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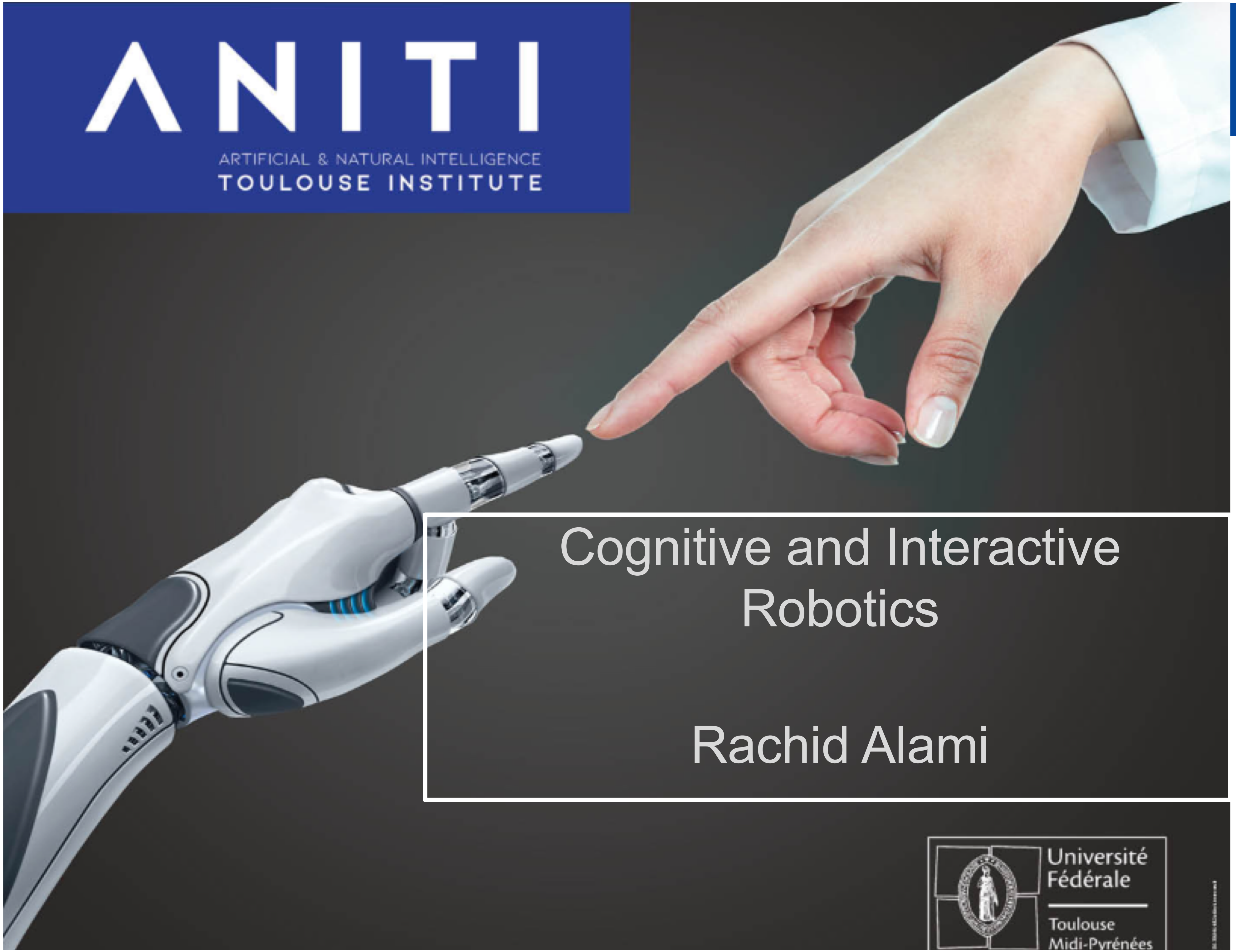


Cognitive and Interactive Robotics

Rachid Alami

Université Fédérale
Toulouse Midi-Pyrénées

Chair and Co-chairs

Rachid Alami

François Félix Ingrand

Thierry Siméon

Aurélie Clodic

Arthur Bit-Monnot

Chair and Co-chairs

- **Rachid Alami (CNRS Senior Scientist)** https://homepages.laas.fr/rachid/

  Robotics and Artificial Intelligence, Cognitive Robotics, Human-Robot Interaction, Task and Motion Planning, Multi-Robot Coordination and Cooperation, Robot Control Architectures

- **François Félix Ingrand (CNRS Senior Scientist)** https://homepages.laas.fr/felix

  Cognitive Robotics, Decisional Architectures, AI Planning, Validation and Verification for Autonomous Systems

- **Thierry Siméon (CNRS Senior Scientist)** https://homepages.laas.fr/nic/

  Sampling-based Planning Algorithms, Autonomous navigation, Multiple robots, Human-Aware Motion Planning, Application of Planning algorithms to bioinformatics

- **Aurélie Clodic (CNRS Research Engineer)** https://homepages.laas.fr/aclodic/

  Human-Robot Interaction, Social Robotics, Decision for Interactive robot

- **Arthur Bit-Monot (INSA Assistant Prof.)** https://arthur-bit-monnot.github.io/

  Ai Planning, Temporal Reasoning, Combined Task and Motion Planning

The Scientific Challenge

The scientific challenge is to devise and build the **cognitive** and **interactive** abilities to allow **pertinent**, **transparent, legible** and **acceptable** behaviors for a that is able to perform collaborative tasks with a human partner.

the assistant and the teammate robot

The Scientific Challenge

The envisaged architecture should integrate **incremental learning** that will allow the robot to acquire new abilities for human-robot collaboration while ensuring **transparency**_and **explainability** of the overall decisional abilities and their evolution over time.

Situated multi-modal dialogue will be used as a means to inform the human and interpret correcly her/his signals and ensure coherence.

The Scientific Challenge

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

- The **deployment of AI-enabled robotic** systems with potential users:
  - therapists
  - manufacturing and service industry

- The **evaluation** in contexts where the robot is used to conduct joint action and/or learn or refine abilities with non-specialist users.

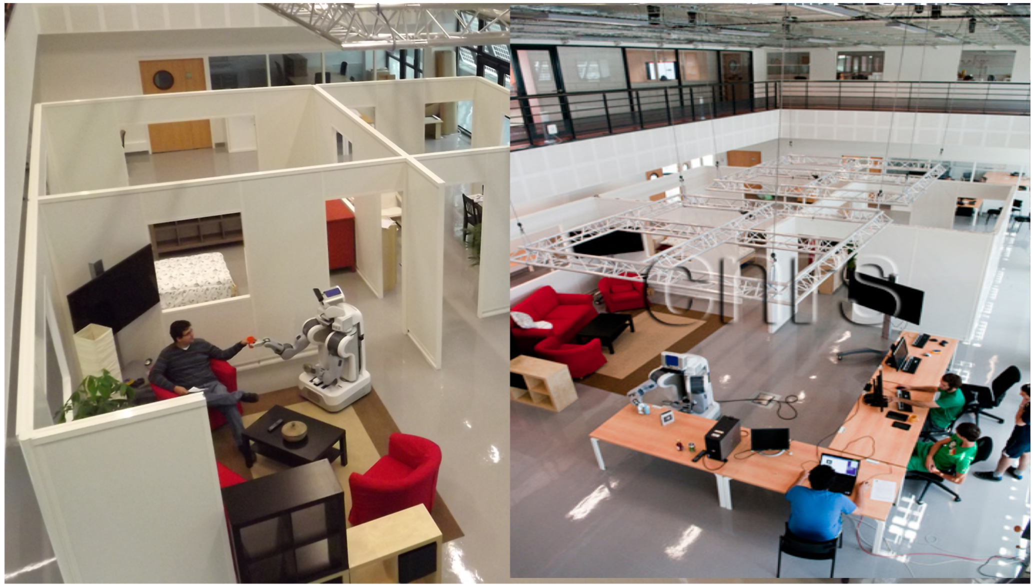
Resources

Lab Resources: already available at LAAS:

