Projet Joint Action for HRI

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Design of a robot control architecture enabled for joint action with humans

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Institut | Nicod CNRS-EHESS-ENS

LAAS CNRS INSTITUT CARNOT LAAS CNRS

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Executive summary

This document describes the main steps of the elaboration of a robotics architecture for collaboration with humans.
A collaborative effort has been dedicated to identify its main ingredients and to prepare the contexts of the tests that will be conducted to illustrate to implement and illustrate the main project findings.
This architecture will serve as a framework, in the second half of the project, for refining and illustrating several key aspects of Human-Joint Action.
This will finally result in a second iteration of the robotics architecture which will delivered by the end of the project.

1. Introduction

The document describes essentially the activity corresponding to the study of the challenges and requirements for an architecture of a cognitive and interactive robot specifically enabled for allowing the robot to conduct joint action with a human partner.

A set of illustrative examples have been chosen and refined in order to make as concrete as possible the main ingredients and their articulation.

Another aspect, essential for the effective implementation, is the elaboration of the models that will be used for the effective development of the main algorithms.

Finally, an architecture will be proposed that will serve as a framework, in the second half of the project, for implementing all the necessary ingredients to run the illustrative examples on a real robot and in a realistic set-up.

2. Challenges and requirements for a robotic architecture enabled for joint action

We have conducted a cross-disciplinary discussion in order to refine the challenges of human-robot joint action as a first step toward the development of a framework for human-robot interaction grounded in human-human interaction.

We have essentially addressed the following questions:

- What knowledge does a robot need to have about the human it interacts with, and which processes does it need to handle to manage a successful interaction?
- Conversely, what information should the human possess to understand what the robot is doing and how the robot should make this information available to its human partner?

This resulted in research paper [Clodic-17].

3. Illustrative examples of Human-Robot Joint Action

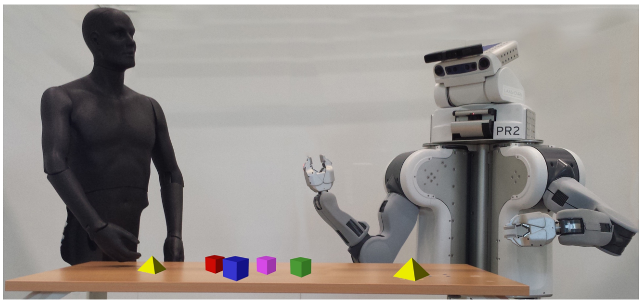
We have chosen to study and develop robot abilities for several tasks considered as joint actions:

1. H&R Building a stack together
2. Navigation in narrow spaces populated with humans
3. Providing route directions

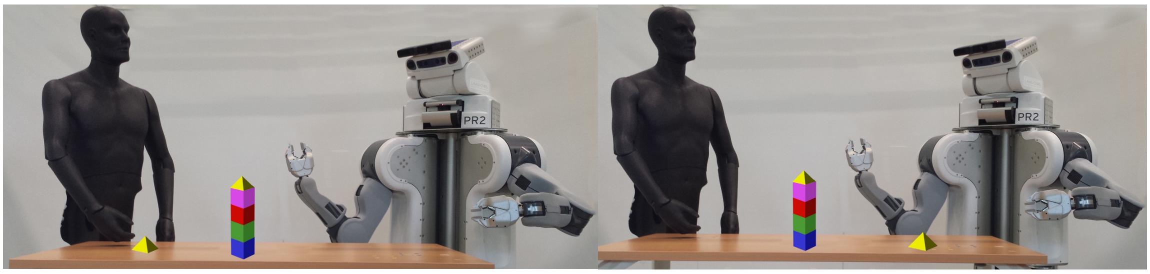
3.1. H&R Building a stack together

The problem involves a Human and Robot, in a face to face situation with mutual observation and multi-modal communication, collaborating in a joint objects manipulation activity such as building a desired stack of objects. Various variants can be devised in order to focus or exhibit more clearly one aspect or the other: for instance, some instances cans include occlusions or uncertainties.

