SAPHARI

SAFE AND AUTONOMOUS PHYSICAL HUMAN-AWARE ROBOT INTERACTION

SEVENTH FRAMEWORK PROGRAMME

COGNITIVE SYSTEMS & ROBOTICS

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Deliverable D7.2.1

An implemented human-aware navigation and placement planner

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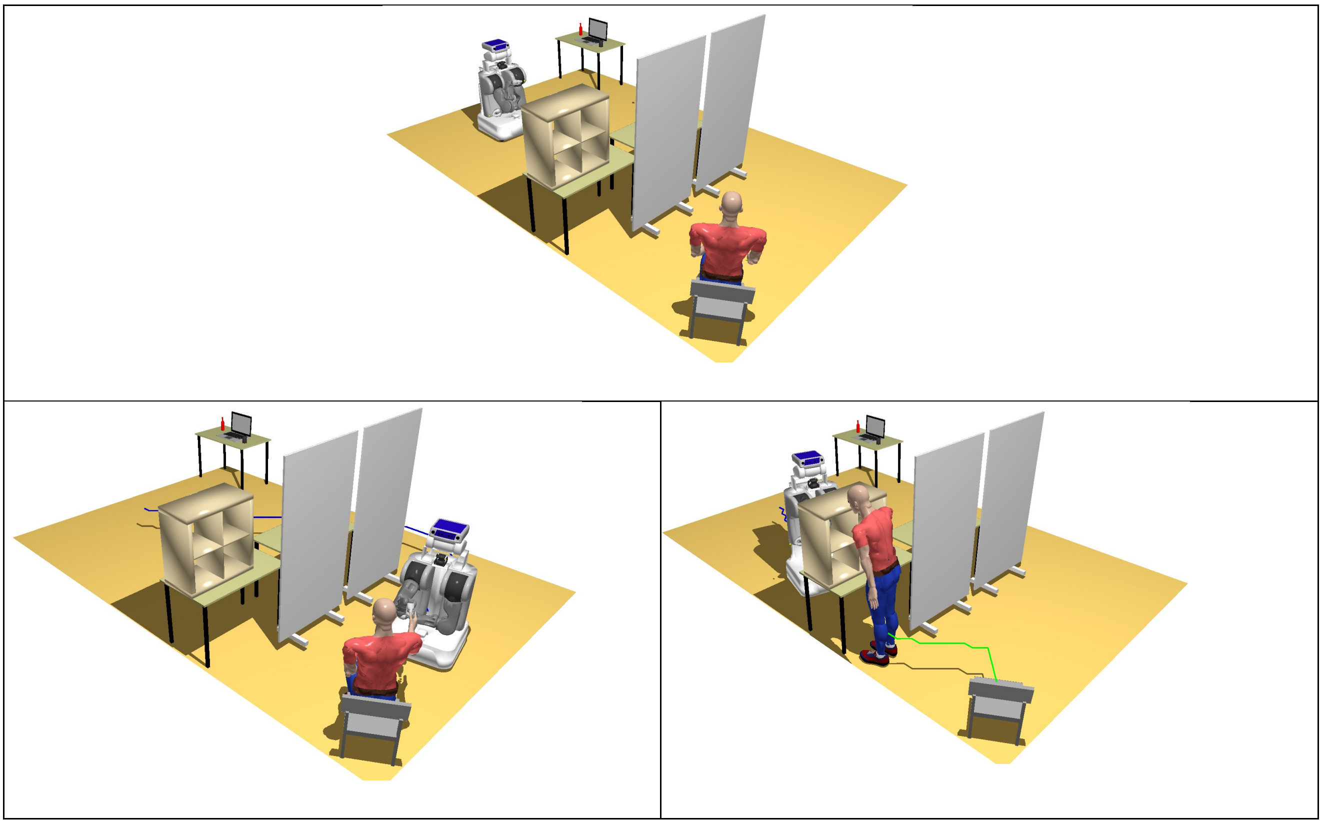
Executive Summary

This deliverable of workpackage WP7 reports on the availability of a software prototype of a human-aware navigation and placement planner. Indeed, there is a first issue, which is called human-aware or social navigation in dynamic environment populated by humans. Bur there is another aspect that we have investigated and to which we have proposed algorithms: it is important to take into account the nature of the subsequent action (a handover, a pick or a place, servicing a machine.). As a result, navigation involves two or several inter-related motions planning steps. The main constraint for a teammate robot is not only the feasibility of the task but also the human safety as well as acceptability and ease of legibility of the behavior of the robot by the human. We also contributed to a key notion in human-robot collaboration linked to the notion of balancing effort between robots and human depending on the context or on human desire.