- LAAS ADREAM experimental room: fully equipped, reconfigurable
- 2 PR2s, 2 Peppers, 2 Kuka LWR, 2 Franka Emika, Motion Capture System

ANITI : 2 Posdocs + 2 PhDs

1 PhD CIFRE (ALTRAN ?)



7 PhDs + 1 PostDoc at LAAS

- Ecoles Doctorales: 2
- H2020: 3
- ANR: 2
- Other: 1

Teaching

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- Decisional issues for Human-Robot Joint Action and Interaction
- AI Planning
- Motion Planning
- Combined Task and Motion Planning
- Human-Aware Task and Motion Planning
- Theory of Mind for Cognitive and Interactive robots
- Robot Control Architectures
- Validation and Verification for Autonomous Systems
- Evaluation of Assistive and Collaborative robots

- Human-Robot Joint Action Workshops

Potential links with other chairs

Nicolas Mansard: Robot Motion Synthesis

Frédéric Dehais: Human-Robot Teaming

Leila Amgoud - Emiliano Lorini: Explication / Theoryb of mind

Claire Pagetti: Certifiable Robot Decision

Nicolas Asher: Situated Dialogue for HRI / Grounded communication

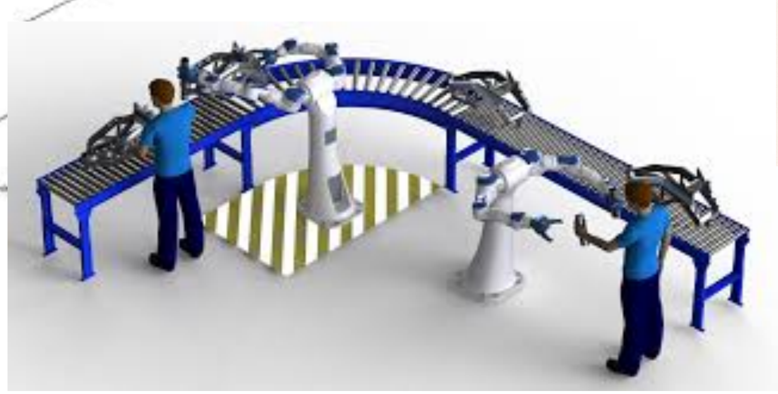
…..

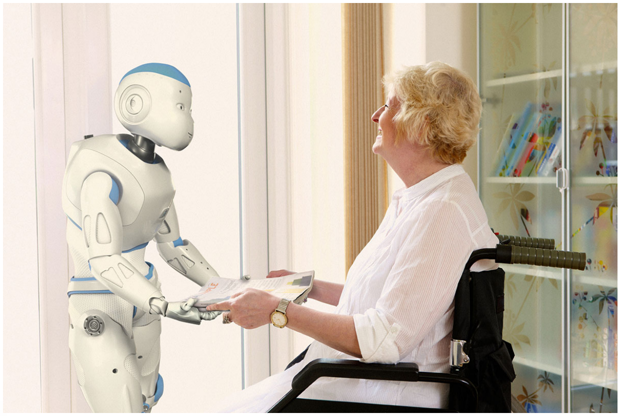
Joao-Marques Silva : Hybrid AI

Fabrice Gamboa: Geometric Constraints in Task Planning

….

Decisional issues during Human-Robot Joint Action





Decisional issues during Human-Robot Joint Action

How are we able to collaborate successfully?

What is necessary to be a good partner?

Integrative approach for a robot that acts in interaction with humans

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Work on Collaborative / Interactive task achievement

- based on a study of human-robot interaction
- inspired from Joint activity / Teamwork

- stemming Our experience and intuition

- concretized as a set of robot decisional abilities and their articulation

Integrative approach for a robot that acts in interaction with humans

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Work: Inspiration and Collaboration

- Cohen P. R., Levesque H. J. (1991), Tambe (Teamwork)
- H. Clark (Dialogue as Joint Activity)
- Bratman (1992,1999). Shared cooperative activity. Intentions and Plans
- Tomasello M. Warneken F. et al (2005 - ..) cooperation and communication social cognition, social learning
- Knoblich G. Sebanz N. et al. (2009 - ..) social cognition and social interaction
- Pacherie, E. (2012 - ..), philosophy of mind and action, joint action

A task-oriented architecture for a collaborative robot

H&R Sharing Task and Space

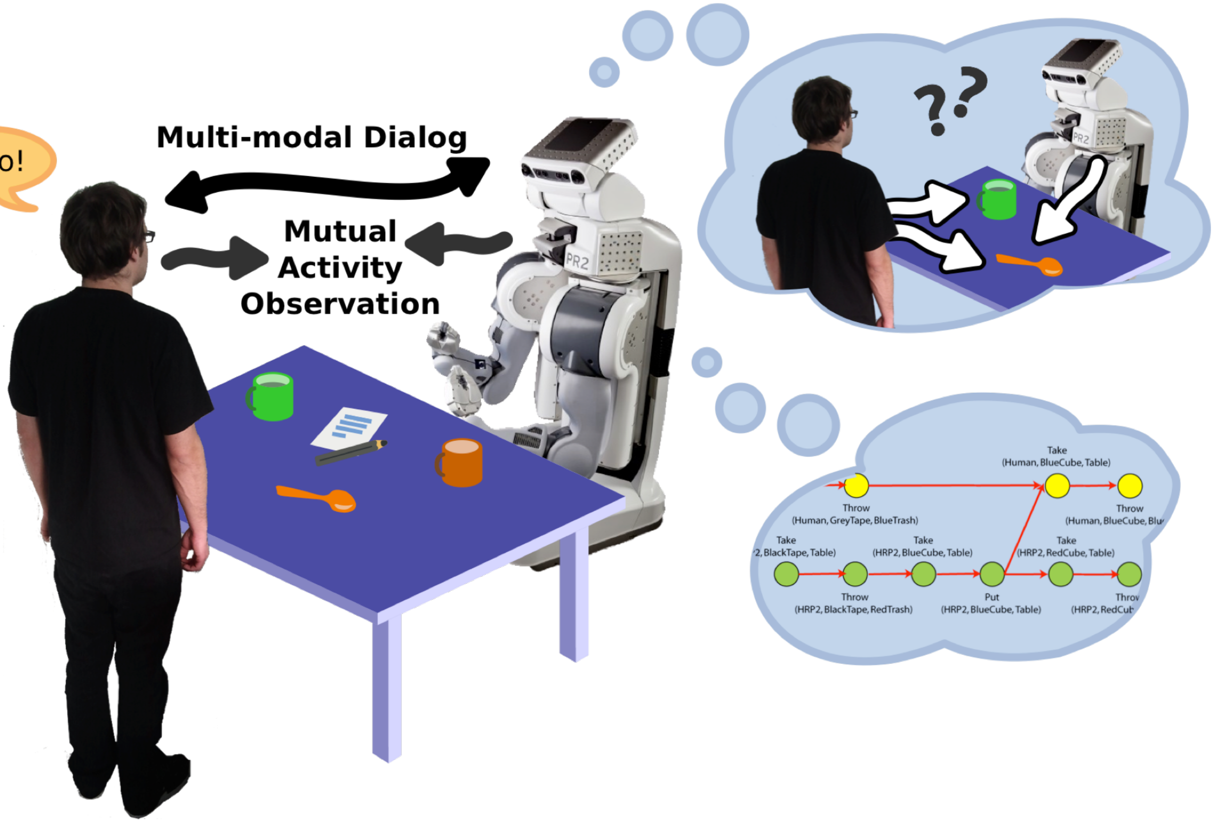
Task-Oriented: How to perform a task, in presence or in interaction with humans, <u>in the best possible way</u>