A simple stack-building example:



Initial situation

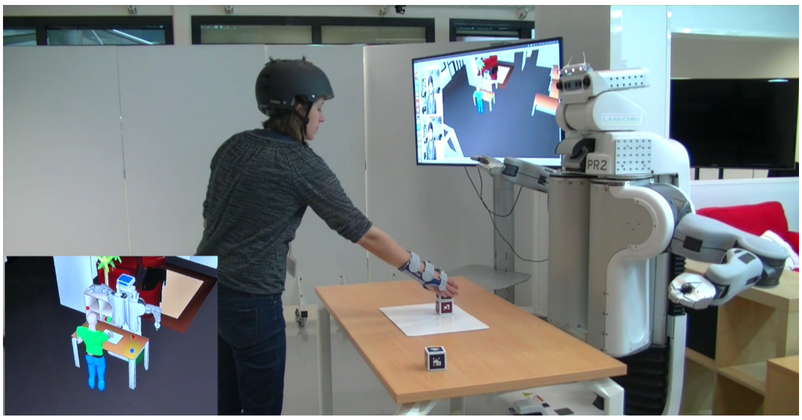


Two possible end states

We have proposed this stack building example as a "canonical" example to study in the Joint Action Workshops we have organized (see https://fja.sciencesconf.org/).

It has also been chosen for the experiments with children in the BabyLab (CLLE)

Finally, we have developed and tested a first instance at LAAS using a PR2 robot. This has allowed to enhance the initial supervision through a more elaborate reasoning on human mental state in order to improve fluency of the interaction [Devin-17].



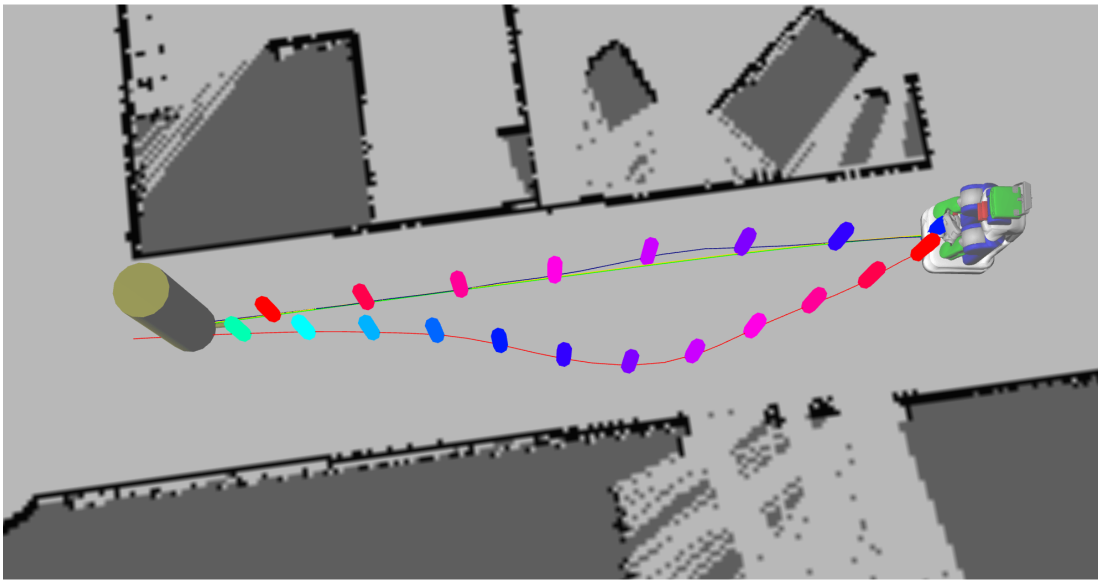
Implementation of the H&R stack-building at LAAS

3.2. Navigation in narrow spaces populated with humans

While various contributions, including some pioneering work at LAAS, have provided pertinent solutions to the so-called human-aware or social navigation problem, we have decided to focus a very constrained version of it, which was not yet studied: navigation of a robot in a narrow space (such as a corridor) populated with humans.

In such a situation, Human-Aware Navigation switches to HR Joint Action when it appears necessary that both agents (H & R) need to contribute to the solution. It can then be considered and dealt-with as an interesting instance of (implicit) joint action.

We have proposed a first, optimization-based method that considers the ability of the robot to reason about the plans of the humans while considering Issues of legibility, acceptability, adaptability and pro-activity of the robot behavior [Khambhaita-17a] [Khambhaita-17b].



