
ANITI
ARTIFICIAL & NATURAL INTELLIGENCE
TOULOUSE INSTITUTE
Robotics and AI (Collaborative AI)
Theme11
September 28-29 2020
Université
Fédérale

# MEMBERS

**Chairs (co-chairs):**

- **Human-Robot Interaction** - Rachid Alami (Aurélie Clodic, Félix Ingrand, Arthur Bit-Monnot, Thierry Siméon)
- **Motion Generation for Complex Robots** - Nicolas Mansard (Olivier Stasse)
- **Neuro-inspired deep learning** - Rufin van Rullen (Reddy, van de Cruys)
- **Neuroergonomics** - Frédéric Dehais (Caroline Chanel, Nicolas Drougard, Raphaelle Roy)
- **Reverse-engineering the brain** - Thomas Serre
- **Certification** - Claire Pagetti (Charles Lesire-Cabaniols)
- **Legal Issues** - Céline Castets-Renard (Claire Boine)
- - Nicolas Asher

# LINK WITH OTHER THEMES

- Acceptable AI
  - Theme 1 Human-centered AI (Thread 1.2 Responsibility: Legal and Ethical Issues)
- Certifiable AI
  - Theme 6: Certifiable and embeddable AI (Thread 6.2 Formal verification and run time assurance of ML systems)
- Collaborative AI
  - Theme 10: Language (Thread 10.2 Language and multimodality)
  - Theme 12: Understanding, monitoring, improving human cognition with AI

## Definition/scientific perimeter of the theme

Robotics is a core theme of Collaborative AI in ANITI. It features threads pertaining to various aspects of robotics—the analysis of motion and its generation, motion and task planning, and human robot collaboration and interaction.
Beside the challenges of autonomous functional and decisional abilities necessary to performs tasks in the physical environment and in presence of uncertainties, the integrative challenge of AI is fully realized in robot human interaction and more precisely on human robot collaboration when humans and robots decide and act together and share the space and the task.

# Theme 11 organisation

- 11.1 Motion Planning and Control
  - 11.1.1 Motion Mathematical Foundations
  - 11.1.2 Legged Robot with Arm(s)
  - 11.1.3 Human Aware Motion Planning
- 11.2 Cognitive Abilities and Communication
  - 11.2.1 Cognitive Abilities Models
  - 11.2.2 Knowledge representation and Language
- 11.3 Architecture, Decision and Interaction
  - 11.3.1 Task Planning, Learning and Decision Making for (interactive) robot(s)
  - 11.3.2 Architecture, Verification and Certification
- 11.4 Social and societal aspects of HRI

# Thread 11.1 Motion Planning and Control

## 11.1.1 Motion Mathematical foundations

Enable discussions with all other relevant threads and chairs, related to the fundamental aspects, in particular mathematical aspects, of motion generation and motion understanding. In particular, links with research in optimal control, reinforcement learning and constrained optimization will be emphasized.
This is a basic-research thread, that will mostly involve discussion and workshops.

**People involved**

- Mansard, Serre, Alami, Lasserre, Dehais, Renaud, Olivier Cots, Milan Corda, Emmanuel Rachelson, Sébastien Gerchinovitz, Jérôme Bolte?

# Thread 11.1 Motion Planning and Control

## 11.1.1 Motion Mathematical foundations

The motion of a robot can be described as an optimal control problem:

$$\min_{\{x\},\{u\}} \int_0^T \ell(x_t, u_t)dt + \ell_T(x_T)$$

$$subjectto \quad \dot{x}_t = f(x_t, u_t), \forall t = 0..T$$

$$g(x_t) \geq 0, \forall t = 0..T, \qquad x(0) = \hat{x}, \qquad x(T) \in \mathcal{X}^*$$

where $\{x\} : t \to x(t)$ is the state trajectory, $\{u\} : t \to u(t)$ is the control trajectory, $\ell$ is the objective (cost or reward) function, $f$ is the robot dynamics, $g$ represents the robot constraints, $\hat{x}$ is the estimated (current) state and $\mathcal{X}^*$ is the viability set (i.e. the state set from which feasible control can be found which lead the robot to stay in the set).

# Thread 11.1 Motion Planning and Control

## 11.1.1 Motion Mathematical foundations

### On-going collaboration between chairs

- A monthly workshop has been set up to discuss.