- Efficiency
- Safety
- Acceptability
- Intentionality, Legibility

Plan-Based: Planning and On-Line Deliberation

- Reasoning
- Anticipation
- Pro-active behaviour

Theory of Mind – Predicting and reasoning about human activity and mental state



Questions for a robot which collaborates with humans

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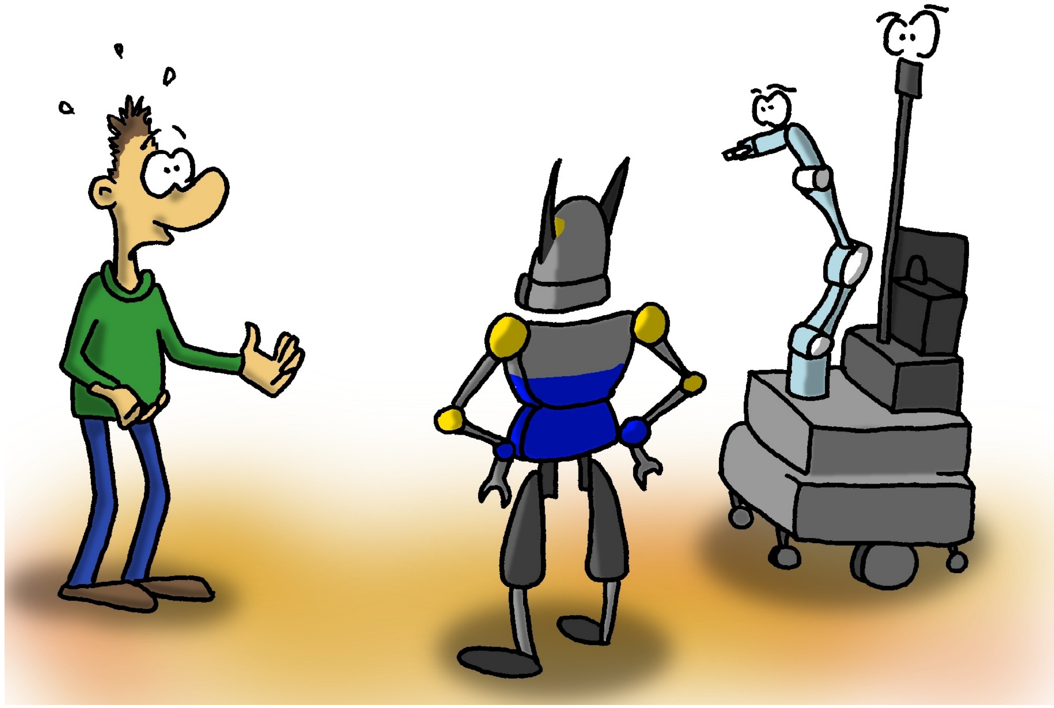
what, who, where, when, how?

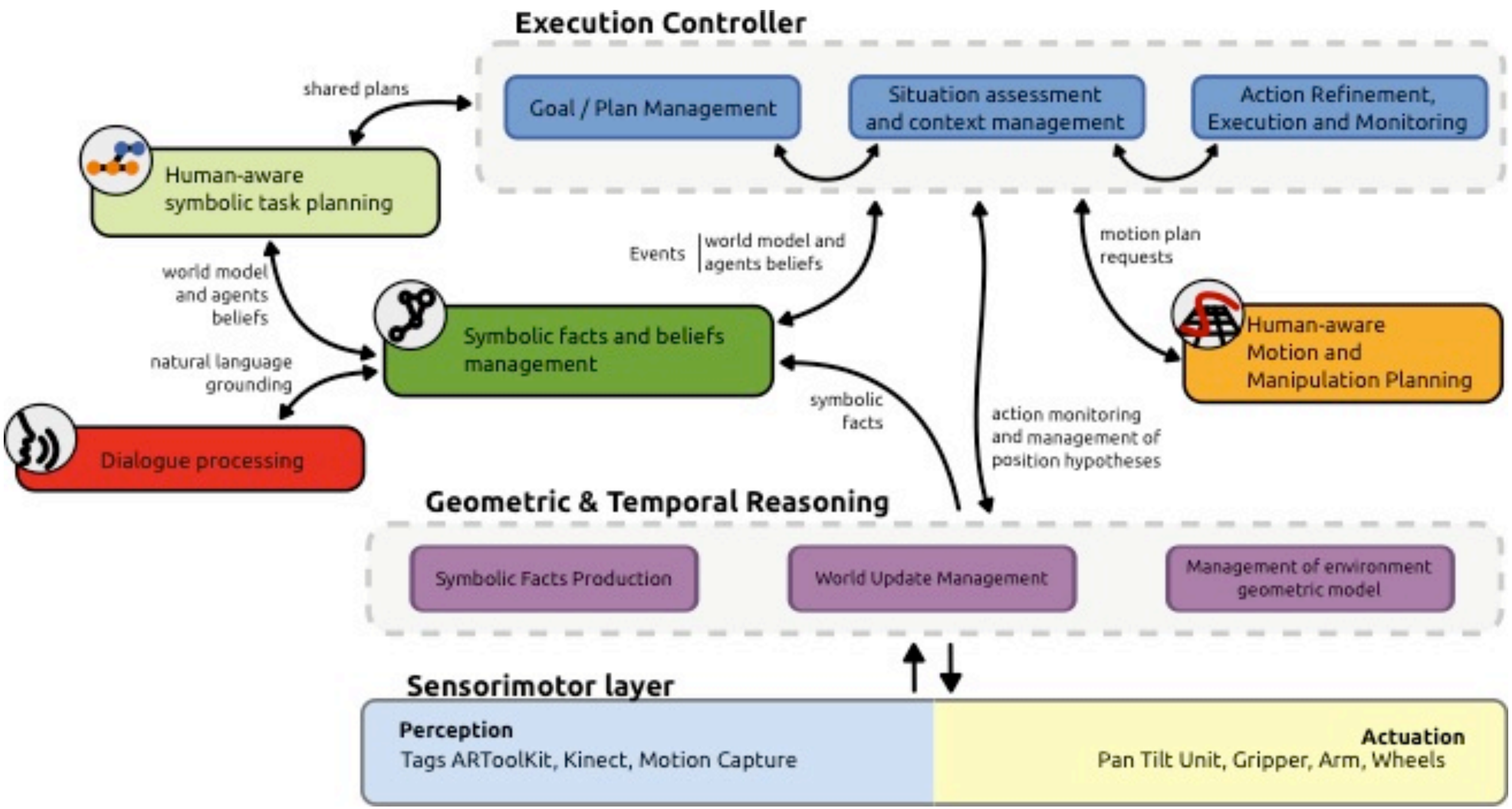
At various levels of abstraction

With various time horizons



→ In the quest of models

Robot Decisional Architecture: a constructive approach



S. Lemaignan, M. Warnier, E. A. Sisbot, A. Clodic, R. Alami: Artificial cognition for social human-robot interaction : An implementation. Artificial Intelligence 247 : 45-69 (2017)