While a standard planner would have concluded that there is not solution, the proposed scheme allows the robot not only to find a solution which needs the contribution of the human (represented here as a cylinder) but also to proactively exhibit its choice. Note that there can be asymmetry: the robot takes more load.

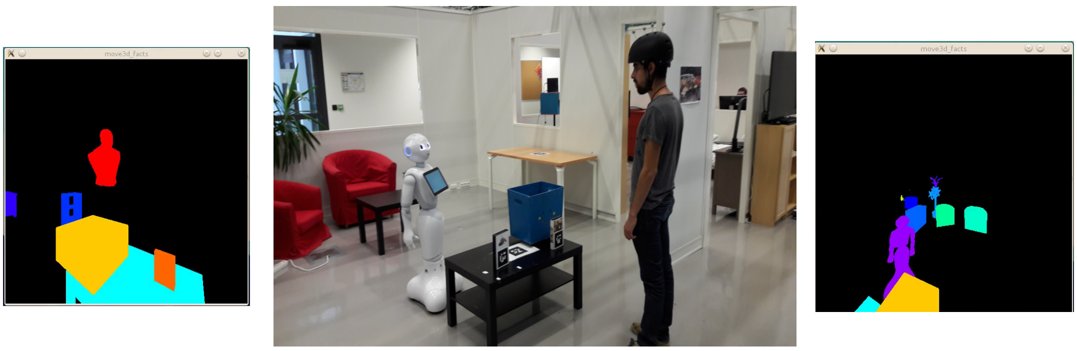
3.3. Providing route directions

The third example has been built through our contribution to the H2020 MuMMER project (MultiModal Mall Entertainment Robot http://mummer-project.eu/). Our main topic here concerns the development and the evaluation of the decisional capabilities of an interactive and cognitive robot in interaction with humans in the context of a mall: interplay between decision and dialog, perspective-taking, motion and task planning for the robot and the humans, human-aware motion planning and social navigation.

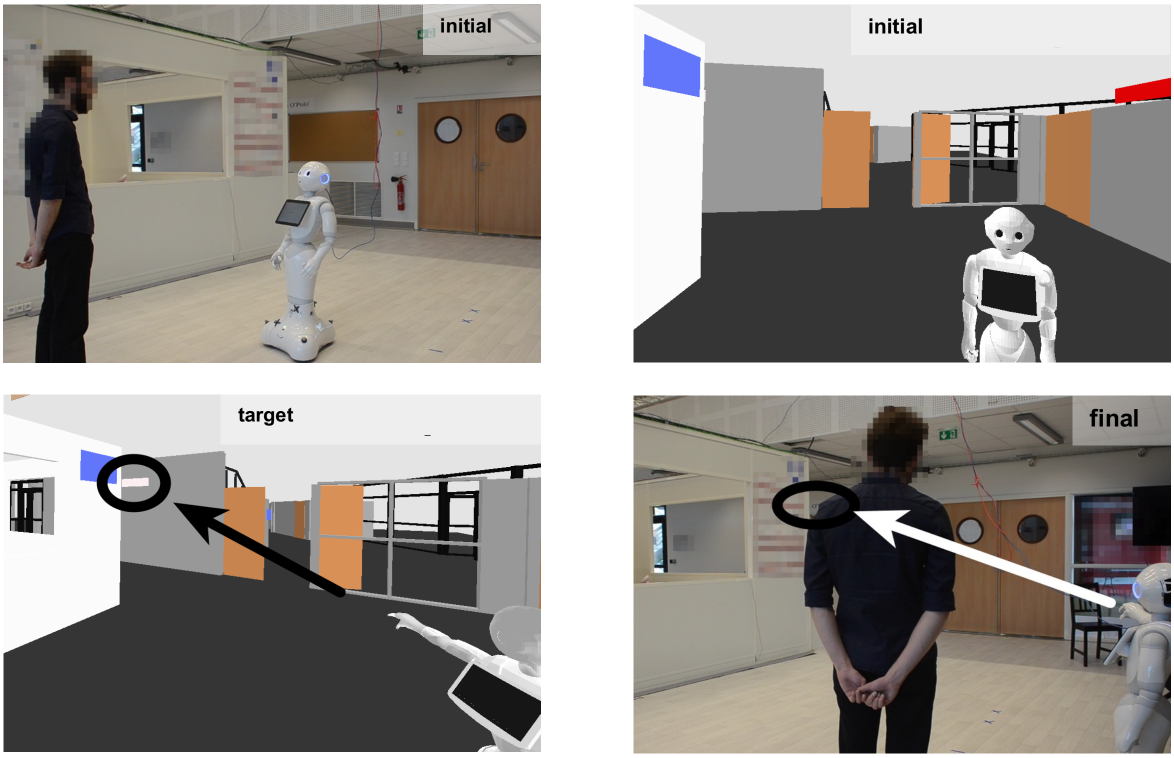
One very interesting activity of the MuMMER robot in the mall is route guiding. The robot is meant to provide information to customers about how to reach a given shop.
Our study has shown that it can be dealt with as a joint action between the human customer (or a group of customers such as a family) and the robot.