Planning and exploring several strategies to achieve a hand-over task with the contribution of the human

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Introduction

This deliverable of workpackage WP7 reports on the availability of a software prototype of a human-aware navigation and placement planner. It is composed of several planners that can be used depending on the task and the context.

The next sections describe briefly the different planners essentially through illustration. We then report on its integration and use in SAPHARI. Detailed description of the algorithms is available in the published papers listed at the end of the document.

Planning human-aware navigation

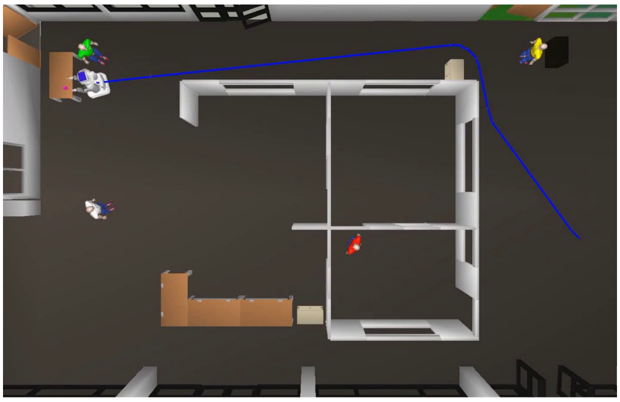
The planning of robot navigation motions uses an A* algorithm in a 2D grid. We use it not only to find a short path, but also a low-cost one. Grid cells are weighted with a cost relative to the distance to the humans and their orientation. So the robot path will avoid getting close to human, and will not approach them in their back.

We are currently considering the following criteria:

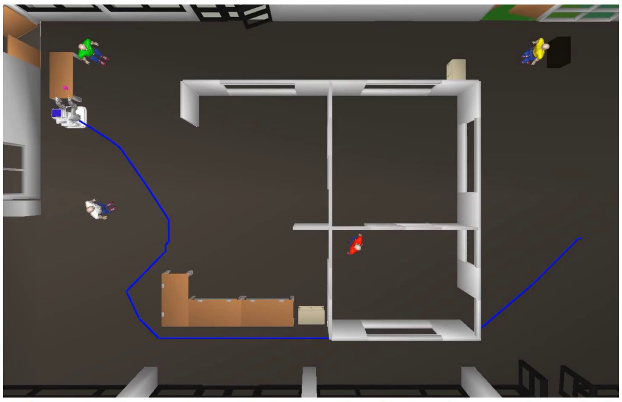
- Distance: it is essential to avoid obstacles whether they are humans or not. But, we add an additional cost if the closest obstacle is a human. This allows us to take into account the uncertainty in human sensing and human motion.
- Visibility: the sooner the robot enters the field of view of the humans, the better it is in order to avoid surprise.
- Reachability: we use this costmap to reduce discomfort during handovers: it is indeed preferable to exchange an object where the robot and the human are « face-to-face ».

In addition, we also are decomposing every motion into 3 sub-motions. This aims to increase the legibility of the robot behavior. The 3 steps are:

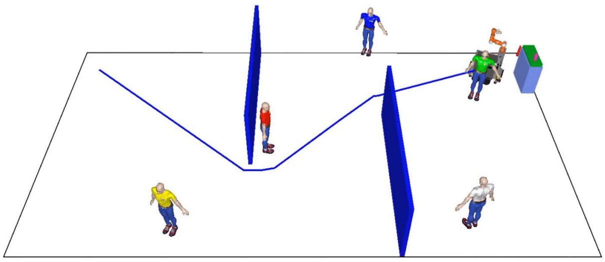
- Disengagement: the robot moves away from the human, not necessarily towards the goal
- Navigation: the robot moves to a location near the goal position
- Reengagement: the robot moves to the human and the goal position



