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ANITI Chair on Cognitive and Interactive Robotics





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AI



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e Arthur Bit-Monnot



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Université Fédérale

Toulouse Midi-Pyrénées Devise and build the **cognitive** and **interactive** abilities to allow **pertinent**, **legible** and **acceptable** behaviors for a robot that is able to perform **collaborative tasks** with a human partner.

 \rightarrow the assistant and the teammate robot





→ Ambition to cover the full spectrum of the needed Robot Abilities

- 1. A principled and long-term **multi-disciplinary collaborative research** with philosophers, development psychologists, ergonomists
- Incremental Development of key components and their articulation within a Cognitive Architecture
- 3. The **deployment of AI-enabled robotic** systems with potential users
- 4. The **Evaluation** in contexts where the robot is used to conduct joint action and/or learn or refine abilities with non-specialist **users**.



Constructive approach:

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- Adoption and Adaptation of Joint Action Concepts and Mechanisms
- Models of Human beliefs, intentions, abilities and preferences

Situation Assessment in H&R context

- Perspective-Taking
- Estimation of Human Mental State (ToM)
- * Human-Aware Task and Motion Reactive Planning for
 - Collaborative Task Achievement
 - and Situation-based Dialog



S. Lemaignan, M. Warnier, E. A. Sisbot, A. Clodic, R Alami, Artificial Cognition for Social Human-Robot Interaction: An Implementation, Artificial Intelligence, Elsevier, 2017

A. Clodic, R. Alami, What Is It to Implement a Human-Robot Joint Action? Robotics, AI, and Humanity, Springer International Publishing, pp.229-238, 2021,

- 1. HR Situation assessment and estimation of Human belief about environment and task
- 2. Human-Aware Planning and Control for H&R collaborative task achievement
- 3. Deployment of interactive robots systems





1- Situation assessment and estimation of Human beliefs about environment and task

- Visual Perspective-taking estimated by the Robot
- Management and maintenance of semantic knowledge, and chronicles for the robot and estimation of the beliefs its of Human partner
- Simulation-based physics reasoning for consistent scene estimation



Robot able to track the state of the yellow object manipulated by the Human even when it is inside the blue box or poured into the green box

Y. Sallami, S. Lemaignan, A. Clodic, R. Alami, Simulation-based physics reasoning for consistent scene estimation in an HRI context, IEEE IROS 2019

G. Sarthou, A. Clodic, R. Alami, Ontologenius : A long-term semantic memory for robotic agents, IEEE RO-MAN 2019





1- Referring Expression Generation (REG) in Human Robot Interaction

- Exploits Distinct Human and Robot Perspectives (Visibility / Affordances)
- Ontology based: using object attributes, relations and related objects, task description
- Cost-based Algorithm:
 - ensures non-ambiguity of the target entity in the REG
 - uses shared knowledge about past Human-Robot collaborative activity



« (?0, isA, Pen), (?0, In, ?1), (?1, isA, Cup), (?1, Color, blue) »





G. Sarthou



G. Buisan

« the knife with which Tony prepared the salad »

G. Buisan, G. Sarthou, R. Alami, Human Aware Task Planning Using Verbal Communication Feasibility and Costs, ICSR 2020.

G. Sarthou, G. Buisan, A. Clodic R. Alami, Extending Referring Expression Generation through shared knowledge about past Human-Robot collaborative activity, IEEE IROS 2021

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2 - Human-Aware Planning and Control for H&R collaborative task achievement

• Cost-based Human-Aware Motion Planning:

• Human-Aware Navigation planning for Social Navigation

P.T. Singamaneni, R. Alami, HATEB-2: Reactive Planning and Decision making in Human-Robot Co-navigation, IEEE RO-MAN 2020

P.T. Singamaneni, A. Favier, R. Alami, Human-Aware Navigation Planner for Diverse Human-Robot Contexts, IEEE IROS 2021.

