Human-Robot Interaction: a New Challenge

Robotics and Artificial Intelligence

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Outline

- The personal robot assistant
- Motion, Manipulation and Task planning in Human (in-doors) Environments
  - HRI decisional and functional framework
  - Perception of the human
  - Navigation and Motion Planning
  - Manipulation and Interaction
  - Decision, Planning and Interaction
- Prospective

The Personal Robot Assistant

1. the robot should be able to operate in an environment which has been essentially designed for humans

2. the robot will have to perform its tasks in the presence of humans and even in interaction with them

- Task-Oriented:
  - How to perform a task, in presence or in interaction with humans, in the best possible way
  - Efficiency, Safety, Acceptability, Legibility

COGNIRON: The Cognitive Robot Companion Project http://www.cogniron.org

Some LAAS contributions

- We will review and discuss a (limited) number of results and on-going work that are relevant to robot action (motion and manipulation) in human environment and interaction with humans

Rackham

HRP2

Jido

Our objective: an integrative approach for a robot that acts in interaction with humans

- Work on Collaborative / Interactive task achievement
  - based on a study of human-robot interaction
  - inspired from Joint activity / teamwork
  - concretized as a set of robot decisional and functional abilities

- is progressively producing a coherent basis for **Joint Human-Robot Activity**

- HRI decisional and functional framework
- Perception of the human
- Navigation and Motion Planning
- Manipulation and Interaction
- Decision, Planning and Interaction

HRI Decisional Framework

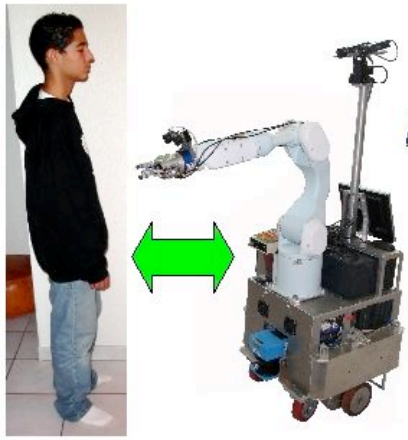
Detect Humans

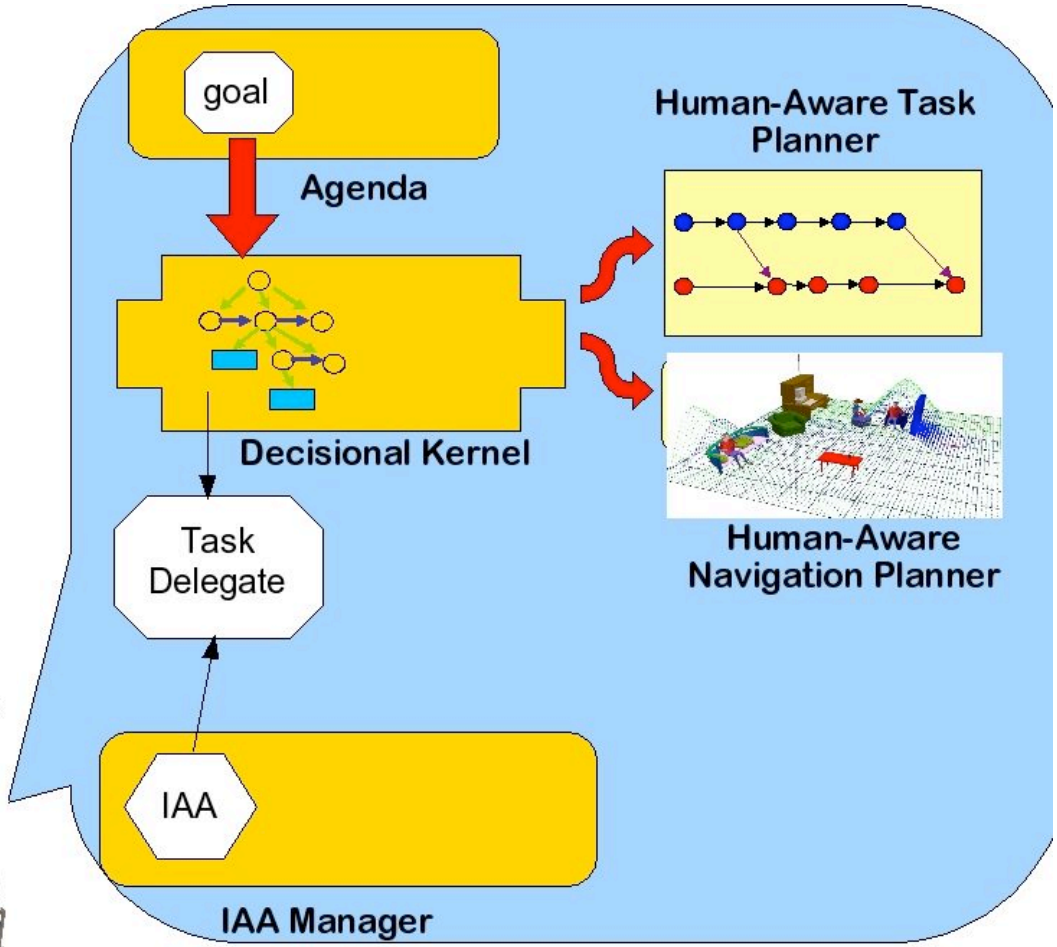
- Instantiate IAAs
- Task-Oriented Interaction with IAAs

A complete process of:

- establishing a joint goal,
- achieving it (in coordination)
- monitoring and reacting to the commitment level of the human partner

- Functiunal systems designed to work in human environment



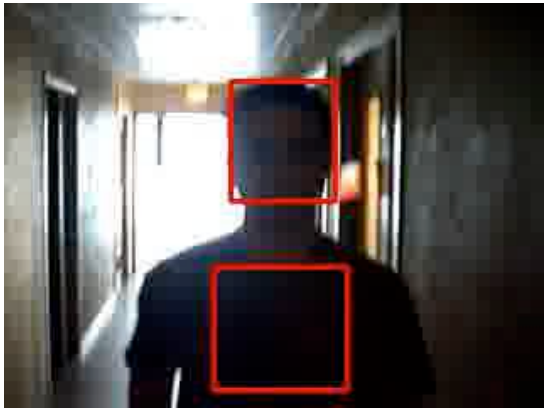


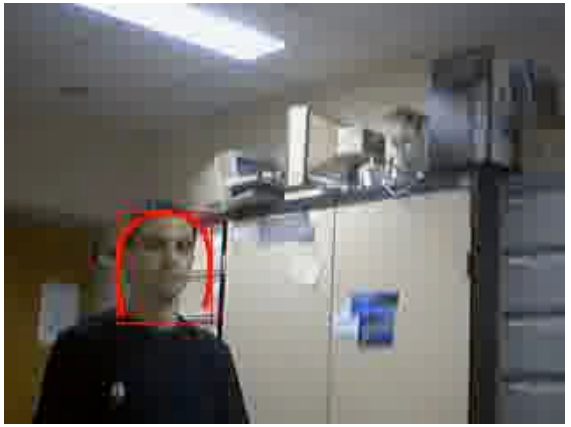
the IAA (InterAction Agent) represents the human state, abilities and preferences.

- HRI decisional and functional framework
- Perception of the human
- Navigation and Motion Planning
- Manipulation and Interaction
- Decision, Planning and Interaction

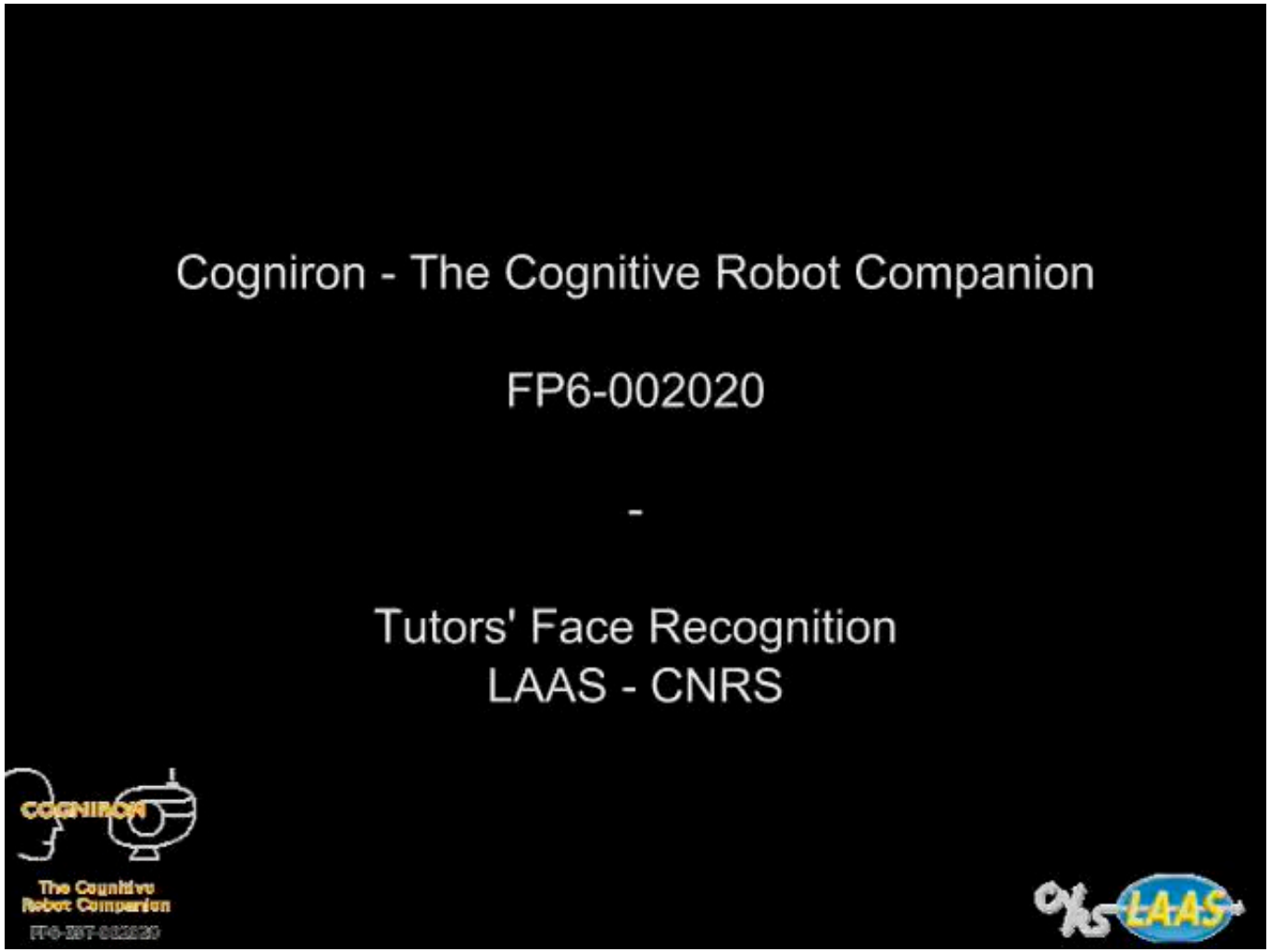
2D Visual Tracking of People

- 3 HRI modalities of 2D tracking strategies (associating several visual cues and several PF schemes)
  - long-range tracking
  - Intermediate distance tracking
  - short-range interaction partner tracking in an active interaction context
- Extensive evaluation in terms of…
  - error, failure ratio, processing time
  - …under several working conditions: "ordinary", illumination changes, dynamic jumps, presence of another human w/o occlusion, occlusion (either by a non-targeted object or by a human), target leaving and reentering the camera FOV,…