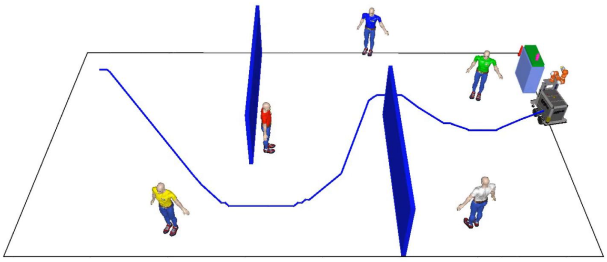
When using a standard navigation planner, the robot minimizes the travel time and passes very close to the human in yellow.



When using Human-Aware Navigation, the planner chooses a longer but more confortable and safe path and stays far enough from the human in white



Non Human-Aware Navigation implies navigating close to humans, and choosing the closest final configuration which appears to be too close to the human in green and uncomfortable.



Human-Aware Navigation enables to travel far enough from humans and to choose a better final configuration where the robot does not disturb humans.

This component is fully functional and has been integrated and made available in demos involving the full robot decisional capabilities and also provided to the AIRBUS T8.3 use case.

Planning human-aware collaborative motion in navigation

While human-aware navigation is an important ability for a teammate robot, it appears that it is important to integrate to the planning the subsequent action. Indeed, very often, there is latitude to adapt the motion or even to select in a relevant manner the target position of the navigation task. For example, it can be very pertinent to integrate in the reasoning the planning of the appropriate relative placement of the robot and the human be based, for instance on spatial perspective-taking, affordance to ensure or specific constraint to satisfy (e.g. reachability and or visibility of an object by the human partner). In the following we summarize the planners developed for human-robot handovers.

Planning human-aware navigation and approach for an handover task

Consequently, we have developed a new and more elaborate task planner for hand-over. Here the task is seen as an instance of a collaborative task. This becomes more clear in situations where the robot has to hand over an object to its human partner but there is no possibility for the robot to reach the human if the human stays where he is.

Hence, the robot must take explicitly into account the human, his abilities and his preferences. As the human is able to move, the robot should account for his desire to participate actively in the handover process without discarding the notion of comfort during the interaction. We have formalized these constraints and the hand-over planning problem that consists of finding handover configurations specified by the robot and the human full postures. We have then developed an algorithm to solve this problem and implemented it on the PR2 robot [Mainprice12]. The algorithm plans for the motion of the human as well as the robot and can be described as follow:

The method loops over the following steps, until no more better handover configuration is found:

Sampling human positions: finding some positions that are accessible for the human, and where the handover might be possible.

Finding a handover configuration: The choice is done among a predefined set of configurations that are loaded in the initialization phase. The chosen configuration is one that is collision free, and which the robot can reach from its current location.

Choosing the best configuration: regarding the preferences of the human, a configuration comfort cost is computed.

This algorithm enables to find solutions for easy and simple scenarios, as well as for more cluttered scenes, such as disconnected workspaces where the solution can only be found over a counter or through a window. In addition to that, we have introduced the notion of mobility to tune the amount of effort asked to the human: if the human wants the object as fast as possible, the robot will plan for both protagonist a place where they share the effort, otherwise, the robot will plan a way to decrease human efforts (see Figures 1 to 3)

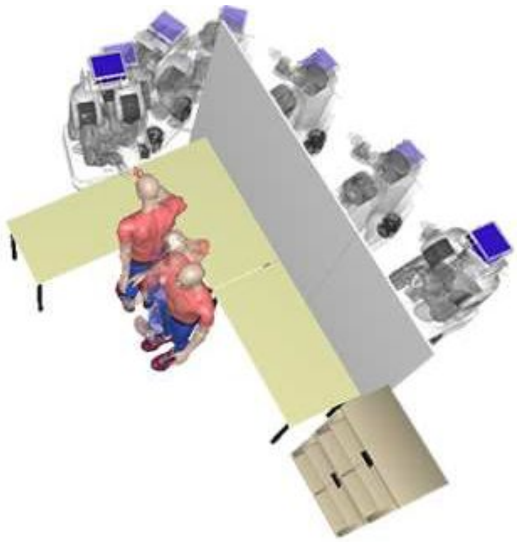


Figure 1: A example where planning for a hand-over configuration needs both the human and the robot to move

