)

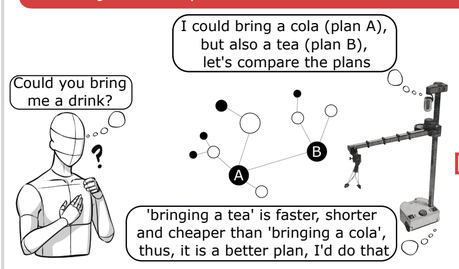
OCRA + NEEM

Store the knowledge in an **episodic memory** using the ontology OCRA

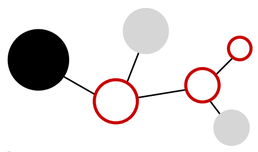
AXON

Algorithm to **retrieve** knowledge of events when they happened and **construct** a textual explanatory narrative

Beyond plain narratives of collaborative and adaptive experiences..plans comparison and contrastive explanatory narratives



During interactive tasks..



Generate alternative **plans** (e.g. for each drink) and abstract their attributes (e.g. cost)

Ontology + Episodic memory

Store the knowledge in an **episodic memory** using the novel ontological model for plan comparison

Inference

Run the **logical rules** to compare the plans' attributes and infer which plan is better

ACXON

Retrieval of **divergent** knowledge of plans and construction of a contrastive explanatory **narrative**

the end?

The thesis is **submitted** and the **defense** will probably be in **December 2024**

Postdoc at IRI — ARISE

Start date — 01/02/2019
Thesis Project Defense — 30/09/2019

- **Supervision** of **3 bachelor** thesis and **1 master** thesis
- **Secretary** of IEEE-SA **1872.2** and **Vice-Chair** of **1872.3** standards
- **EASE Fall School 2019** at University of Bremen
- **Research secondment** (2022) at the **Laboratory of Applied Ontology**, ISTC-CNR, under the supervision of **Dr. Stefano Borgo**
- **Research secondment** (2023) at the Department of Informatics of **King's College London**, under the supervision of **Dr. Gerard Canal**

Grant FI-UPC funded by AGAUR
SIMBIOTS (CSIC) funded by ACCIÓ
COHERENT (CSIC) funded by MCIN / AEI
ARISE (CSIC) funded by EU Horizon

PhD day 2024

[1] Olivares-Alarcos, A., Beßler, D., Khamis, A., Gonçalves, P., Habib, M. K., Bermejo-Alonso, J., ... & Li, H. (2019). ***A review and comparison of ontology-based approaches to robot autonomy.*** The Knowledge Engineering Review, 34, e29.

[2] Olivares-Alarcos, A., Foix, S., & Alenyà, G. (2019). ***On inferring intentions in shared tasks for industrial collaborative robots.*** Electronics, 8(11), 1306.

[3] A. Olivares-Alarcos, S. Foix, and G. Alenyà, Human-Robot Collaboration: Unlocking the potential for industrial application, ch. ***Time to Contact for Robot Safety Stop in Close Collaborative Tasks***, pp. 1–17. The Institution of Engineering and Technology, to appear.

[4] Olivares-Alarcos, A., Foix, S., Borgo, S., & Alenyà, G. (2022). ***OCRA–An ontology for collaborative robotics and adaptation.*** Computers in Industry, 138, 103627.

[5] Olivares-Alarcos, A., Andriella, A., Foix, S., & Alenyà, G. (2023). ***Robot explanatory narratives of collaborative and adaptive experiences.*** In 2023 IEEE International Conference on Robotics and Automation (pp. 11964-11971). IEEE.

[6] Olivares-Alarcos, A., Foix, S., Borràs, J., Canal, G., & Alenyà, G. (2024, May). ***Ontological modeling and reasoning for comparison and contrastive narration of robot plans.*** In Proceedings of the 2024 International Conference on Autonomous Agents and Multiagent Systems (pp. 2405 - 2407).