Face recognition



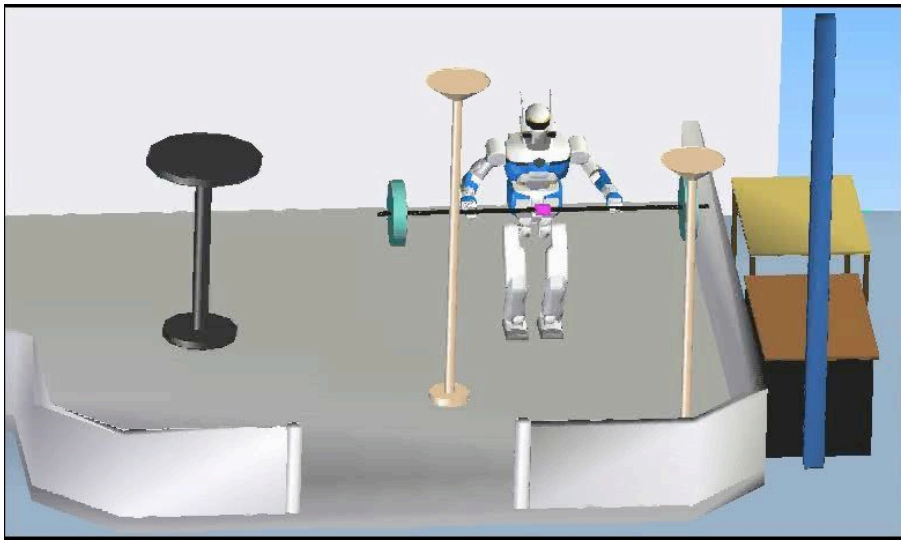
Lerasle, Germa, Danes, Fontmarthy, Brethes

Detecting and 3D-Tracking of Face and hands

Lerasle, Burger, Danes

- HRI decisional and functional framework
- Perception of the human
- Navigation and Motion Planning
  - Humanoid motion planning
  - Navigation in presence of humans
- Manipulation and Interaction
- Decision, Planning and Interaction

Motion Planning for a Humanoid

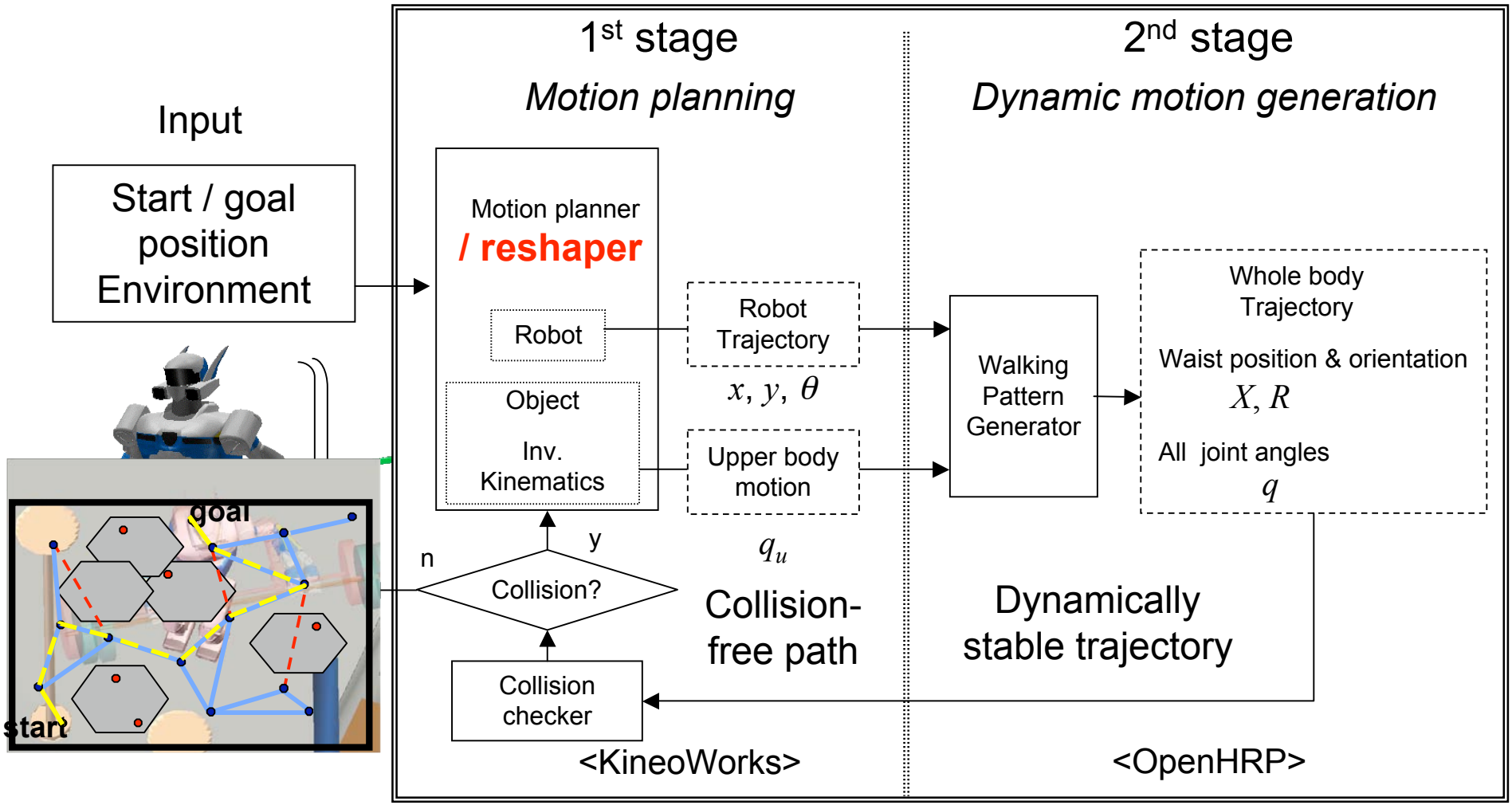


(Off-line planning)

Esteves, Laumond, Yoshida, Mallett

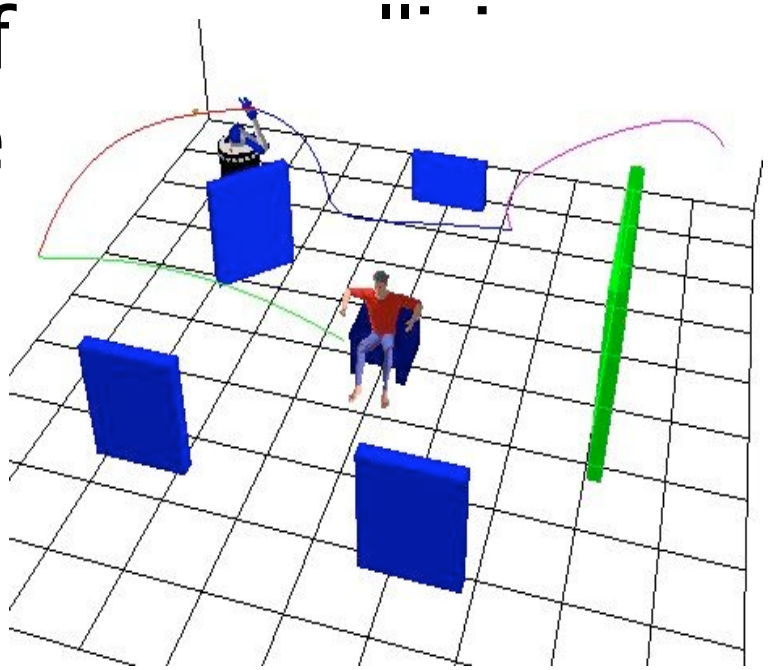
- 2-stage
  - Collision-free path planning
  - Dynamic trajectory generation
- Iterative
  - Interaction between 2 stages
  - Replanning & reshaping

Motion Planning for a Humanoid: 2-stage & iterative



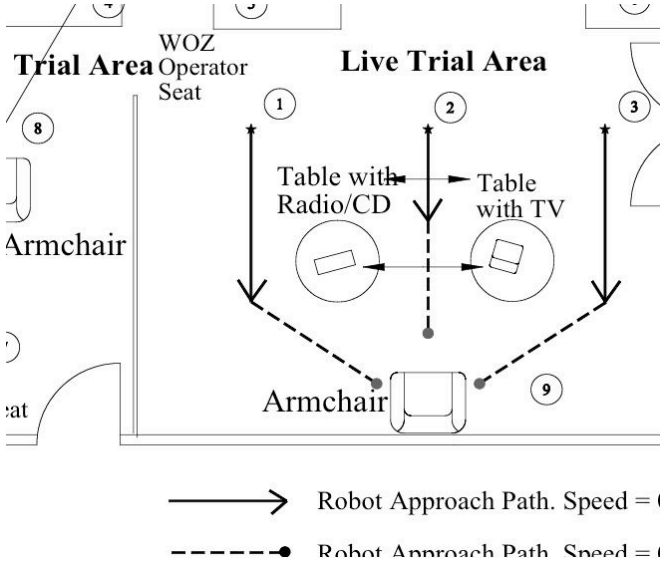
Navigation in presence of humans

- Classical Motion Planning methods do not take into account specifically the presence of humans: obstacle free paths, coordination f dead-lock avoidance

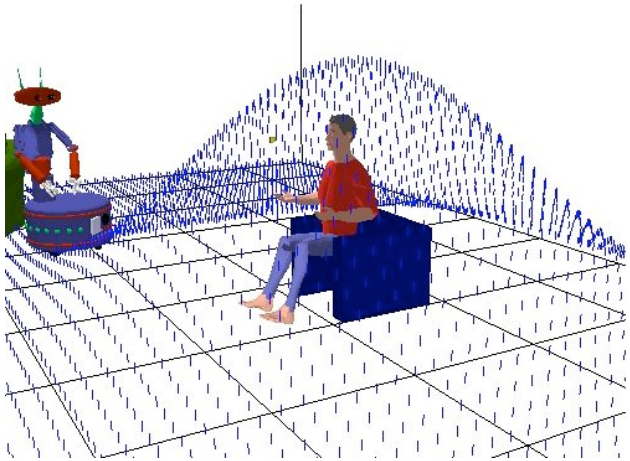


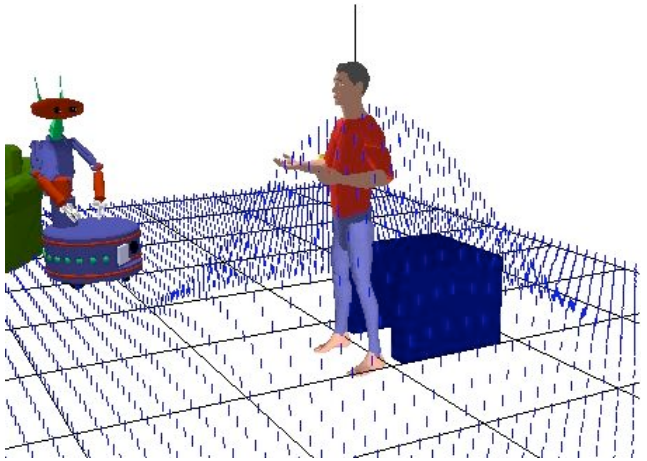
- Need to generate robot motion that is acceptable, legible and compliant with social rules