### On-going collaboration with ANITI Industrial partners

- Key applicative problems are coming from the discussions with Continental and Airbus

### On-going collaboration with external projects

- EU project Memmo (Mansard)
- Naver Labs EU (Grenoble, integrated to 3IA MIAI)

### On-going ANITI Phd & Post doc

- Amit Parag (N. Mansard): model based reinforcement learning
- Ewen Dantec (N. Mansard, M. Taix): real-time (kilohertz) whole-bodypredictive control for robot with legs and arms.

# Thread 11.1 Motion Planning and Control

## 11.1.2 Legged robots with arms

Develop methods for planning and controlling the motion of complex robots, i.e. mobile robots with arms and/or legs.
One of the core advances that is expected from advanced (IA) methods for robotics is a unified integration of what is typically decomposed in sensing/deciding/planning/controlling, into a single decisional unit, able to take complex (task related) decisions without explicit decomposition from raw sensor data.

**People involved**

- N. Mansard, O. Stasse, O. Cots

# Thread 11.1 Motion Planning and Control

## 11.1.2 Legged robots with arms

**On-going work**

- This thread studies in parallel advanced numerical algorithms (such as sparse constrained solvers) and their implementation into effective software able to solve on realistic robot experiments.
- We have developed a new method and released an open-source project for solving whole-body optimal control problems.
- We have developed a dedicated multiple-shooting solver for direct resolution, relying on an extension of the classical "differential dynamic programing (DDP)" algorithm to handle the problem sparsity. The algorithm has been implemented in a software called Crocoddyl

# Thread 11.1 Motion Planning and Control

## 11.1.2 Legged robots with arms

*On-going collaboration with ANITI Industrial partners*

- Collaboration with Airbus through the joint lab Rob4FAM. The experimental benchmark and proof-of-concept scenarios are provided by Airbus.

*On-going collaboration with external projects*

- Toulouse start-up Toward, Wandercraft (Paris, CIFRE thesis)
- IDIAP (Switzerland, S. Calinon et al) and Univ. Edinburgh (UK, S. Vijayakumar, S. Tonneau et al), Max-Planck Institute, New-York University (Machine in Motion lab): co-supervised thesis of Sebastien Kleff

*On-going ANITI Phd & Post doc*

- Ewen Dantec: model predictive control for humanoid and other legged robots (Mansard-Taix)
- Post-doc to be recruited (Mansard)

# Thread 11.1 Motion Planning and Control

## 11.1.3 Human-Aware Motion Planning

Elaboration and execution of highly constrained robot motion plans, e.g. robot motions in the presence or in synergy with humans.

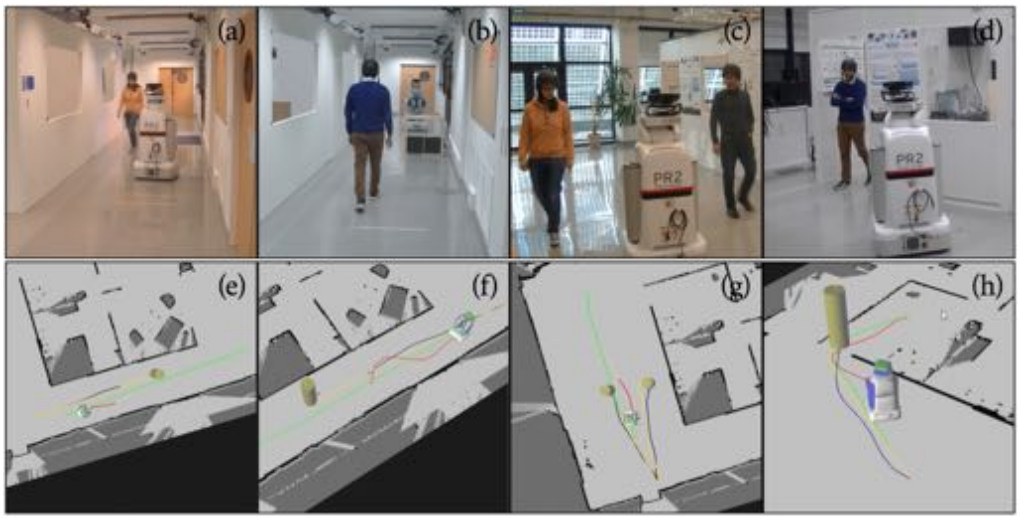
- Build predictable/legible/acceptable robot trajectories by taking explicitly into account, in the motion and physical action synthesis process:
  - the on-going (shared) task
  - an estimation of humans state/intentions/preferences
  - social norms

**People involved**

- R. Alami, T. Siméon, A. Bit-Monnot

# Thread 11.1 Motion Planning and Control

## 11.1.3 Human-Aware Motion Planning




Example of a Human-Aware motion planning problem: Trajectories generated by cooperative robot navigation planner for different situations and contexts: (1) A corridor crossing situation where human and robot share effort to avoid colliding with each other; (2) A more confined corridor crossing situation where the robot facilitates the human to cross the corridor with sufficient space; (3) An open area situation where two human decide to move on either side of the robot. (4) A door crossing situation where the robot facilitates the human by waiting near the door until the human passes through.

