ANITI Chair on Cognitive and Interactive Robotics




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The Scientific Challenge

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.

→ the assistant and the teammate robot

The Scientific Challenge

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

1. A principled and long-term **multi-disciplinary collaborative research** with philosophers, development psychologists, ergonomists

2. **Incremental Development** of **key components** and their articulation within a C**ognitive Architecture**

3. The **deployment and 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.**

Research topics

- **1 - Motion Planning**
  - Socially Aware Motion are and Context-dependent navigation
  - Control-Aware Motion Planning

- **2 - Combined Task and Motion Planning**
  - Integration of Geometric & Symbolic Planning
  - Use of Deep learning to speed up CTAMP problem solving

- **3 - Task Planning and Learning / Human-Aware Task Deliberation**
  - Solver for Planning / Scheduling: Temporal & Hierarchical Planning
  - Refinement–based Acting Engine with a Hierarchical Temporal Planner
  - Learning Plan and Task Operational Models from Demonstrations
  - HR Situation assessment and estimation of Human belief about environment and task
  - Planning shared H&R plans with explicit management of H & R beliefs

- **4 - Architecture, Verification and Certification**
  - Formal Models and Tools to Control and Verify Critical Real-Time Systems (Hi
  - Architecture to implement an Integrated approach to HR collaboration

1- Socially Aware Motion Planning

CoHAN: Cooperative Human Aware Navigation

- A Human-Aware **navigation** system which can handle various H&R interaction schemes including **cooperative schemes**

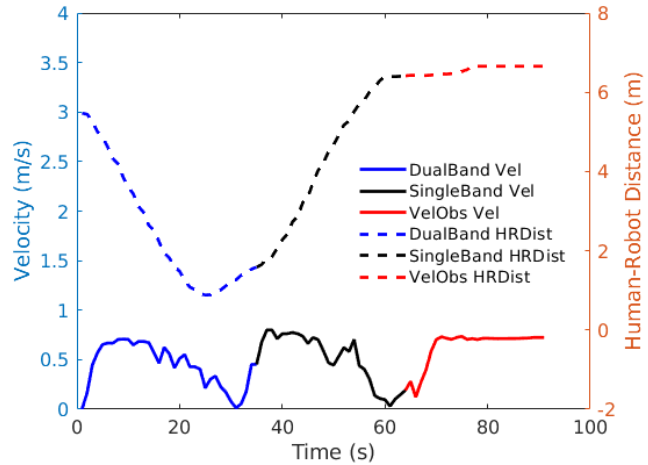
  - ✓ Human-aware constraints for **promoting legibility and acceptability** integrated in a reactive **optimization process**

  - ✓ 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 freezing problem

Proposes solutions in case of intricate conflicts



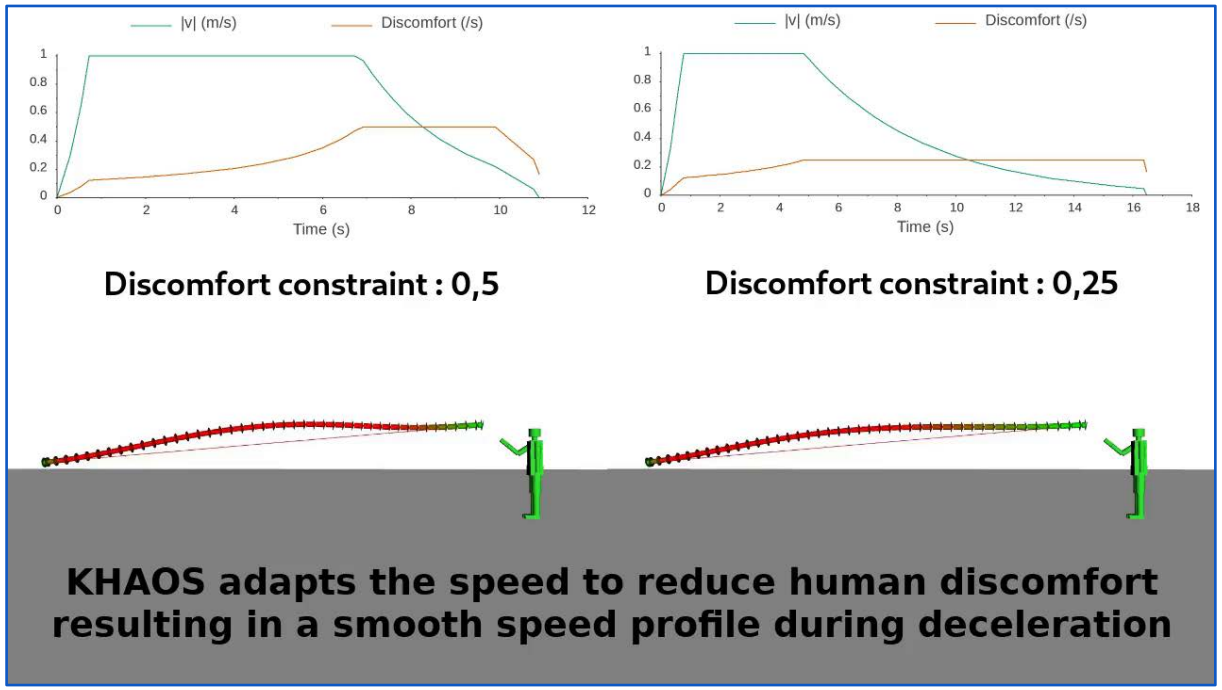
P. T. Singamaneni

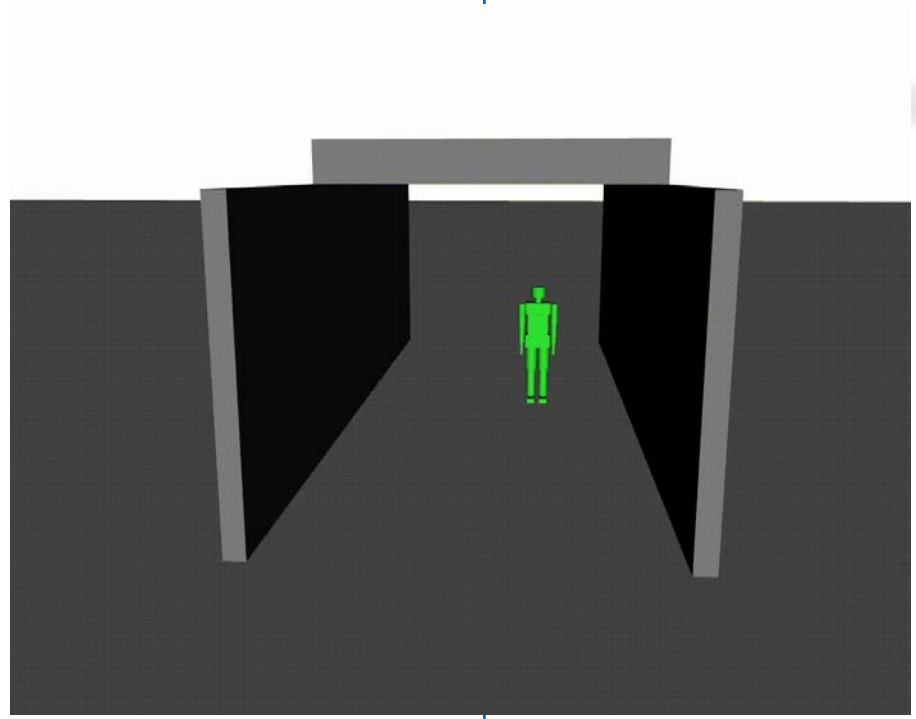
Code: https://github.com/sphanit/CoHAN_Planner

Human-aware Motion Planning of an Autonomous Aerial Manipulator

KHAOS : a Kinematic Human Aware Optimization-based System for Reactive Planning of Flying-Coworker

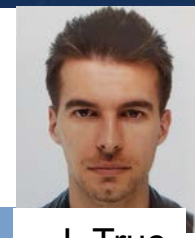
- Planning Human-aware motion integrating **visibility**, **proxemics** and **comfort**
- Reactive planning UAV + Manipulator





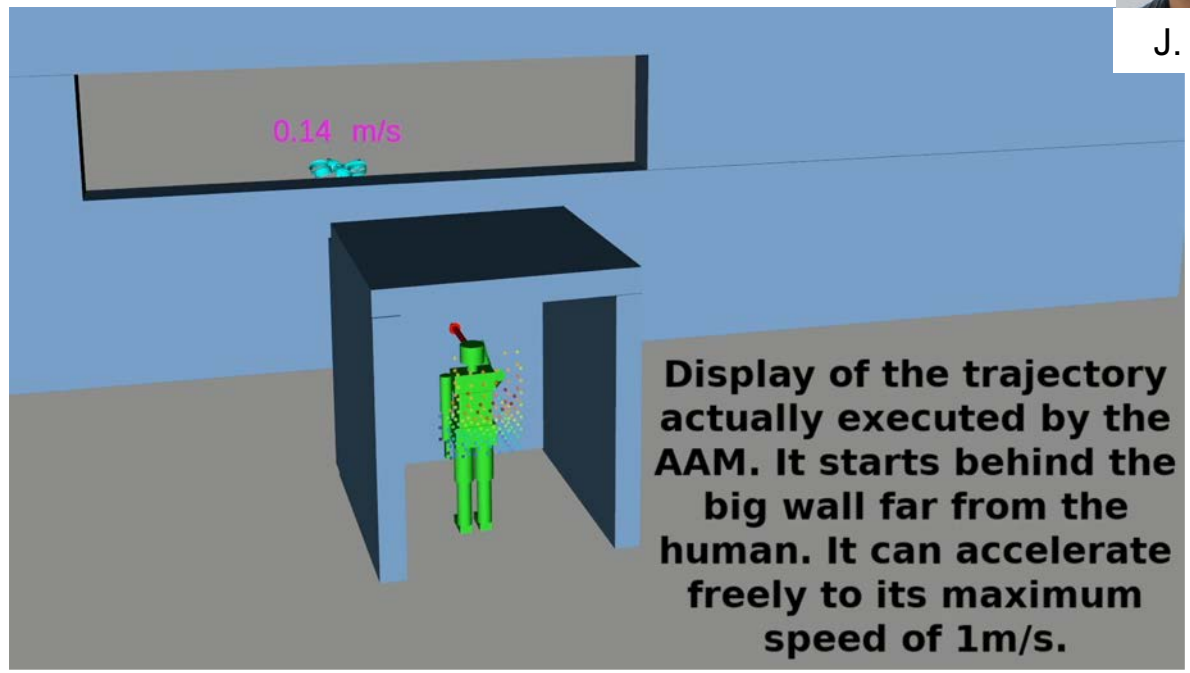
J. Truc, D. Sidobre, S. Ivaldi, R Alami, **KHAOS: a Kinematic Human Aware Optimization-based System for Reactive Planning of Flying-Coworker,** IEEE ICRA 2022, Philadelphia.