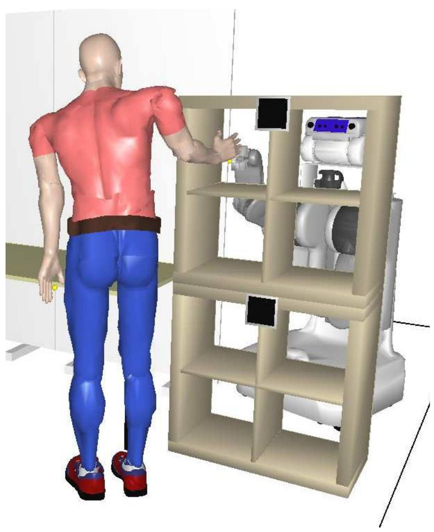


Figure 2: Finding a non-trivial hand-over human-robot placement

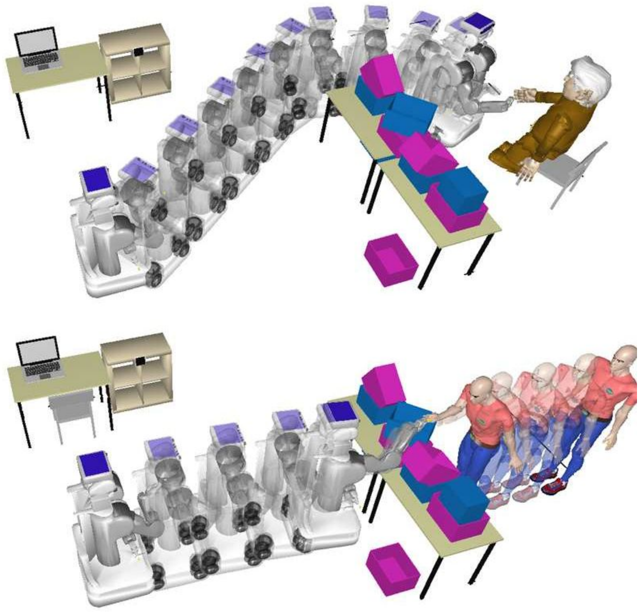


Figure 3: Choosing a hand-over configuration based on various levels of human efforts

The planner has been fully implemented the planner and integrated it on a physical robot: a PR2 from Willow Garage. The system includes a full scenario where the robot perceives the human position and posture (using a Kinect for instance) and synthesizes and executes a hand-over plan (see [Gharbi13]).

Figure 4: Implementation of the hand over navigation planner on the PR2 robot

Hence, the planning of the appropriate relative placement of the robot and the human will be based on the notion of affordances and perspective taking.

Multi-handover planner

This second planning component extends the work presented last year with the capacity of exchanging objects between multiple agents, robots and/or humans. The objective is not only to find the sequence of actions but also to determine where the exchange of object can take place and to minimize the efforts of each agent.

Our current implementation uses a 2D pre-computed grid representing the position of the agent holding the object. In order to travel from one node to another, there are 2 possibilities: the holding agent moves or the object is transferred to another agent.

In the first case, the cost of the action is only the motion cost; our current work consists in using human-aware planning in order to compute it.

In the second case, we take into account the motion of the agent from its previous position to the transfer position plus the cost of the actual transfer (infinite if there is no achievable solution, null if it is between robots, « human-aware » if at least one of the agent is human).