# Thread 11.1 Motion Planning and Control

## 11.1.3 Human-Aware Motion Planning

### On-going collaboration with external projects

- ANR "The Flying Coworker", H2020 MuMMER, H2020 Terrinet
- Collaborative project with Center for Ubiquitous Computing (UBICOMP), University of Oulu (Prof.Steven M. LaValle ): "Comfortable and Natural 360° Robotic Telepresence" - Financement Suomen Akatemia / ANITI / LAAS-RIS

### On-going Phd & Post doc

- Phani Teja Singanameni (R. Alami): Elaboration et Apprentissage de fonctions interactives pour un robot
- Jérome Truc (D. Sidobre, R. Alami) : Human-aware motion and manipulation planning for a Flying co-worker robot
- Yohann Charreire (T. Siméon, R. Alami, A. Bit-Monnot) Une approche hybride 'géométrique et symbolique' (CTAMP) pour la planification de tâches de manipulation collaboratives humain-robot

# Thread 11.2 Cognitive and Communication Abilities

## 11.2.1 Cognitive abilities models

Study how we can model cognitive abilities to be used by a robot and how monitoring tools used for human brain study could benefit to robotics:

- Understanding and model human cognition (via AI) for robotics purpose:
  - Visual reasoning abilities, Attention, Joint attention, Theory of Mind, Perspective-Taking and Affordances
- Monitoring human
  - To get objective measures in user studies
  - To monitor on-line quality of interaction

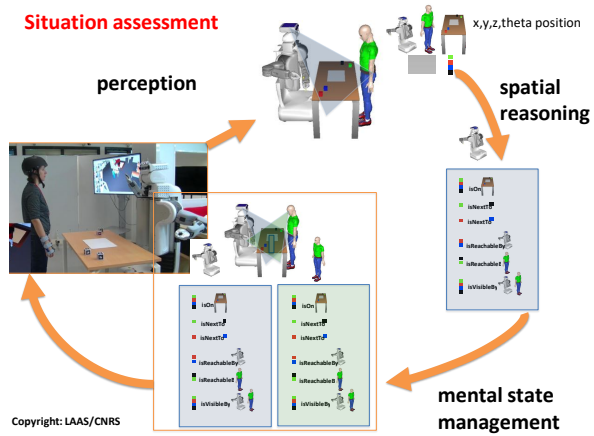
**People involved**

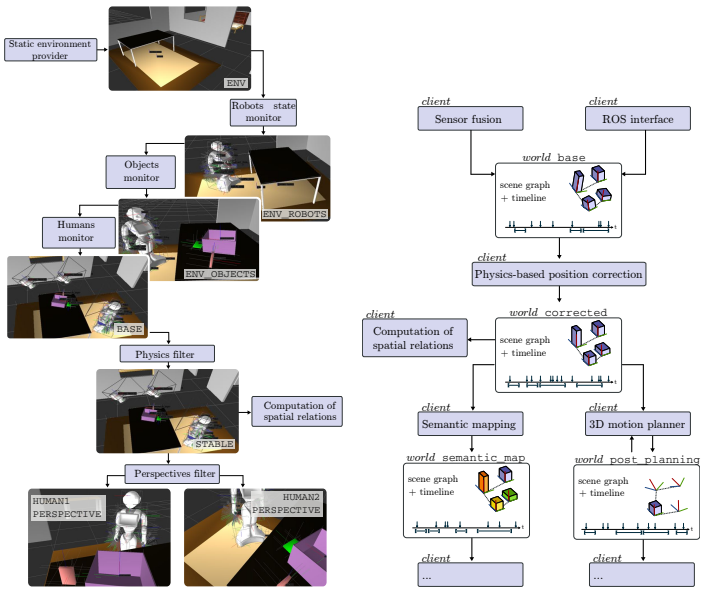
- Alami, Van Rullen, Serre, Dehais, Roy, Clodic