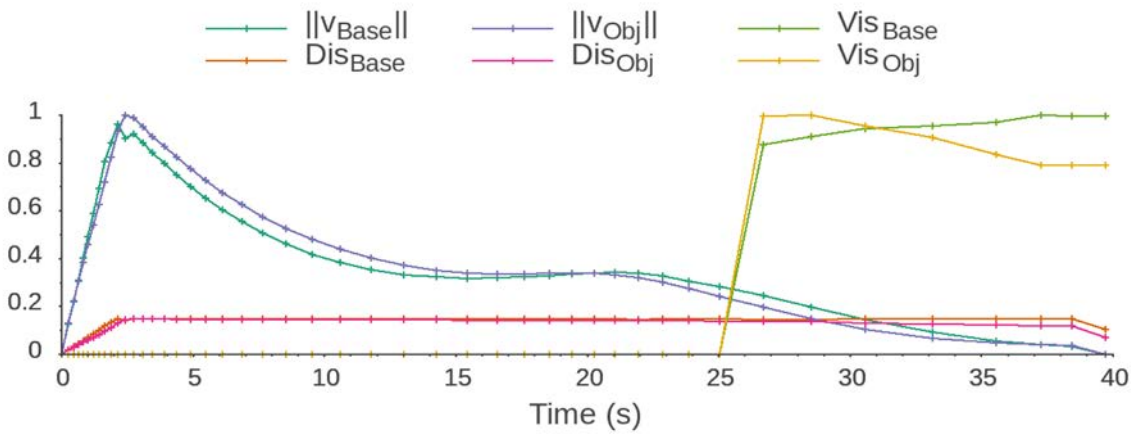
Reactive Planning for Coordinated Handover of an Autonomous Aerial Manipulator



J. Truc

Human Aware Reactive kinodynamic Planning of a coordinated motion (UAV + Arm) for a **handover** taking into account **human reach**, visibility, proxemics and comfort





Approach and hand-over in a constrained environment and from behind

J. Truc, D. Sidobre, S. Ivaldi, R Alami, **Reactive Planning for Coordinated Handover of an Autonomous Aerial Manipulator**, ACM/IEEE HRI 2023, Stockholm.

Contribution to the creation of a community on social aware navigation

1. **Seminars and collaborative work in 2022 et 2023.**
    - Partners: NVIDIA, Stanford, Google, EPFL, Purdue, CMU, UT Austin, MIT, Northeastern, Georgia Tech, Aston UK, Bar Ilan , Adobe, LAAS-CNRS, Sony AI, Honda, Yale, GMU, Apple
    - A publication "**Principles and for Evaluating Social Robot Navigation Algorithms**" (sur ArXiv https://arxiv.org/abs/2306.16740) submitted to à ACM Transactions on HRI.
2. Editorial board of a Frontiers of Robotics and AI "Human-Aware Navigation for Autonomous Systems"
3. Two workshops at International IROS 2022 and IROS 2023
4. **Direct Collaborations**
    - Aston University, ISTC-CNR Roma, Sapienza University University of Extremadura, UPC Barcelona, University of Leon, INRIA, CLLE
    - Joint Publications
    - Survey: **A Survey on Socially Aware Robot Navigation: Taxonomy and Future Challenges**, P. T. Singamaneni, P. Bachiller-Burgos, L. J. Manso, A. Garrell, A. Sanfeliu, A. Spalanzani, R. Alami (https://arxiv.org/abs/2311.06922) submitted to IJRR

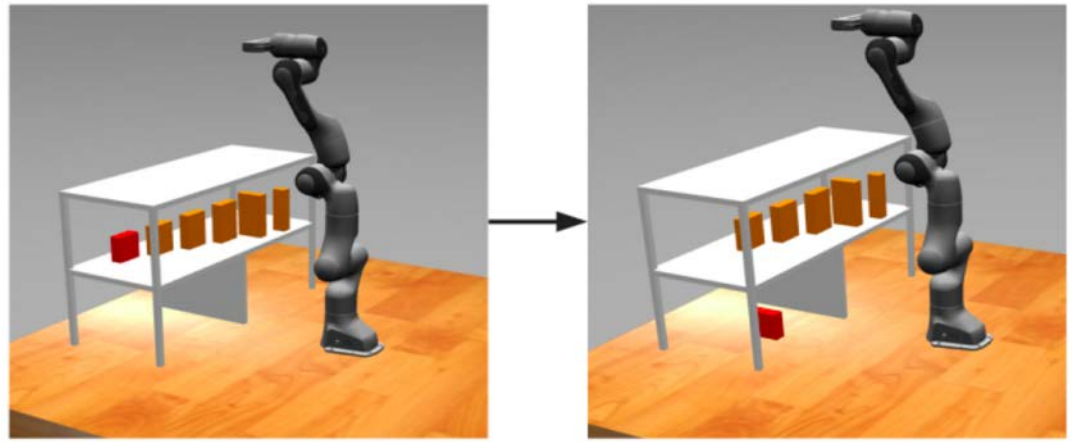
2- Combined Task and Motion Planning

Combined Task and Motion Planning

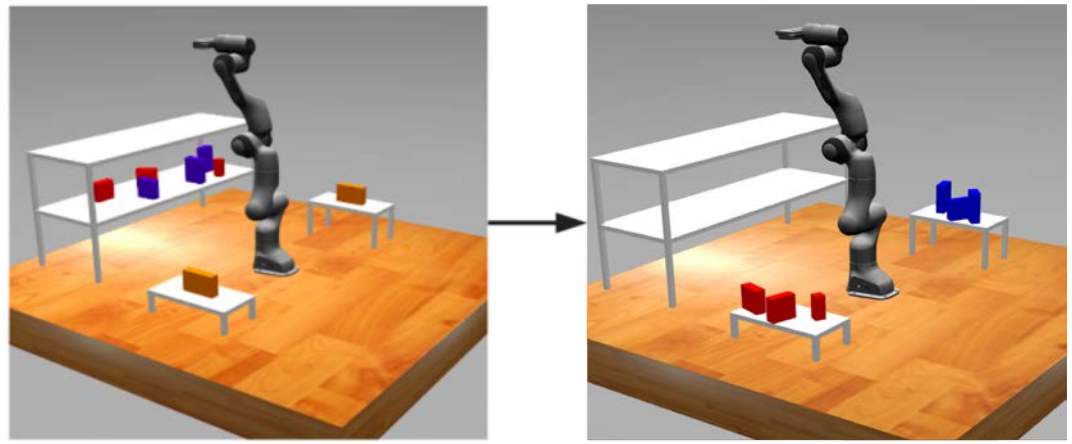
CTAMP: Intricate problems which cannot resolved in a classical hierarchical decomposition: Symbolic Task Planner then Geometric Planning

Previous contribution to CTAMP: Formulations / Algorithms

→ The combination of discrete symbolic search with continuous geometric planning results often in a combinatorial explosion



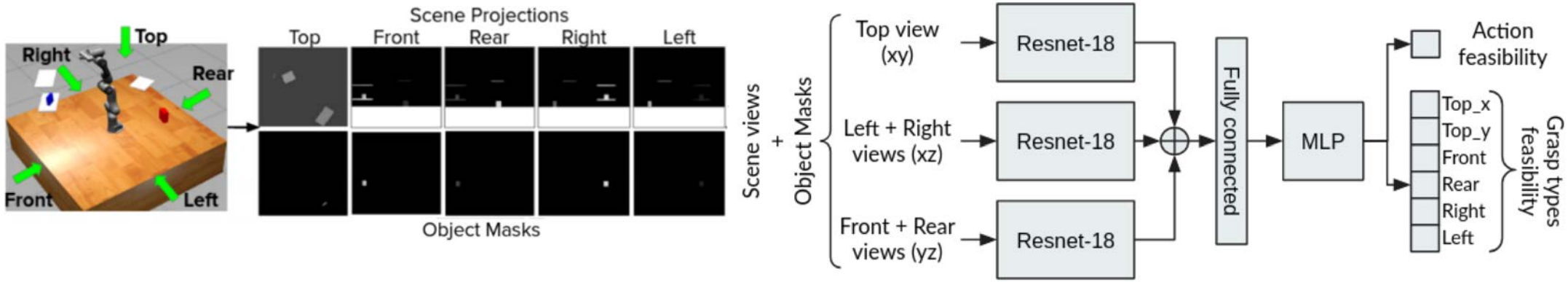
(a) *Access* domain



(b) *Sort* domain

Combined Task and Motion Planning (AGFP-Net)

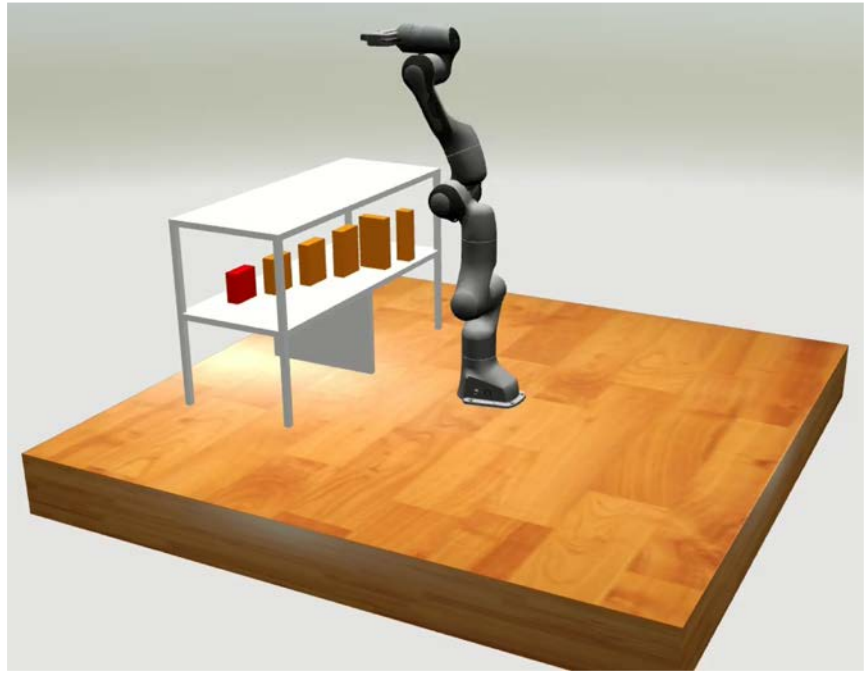
S. Bouhsain



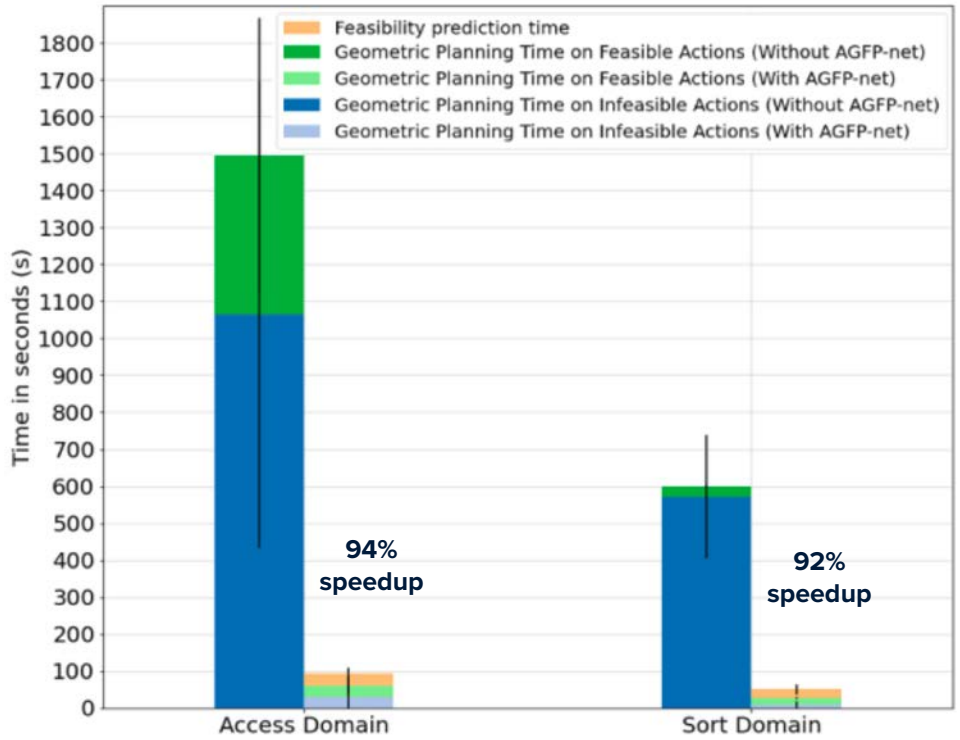
- Simultaneous Action and Grasp Feasibility Prediction for Task and Motion Planning through Multi-Task Learning:
  - **AGFP-Net predicts the feasibility of pick and place actions separately**
  - A complete pick-place action is feasible only if there is at least **one common feasible grasp** between the separate pick and place actions
  - **Rich geometric information** given to the TAMP algorithm by the neural network
  - Handle fully-specified and partially-specified goals