Decisional ingredients for an Interactive Autonomous Assistants

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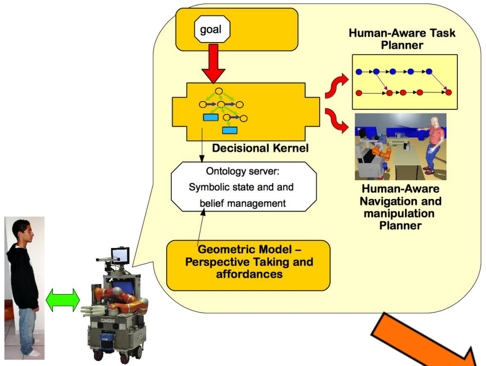
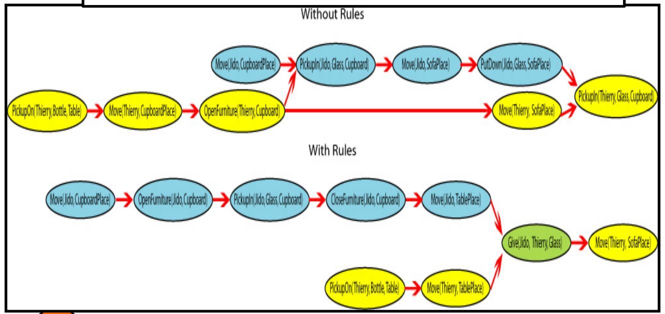
A Control Architecture for a Cognitive Assistant

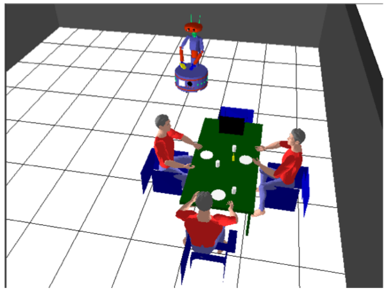


SHARY: Cooperative Task Achievement

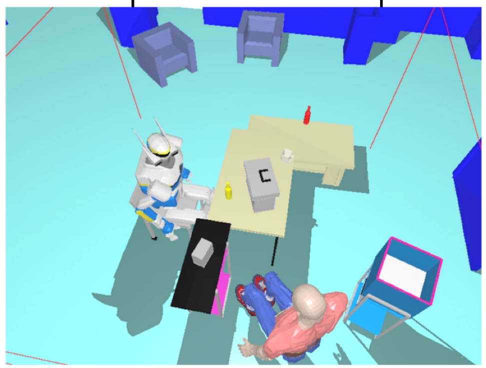
Human Aware Task Planning



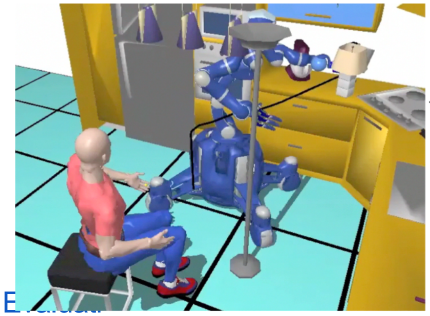
Human Aware Navigation



Affordances



Human Aware Manipulation



Perspective Taking

Soft Motion

on 2009

Outline

1. Situation assessment, Theory of Mind, Perspective-Taking and affordances
2. Plan elaboration based on each agent abilities
3. Action refinement taking into account human preferences and needs
4. Managing Commitment in Joint task achievement

1 - Perspective-taking and affordances in interactive contexts: a key element for the Theory of Mind

Ros R., Sisbot E. A., Alami R., Steinwende J., Hamann K., & Warneken F. (2010, March). Solving ambiguities with perspective taking. HRI-2010

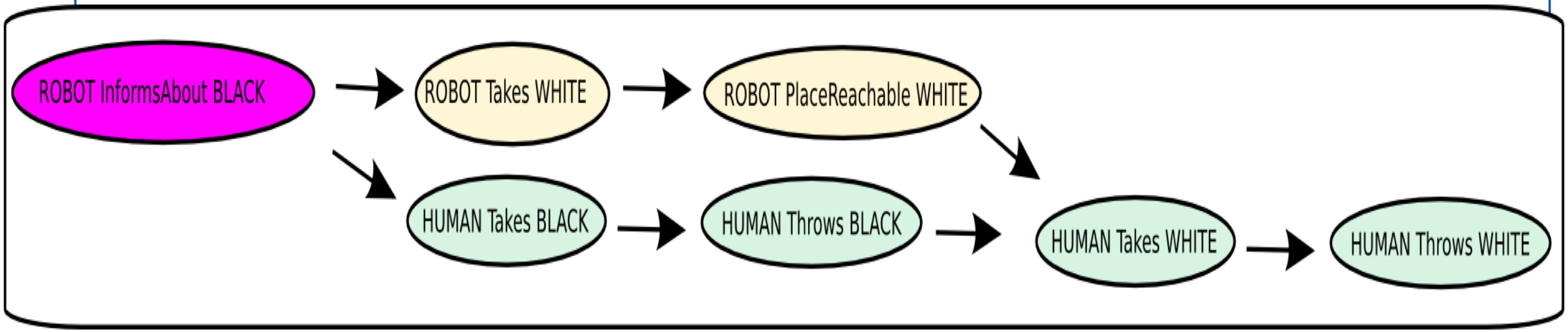
S. Lemaignan, R. Ros, E. A. Sisbot, R Alami, M. Beetz, Grounding the interaction : anchoring situated discourse in every- day human-robot interaction Acceptable Robot Motions, International Journal of Social Robotics, Volume 2, Issue 3, April 2012

If the goal is « to clean the table »….