Study of the route guiding task performed by a Human [Belhassein-17]

A number of key issues have to be considered: (1) signs and landmarks visibility, (2) estimation of perspective of the human, (3) finding a suitable placement of the robot and the human in order to share a perspective of a given landmark, (4) maintaining the interaction until the problem is solved (or abandoned) by permanently monitoring the human and adapting to his behaviour and needs.



The robot is able to build a correct estimation of the Human perspective [Lemaignan-18]



Computing a Human and Robot placement in order to share a perspective [Waldhart-18]

4. Models for joint action

An aspect that is essential for the effective implementation on the robot of the joint action ingredients, is the study and elaboration of the suitable models that will be used to effectively develop the algorithms.

Perspective-taking: an implementation of the visual perspective of the human is done through geometrical computations of her/his view of the scene, when her/his position is known to the robot [Lemaignan-17].

Environment description: Based on [Lemaignan-17], the robot is also able to estimate the beliefs of it human partner concerning a symbolic representation of the context (visibility and reachability of objects, spatial relations between objects, environment topology.

High-level task description: a BDI approach is used combined with a symbolic description of the environment, of the actions, their precondition and effects [Lallement-18], [Sebastiani-17].

Theory of Mind: An estimation of the Human mental state concerning her/his beliefs on the task and the environment state has also been proposed and illustrated in [Devin-17].

Social Practices: we have studied the pertinence of the use of social practices by the robot in order to encode the influence of the social context on the way an action should be performed and its social interpretation. Indeed, social practices describe physical and social patterns of joint action as routinely performed in society and provide expectations about the course of events and the roles that are played in the practice [Clodic-18], [Dignum-18].

Human-Aware Cost & Utility based planning: a set of criteria have been defined in order to guide the planners towards solutions that satisfy the acceptability of the robot behaviour by the human. This is done at two levels: motion planning [Khambhaita-17a] and task planning [Waldhart-18], [Lallement-18].

Means for Monitoring and Evaluation of the quality of the interaction: We have also contributed to the evaluation of the quality of the HR interaction and more particularly of a key aspect when considering joint action: the pertinence of robot decisions [Devin-18].

5. Architecture framework

We have elaborated a first architecture which will serve as a framework, in the second half of the project, for refining and illustrating several key aspects of Human-Joint Action.