Parameters deduced from user trials

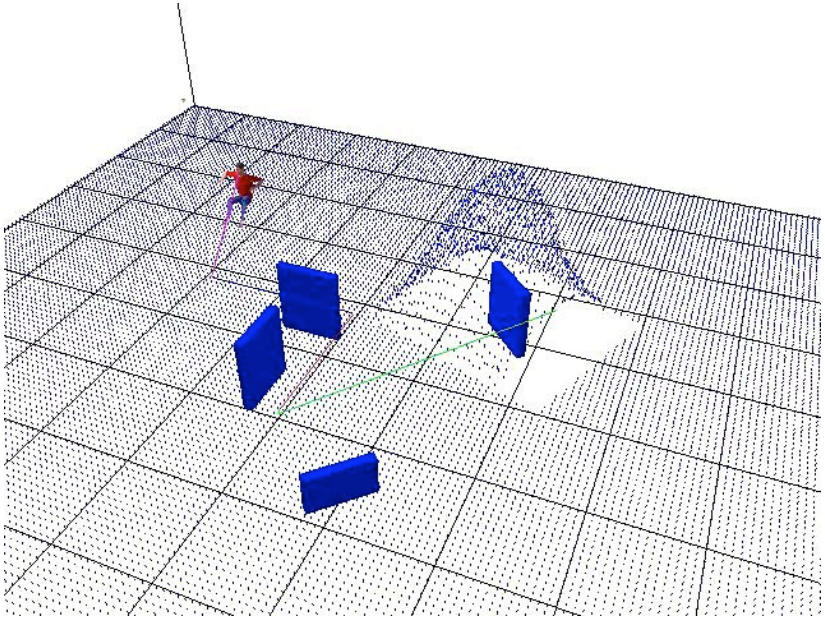


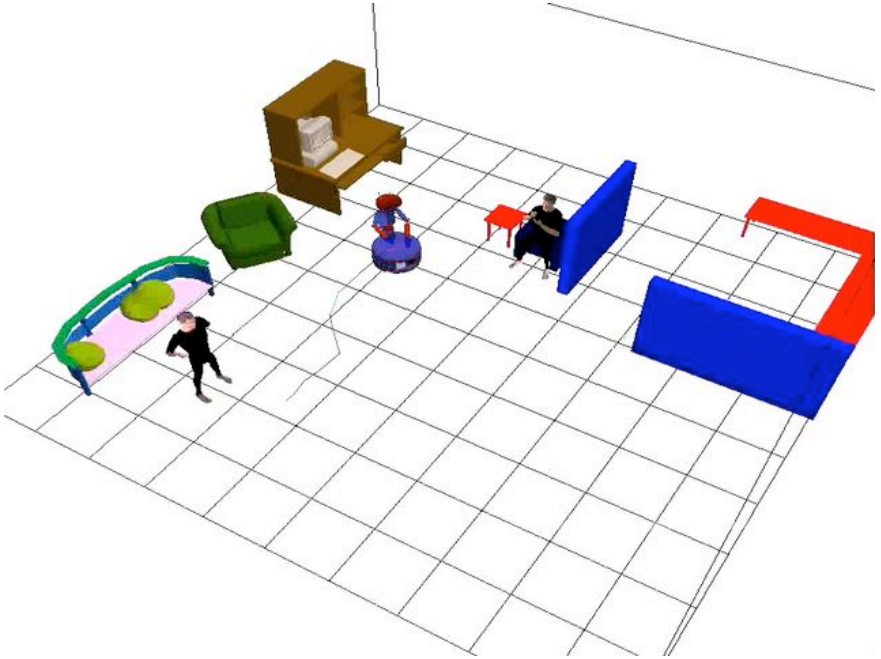
User trials performed at Univesity of Hertfordshire





Human-friendly navigation





Real-time cost evaluation:
distance, posture, visibility

Incremental path adaptation

Crossing

Avoiding to loom too close

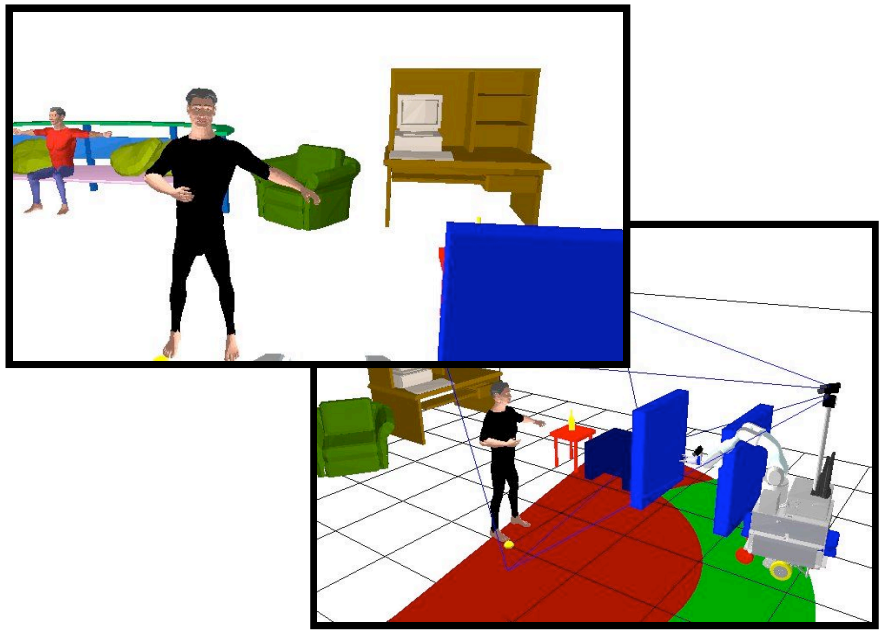
One key robot capability: reasoning about placements and perspectives

- Relative Placement and Motion with respect to humans and objects in an environment
- Reasoning on the human (and the robot) perception and manipulation abilities
- In order to answer a number of questions such as:
  - Can the human see that object ? Can the human see the a given part of the robot ? (perspective)
  - Can human reach an object (grasp)
  - Where to place the robot in order to be able to see simultaneously an object, the hand and the face of a human partner (home tour, object handing)

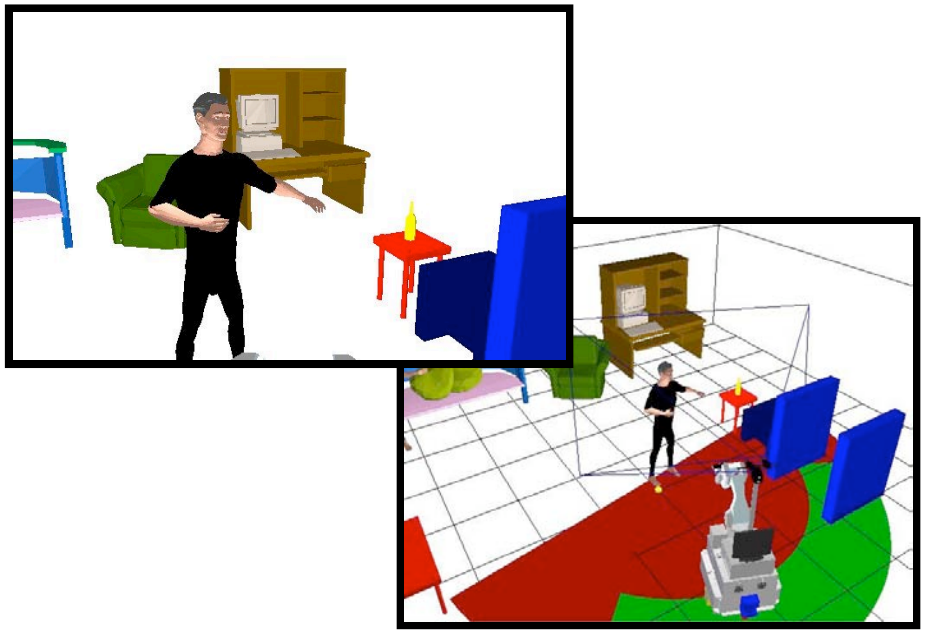
Perspective Placement

Robot (sensor) placement that satisfies:

- task feasibility,
- sensor placement for task monitoring (servoing),
- visibility by the person.