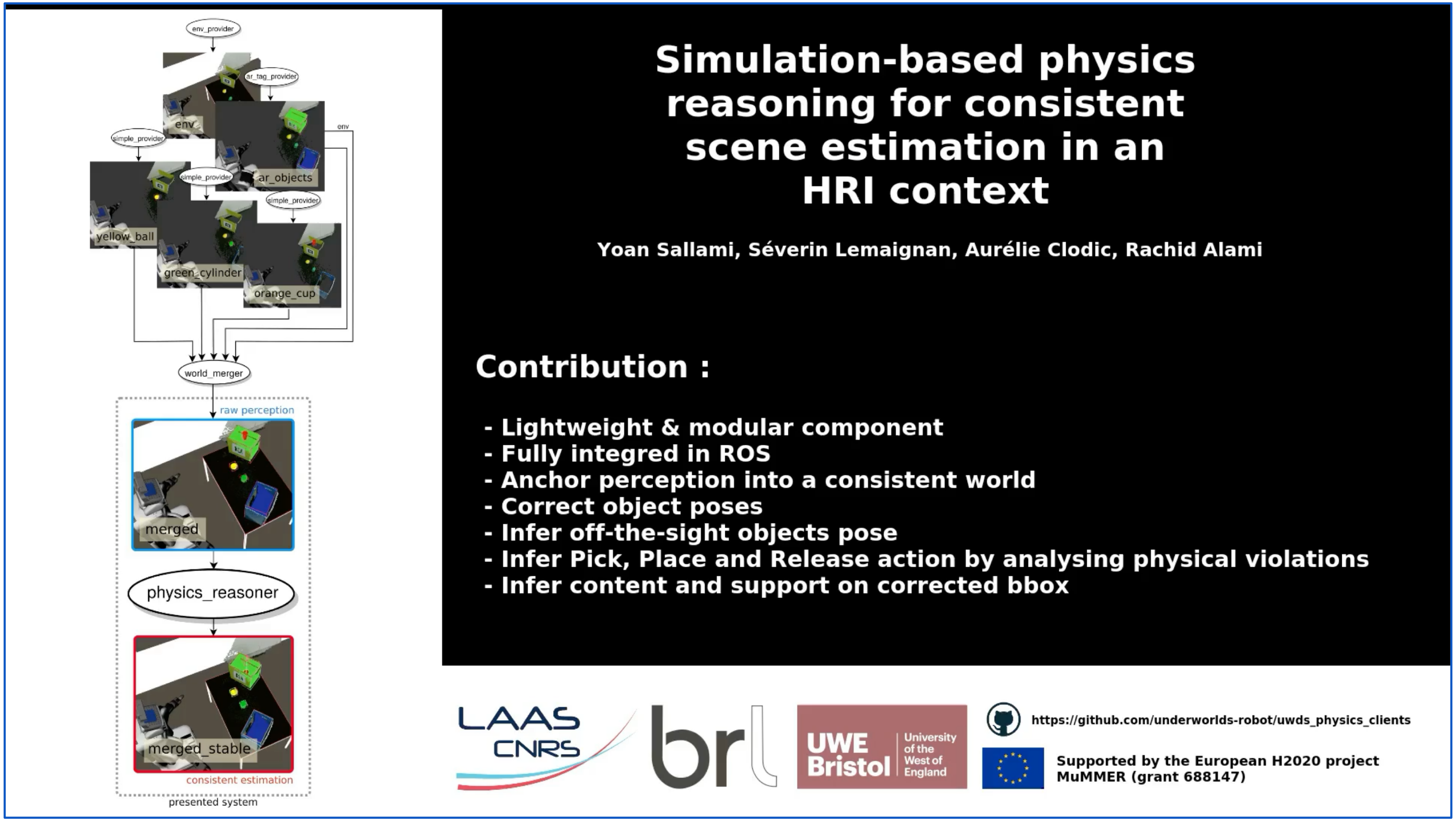
Robot can synthesize a shared plan based on:

- its current knowledge of the state
- its estimation of the beliefs of its human partners
- and provide information (adds in the plan communication actions) to its human partners when necessary

Robot has computed that BLACK object is reachable but not visible by Green



More elaborate situation tracking integrating a physical simulator with symbolic reasoning



2- Elaborating a shared plan

Lallement R., De Silva L., & Alami R. (2014). Hatp: An htn planner for robotics, ICAPS, CoRR abs/1405.5345 (2014) – AAMAS 2018

HATP (Human-Aware Task Planner)

- **Hierarchical planner (HTN)** **[Alili et al., 2008]**
- **Multi-agent / H and R plan**
  - From the point of view of the robot
  - 1 stream of actions per agent
  - Synchronization (causal links)
- **Setting of the level of cooperation**
  - Cost functions
  - Social rules

HATP plan construction

A plan = tree + projection

- HTN (Hierarchical task Network)
- temporal plan projection on Directed Acyclic Graph

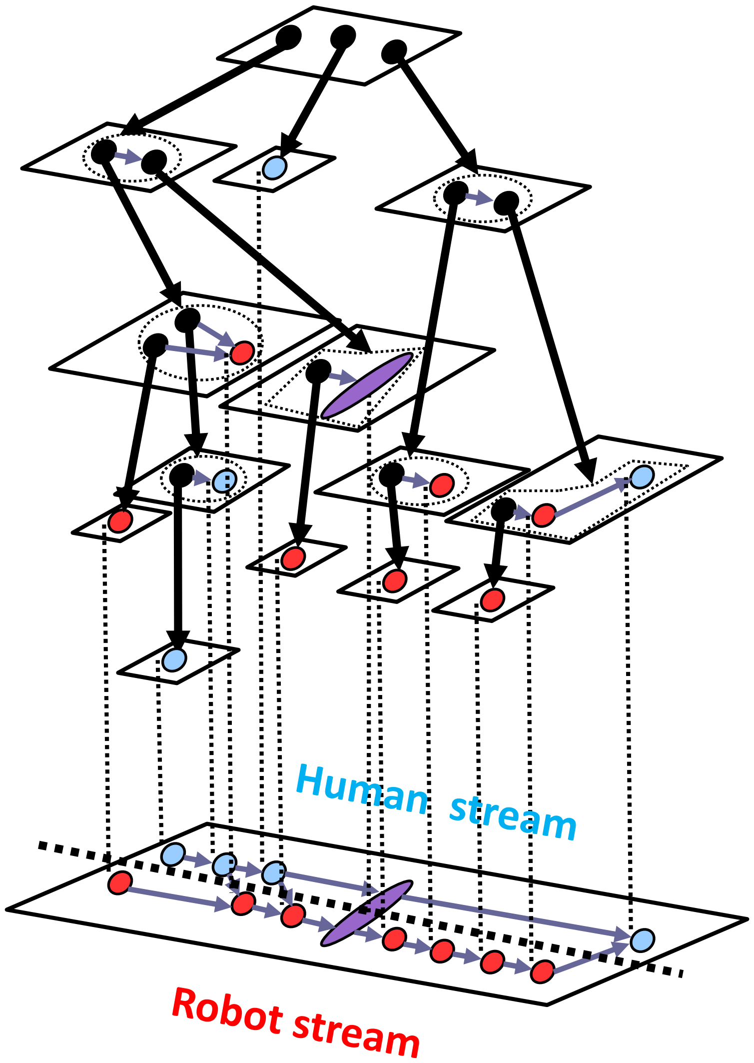
Maximizing plan utility to help assist human / minimize human effort: partner, teammate, assistant

Agent abilities and preferences: costs associated to each action he can perform.