    → **Tackle problems with higher combinatorial complexity**

Performance of Feasibility-Informed TAMP



Domain	Method	Heuristic	Infeasible Task Plans	Total Planning Time (s)
Sort	Bouhsain et al. 2023	Not handled		
	Proposed	None	108.3	599.1
		AGFP-Net	**1.1**	**50.0**
Access	Bouhsain et al. 2023	Planning Failure		
	Proposed	None	339.3	1500.1
		AGFP-Net	**1.9**	**95.2**



Recent extensions

S. Bouhsain

Smail Ait Bouhsain, Rachid Alami, Thierry Siméon, **Learning to Predict Action Feasibility for Task and Motion Planning in 3D Environments**, IEEE ICRA 2023, London:

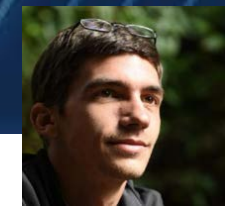
Smail Ait Bouhsain, Rachid Alami, Thierry Sméon, **Simultaneous Action and Grasp Feasibility Prediction for Task and Motion Planning through Multi-Task Learningments**, IEEE IROS 2023, Detroit

3- Task Planning

Task Planning and Learning / Human-Aware Task Deliberation

- Solver for Planning / Scheduling: Temporal & Hierarchical Planning
- Refinement–based Acting Engine with a Hierarchical Temporal Planner
- Learning Plan and Task Operational Models from Demonstrations
- HR Situation assessment and estimation of Human belief about environment and task
- Planning shared H&R plans with explicit management of H & R beliefs

Hybrid CP-SAT for Planning & Scheduling



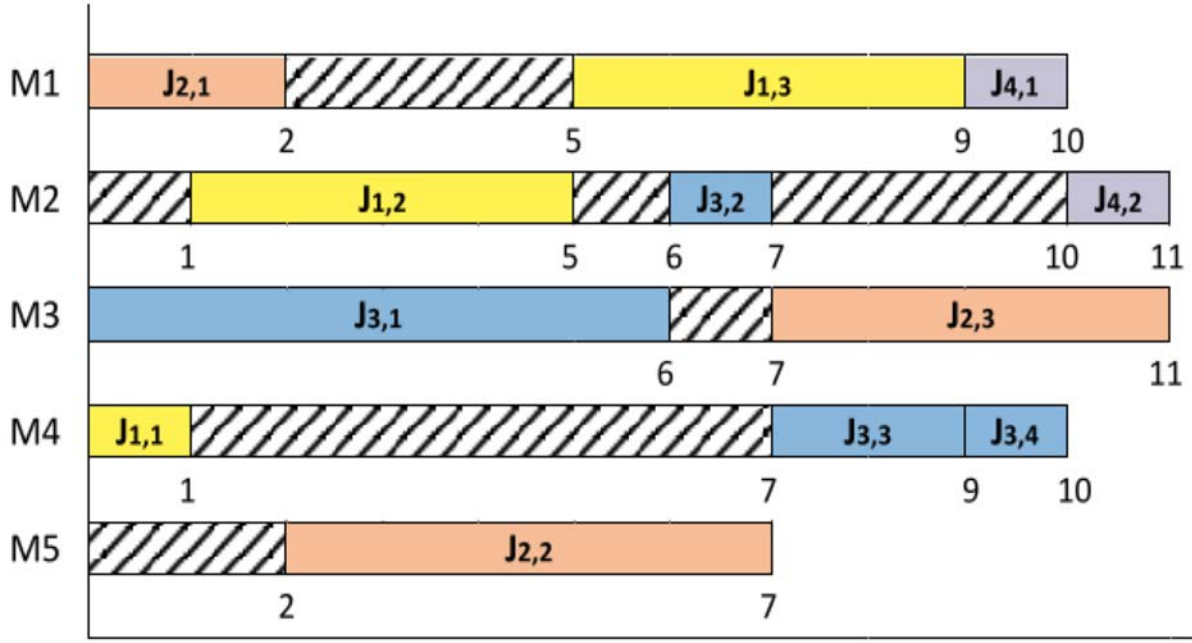
In-house solver for disjunctive scheduling

Fluid integration of approaches from CP and SAT

- Focus on variables with large domains

State of the art on Disjunctive Scheduling (jobshop, openshop) [1]

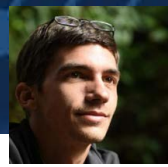
Experimental exploitation for temporal/hierarchical planning [2]



[1] A. Bit-Monnot , **Enhancing Hybrid CP-SAT Search for Disjunctive**, A. Bit-Monnot. ECAI 2023

[2] A. Bit-Monnot , **Experimenting with Lifted Plan-Space Planning as Scheduling**, IPC 2023

Temporal plan execution under partial observability

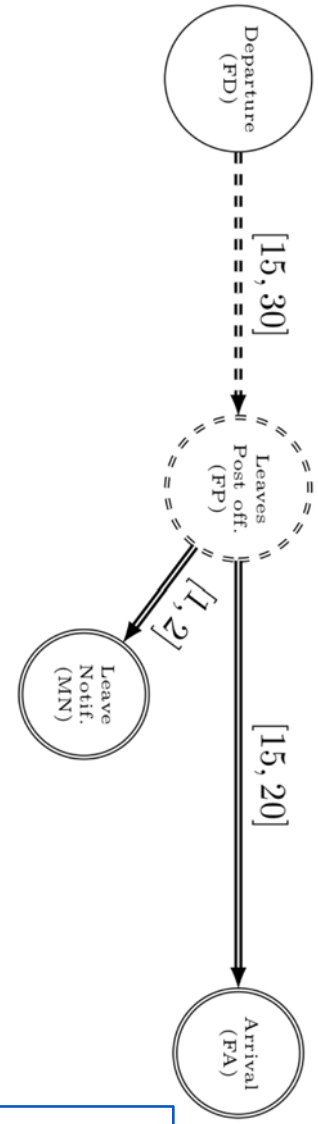


Adapts STNU to work in partially observable environments

- Temporal plans with exogenous events & uncontrollable duration
- Subset of events non-observable

Check for *dynamic controllability* of network

Derives *execution strategies* (dependent on observation)



A. Bit-Monnot, P. Morris , **Dynamic Controllability of Temporal Plans in Uncertain and Partially Observable Environments,**, JAIR 2023

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Learning Hierarchical Planning Models from Demonstrations

P. Herail

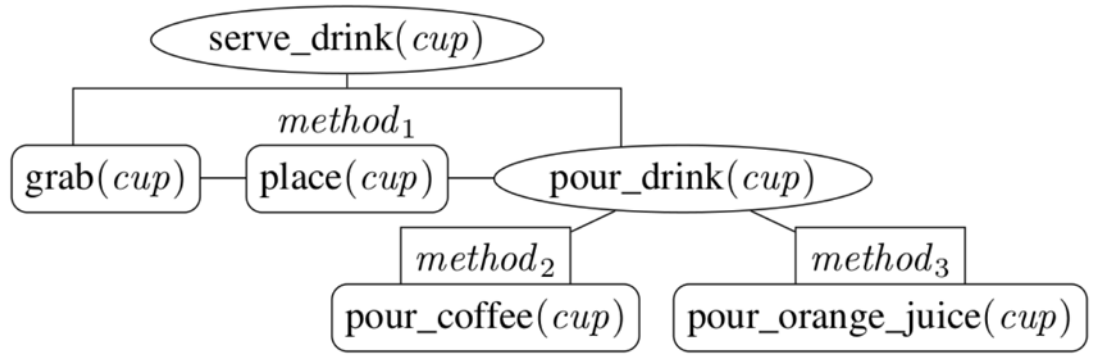
Input: demonstrations of a task

- Action sequences
- From human teacher or optimal solver

Output: hierarchical planning models (HTN)

- Decomposition of task in several alternatives (methods)
- Generic with respect to parameters & state

Exploited to improve quality and scalability of existing planners



P. Hérail, A. Bit-Monnot., **Leveraging Demonstrations for Learning the Structure and Parameters of Hierarchical Task Networks**. FLAIRS 2023

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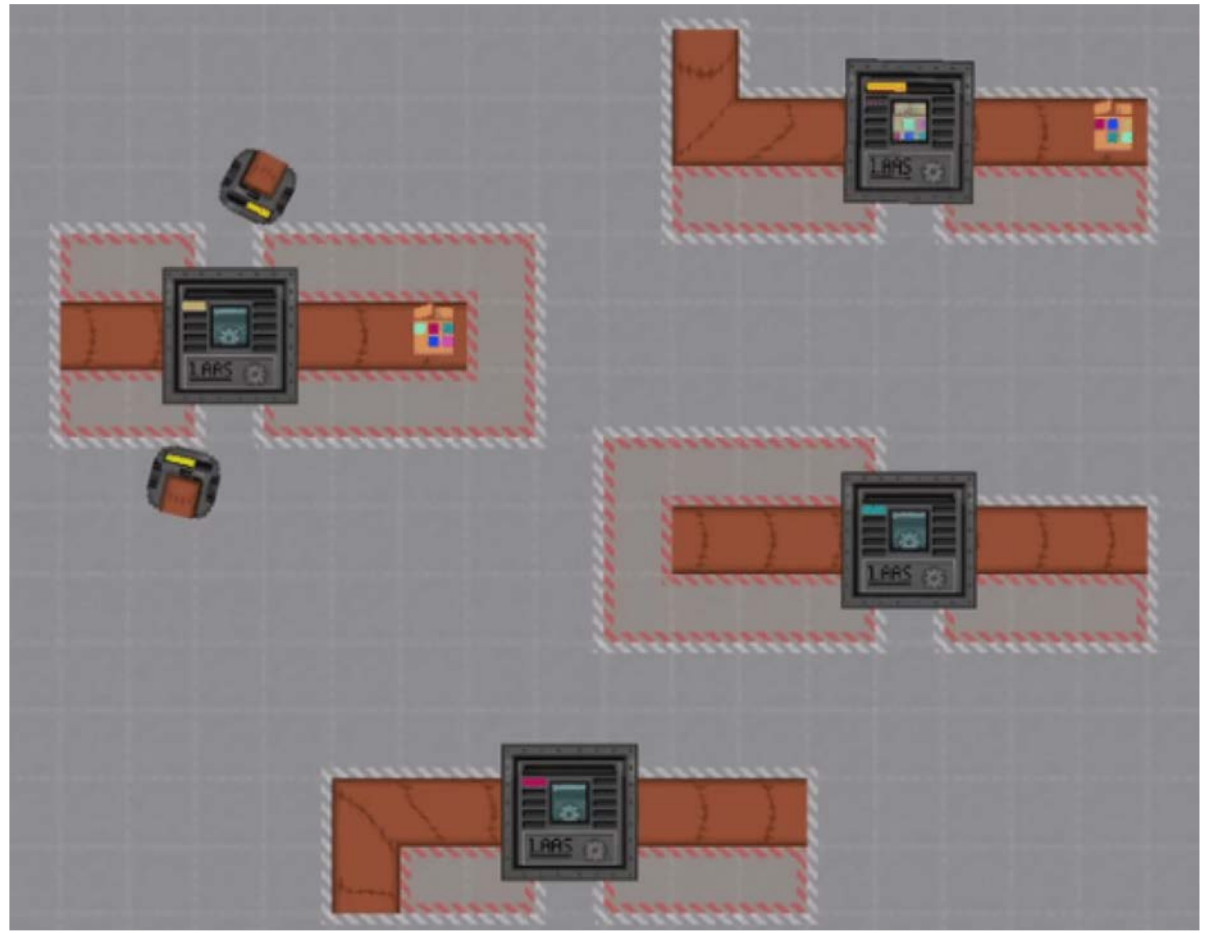
Guiding A Robotic Actor