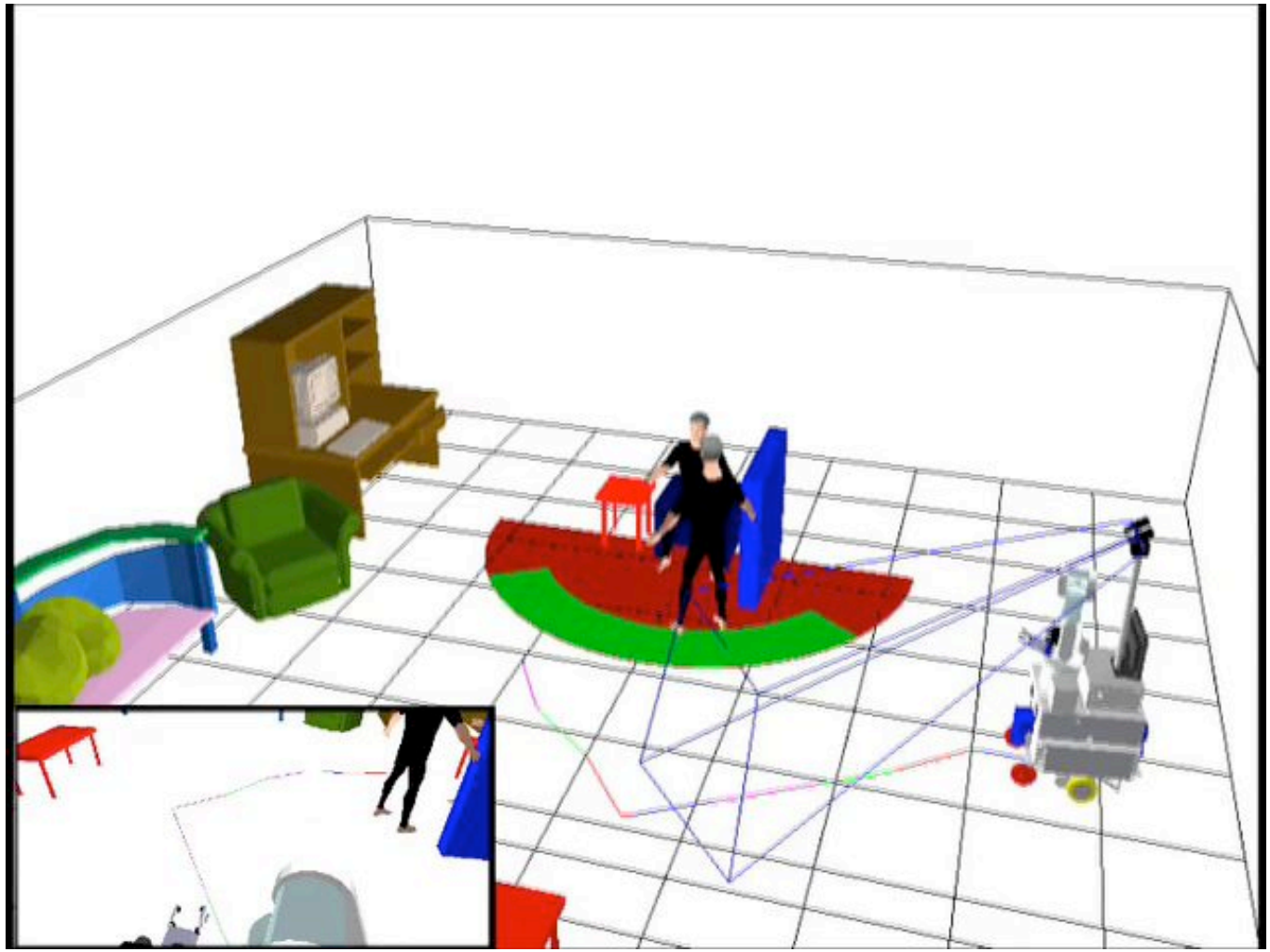


Pointed object not visible from the current Robot configuation



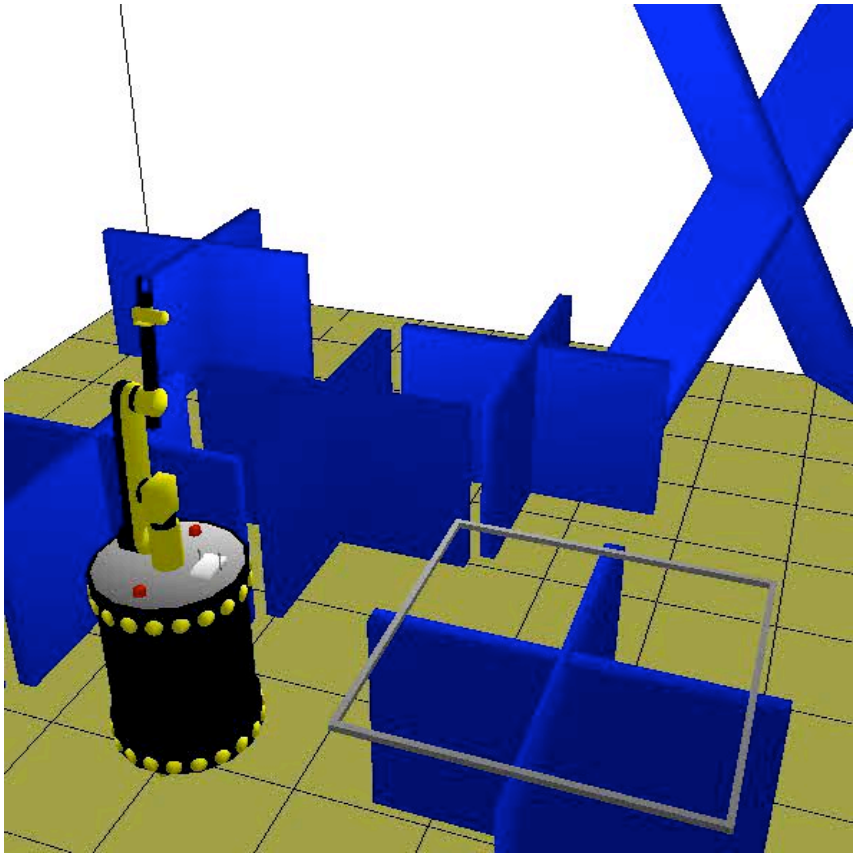
Robot moves to see the pointed object

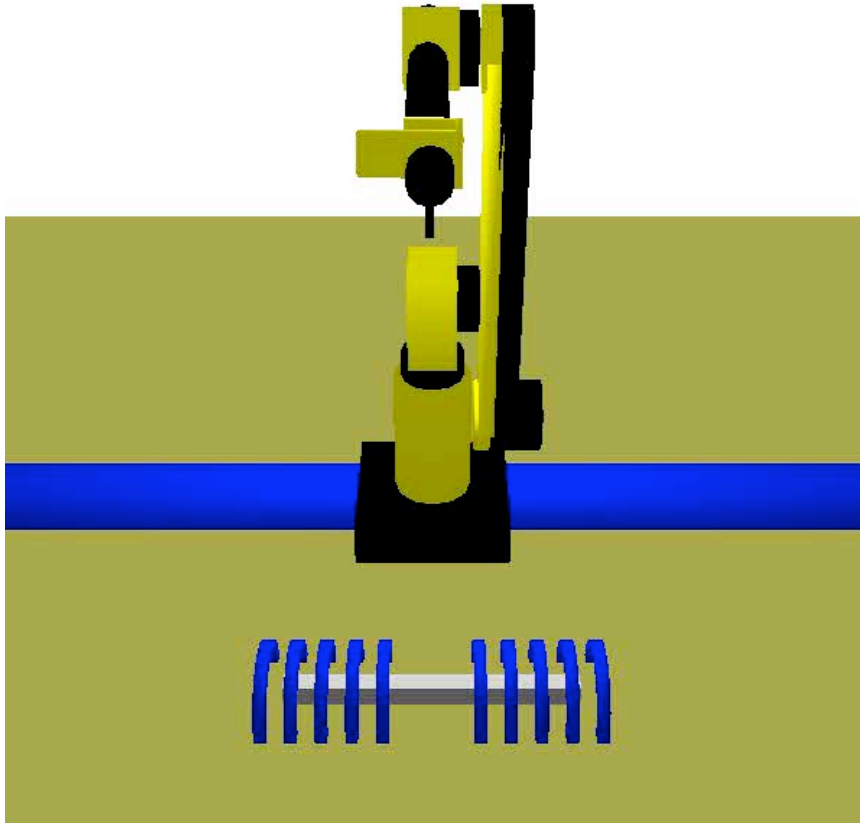
Perspective planning



- HRI decisional and functional framework
- Perception of the human
- Navigation and Motion Planning
- Manipulation and Interaction
  - Dynamics of the motion
  - Object grasping
  - Handing an object to a person
  - Bulky objects manipulation by a Humanoid robot
- Decision, Planning and Interaction

Manipulation Planning: a framework for solving intricate symbolic and geometric constraints

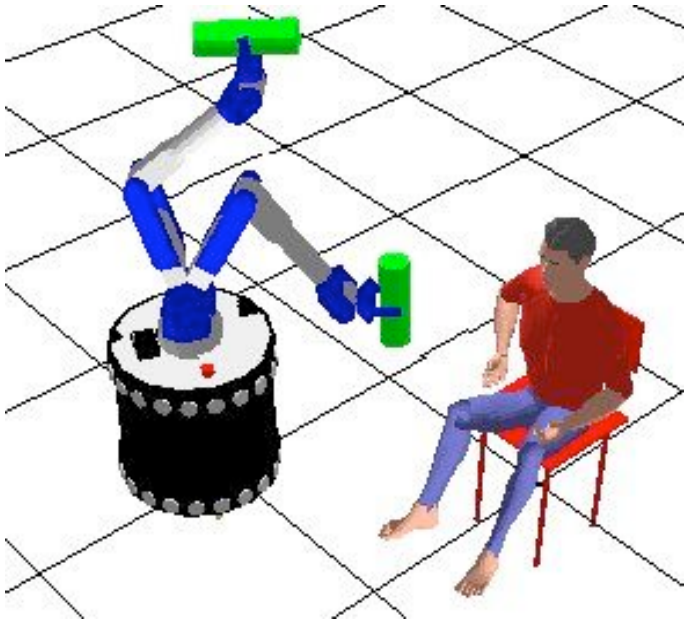




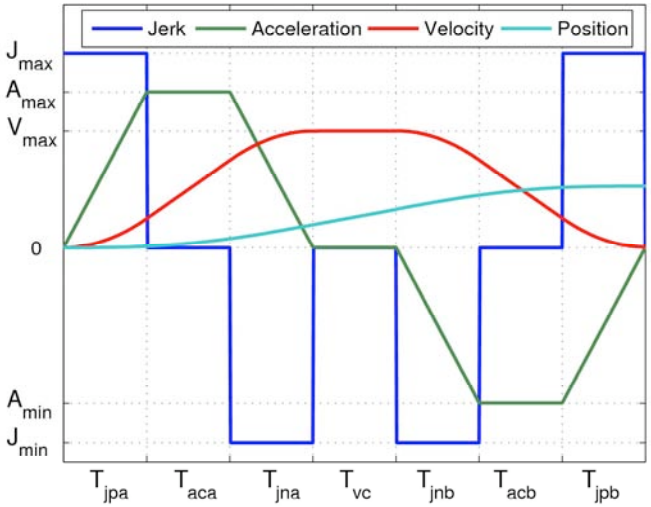
A formulation that allows to identify various manifolds in the confugration space
Transit and transfer motions
Manipulation task: a sequence of transfer and transit actions

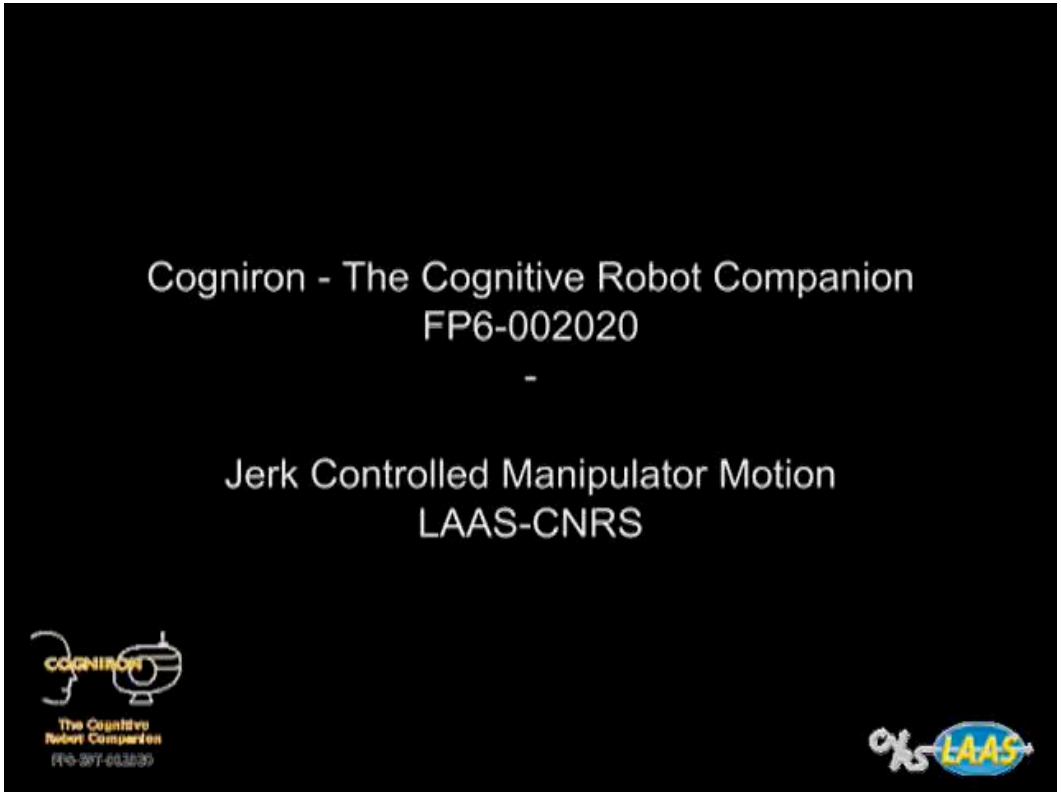
What Manipulation? Where ? How ?