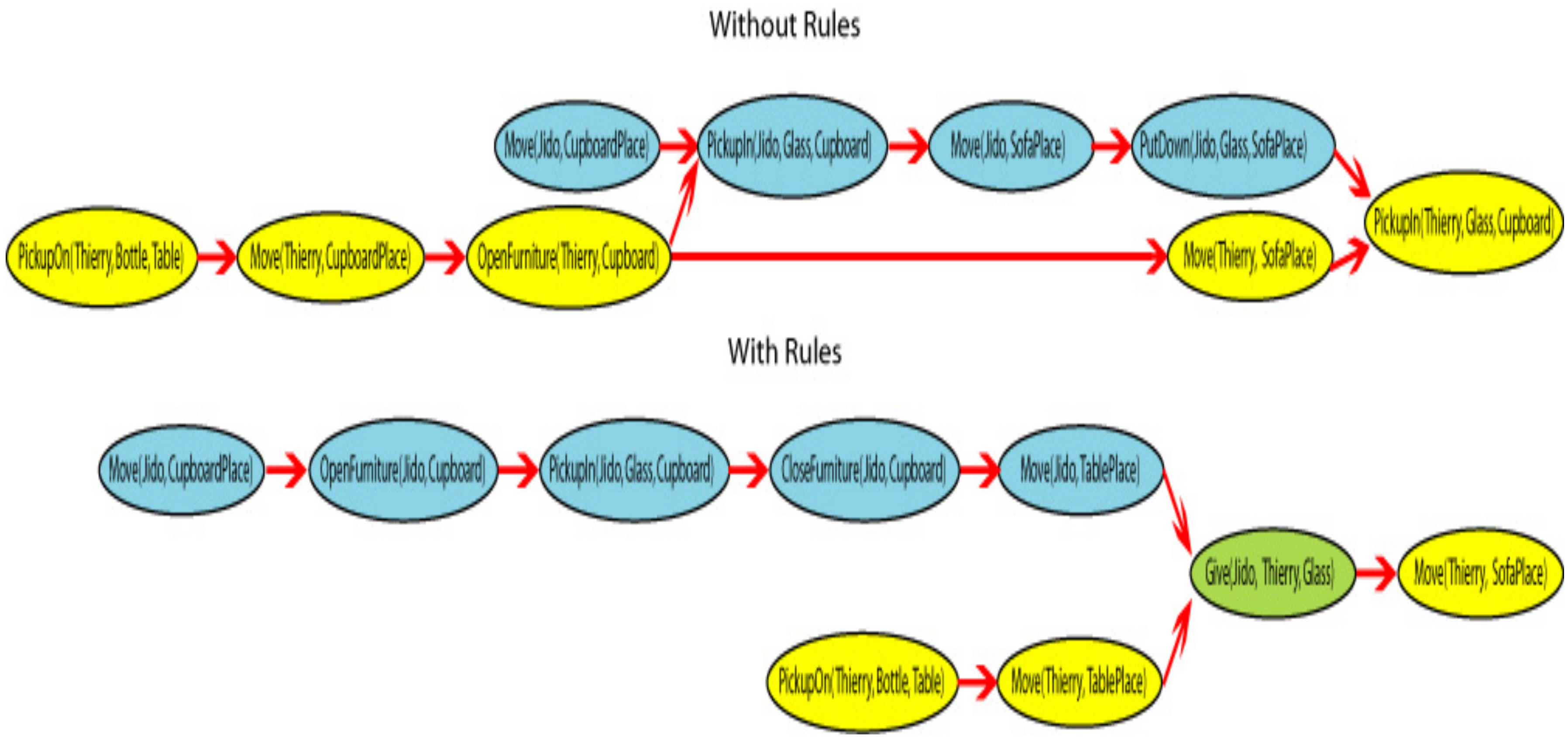
Setting of the level of cooperation: Cost functions

Social rules:

- Avoid undesired states or undesired sequences of actions
- Satisfy social conventions
- Promote fluency, legibility…



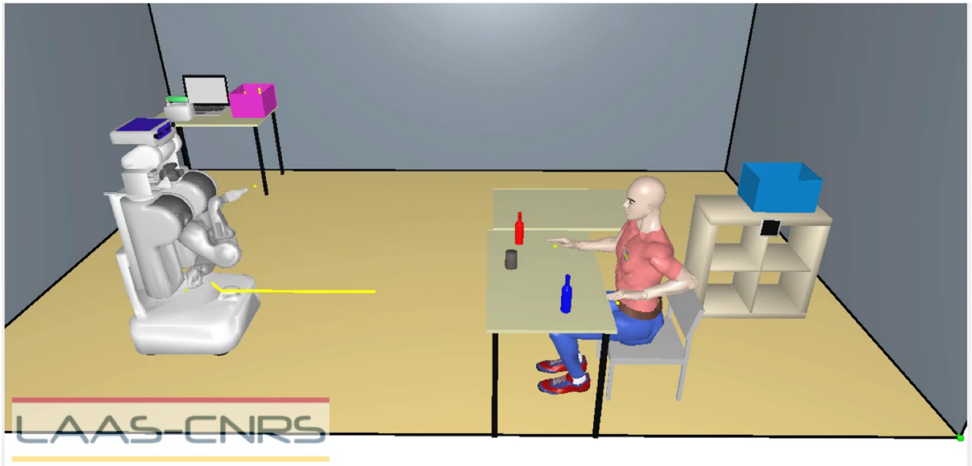
HATP example: Implementation of the concept of shared plans