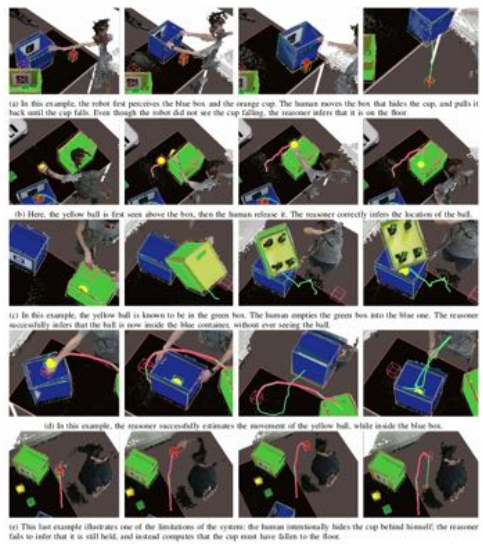
# Thread 11.2 Cognitive and Communication Abilities

## 11.2.1 Cognitive abilities models

E.g Situation assessment in HRI (Alami)



# Thread 11.2 Cognitive and Communication Abilities

## 11.2.1 Cognitive abilities models

### On-going collaboration with ANITI Industrial partners

- PhD project Airbus/ANITI (chair: VanRullen, candidate: M. Giraud, to be confirmed): Grounded language learning in situated environments

### On-going ANITI Phd & Post doc

- Hendry Chame (post-doc from 07-2020, Alami's chair) investigating and implementing interactive attention-based multi-modal and bi-directional human-robot abilities
- Vaishnav (PhD, Serre) cognitive mechanisms for visual reasoning.
- Zerroug, Boutin & Ben Tanfous (PhD, 2 post-docs, Serre) and Choksi, Alamia, Mozafari (PhD, 2 post-docs, VanRullen) work on brain-inspired recurrent models of visual reasoning
- Bielawski, Devillers and Giraud (2PhD, 1 intern, VanRullen) work on multimodal grounding of language information

# Thread 11.2 Cognitive and Communication Abilities

## 11.2.2 Knowledge representation and Language

- How to model knowledge holds by the robot and its interlocutor? How to handle common ground information and at first how to infer that an information is common ground? How to handle information memorization? How to manage information disambiguation?
- How the integration of differences among interlocutor perspectives and the estimation of interlocutor beliefs during the course of an interaction helps the robot to ground and maintain the (conversational) interaction in the context?
- How the interplay between conversation, collaborative problem-solving, learning, and task planning approaches can be developed in contexts where the robot and human share a task and a space?

### People Involved

- Alami, Asher, Van Rullen, Muller, Clodic

# Thread 11.2 Cognitive and Communication Abilities

## 11.2.2 Knowledge representation and Language

**On-going collaboration between chairs**

- Alami and Asher setup a PhD project with Linagora (cf Kate Thompson PhD)

**On-going collaboration with ANITI Industrial partners**

- Kate Thompson (will begin fall 2020) "Models and processes for effectively integrating human-machine dialogue and conversation systems with the decisional processes involved in human-robot joint task achievement" , Advisors : Rachid Alami, Nicolas Asher, Aurélie Clodic (Finacement ANITI / Cifre Linagora)
- Discussion with Luc Truntzler from Inbenta to get a funding of Crédit Agricole to participate to the Caly project. The funding opportunity has been withdrawn due to COVID-19.

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.1 Task Planning, Learning and Decision Making

Planning and decisional processes that are necessary for a cognitive robot to achieve a desired goal or to conduct a collaborative activity with humans and other robots.

- Planning: Planning in presence of uncertainty, (Human-aware) task planning, Hierarchical and interactive planning framework, Plan explainability
- Decision: Decisional processes for collaborative task achievement, Mixed-initiative, Automated decision-making
- Learning: Integration of learning and planning

**People involved**

- Alami, Dehais, Pagetti, Clodic, Chanel, Lesire, Ingrand, Bit-Monnot

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.1 Task Planning, Learning and Decision Making