- In the close proximity of the human,
  - the robot must not cause fear or surprise
  - the motion of the robot must be predictable
  - the robot must respect the humans preference zones
- Not only the robot motion and the speed but also robot postures have to be adapted to human needs and preferences



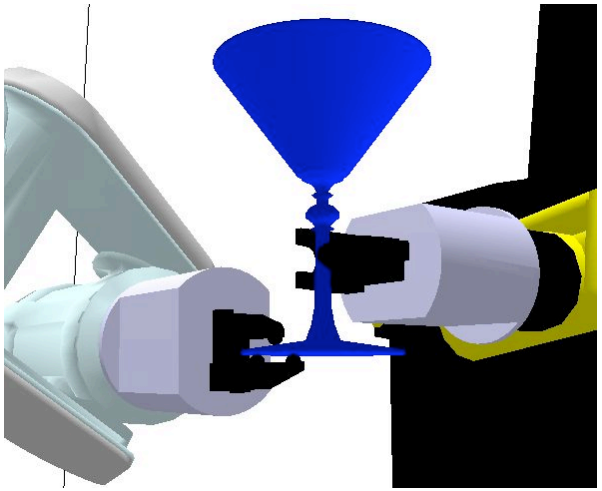
Smooth motion

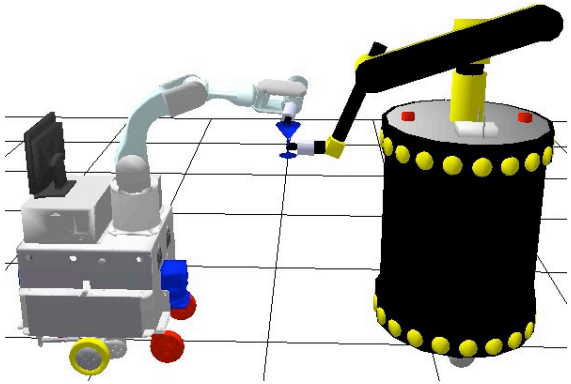


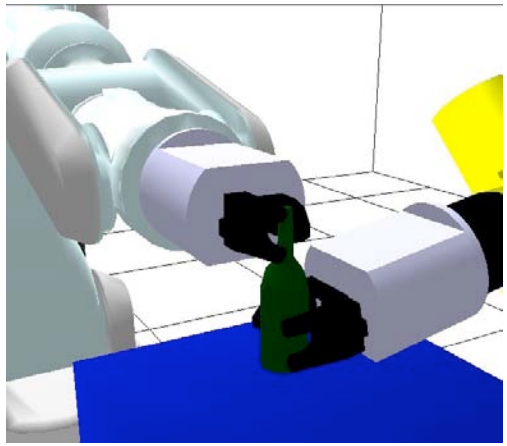


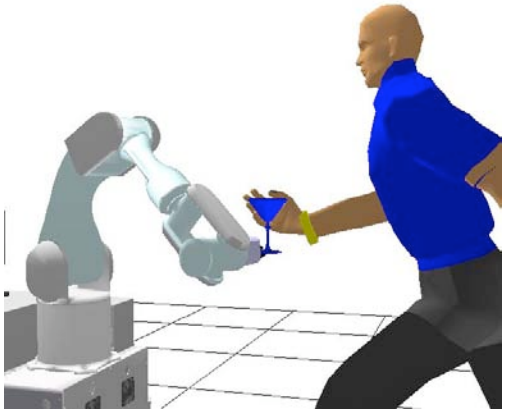
- Bounded velocity acceleration and jerk
- Soft trajectory planning : seven cubic polynomial curves

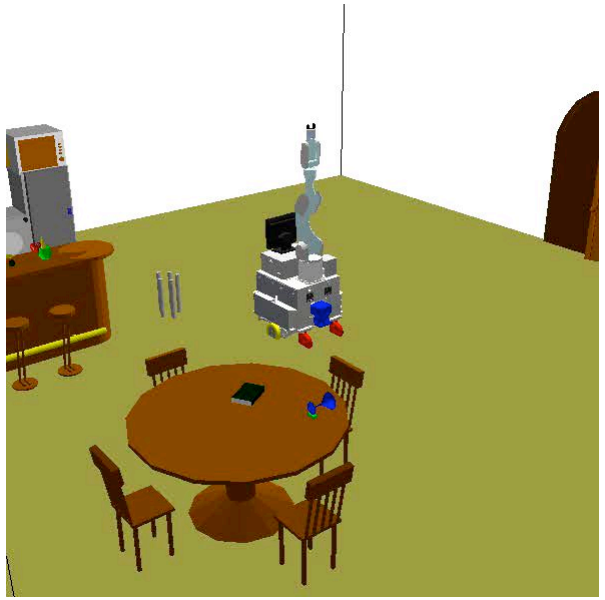
« Double-Grasp » for handing objects





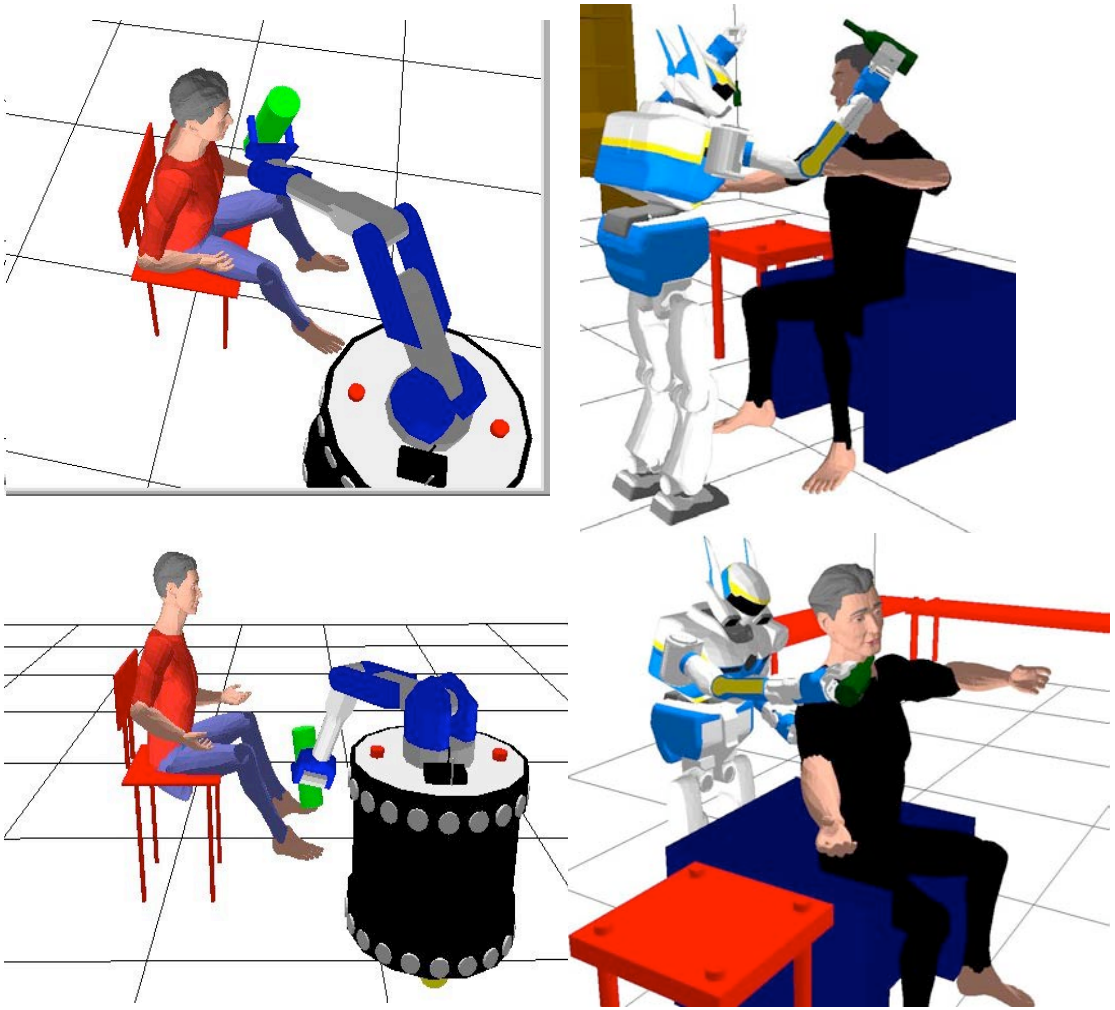




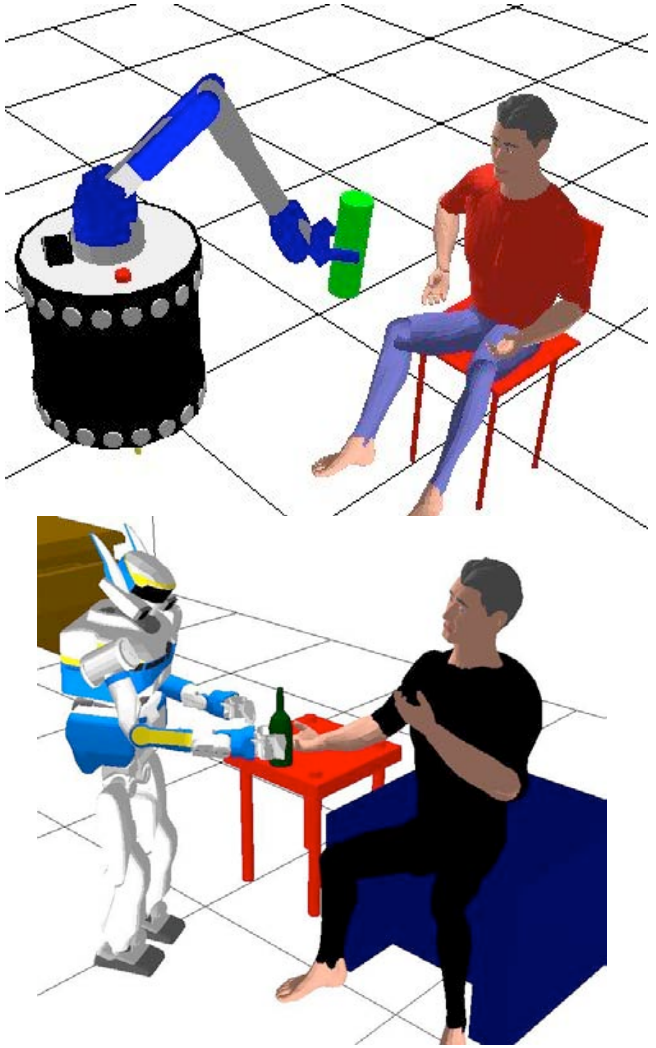


Lopez-Damain, Sidobre

How to hand an object to a person?

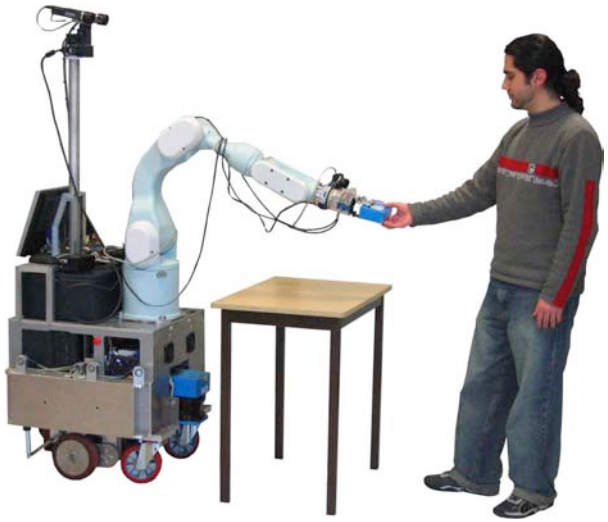


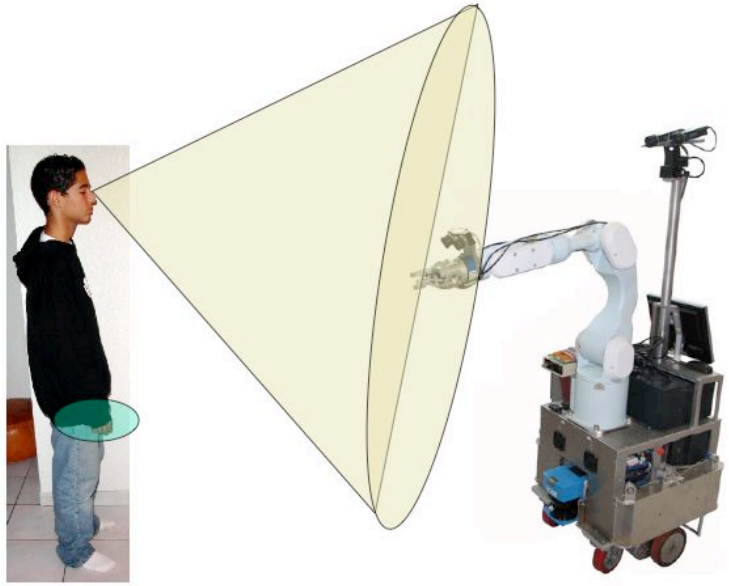
Undesirable Placements /Motions



“acceptable” placements

How to hand an object to a person?