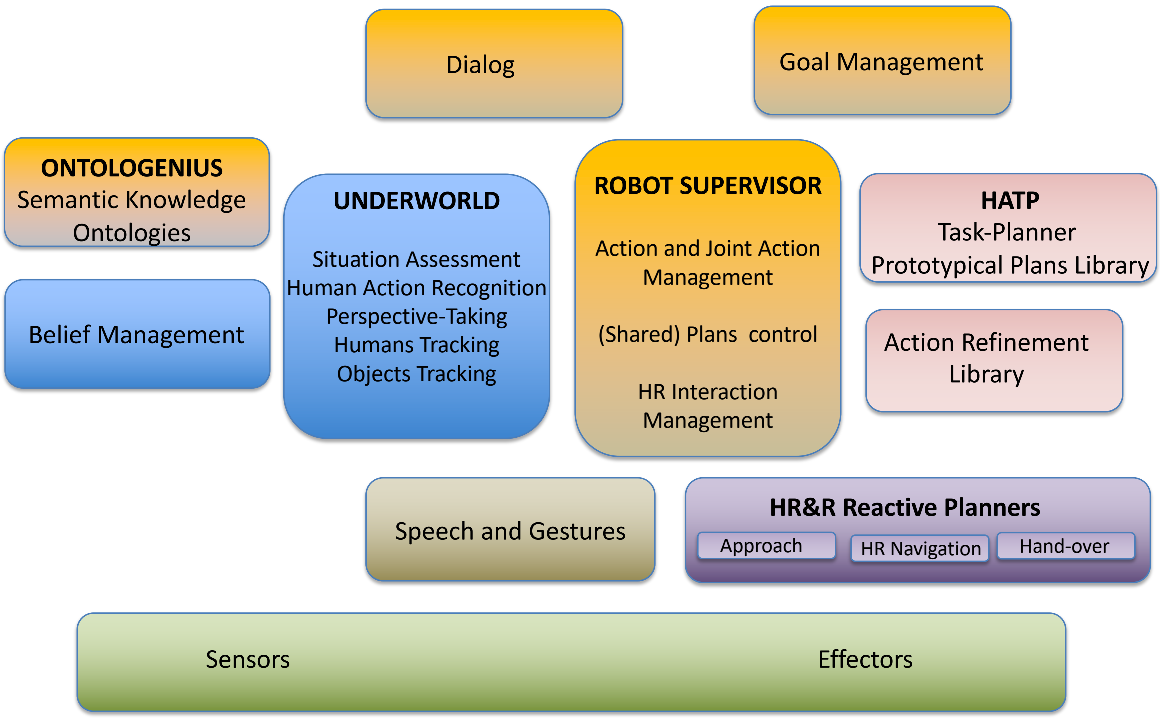
This will finally result in a second iteration of the robotics architecture which will delivered by the end of the project.

5.1. A generic architecture for HR Joint Action

This architecture is based and extends/refines the architecture elaborated previously by LAAS and published in Artificial Intelligence Journal [Lemaignan-17]. We also intend to distribute it in open-source by the end of the project.

Several new components have been designed:

- Underworld: for situation assessment, belief management and activity tracking [Lemaignan-18]
- Ontologenius: an ontology manager https://sarthou.github.io/ontologenius/
- A new High-level controller based on Jason (http://jason.sourceforge.net/wp/) a flexible BDI programming environment
- Development of API to control ROS-based components