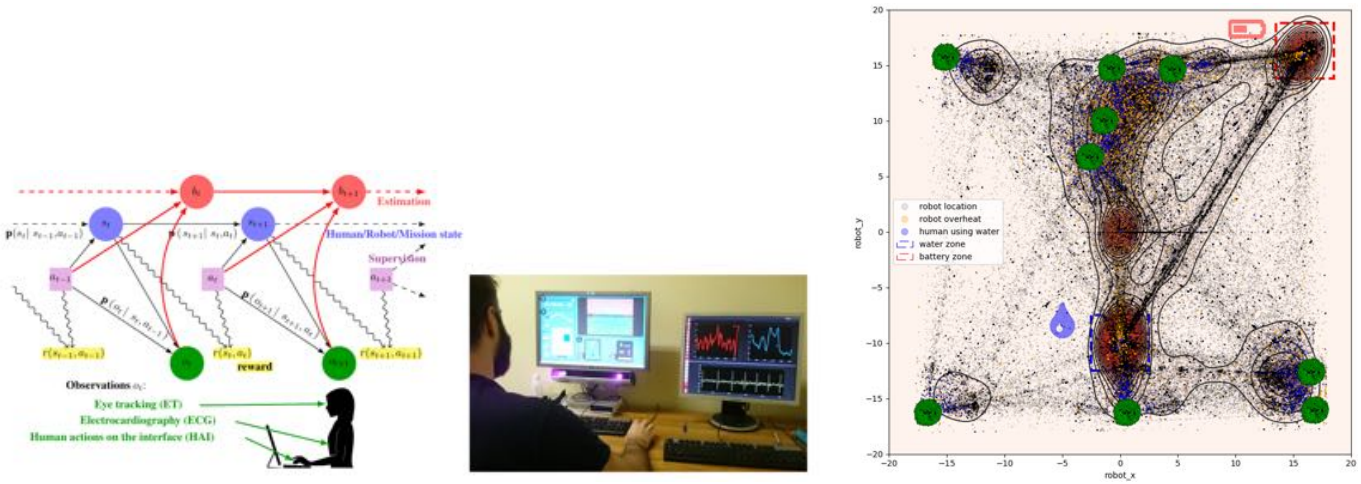
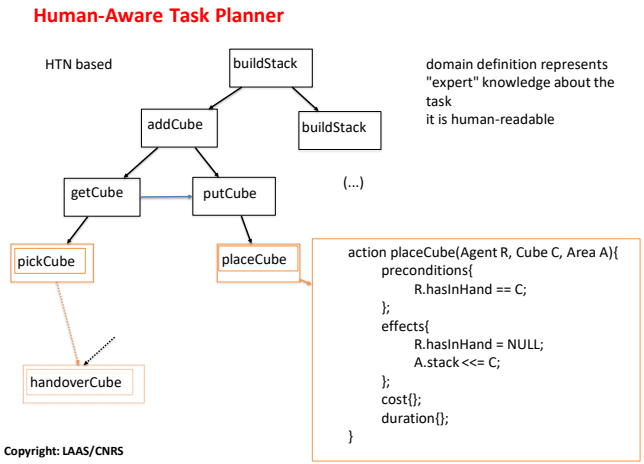
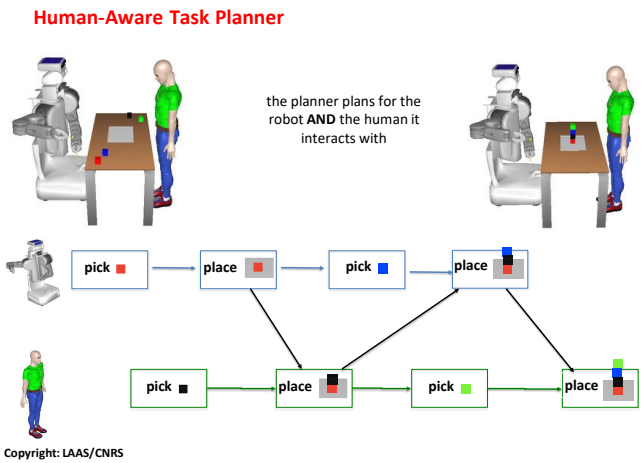



Figure: POMDP model schema relying on physiological markers and human actions on the interface

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.1 Task Planning, Learning and Decision Making