• **Planning** H&R placements for H&R **Shared Visual Perspective**

J. Waldhart, A. Clodic, R. Alami, Reasoning on Shared Visual Perspective to Improve Route Directions, IEEE RO-MAN 2019

- Human-Aware Task Planning : HATP and HATP/EHDA
 - Planning shared H&R plans
 - Explicit management of H & R beliefs
 - Anticipation of Human Action & Decision
 - Elicitation of human action
 - Planning context and task dependent **communication acts**

G. Buisan, R. Alami, A Human-Aware Task Planner Explicitly Reasoning About Human and Robot Decision, Action and Reaction, HRI '21

G. Buisan, G. Sarthou, R. Alami, Human Aware Task Planning Using Verbal Communication Feasibility and Costs, ICSR 2020.



CoHAN: Cooperative Human Aware Navigation

- A Human-Aware navigation system which can handle various H&R interaction schemes including cooperative schemes
 - Human-aware constraints for promoting legibility and acceptability integrated in a reactive optimization process
 - Several modes (e.g. simple / double elastics band..) depending on context and human behavior
 - Proactive behavior based on trajectories
 for human & robot

 Tackles the robot
 Proposes solutions in case of intricate conflicts



Time (s)

9

Code: https://github.com/sphanit/CoHAN_Planner

A Robot Task Planner specially dedicated to Human-Robot collaborative task achievement

- Maintains and reasons about distinct beliefs of the robot and the Human and their evolution over time
- Plans for the robot and Anticipates Human
 Planning
- Can Anticipate and/or Elicit Human Decisions and Actions
- Plans communication actions when needed
- Considers situations where H&R share a joint goal or not



(a) Goal of the stack task

ask (b) A human and a robot assembling the cube stack



HATP/EHDA: A Robot Task Planner Anticipating and Eliciting Human Decisions and Actions, G. Buisan1, A. Favier, A. Mayima and R. Alami, IEEE ICRA 2022