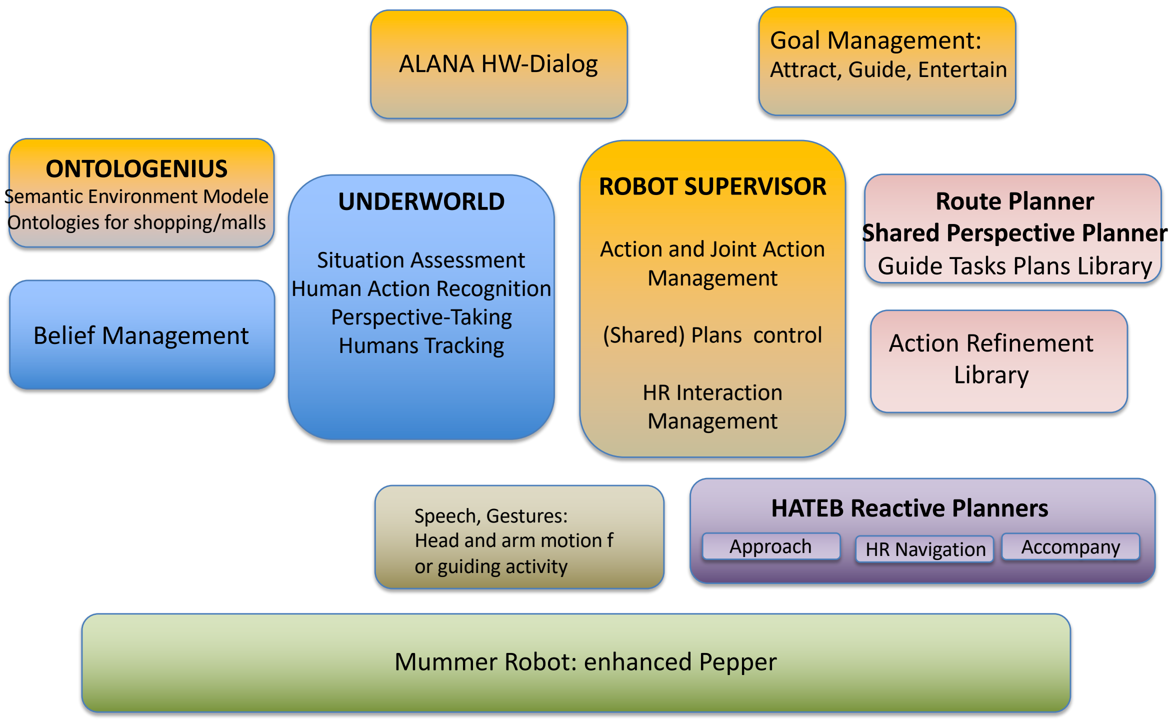


5.2. Instantiation of the Generic Architecture for MuMMER

An instantiation of the generic architecture has also been proposed and is already used to implement the route guiding task as a joint activity between the robot and a human or a group of humans.

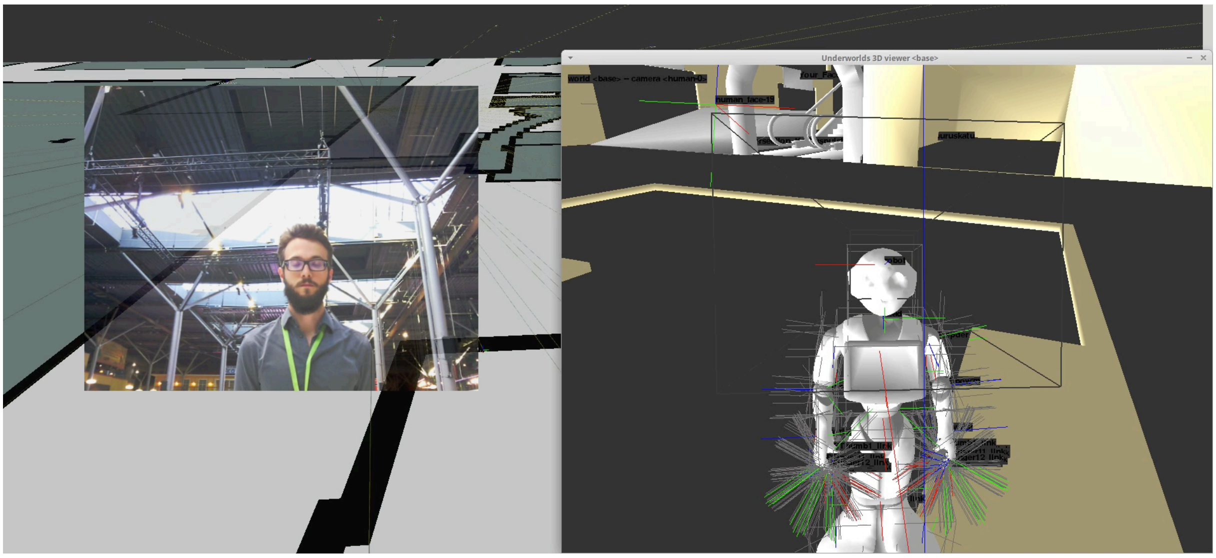
Several components have been adapted and will be tested and refined progressively:

- At supervision level: management of "interaction sessions": establishing a common goal, and commitment management at different levels of abstraction
- At supervision level: a permanent estimation of the joint activity: evaluating permanently the quality and the pertinence of the interaction, what can wrong, etc
- Perspective-taking planner: reasoning about human perspective, planning and achieving H&R Joint perspective
- Dialog based on a semantic description of the environment (encoded in the ontology) and on the use of a route planner and verbalisation system.



Some first experiments have already been tested but the overall integration of the MuMMER project has not yet been achieved.

First experiment of route guiding with effective planning and achievement of human and robot placement for shared perspective



Robot camera *Estimation of human perspective*

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