- **Architecture for (high-level) robot control**
- **Focus concurrency & time => fleets**
- **Automatic analysis for robot programs to identify decision points**
  - Method selection for task
  - Access priority to resources
- **Planning to provide guidance over decision points**
  - Optimize behavior with a global view (resource efficiency, makespan, …)



J. Turi

J. Turi, A. Bit-Monnot. **Extending a Refinement Acting Engine for Fleet Management: Concurrency and Resources.** ICTAI 2022

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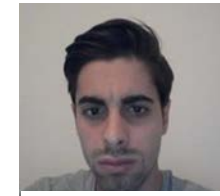
1- Situation assessment and estimation of Human beliefs about environment and task

- **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



Y. Sallami

G. Sarthou

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,** then the **red object** poured from the **green box** to the **blue box.**

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

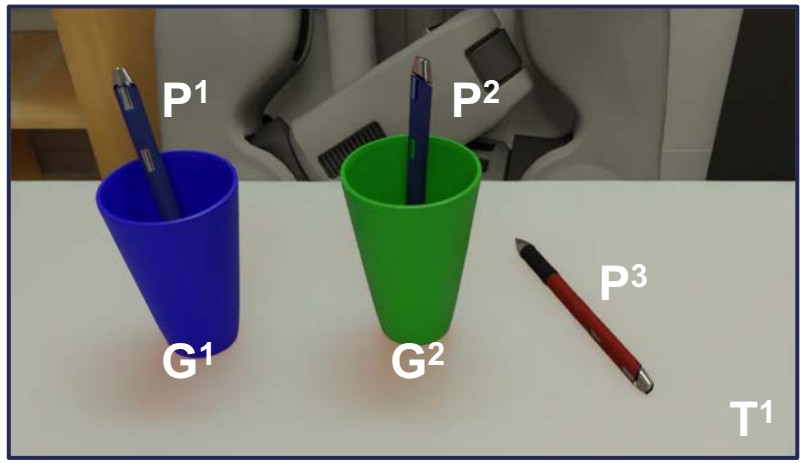
G. Sarthou, A. Clodic, R. Alami, **Ontologenius : A long-term semantic memory for robotic agents**, IEEE RO-MAN 2019

Referring Expression Generation (REG) in Human Robot Interaction

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

G. Sarthou

G. Buisan



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

« the knife with which Tony prepared the salad »

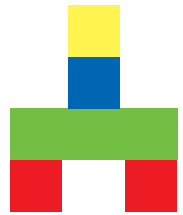
G. Buisan, G. Sarthou, R. Alami, **Human Aware Task Planning Using Verbal Communication Feasibility and Costs**, ICSR 2020.

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

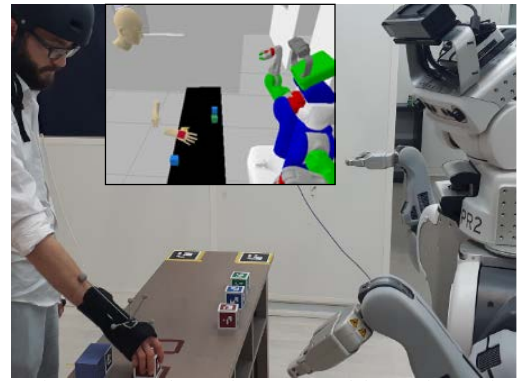
HATP/EHDA:
Planning with Emulation of Human Decision and Action

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

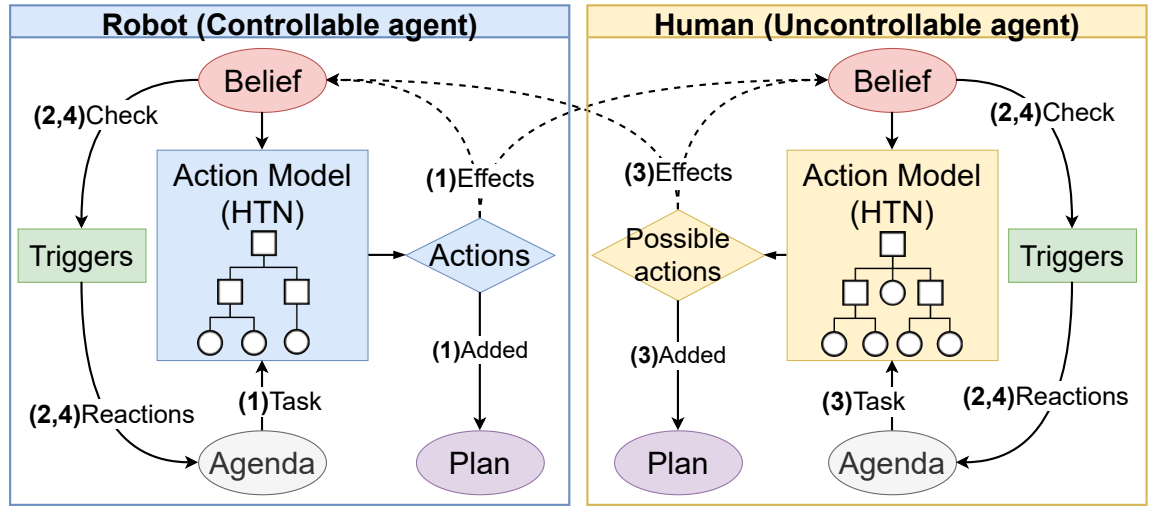
- Maintains and reasons about **distinct beliefs of the robot and the Human** and their evolution over time
- **Plans for the robot** and **Anticipates Human Planning**
- Can **Anticipate** and/or **Elicit** Human Decisions and Actions
- Plans **communication** actions when needed
- Considers situations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



(a) Goal of the stack task

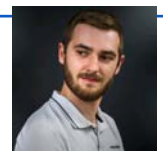


(b) A human and a robot assembling the cube stack



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

G. Buisan 

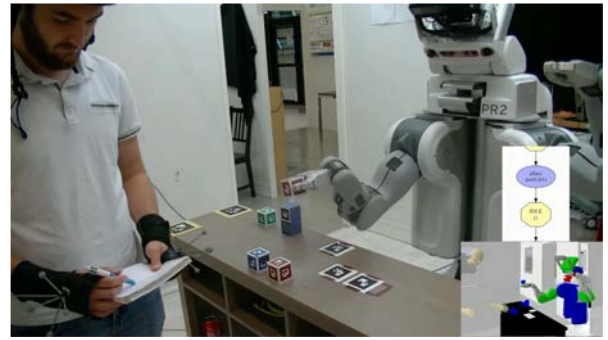
A. Favier 

S. Shashank 

Conditional Plan Produced par HATP/EHDA

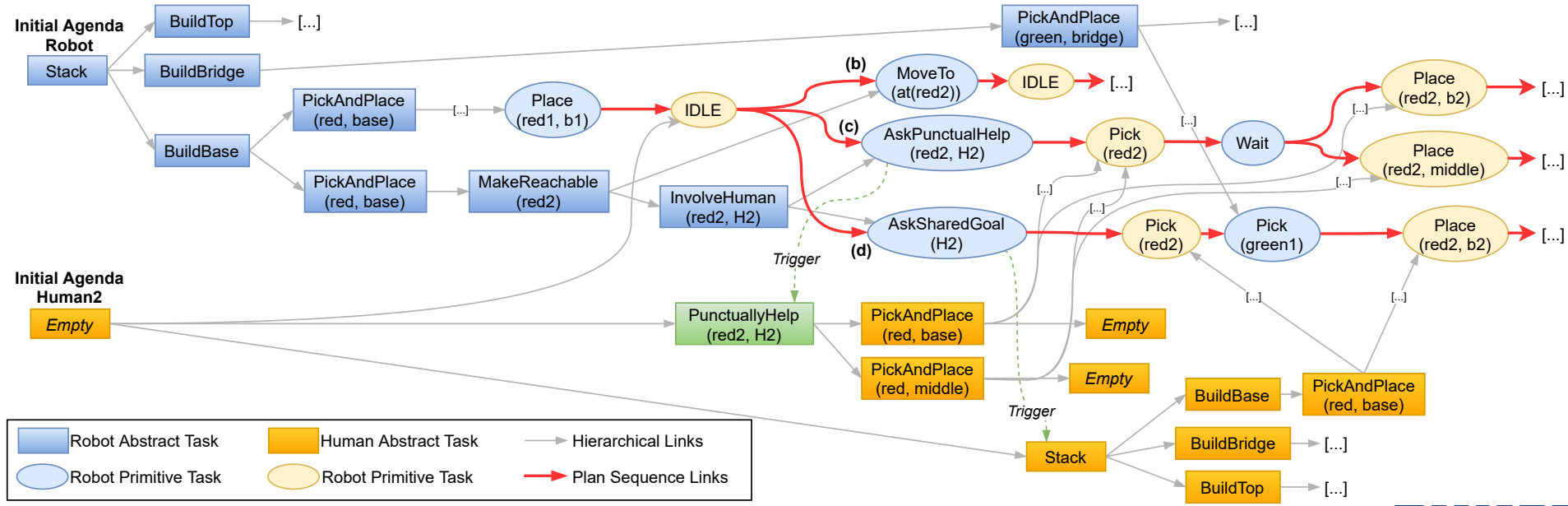
Robot asks for punctual help

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



Robot Control Architectures – V&V

Architecture to implement an Integrated approach to HR collaboration

Constructive approach:

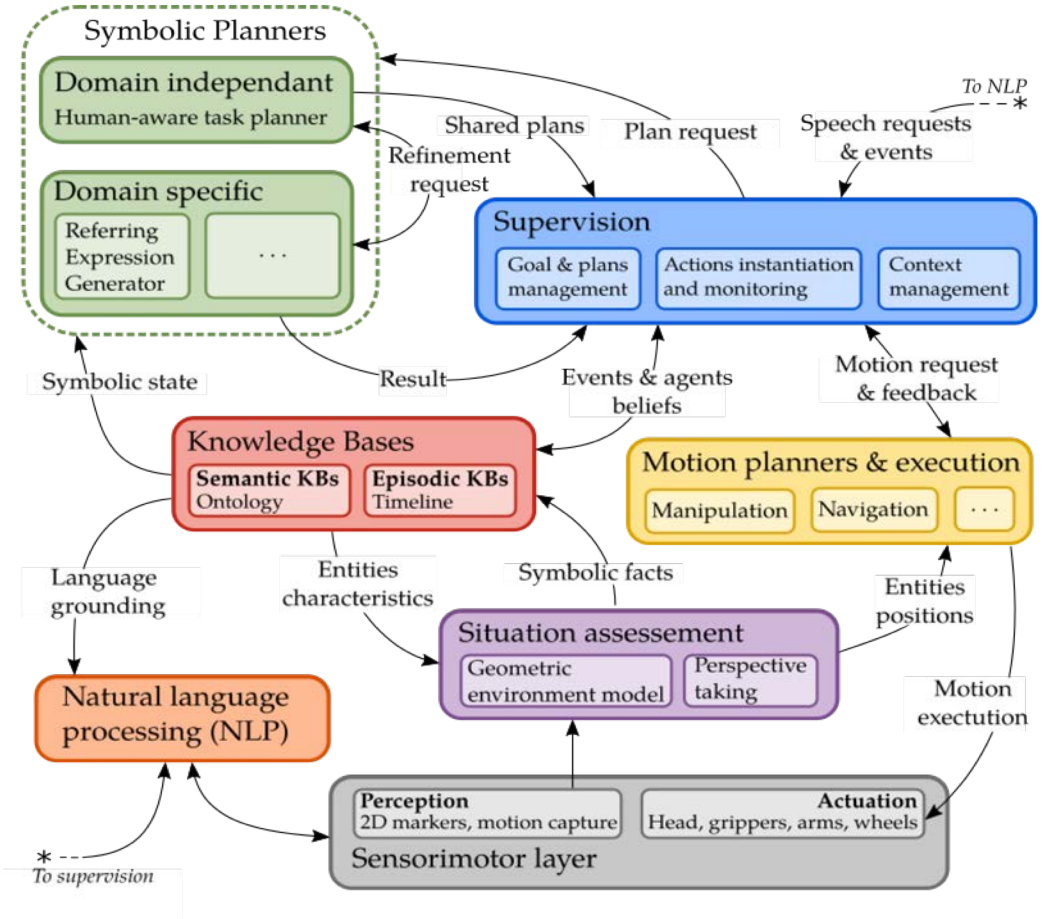
- Adoption and Adaptation of **Joint Action Concepts and Mechanisms**
- **Models** of Human beliefs, intentions, abilities and preferences

❖ **Situation Assessment in H&R context**

- Perspective-Taking
- Estimation of Human Mental State (ToM)

❖ **Human-Aware Task and Motion Reactive Pl**anning for

- Collaborative Task Achievement
- and Situation-based Dialog



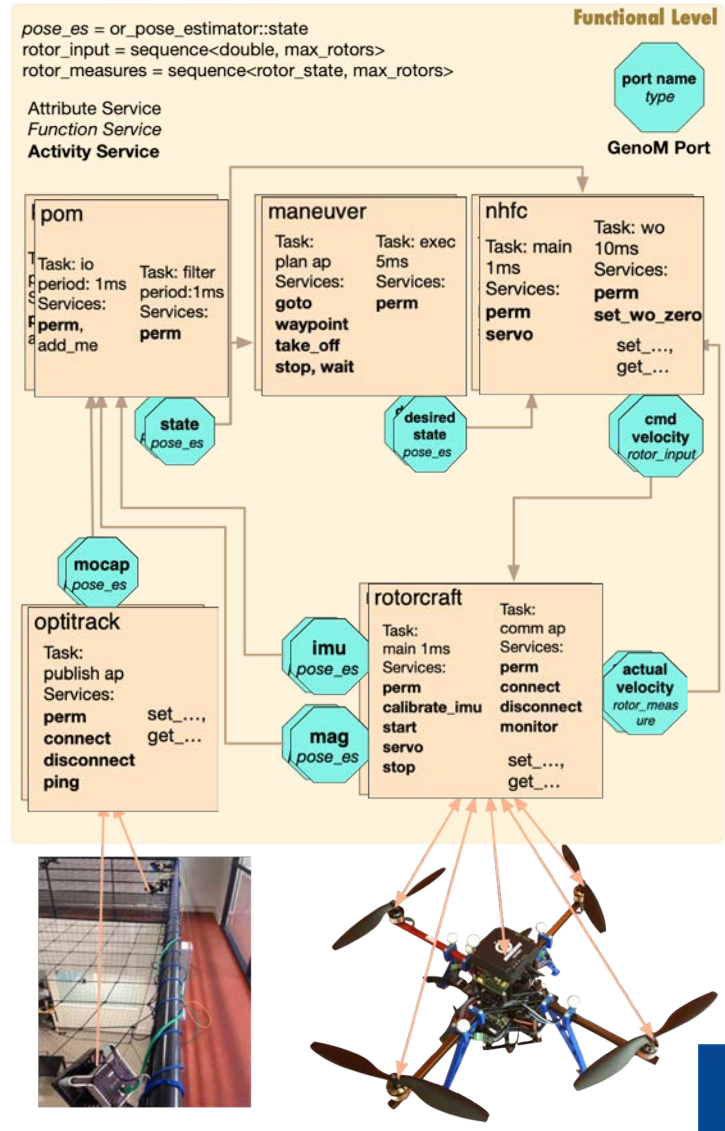
S. Lemaignan, M. Warnier, E. A. Sisbot, A. Clodic, R Alami, Artificial Cognition for Social Human-Robot Interaction: An Implementation, Artificial Intelligence, Elsevier, 2017

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,

Functional components specification

- **GenoM specification language**
- **Autonomous robots at RIS follow a component based architecture**
- **Example:**

  Components for
  - localisation (pom and optitrack or GPS),
  - flight control (nhfc),
  - navigation (maneuver),
  - rotorcraft (IMU / mag / propellers measure and velocity control)



Fiacre Formal Framework: TINA (offline), Hippo (Runtime)

Process:
- automata, guarded and timed transitions on ports interaction, with code execution
- local variables
- building components connecting ports

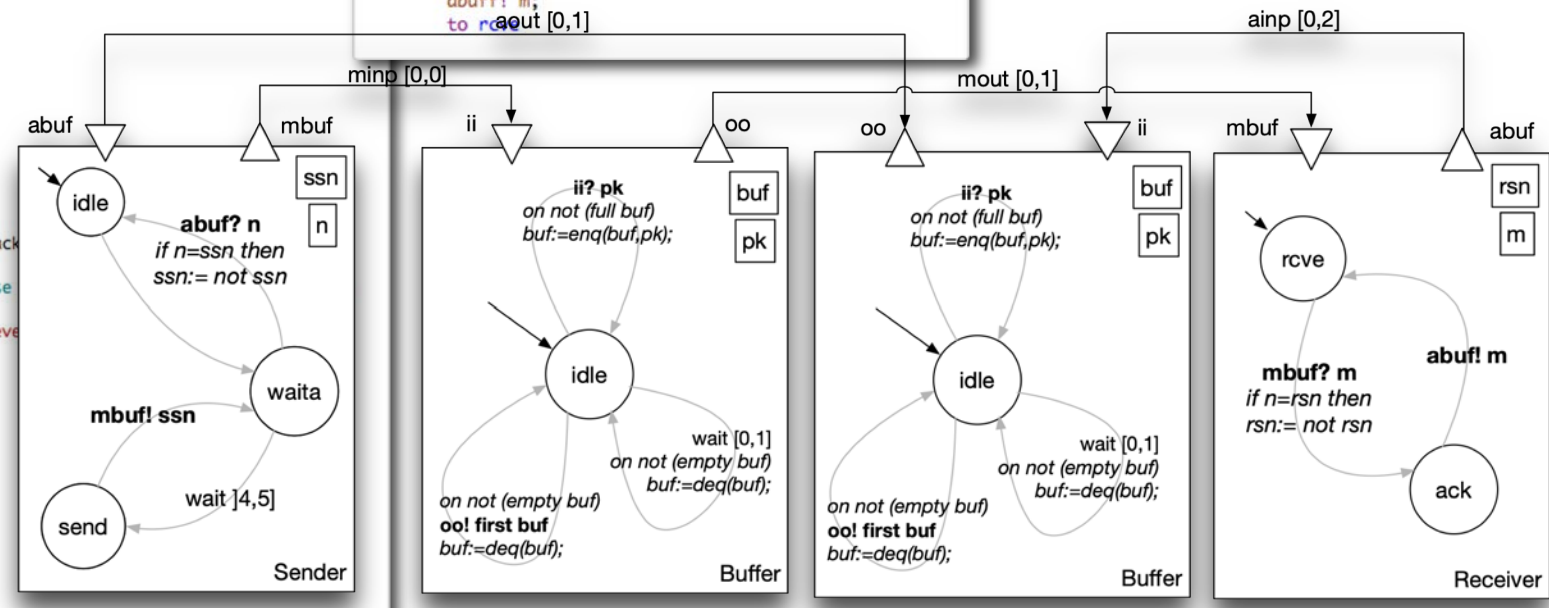
Model checking the resulting TTS with TINA,

Runtime verification with Hippo

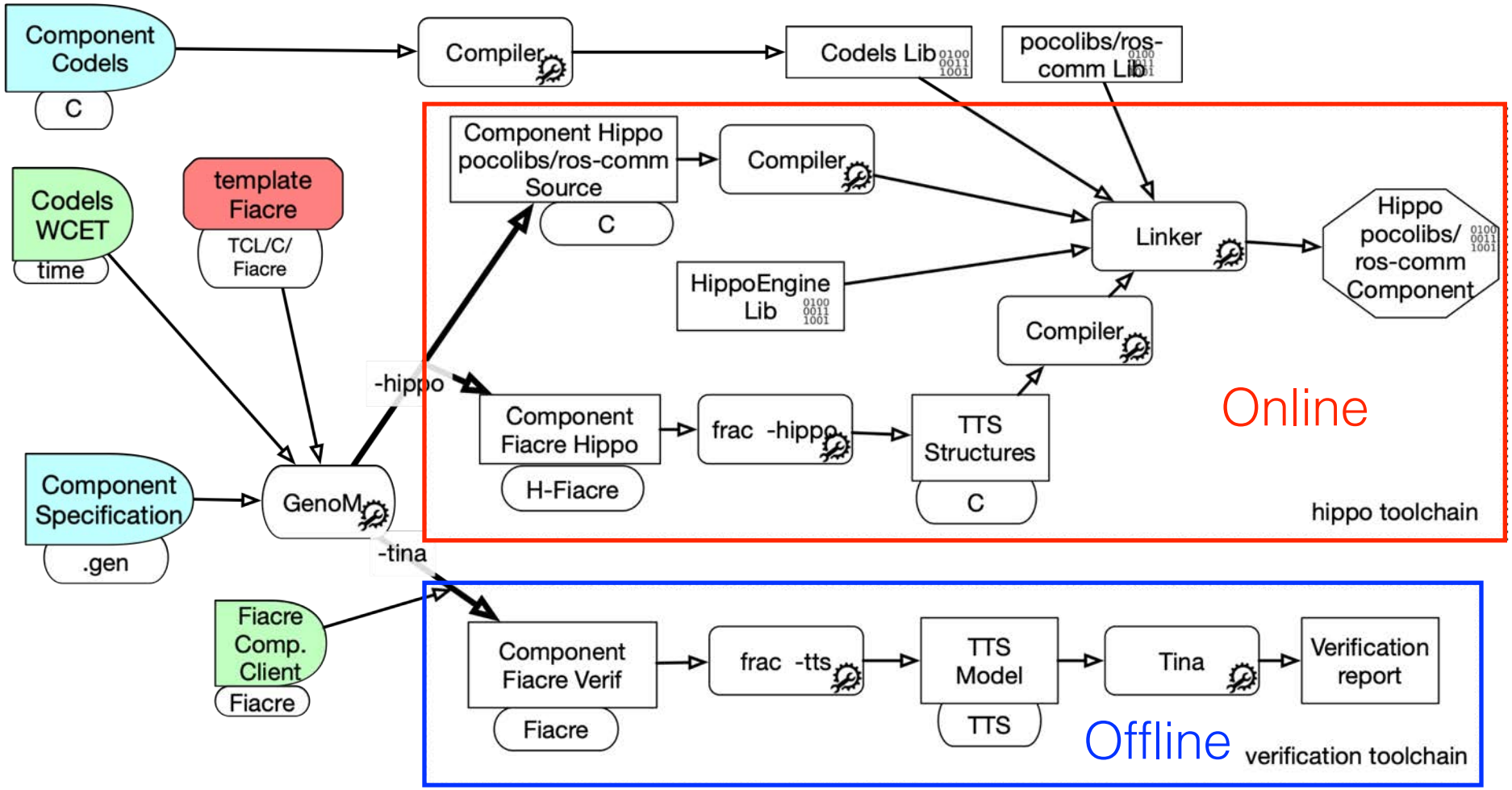
```
/* Processes */

process buffer [ii: in packet, oo: out packet] is
    states idle
    var buff : queue 1 of packet := {||},
        pkt: packet
    from idle
    select
       /* getting new packet */
       ii?pkt;
       on not (full buff);  // should be redundant but prevents
                            // queue exception if time-out too sm
       buff := enqueue (buff,pkt);
       to idle
    [] /* putting first packet */
       on not (empty buff);
       oo!first buff;
       buff := dequeue buff;
       to idle
    [] /* losing a packet */
       wait [0,1];
       on not (empty buff);
       buff := dequeue buff;
       #lost;
       to idle
    end

process sender [mbuff: out pack
    states idle, send, waita
    var ssn, n: seqno := false
    from idle
        /* should also retrieve
        to waita
    from send
        mbuff! ssn;
        to waita
    from waita
      select
         abuff? n;
         if n = ssn
         then ssn := not ssn
         end;
         to idle
       [] wait ]4,5];
         /* resend */
         to send
      end
```

```
process receiver [mbuff: in packet, abuff: out packet]
    states rcve, ack
  var rsn: seqno := false, m: packet := true
      // rsn is expected sequence number
    from rcve
        mbuff? m;
        if m = rsn then
           /* also should deliver data to user */
           rsn := not rsn;
           to ack
        else
           // reject duplicate
           to ack
        end
    from ack
        abuff! m;
        to rcve
```