G. Buisan







Conditional Plan Produced par HATP/EHDA



```
Robot asks for punctual help
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Robot asks for punctual help: Human acts differently



Robot asks to share a joint task



Robot able to anticipate human decisions and to determine when and how to elicit Human contribution

3 - Deployment of interactive robots systems

• Mummer: An interactive direction giving robot in a mall

M. E. Foster, B. Craenen et Al., MuMMER: Socially Intelligent Human-Robot Interaction in Public Spaces, AI-HRI, AAAI Fall Symposium Series 2019, Nov 2019,.

A. Mayima et Al., Direction-giving considered as a Human-Robot Joint Action, User Modeling and User-Adapted Interaction (under review)

• The Director Task: towards the assessment of a set of cognitive and interactive abilities

G. Sarthou, A. Mayima, G. Buisan, K. Belhassein, A Clodic, The Director Task, a Psychology-Inspired Task to Assess Cognitive and Interactive Robot Architectures, IEEE RO-MAN 2021, Best Paper Finalist.

Robot controller for shared plan execution control and coordination with human activity
 → enriched with the ability to perform online an evaluation of Quality of Interaction

A. Mayima, A. Clodic, R. Alami, Towards Robots able to Measure in Real-time the Quality of Interaction in HRI Contexts, International Journal of Social Robotics, https://doi.org/10.1007/s12369-021-00814-5, 2021



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Mummer: Giving Directions in a mall

- Planning and verbalizing a route for the human
- Planning HR shared perspective
- Adapting to human action and requests
- Executing Human-Aware Motion









European

Commission







A. Mayima K. Belhassein



On-line Evaluation of Quality of Interaction

QoI = a measure by the robot indicating how good is the interaction

- Assessment of the QoI at 3 levels : session, task, action
- A set of metrics

 \rightarrow A guide robot performing a Direction giving Task







A. Mayima

Contribution as a key member of the European Robotics and AI community :

COR BIN Core partner in euROBIN initiative : European Robotics and AI Network



QAIPLAN Partner in AIPlan4EU/H2020 <u>https://www.aiplan4eu-project.eu/</u>

Plenary Keynotes:

- ROBOPHILOSOPHY 2022, August, Helsinki (Finland)
- European Robotics Forum 2022 Rotterdam (Netherland)
- 5th CyPhySS 2021, Bangalore (India)
- 17th Int. Conf. on Principles of Knowledge Representation and Reasoning, 2020, Rhodes (Greece)

KR2020

X

RO-MAN

28th IEEE RO-MAN, New Delhi, Oct 2019 (India)

Invited Talks and Seminars in the period (>20): Université du Québec (Montréal), PlanRob ICAPS 2020, Samsung Al (Cambridge, UK), Dagstuhl Cognitive Robotics (Germany), ERF Malaga (Spain), MBZIRC Symposium 2020 (Abu Dhabi), Institutional Robotics Lisboa (Portugal), Future Intelligence 2021 (Toulouse) ...





Chair Activity: some indicators

Research

5 theses defended in 2021: 4 in Rob. /AI, 1 in Psychology), 2 Post-Docs (1 in Philosophy)

Universität Bremen

lnría

M. Beetz

S. Ivaldi

Japan

F. Charpillet

8 on-going PhDs, 2 Post-Docs •



Y. Sallami G. Buisan G. Sarthou A. Mayima K. Belhassein

Other Projects (on-going)

- Coordination of AI4HRI Trilateral: Germany
- ANR Project "The Flying Coworker" with



Projects recently finished:

- MuMMER H2020 Project http://mummer-project.eu/
- ANR Project **JointAction4HRI** Collaboration with Philosophers, Psychologists ٠
- AI4EU European Artificial Intelligence On-Demand Ecosystem •



T. Kanda



Some papers





- F. Ingrand. Verification of Autonomous Robots: A Roboticist's Bottom-Up Approach. **Software engineering for robotics**, Springer, pp.219-248, 2021,
- P-E. Hladik, F. Ingrand, S. Dal Zilio, R. Tekin. Hippo: A Formal-Model Execution Engine to Control and Verify Critical Real-Time Systems. Journal of Systems and Software, Elsevier, 2021, 181, pp.111033.
- R. Bailon-Ruiz, A. Bit-Monnot, S. Lacroix, Real-time wildfire monitoring with a fleet of UAVs, **Robotics** and Autonomous Systems, Volume 152, 2022,
- A. Bit-Monnot, P. Morris, Dynamic Controllability of Temporal Plans in Uncertain and Partially Observable Environments, **Journal of Artificial Research (** JAIR) (accepted) 2022.
- K. Belhassein, V. Fernández-Castro, A. Mayima, A. Clodic, E. Pacherie, M. Guidetti, R. Alami, H. Cochet, Addressing joint action challenges in HRI: Insights from psychology and philosophy, **Acta Psychologica**, Elsevier, 2022, 222, pp.103476.
- M.Tognon, R. Alami, B. Siciliano Physical Human-Robot Interaction with a Tethered Aerial Vehicle: Application to a Force-based Human Guiding Problem, IEEE Transactions on Robotics, IEEE, 2021, 37 (3)
- A. Mayima, A. Clodic, R. Alami, Towards Robots able to Measure in Real-time the Quality of Interaction in HRI Contexts, International Journal of Social Robotics, Springer
- A. Clodic, R. Alami, What Is It to Implement a Human-Robot Joint Action?, **Robotics, AI, and Humanity**, Springer International Publishing, pp.229-238, 2021
- R. Lallement, J. Cortés, M. Gharbi, A. Boeuf, R. Alami, C. Fernandez-Agüera, I. Maza, A. Ollero, B. Siciliano. Combining Assembly Planning and Geometric Task Planning, Aerial Robotic Manipulation. Research, Development and Applications, 129, Springer, 2019, Springer Tracts in Advanced Robotics,





Thanks Université Fédérale Toulouse Midi-Pyrénées



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