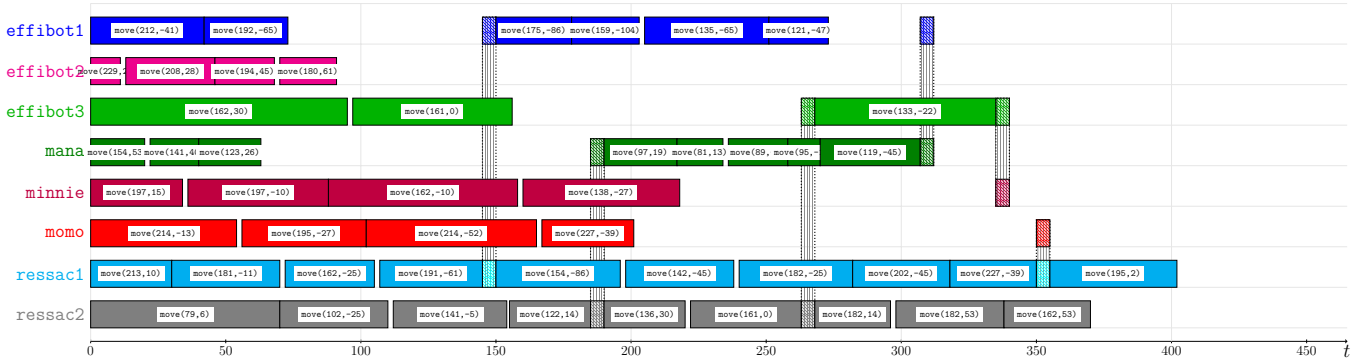



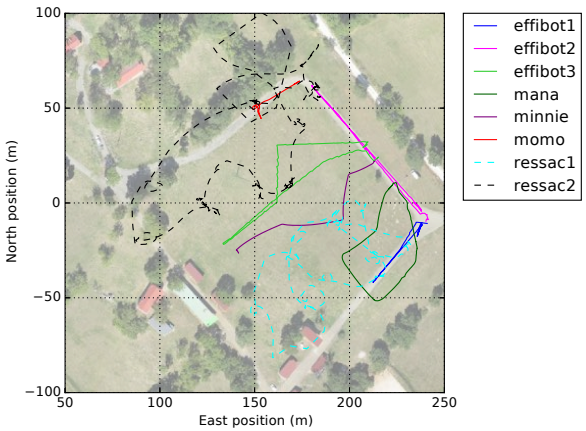

## Human Aware Task Planning:

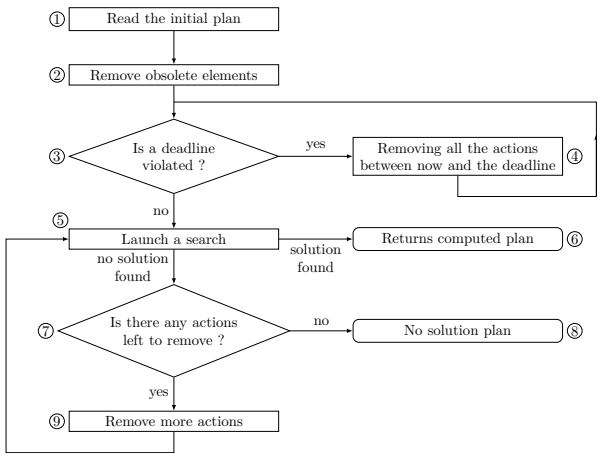
The HATP planning framework extends the traditional Hierarchical Task Network (HTN) planning domain representation and semantics by making them more suitable to produce plans which involve humans and robots acting together toward a joint goal. The HATP planning domain defines a set of methods describing how to incrementally decompose a task and to allocate subtasks and actions to the robot and/or the human depending on the context. This represents the procedural knowledge of the robot as well as its knowledge about the actions that the human partner is able to achieve. It is stored outside of the central knowledge base, using a specific formalism.

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.1 Task Planning, Learning and Decision Making




**Multi-Robot Task Planning and Repair**: Multi-robot task allocation and planning using automated planning (incl. hierarchical and partial-order planning); online distributed repairing processes.

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.1 Task Planning, Learning and Decision Making

**On-going collaboration with external projects**

- Mixed-Initiative Human-Robot Interaction (MI-HRI) research topic is also studied in the Control and Decision research axis of the Dassault Aviation and ISAE-SUPAERO Chair on Design and Architecture of Cognitive Aerial Systems.
- MuMMER H2020, ANR Project JointAction4HRI, AI4EU Project

**On-going ANITI Phd & Post doc**

- PhD Giorgio ANGELOTTI (Chanel) *POMDP model learning and planning to drive Human-Robot Interaction*. Improvement of offline learning for planning algorithms possibly applicable to drive the interaction between human and artificial agents.
- PhD Anthony Favier (Alami, starting 01/2021): Elaboration et Apprentissage de fonctions décisionnelles et interactives pour un robot assistant ou équipier

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.2 Architecture, Verification and Certification

Elaborate and deploy robot control architectures and tools for building autonomous robot systems, it includes work on:

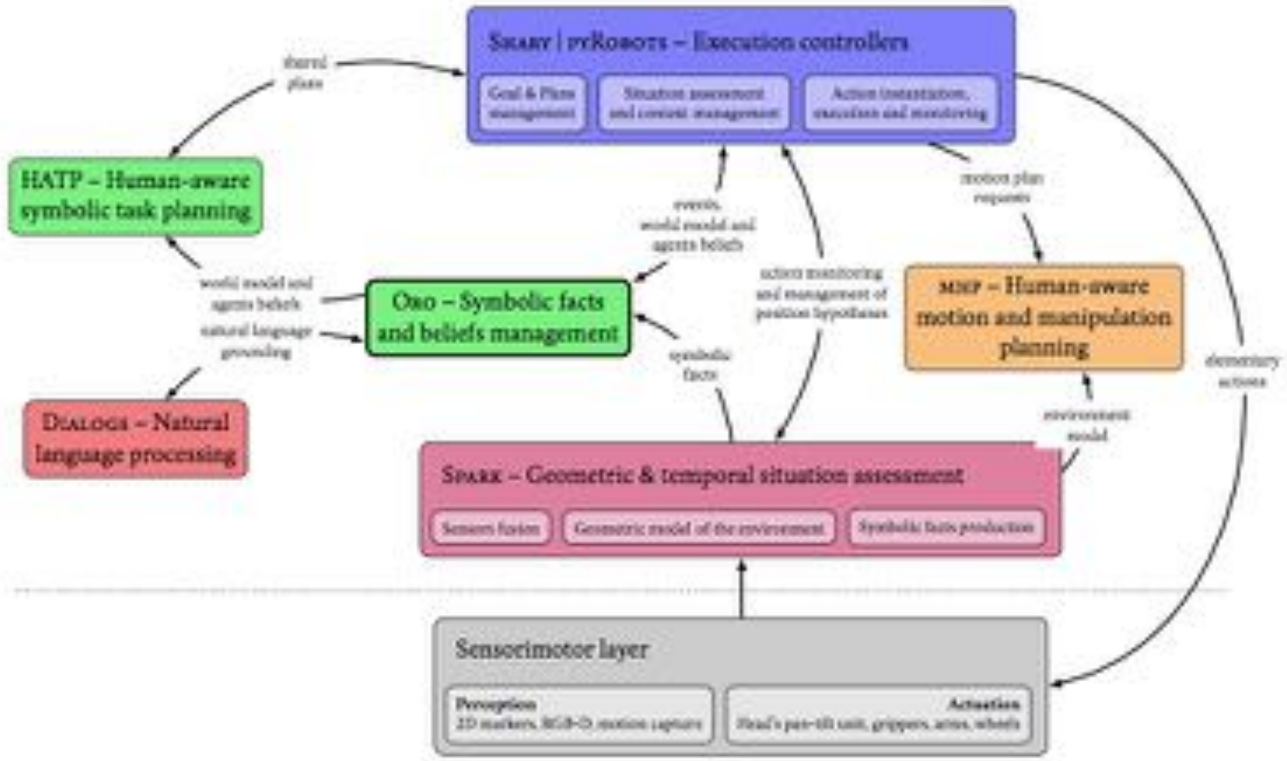
- Tools for Robotic Software Architectures: A modular design approach and associated tools for building Software Architectures for Autonomous Robots
- Robot Control Architectures for cognitive robots
- Robot Control Architectures for HRI

**People involved**

- Alami, Pagetti, Lesire, Clodic, Ingrand

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.2 Architecture, Verification and Certification



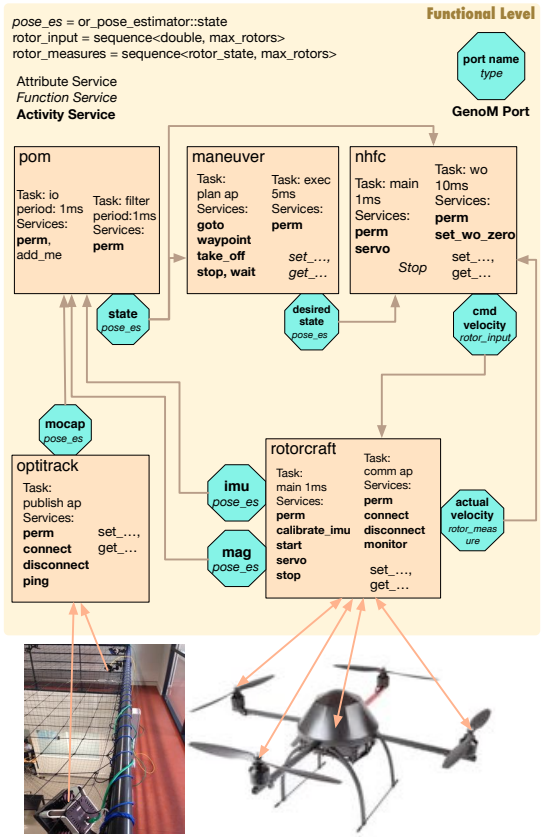

Overview of an architecture for HRI. A deliberative layer, composed of six main modules, interacts with a low-level sensori-motor layer. Knowledge is centrally managed in an active *semantic blackboard*, pictured above with a thick border. The links between components depicted on the figure underline the central role of the knowledge base: many of the data streams are actually symbolic statements exchanged through this semantic blackboard.(from Séverin Lemaignan, Matthieu Warnier, Emrah Akin Sisbot, Aurélie Clodic, Rachid Alami. Artificial Cognition for