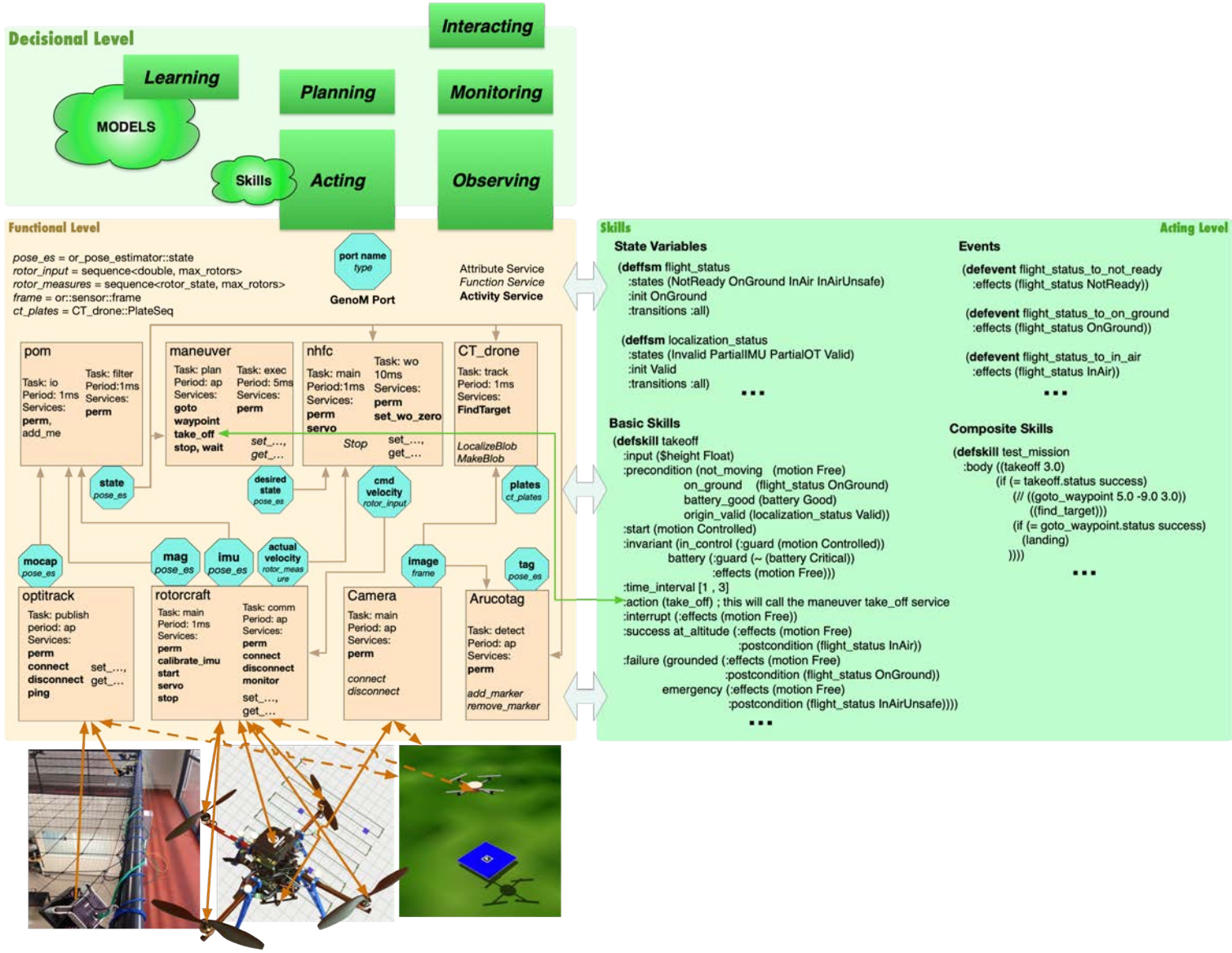
```
/* Main component */

component abp is
    port minp : packet in [0,0],
         mout : packet in [0,1],
         ainp : packet in [0,2],
         aout : packet in [0,1]
    par * in
       sender [minp, aout]
    || buffer [minp, mout]
    || buffer [ainp, aout]
    || receiver [mout, ainp]
    end
```



FIACRE workflow



Skill Task Programming Language



Skill language which maps in a formal framework (Fiacre)

- **Offline validation and vérification with model checking (TTS/TINA)**
- **Online runtime verification with TTS execution with Hippo**

Publications

A formal toolchain for offline and run-time verification of robotic systems
Silvano Dal Zilio, Pierre-Emmanuel Hladik, Félix Ingrand, Anthony Mallet
Robotics and Autonomous Systems, 2023, 159, pp.104301.

Composing Complex and Hybrid AI Solutions
Peter Schüller, João Paulo Costeira, James L. Crowley, Jasmin Grosinger, Félix Ingrand, Uwe Köckemann, Alessandro Saffiotti, Martin Welss

Hippo: A Formal-Model Execution Engine to Control and Verify Critical Real-Time Systems
Pierre-Emmanuel Hladik, Félix Ingrand, Silvano Dal Zilio, Reyyan Tekin
Journal of Systems and Software, 2021, 181

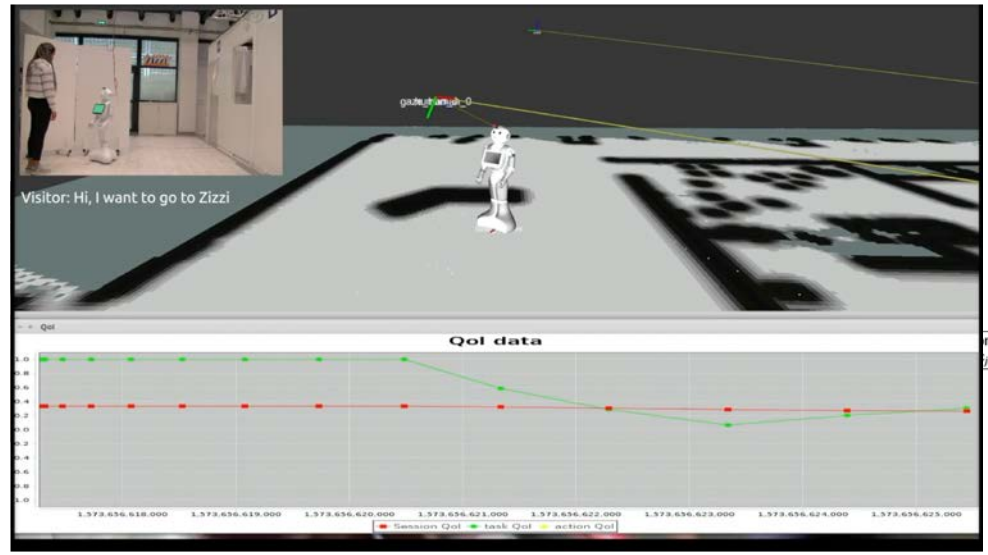
Verification of Autonomous Robots: A Roboticist's Bottom-Up Approach
Félix Ingrand
Software engineering for robotics, Springer, pp.219-248, 2021, 978-3-030-66493-0.

On-line Evaluation of Quality of Interaction

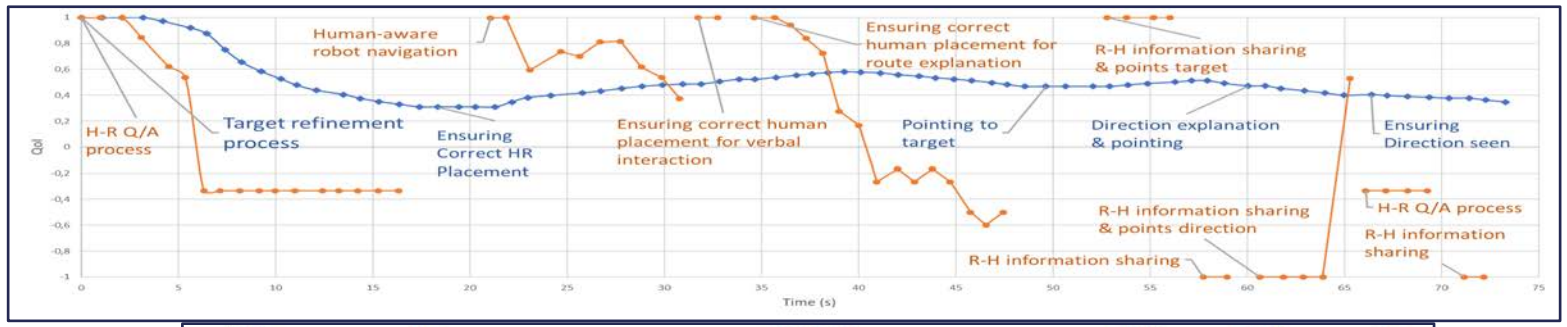
QoI = a measure by the robot indicating how good is the interaction

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

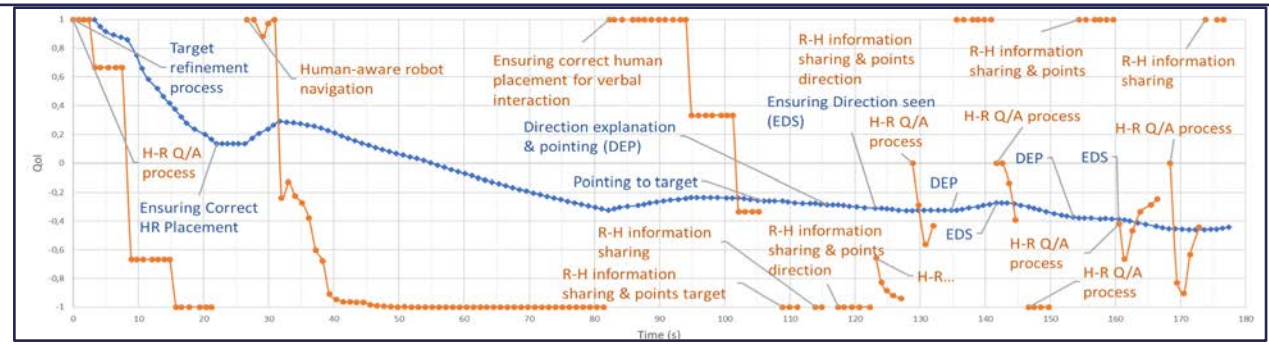
→ A guide robot performing a Direction giving Task