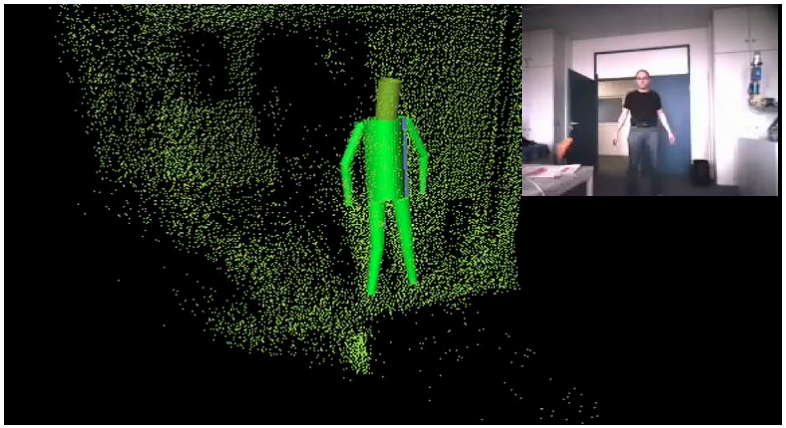


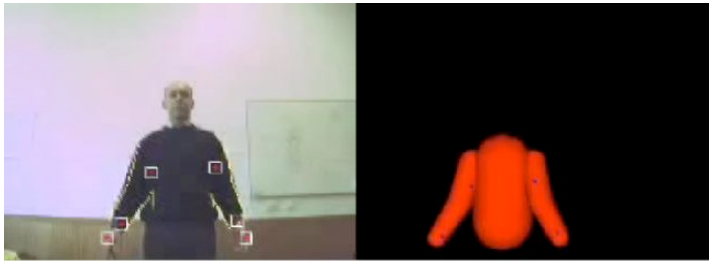


Kinematic reachability

Field of sight

Trajectory and Motion dynamics



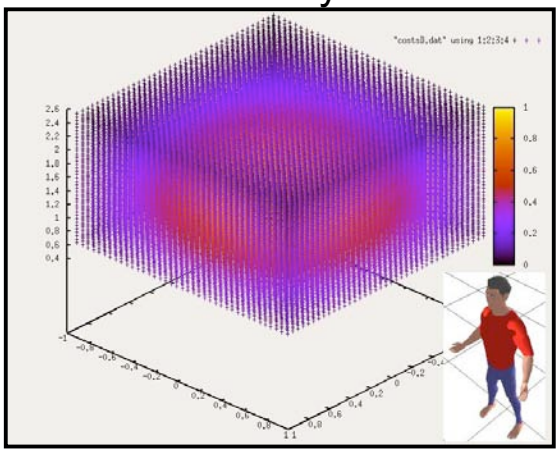


Human Aware Manipulation Planner (HAMP)

Calculating object position

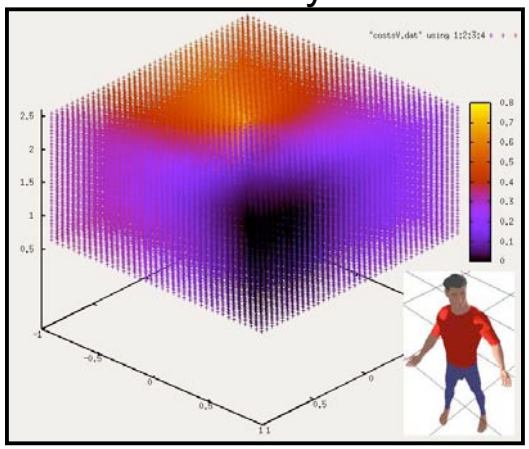
- The object should be placed in a safe and comfortable position.
- 3 different HRI properties are defined and represented as 3D cost grids around the human

Safety



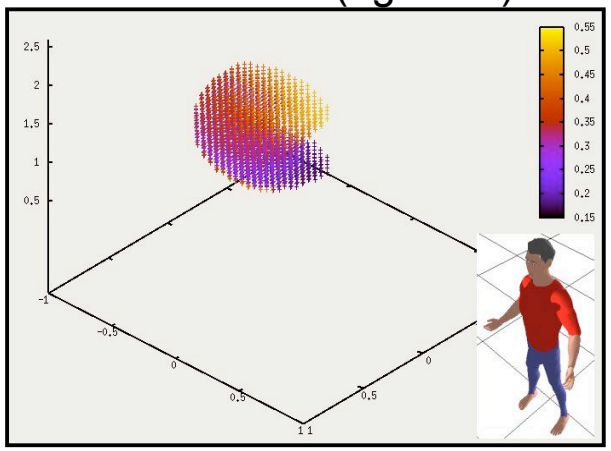
Proportional to the distance to human

Visibility



Reflects the effort to see a point

Arm Comfort(right/left)



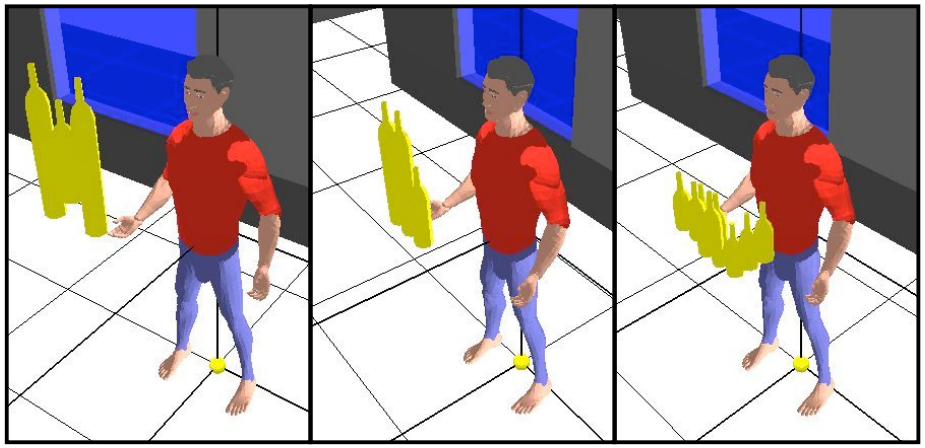
Combination of d.o.f difference and potential energy

COGNIRON

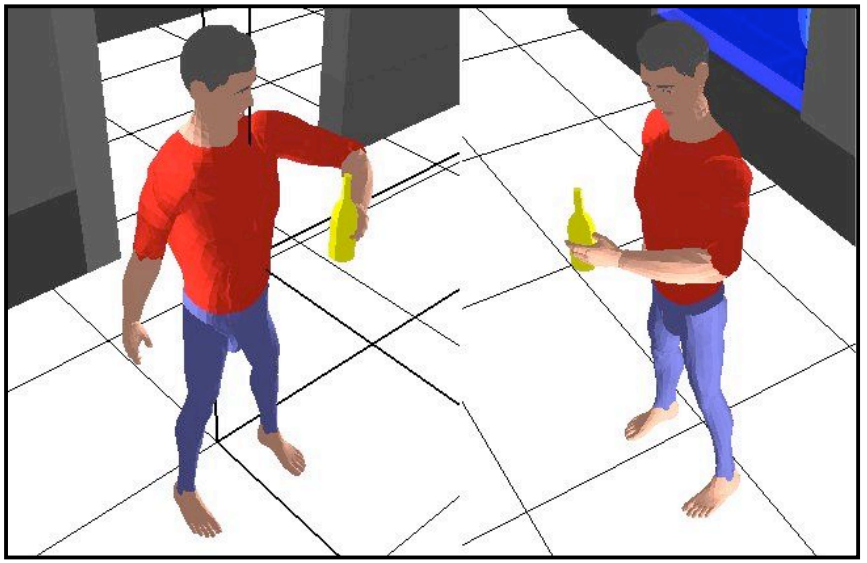
Human Aware Manipulation Planner (HAMP)

1- Calculating object position

- 3 grids are combined to form a final grid that merges all these properties.
- The cell with minimum cost is chosen to be the place where robot will place the object.



Dist > Vis >AC Vis > Dis > AC AC > Vis > Dis



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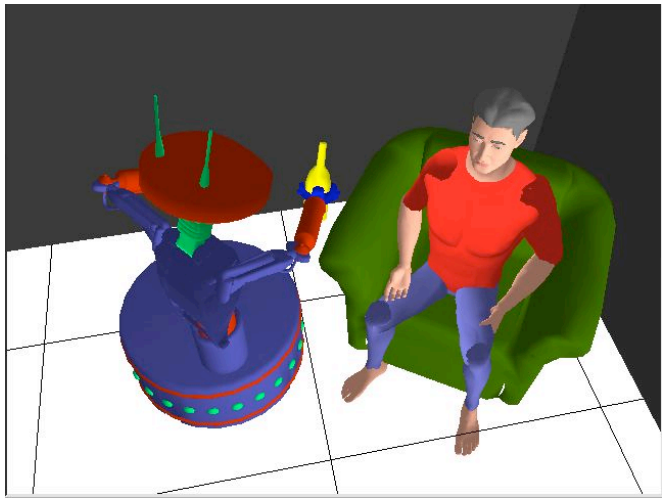
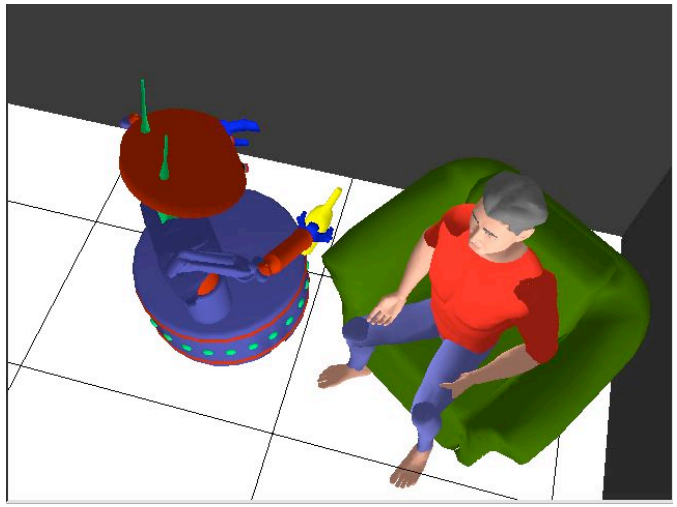
Human Aware Manipulation Planner (HAMP)

Calculating robot path



No human aware motion



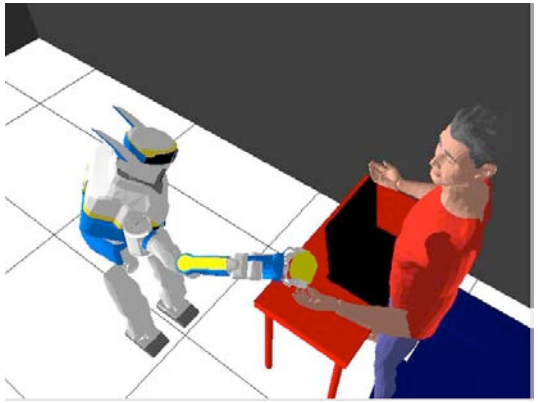
Human aware motion with 2 motion tasks:

- Follow the object path
- Look to the object

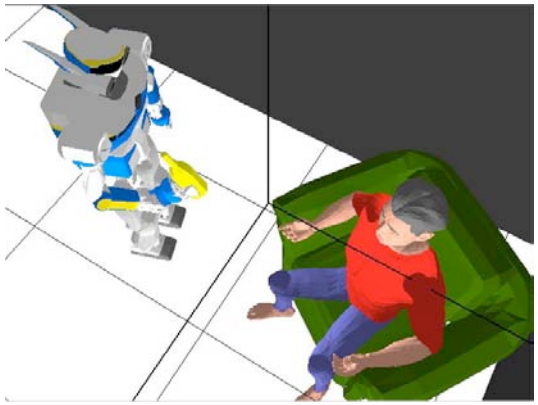
Human Aware Manipulation Planner (HAMP)

Calculating robot path

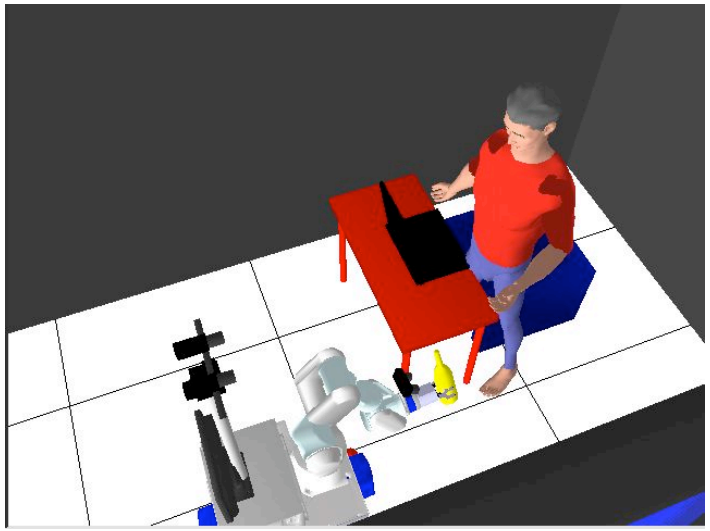
Humanoid, HRP-2 with 2 motion tasks, left handed, standing person



Humanoid, HRP-2 with 2 motion tasks, right handed, sitting person



Easily adaptable to different types of robots

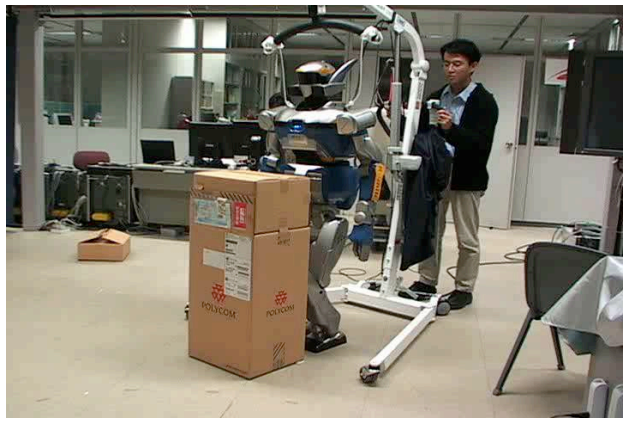


Mobile manipulator, Jido with one task, right handed, standing person

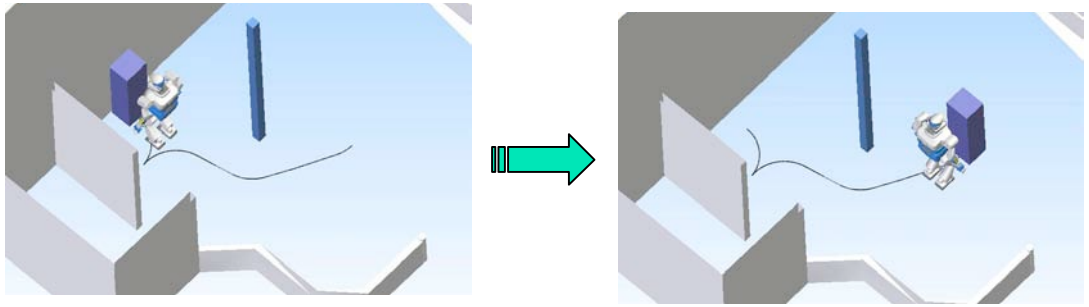
Pivoting: manipulating bulky objects

- Pivoting manipulation

[Yoshida et al. 06, *J. Applied Bionics and Biomechanics*]



- Few motion planning for humanoid manipulation



Start

Goal

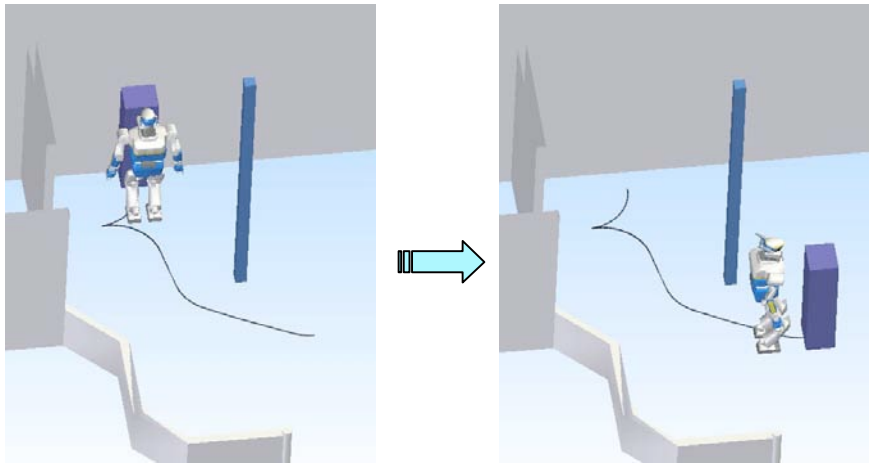
- Collision-free motion planning

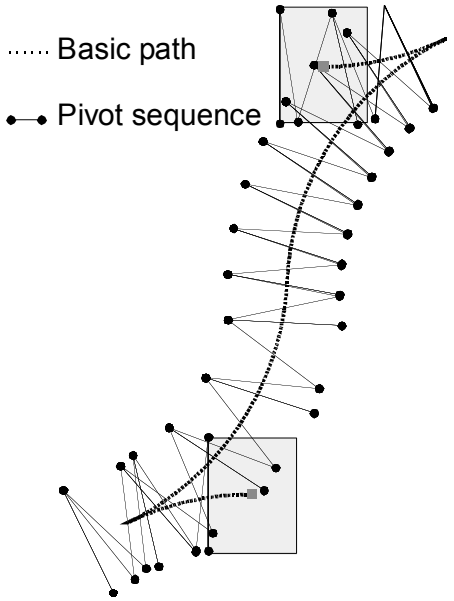
+

- Whole-body motion

"Pivoting" is small-time controllable

- 2-stage collision-free path planning





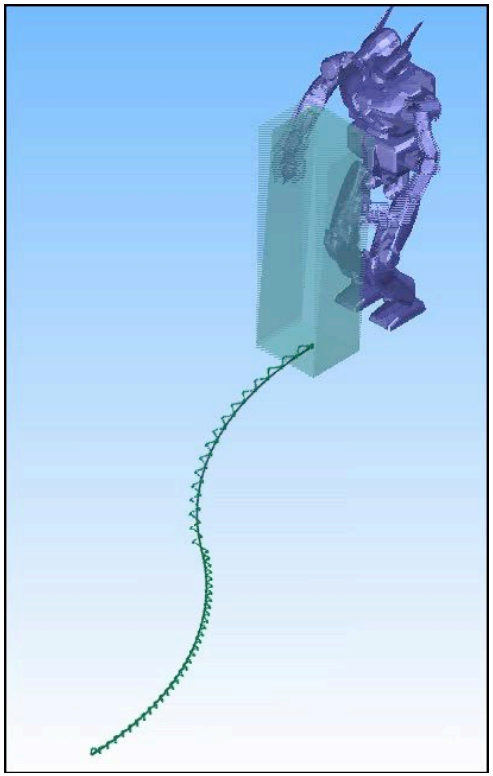
1st stage: Collision-free smooth path
(Reeds & Shepp curve,
small-time controllable)

2nd stage: Pivot sequence

[Yoshida et al. 07, *IROS*]

Planning and Experiments

- Applying whole-body motion generator [Yoshida et al. 06, *Humanoids*]



[Yoshida et al. 08, *ICRA, submitted*]

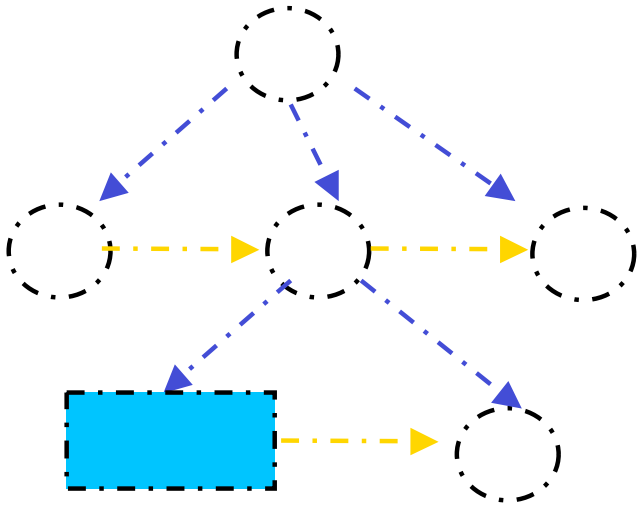
- HRI decisional and functional framework
- Perception of the human
- Navigation and Motion Planning
- Manipulation and Interaction
- Decision
  - Decisional interaction
  - Human Aware Task Planning

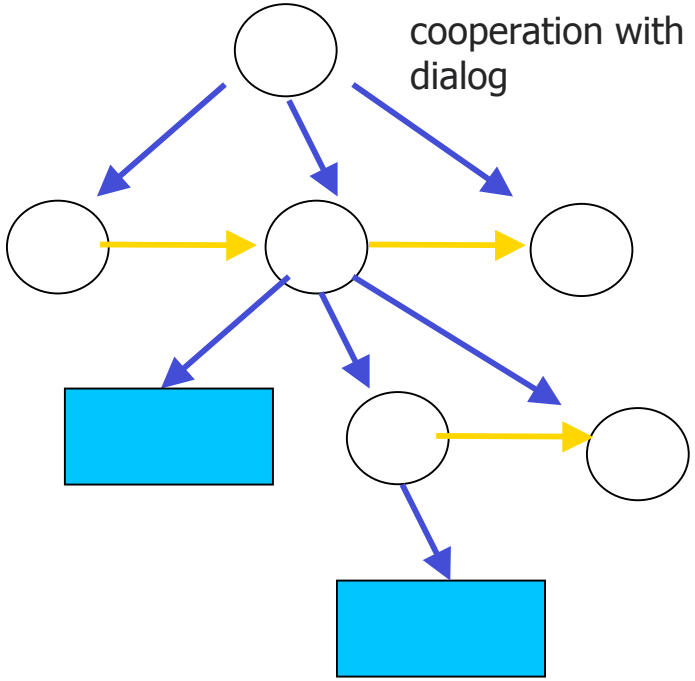
Observation

Dialogue

Explicit representation of the overall decisional process and its link to the human

Provides a sound background to cooperation with multi-modal dialog





Communicate (Goals / Facts / « plans »)

Observe Acticity

Infer Intentions / Commitments

Produce legible / acceptable behabiour

Perform useful tasks

Task achievement in Interaction with Humans

- Combine
  1. Actions and perception to perform task
  2. Multi-modal communicative acts (speech, motions, postures) to support the execution of joint tasks
  3. Monitoring of human commitment

  - Geometry / resources
  - Parallel execution, Monitoring

Combining constraints

« Handing an object to a person »

- Pre-conditions (« symbolic » and « spatial »)
  - Person aware of the task
  - Person willing to participate
  - Person performing its sub-task ..