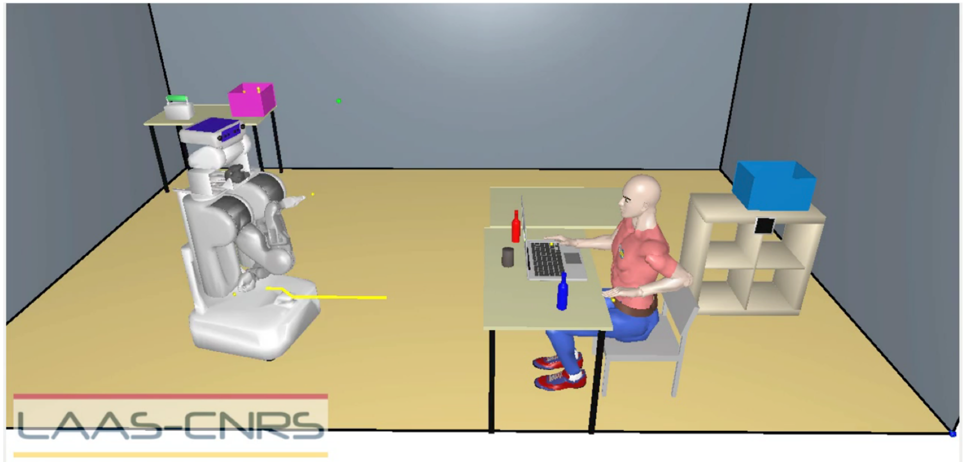


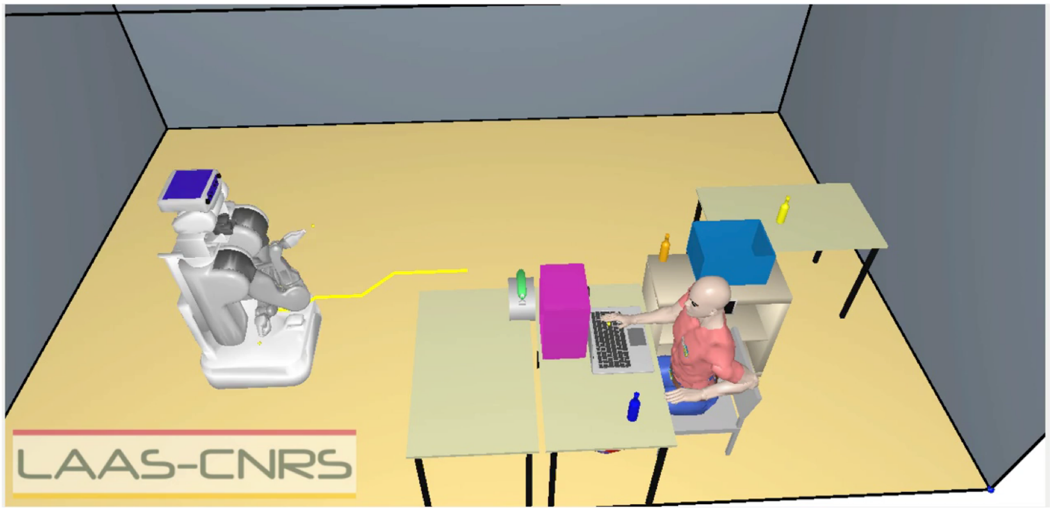
Promoting plans with less intricacies

S. Alili, R. Alami, and V. Montreuil. A task planner for an autonomous social robot. DARS 2009,, Springer, ISBN : 978-3-642-00643-2