# Thread 11.3 Architecture, Decision and Interaction

## 11.3.2 Architecture, Verification and Certification

The goal is to define an architecture and deployment tools to specify functional components for autonomous systems and to automatically synthesize formal models of these components.
These models can then be used to verify offline properties on the integrated experiment, but also online monitor the proper execution and enforce temporal and logical properties. Currently the approach rely on the GenoM tool from LAAS/RIS but also the FIACRE/TINA/HIPPO suite from the LAAS/VERTICS team.
The main result is that we now run onboard a drone the Hippo engine executing at 10 kHz the joint formal model of all the components on the figure **??**. The formal can then be augmented with complex properties to monitor and verify online (e.g. perform an emergency landing in case the localisation is lost).

We plan to extend this approach toward the decisional level, in particular taking into account the acting component of the experiment (see the work on ASPIC by Charles Lesire), and also the interaction with the human.




Architecture of the Drone experiment.

# Thread 11.4 Social and societal aspects of Human-robot interaction

Our social world is highly complex–the social context of a human-robot interaction consists of the multiplicity of roles, norms, conventions, and social practices that we, as humans, explicitly or implicitly define to handle our daily lives together. Even though roboticists did acknowledge this complexity from the very beginning of social robotics, we still lack a general theoretical framework for describing a social interaction context, and stating general and specific requirements.
This thread aims to consider this in several directions:

- first, by studying which social models could be pertinent and how they can be translated into a robotic architecture ;
- second, by studying which impact a cooperative robot could have into our lives and what we need to care about.

**People involved**

- Alami, Castets-Renard, Clodic

# Highlight & main results

**Scientific event organization (conference, workshop, GDR)**

- Workshop and collaboration with other 3iA Institutes: e.g. PRAIRIE (Ponce, Laumond, Carpentier, Schmidt)
- Verification and Synthesis of Human-Robot Interaction, February 17 – 22 , 2019, Dagstuhl Seminar 19081, Organizers: Alami, Eder, Hoffman, Kress-Gazit
- Workshop: In the quest of Social Models for Social Robotics at Robophilosophy 2020 conference, August 2020, Organizers: Clodic, Fernandez-Castro, Hakli, Dignum, half day workshop - 60 persons - audience: philosophers and roboticists
- The Communication Challenges in Joint Action for Human-Robot Interaction at International Conference of Social Robotics ICSR'19, Organizers: Clodic, Fernandez Castro, Belhassein,Alami (LAAS-CNRS), all day workshop - 40 persons - audience: roboticists, psychologists and philosophers

# Highlight & main results

**Submissions to ANR, EU and other related projects**

- HAPOLYNAIR (Human-Aware, resPOnsive and poLYvalent NAvigation for Indoor Robots), Call: H2020 ICT-46-2020 Robotics in Application Areas, Aniti people involved: Clodic, Alami, Ingrand, Siméon
- VASHARO ( VAriable SHared Autonomy RObot for collaborative bimanual grasping, handling and manipulation task), Call: H2020 ICT-47-2020 Research and Innovation, Aniti people involved: Alami, Clodic, Rachid Alami, Siméon
- AI4HRI Artificial Intelligence for Human-Robot Interaction, Trilateral call for proposals France – Germany - Japan on artificial intelligence (AI), Aniti people involved: Aurélie Clodic, Rachid Alami
- AIPlan4EU (Bringing AI Planning to the European AI On-Demand Platform), Call: ICT-49-2018-2020 Artificial Intelligence on demand platform, Aniti people involved: Félix Ingrand, Arthur Bit-Monot, Aurélie Clodic, Rachid Alami

# Scientific animation of the theme

**Description of the theme agenda (weekly seminar,...)**

- bi-monthly meeting to be organized

**Emerging collaboration between chairs & industrial partner**

- already planned (inter-chairs) workshops on specific subjects:
  - Dehais-Alami: on attention models, on physiological data monitoring, on user studies, on planning with POMDP
  - Alami-Dehais-Van Rullen: on cognitive abilities models
  - Alami-Pagetti: on robotic architecture, on certification, on multi-robot Systems and plan explainability
  - ...