  - For performing the task (eg sufficiently near the person)
  - For monitoring (robot should monitor human activity, look at person's face / hand)
  - Communication (face to face, perception by the human of the object, and the arm motion)

SHARY (Superversor for Human-Aware Robot Ynteraction)

- Builds an artificial language for task realization in an HRI context :
  - a set of communicative acts based on joint activity and oriented toward establishing common beliefs about the task and supporting its execution
- Inserts this language in a task refinement mechanism

Supervision of H/R task achievement

Robot Searches for interaction when left alone

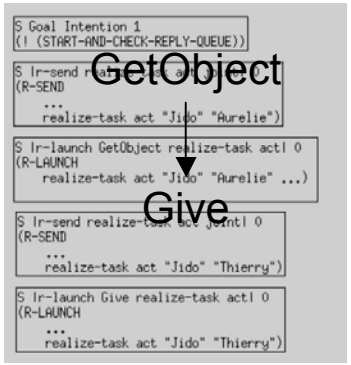
Establishes a common task

Programming a H/R task involving several perception and interaction modalities

Abandons mission if guided person stops following

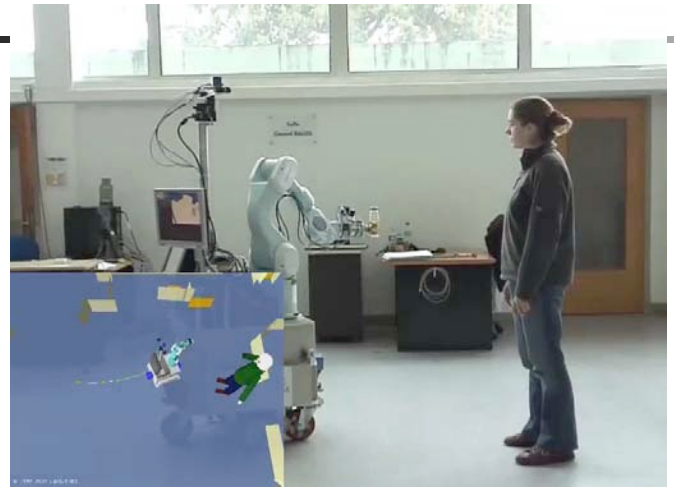
Rackham at « Cité de l'Espace »:

Predictability, Common Ground, Responsiveness



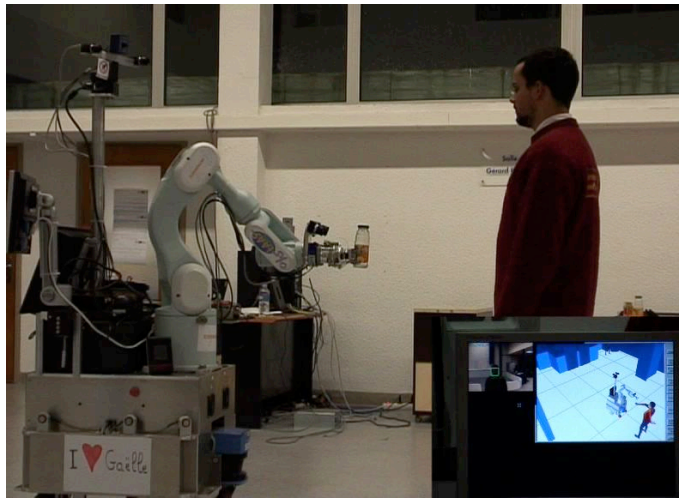
TASKS	EVENTS	
	Jido says : « Please, take it ! »	realize-task act Give ← *expected answers* realize-task act, give-up/cancel/end act, suspend act →
	a) Thierry begins to take the bottle.	realize-task act Give → *expected answers* give-up/cancel/end act, suspend act →
	b) Thierry does not look at the robot (but is still next to him)	suspend-task act_clear Give →
	c) Thierry does not take the bottle	give-up act not-clear Give →
	d) Thierry leaves.	give-up act clear Give →

Handing an object to a person



tvb

Where is Thierry ?

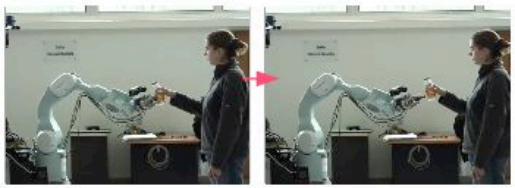


Thierry does not take the bottle

« Disturbed » attention

Handing a bottle to a person

Predictability, Common Ground, Responsiveness



Agent
name : *Aurelie*
category : *human*
position : *near*
interaction : *possible*
object_owned : *none*

Agent
name : *Aurelie*
category : *human*
position : *near*
interaction : *possible*
object_owned : *bottle*

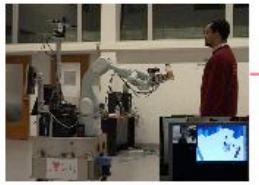
GIVE

H and R: realize *act*

H: end not_clear *act*
H: end clear *act*
H: suspend clear *act*
H: suspend not_clear *act*
H: give_up not_clear *act*
H: give_up clear *act*
H: cancel not_clear *act*
H: cancel clear *act*

R: realize *act achieved*
R: realize *act impossible*
R: realize *act irrelevant*

...

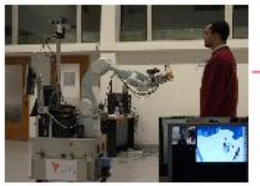


Agent
name : *Thierry*
category : *human*
position : *near*
interaction : *possible*
object_owned : *none*

Agent
name : *Thierry*
category : *human*
position : *near*
interaction : *possible*
object_owned : *none*

Agent
name : *Thierry*
category : *human*
position : *near*
interaction : *possible*
object_owned : *none*

Agent
name : *Thierry*
category : *human*
position : *far*
interaction : *impossible*
object_owned : *none*



Agent
name : *Maxime*
category : *human*
position : *near*
interaction : *possible*
object_owned : *none*

Agent
name : *Maxime*
category : *human*
position : *near*
interaction : *impossible*
object_owned : *none*

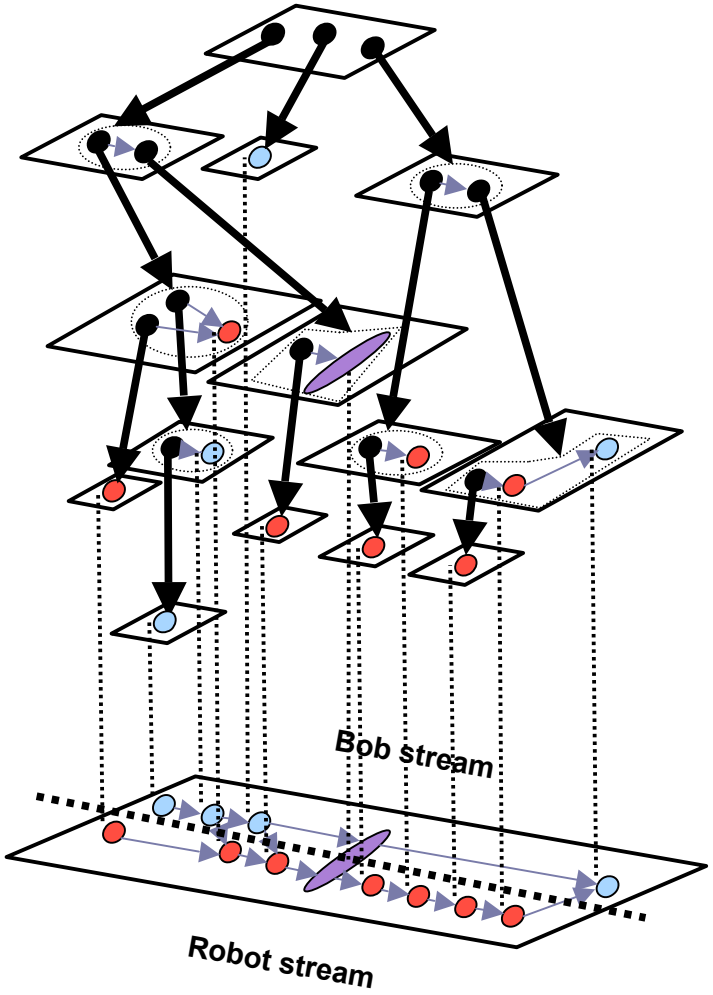
Building a « good » plan

- Managing Joint task achievement
- Legibility of robot actions and intentions (intentionality)
- Acceptability of robot actions
- Compliance with "conventions"
- Coherent attitudes and behaviours

Constraints on robot plans

Human Aware Task Planning

- A plan = tree + projection
  - HTN (Hierarchical task Network)
  - temporal plan projection on Directed Acyclinc Graph managed by IxTeT Library
- Maximising plan utility to help assist human / minimize human effort
- **Agent abilities and preferences:** costs associated to each action he can perform.
- **Social rules:** patterns to detect in the plan structure at different levels
  - Undesired states
  - Undesired sequences of actions
  - Social conventions
- Maintaining the abstraction of the plan.
  - Hierarchy of individual and common action
  - for monitoring and plan presentation and negotiation



A complete sequence

Two high-level task planning Episodes

- go ask/confirm

- achieve task and report

Applicability / Validity ?

- The design choices and the results presented here are still preliminary.
- General scheme might be difficult to implement in a general sense
- We believe that it is a « reasonable » (motivating, fruitful) challenge to implement it in the case of a personal robot assistant essentially devoted to:
  - fetch-and-carry
  - interactive manipulation tasks
  - home tour
  - associated activities.

Prospective

Three « new » FP6 projects

- URUS (**Ubiquitous Networking Robotics in Urban Settings): A fleet of mobile robots in a pedestrian area (guides, object transfer, surveillance)**
- PHRIENDS: Design Hardware and Motion Planning and control algorithms for safe robot action

Physical Human-Robot Interaction: DepENDability and Safety

Specific Targeted Research or Innovation Project IST-045359 supported by the European Commission under the 6th Framework Programme

Design Hardware and Motion Planning and control algorithms for safe robot action

- CommRob: Advanced Behaviour and High-level Multimodal Communication With and Among Robots

Two FP7 projects 2008-

- CHRIS (STREPS) Cooperative Human Robot Interaction Systems

- DEXTMART (IP): DEXterous and autonomous dual-arm/hand robotic manipulation with sMART sensory-motor skills: A bridge from natural to artificial cognition

Two ANR projects coordinated by LAAS

- LOCANTHROPE; Computational foundations of human locomotion.

- AMORCES: study decisional and operational human-robot interaction, and more specifically, the impact of verbal and non-verbal communication on the execution of collaborative tasks between a robot and a human partner

  - Interdisciplinary projects: robotics, AI, graphics, neuroscience, psychology

ADREAM initiative

Ubiquitous Robotics, Ambiant Intelligence

- Devices and (micro)systems
  - Micro-systems
  - Energy
  - Communication
- Development and deployment technologies
  - Embedded systems
  - Network and protocols
  - Resilience and Privacy issues
  - Robotics and decisional systems

Thank you ...