A confused human



A non-cooperative human



A. Mayima

Collaborative Research Projects

Projets

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

(**2022-2026)** Core partner in euROBIN initiative : European Robotics and AI Network

(2018-2021) Partner in AI4EU (Europe's AI-on-Demand Platform) https://www.ai4europe.eu/

(2021-2023) Partner in AIPlan4EU/H2020 https://www.aiplan4eu-project.eu/

REUBEN (2022-2023): Referring Expressions for hUman roBot intEractioN) : Défi Clef « Robotique Centrée sur l'Humain » : Collaboration with Madalina Croitoru (LIRMM, Equipe GraphiK)

AI4HRI (2021-2024) (Trilateral AI Japan-Germany-France) Artificial Intelligence for Human-Robot Interaction (A. Clodic, R. Alami)

The Flying Coworker (2019-2023): Projet ANR en collaboration avec INRIA-Nancy

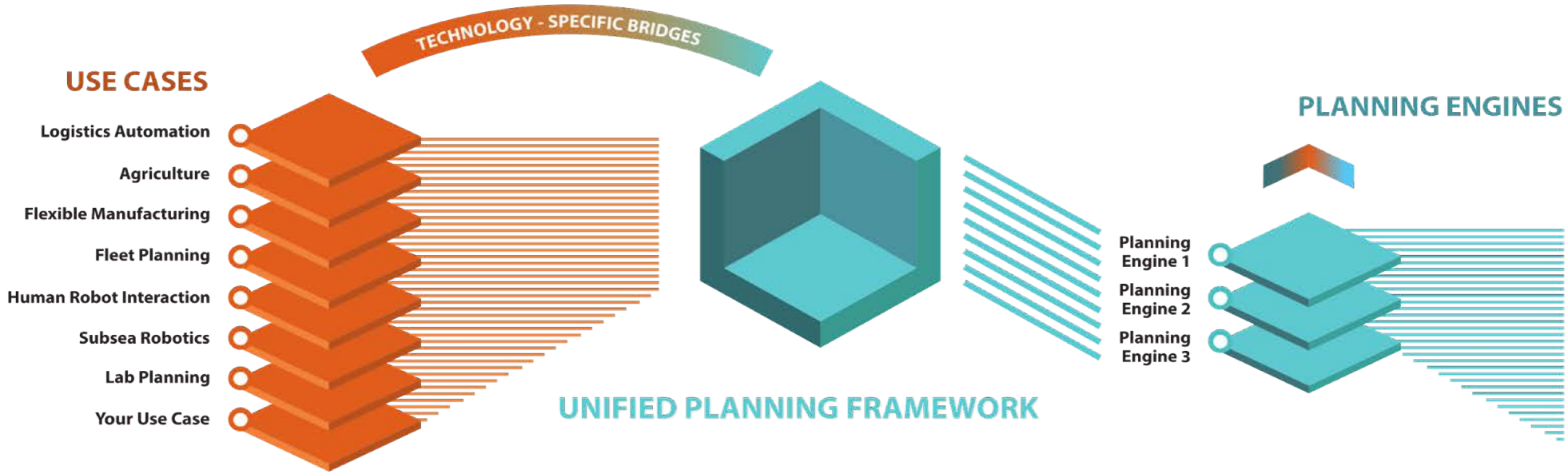
TRAIL (2022-2027) : Marie Curie MSCA Research Network - 2023-2026 (T. Siméon, R. Alami)

INNOVCARE (2024-2028) : Care-led innovation : the case of eldercare in France and in Japan) – Autonomie : Vieillissement et situations de handicap 2021-2026 (France 2030) - Starts Feb. 2024.

PEPR O2R (2023-2028) : Collaboration avec ISIR etet INRIA sur le mouvement expressif Humain-Robot. Starts 2024.

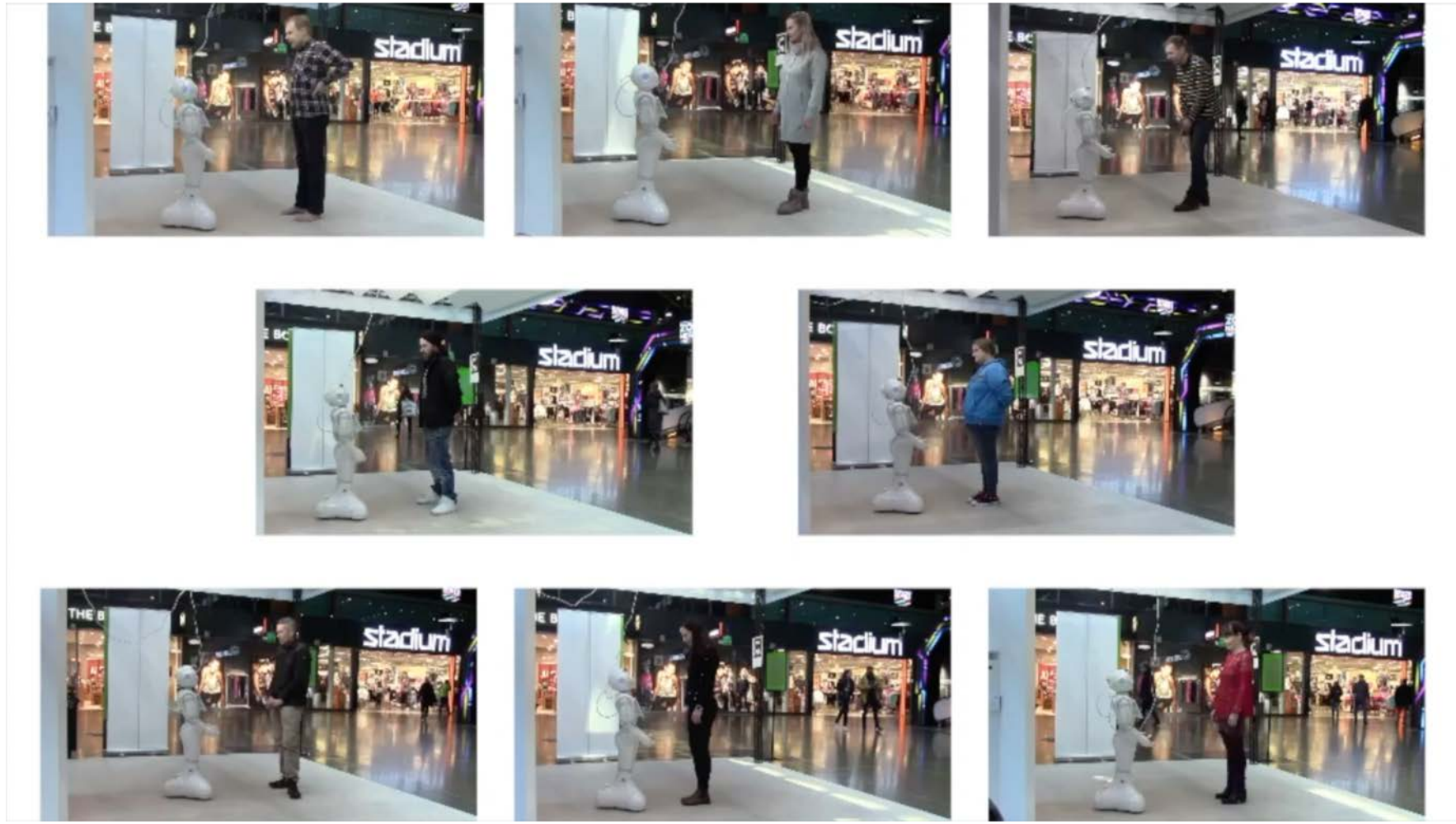
AIPlan4EU (H2020 Project)

- Python library for AI Planning
- Modeling tools & Planner integration
- Strong community involvement
- Ends in December 2023
  - transition to open source organization (4 maintainers, incl. LAAS)



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



MuMMER
mummer-project.eu

European Commission


A. Mayima


K. Belhassein

Chair Activity: some indicators

Plenary Keynotes:

- ROBOPHILOSOPHY 2022, August, Helsinki (Finland)
- ICRES 2022, International Conference on Robot Ethics and Standards, Seoul, July 2022,
- European Robotics Forum 2022 Rotterdam (Netherland)
- 5th CyPhySS 2021, Bangalore (India)
- 17th Int. Conf. on Principles of Knowledge Representation and Reasoning, 2020, Rhodes (Greece)
- 28th IEEE RO-MAN, New Delhi, Oct 2019 (India)

Invited Talks and Seminars in the period (>30) : Université du Québec (**Montréal**), PlanRob ICAPS 2020, Samsung AI (Cambridge, **UK**), Dagstuhl Cognitive Robotics (**Germany**), ERF Malaga (**Spain**), MBZIRC Symposium 2020 (**Abu Dhabi**), Institutional Robotics Lisboa (**Portugal**), Future Intelligence 2021 (**Toulouse**), NII-Shonan **(Japan), …..**

Important Dissemination Activity : 15 events

PhD Award: Kathleen Belhassein , Prix de Thèse 2022 de la Maison des Sciences de l'Homme et de la Société de Toulouse

Paper Awards: 1 Best paper, 2 Finalist Best and Student Paper

Organized events: 7 events

PhDs: Already Defended

1. **Yoan Sallami (2016-2021)** Thesis Defence 01/2021: Perspective taking in HR collaborative context- Université Paul Sabatier - Toulouse III, 2021 (R. Alami)
2. **Guilhem Buisan (2017-2021)** Thesis Defence 07/2021: Planning For Both Robot and Human: Anticipating and Accompanying Human Decisions (R. Alami)
3. **Amandine Mayima (2017-2021)** Endowing the Robot with the Abilities to Control and Evaluate its Contribution to a Human-Robot Joint Action, INSA de Toulouse, 2021. (A. Clodic, R.Alami)
4. **Kathleen Belhassein (2017-2021)** - « Propositions de stratégies communicatives pour une action jointe Humain-Robot efficace, fluide et durable » - Université Jean Jaurès, Décembre 2021 (M. Guidetti, R. Alami)
5. **Guillaume Sarthou (2018-2021)** - Knowledge representation and exploitation for interactive and cognitive robots - Université Paul Sabatier - Toulouse III, 2021
6. **Phani Teja Singanameni (2019-2022) -** Combining proactive planning and situation analysis for human-aware robot navigation - Université Paul Sabatier - Toulouse III, 2022.
7. **Jérome Truc (2019-2023) -** Human-aware motion planning and control for a flying coworker Université Paul Sabatier - Toulouse III, 2023. English. (co-encadré avec D. Sidobre)

PhDs: ongoing

1. **Anthony Favier (2021-2024) :** Human-Aware Task Planning (ANITI)
2. **Jérémy Tury (2021-2024) :** Refinement–based Acting Engine with a Hierarchical Temporal Planner
3. **Philippe Hérail (2021-2024) :** Learning Plan and Task Operational Models from Demonstrations (A. Bit-Monnot)
4. **Smail AIT BOUHSAIN (2021-2024) :** Combined Task and motion planning (T. Siméon, R. Alami)
5. **Simon Wasiela (2021-2024) :** Control-Aware Motion Planning (T. Siméon)
6. **Emmanuel Bazucchi (2021-2024) -** co-advised with Anne-Laure Gatignon Turnau
7. **Kevin Alcedo (2023-2026) –** co-advised with Prof. Pedro Lima (IST Lisbonne)