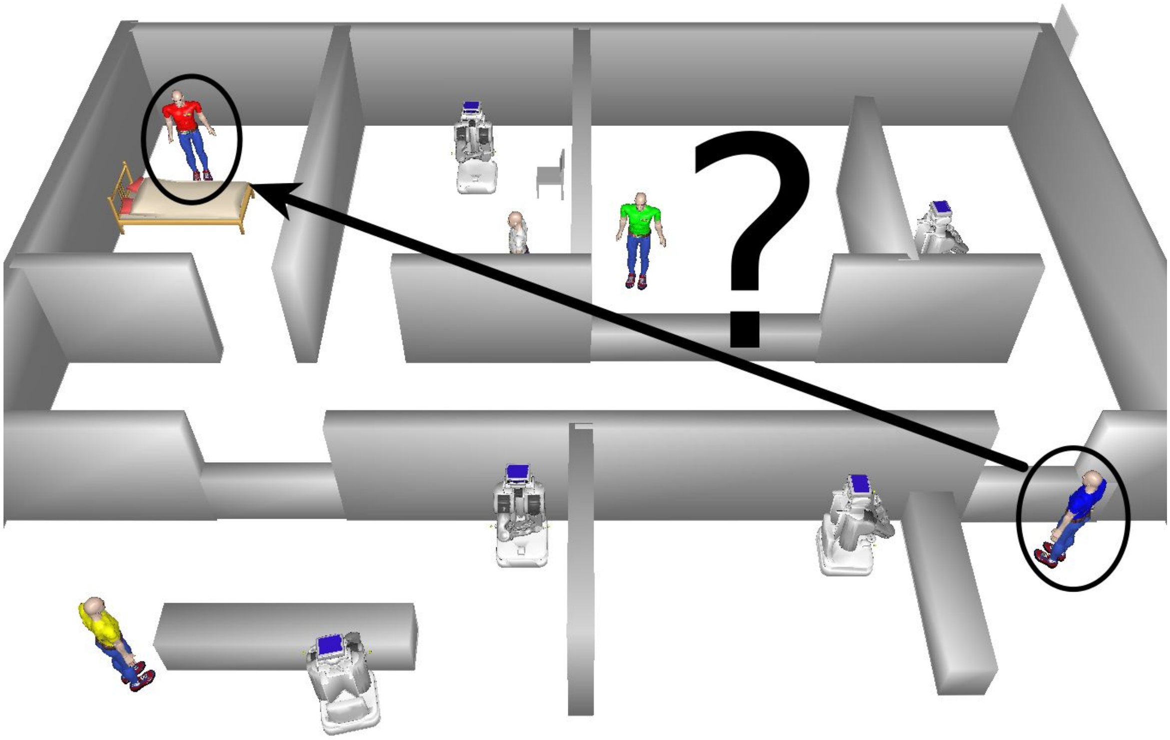


Figure 5: The human in blue wants to give an object to the human in red

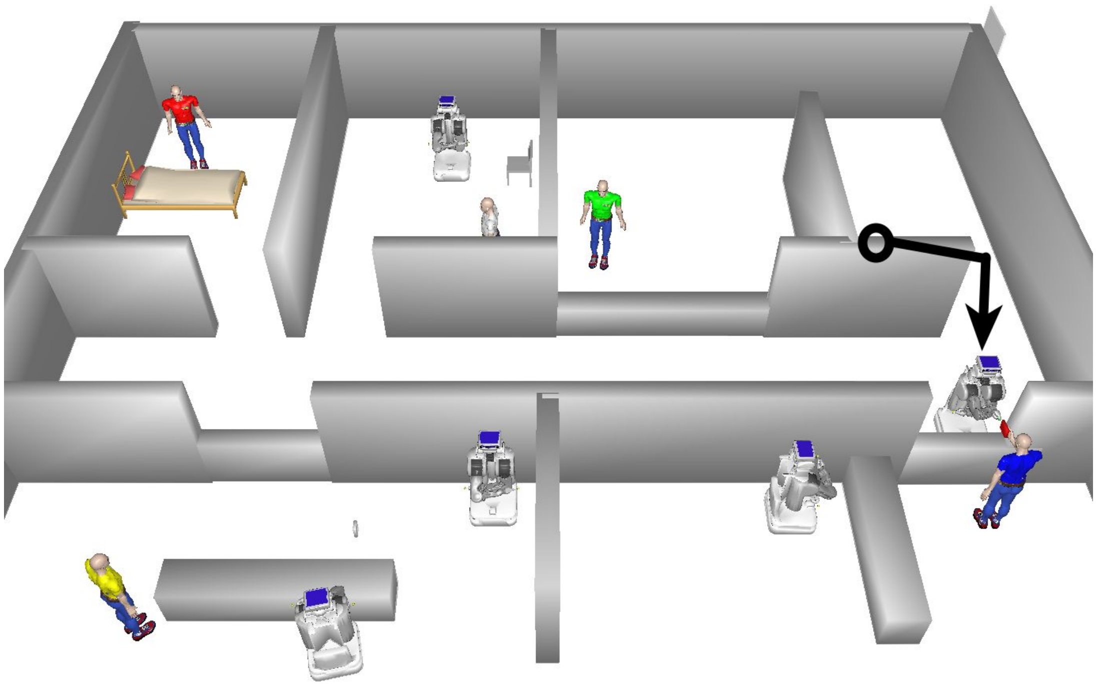


Figure 6: The planner chooses a robot to go and get the object from the first human

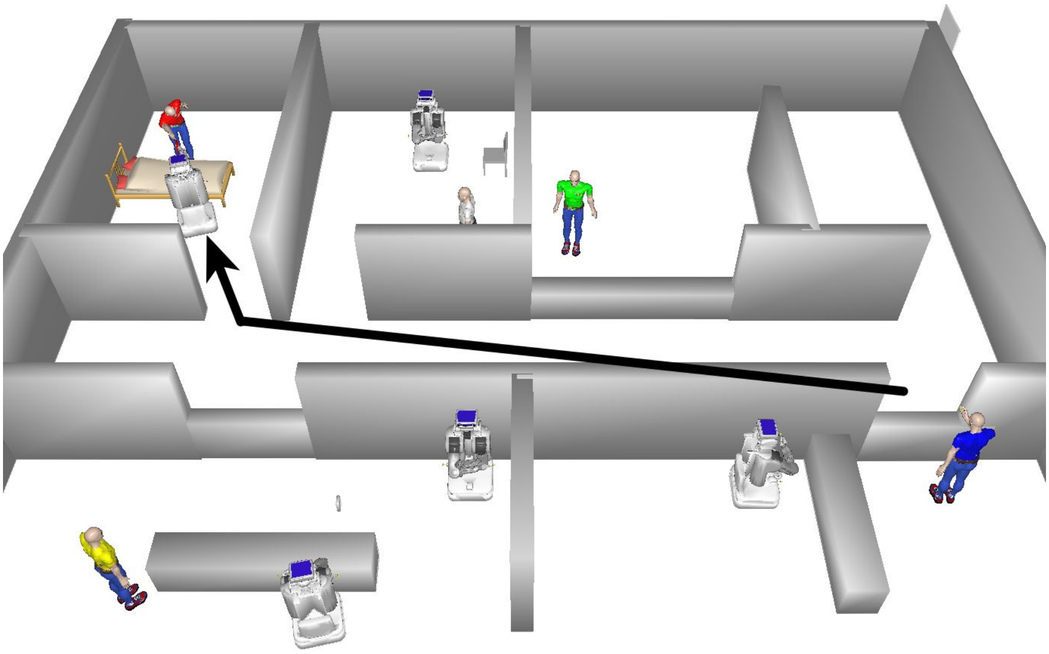


Figure 7: The robot gives it to the second human. Note the placements of the humans: They are computed by the planner in order to find a pertinent way to hand out the object.

Software use and results

Since this document has been delivered with delay, we take the opportunity to mention that the set of planners prototypes describes here have been used extensively in the framework of SAPHARI and also in other projects (for instance SPENCER STREP FP7 project and MARDI French National project supported by ANR).

In the framework of SAPHARI they have enriched the set of planning primitives used to plan human-robot collaborative task as well as service tasks (see D7.3.1 where the GRP framework is described. Consequently the software prototype of human-aware navigation and placement planner has been used on several types of robots: PR2s in the AIRBUS use case mock-up deployed at LAAS, AIRBUS use case mobile manipulator deployed in T8.3.

	
Initial situation: The green person needs an object near blue PR2	Step 1: Computation and motion for a first handover between blue PR2 and blue person (through a window)
	
Step 2: Second hand over between blue human and red PR2	Step 3: Finally red PR2 gives the object to green human

Figure 8: implementation of a multi-handover in the mock-up of the AIRBUS Ariadne use case deployed at LAAS (Other effort balance parameters would have provided different combinations of handovers)

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