Post-Docs

1. **Víctor Fernández-Castro (2019-2021):** Philosopher – Joint Action - Commitments in Human-Robot Interaction

2. **Hendry Ferreira Chame (2020-2021):** Sensori-motor processes for Human-Robot Interaction – Joint Intention (ANITI)

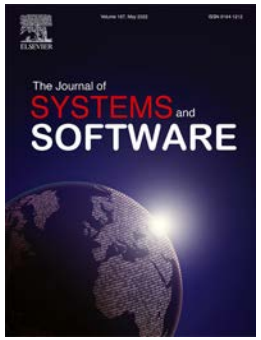
3. **Phani Teja Singamaneni (2022-2024):** Human Aware social robot Navigation

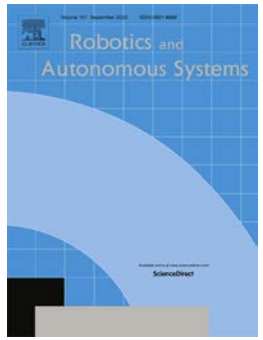
4. **Shashank Shekhar (2021-2024):** Integration of Semantic reasoning and Epistemic Planning in Human-Aware Task Planning –

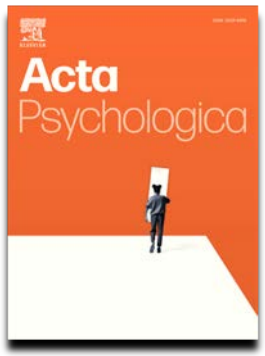
Visiting researchers

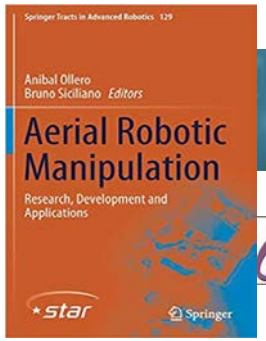
- **Vicente Matellán Olivera**, Universidad de León (September 2021-July 2022)
- **Camino Fernandez Llamas**, Universidad de León (September 2021-July 2022)
- **Alessandro Umbrico** , CNR Rome (November 2022)
- **Gerardo Pérez González**, Universidad de Extremadura (June 2023- October 2023)

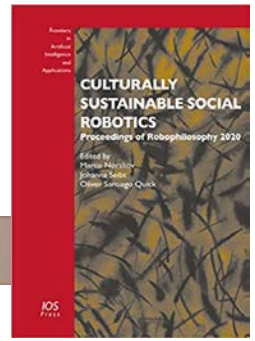
Some papers

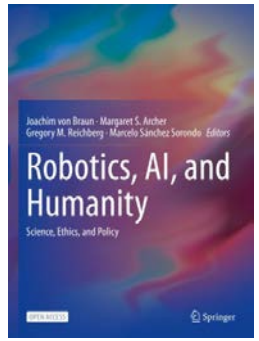












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- F. Ingrand. Verification of Autonomous Robots: A Roboticist's Bottom-Up Approach. **Software engineering for robotics**, Springer, pp.219-248, 2021,
- P-E. Hladik, F. Ingrand, S. Dal Zilio, R. Tekin. Hippo: A Formal-Model Execution Engine to Control and Verify Critical Real-Time Systems. **Journal of Systems and Softw**are, 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.
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- 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
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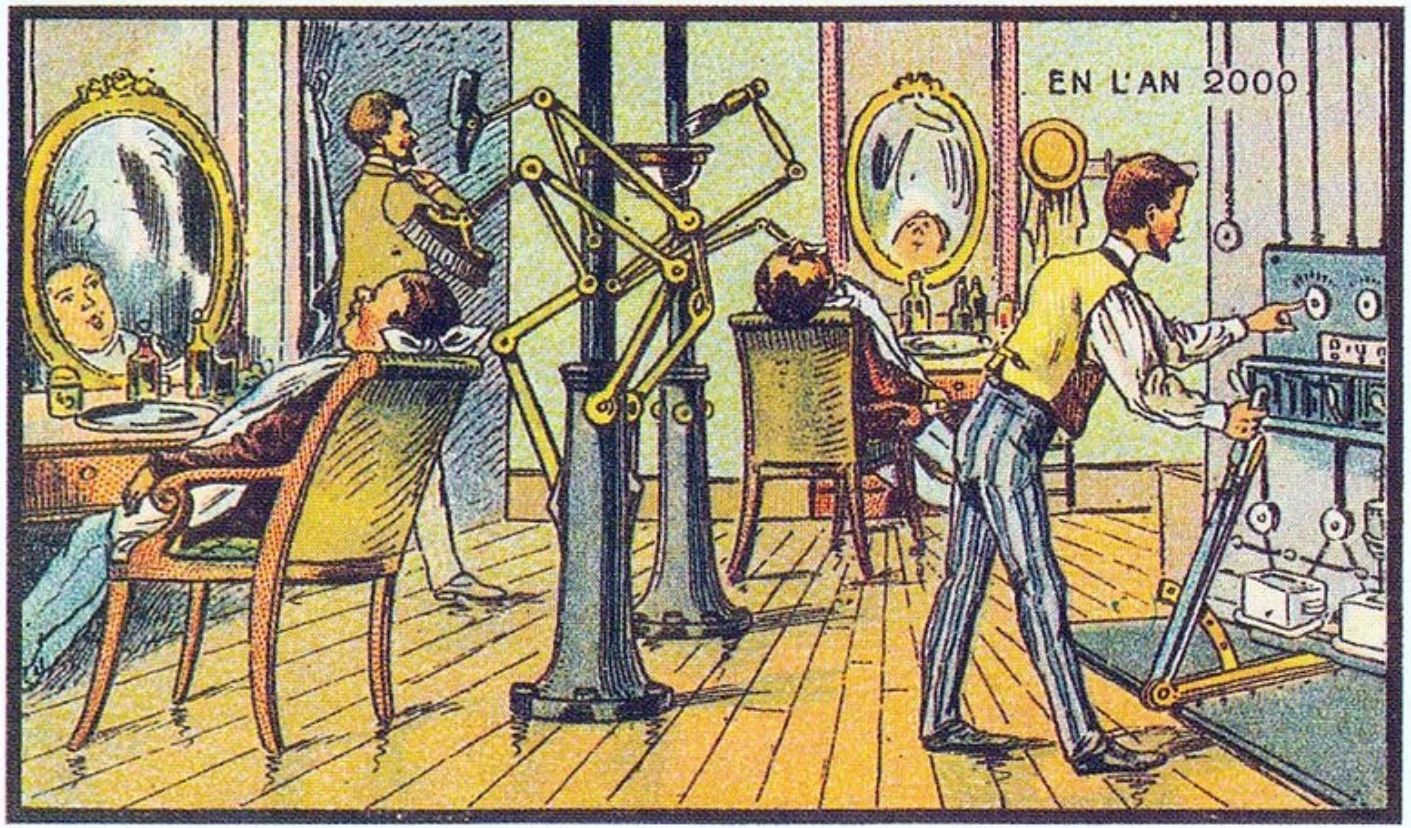
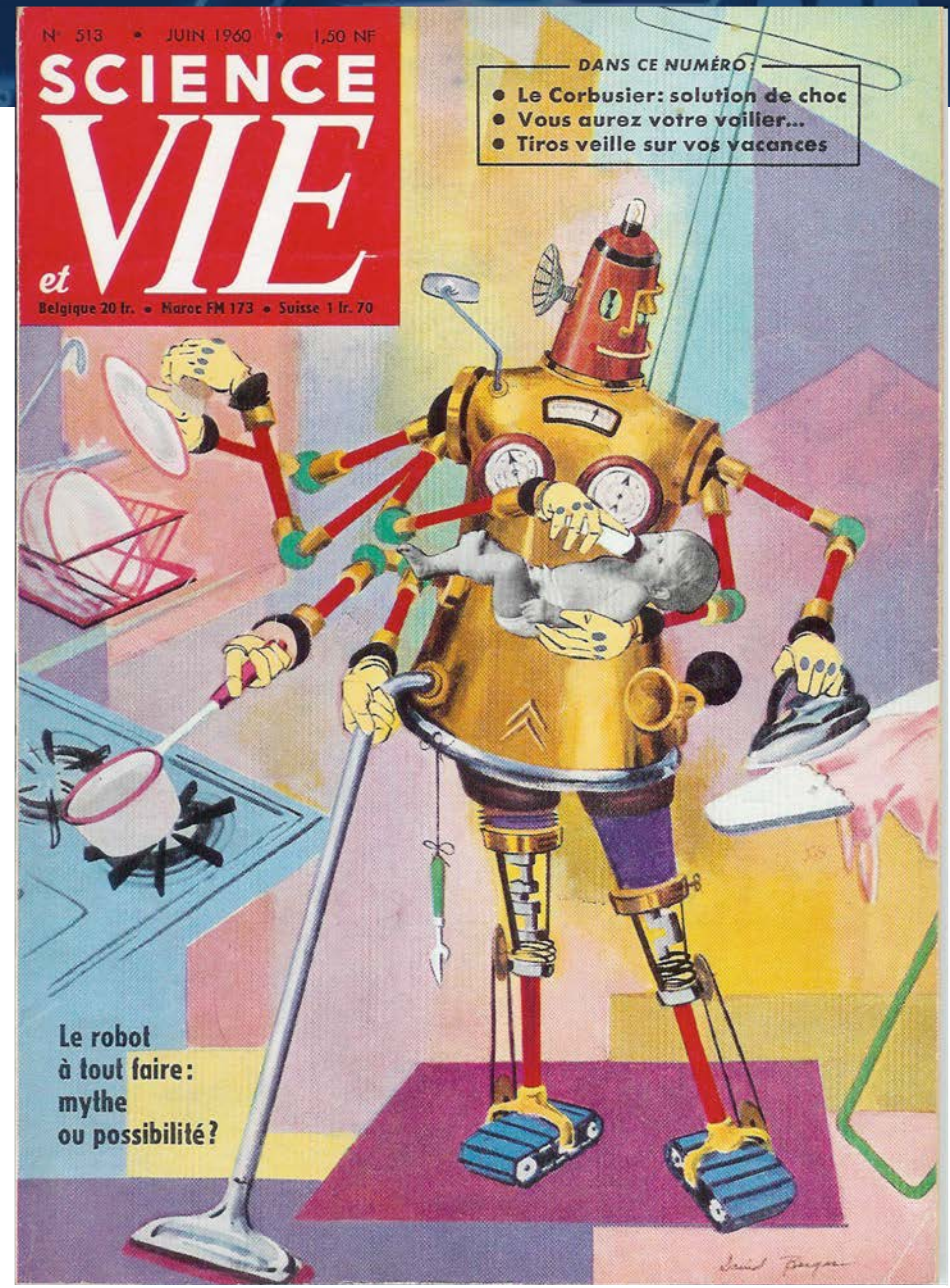
- R. Lallement, J. Cortés, M. Gharbi, A. Boeuf, R. Alami, C. Fernandez-Agüera, I. Maza, A. Ollero, B. Siciliano. Combining Assembly Planning and Geometric Task Planning, Aerial Robotic Manipulation. Research, Development and Applications, 129, Springer, 2019, **Springer Tracts in Advanced Robotics**,

Thanks… Questions ?



The New-Fangled Barber

Futuristic pictures by Jean-Marc Côté issued in France in1900
(cited by I. Asimov)



« Science et Vie » magazine
June 1960