Planning for human and robot



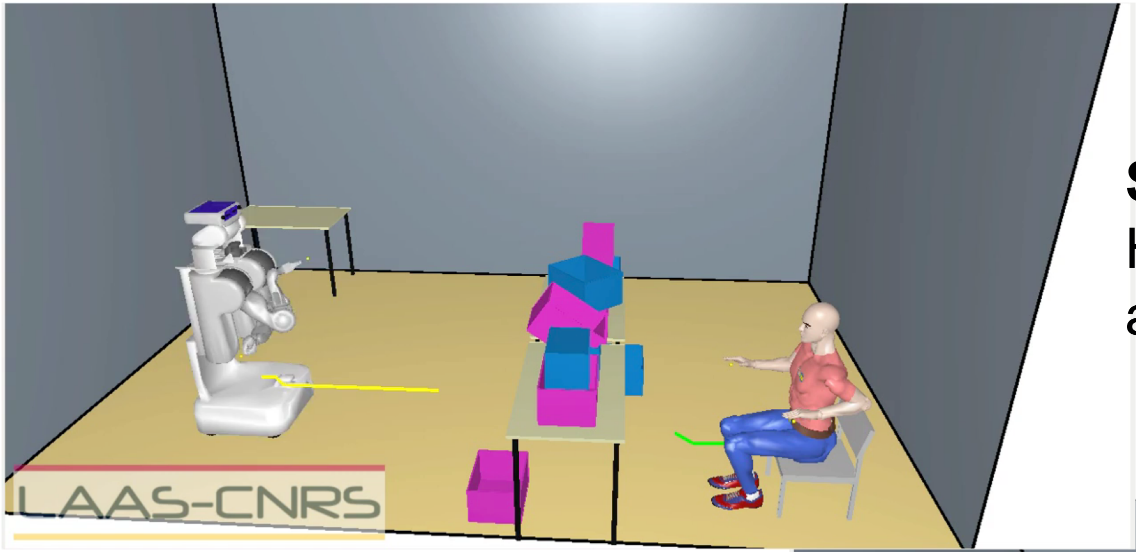




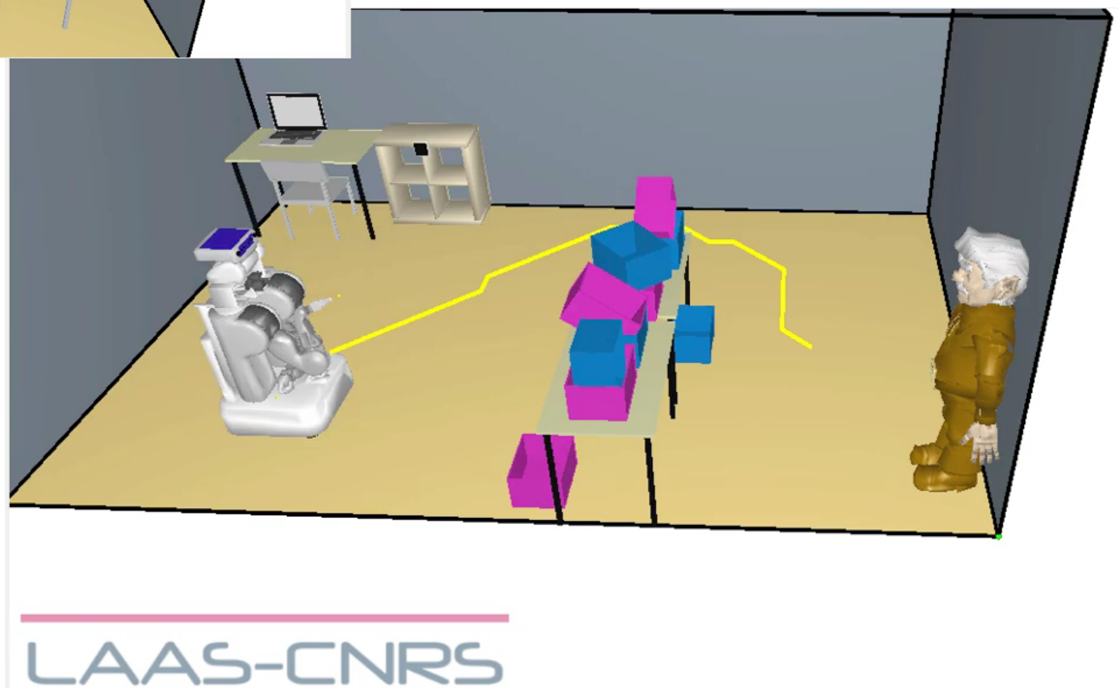
Planning for human and robot

Robot behaviour can be tuned and adapted to human preferences

Sharing the load for efficiency : Human needs the task to be achieved quickly



Elderly people prefer the robot to do more



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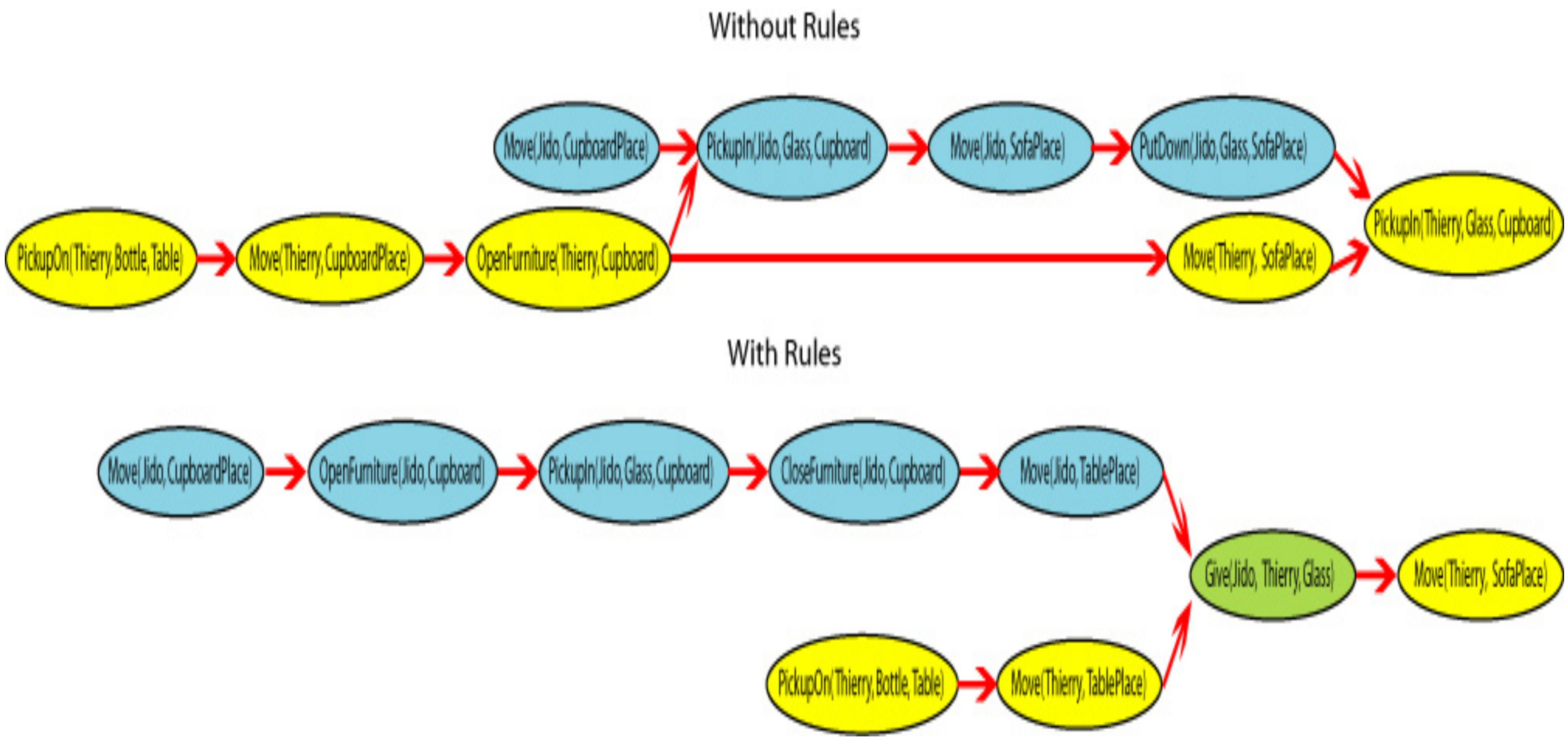
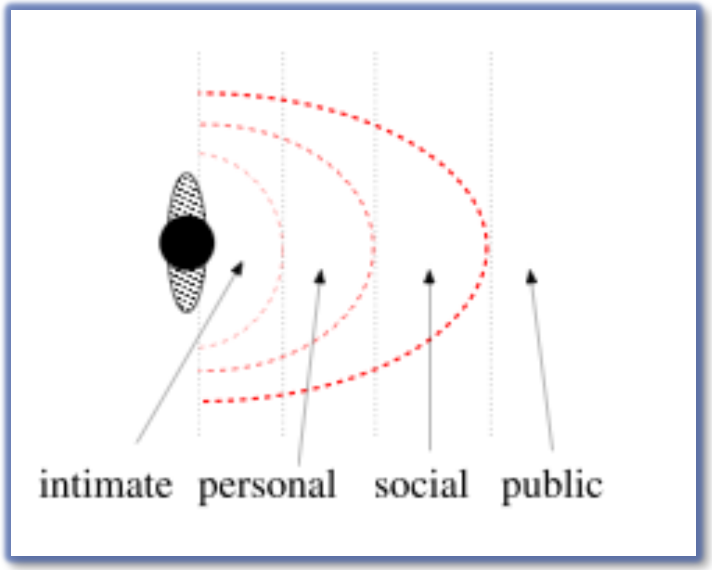


Promoting plans with **less intricacies**

S. Alili, R. Alami, and V. Montreuil. A task planner for an autonomous social robot. DARS 2009, Springer, ISBN : 978-3-642-00643-2

Sharing space

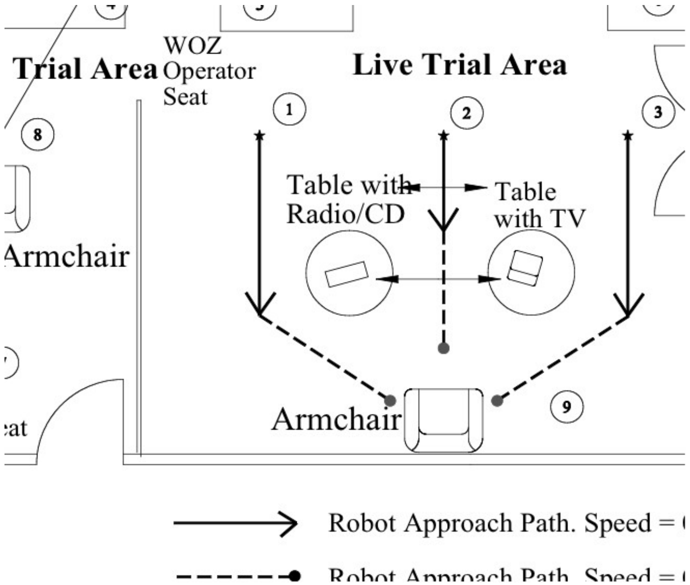
Robot motion and placement deduced from user trials

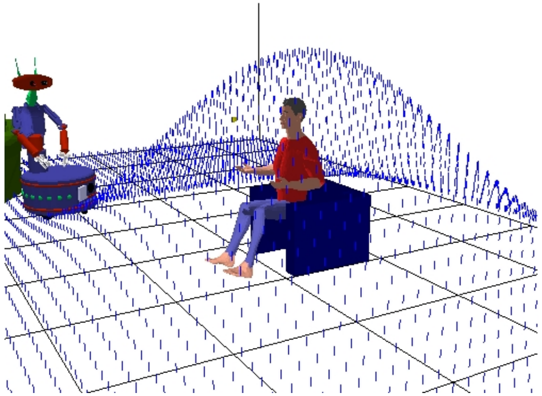


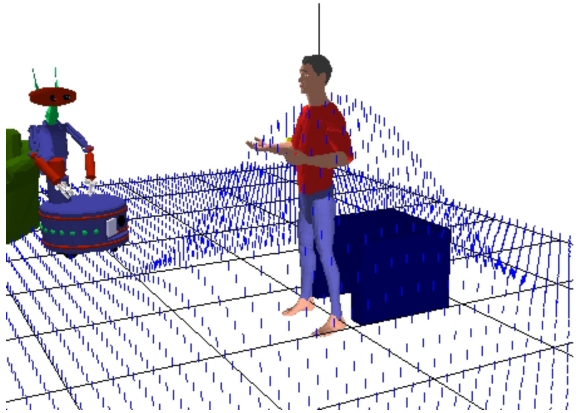
Proxemics (Hall 66)

User trials performed at University of Hertfordshire

K.L.Koay et Al "Exploratory Studies of a Robot Approaching a Person in the Context of Handing Over an Object »AAAI Spring Symposium - 2007

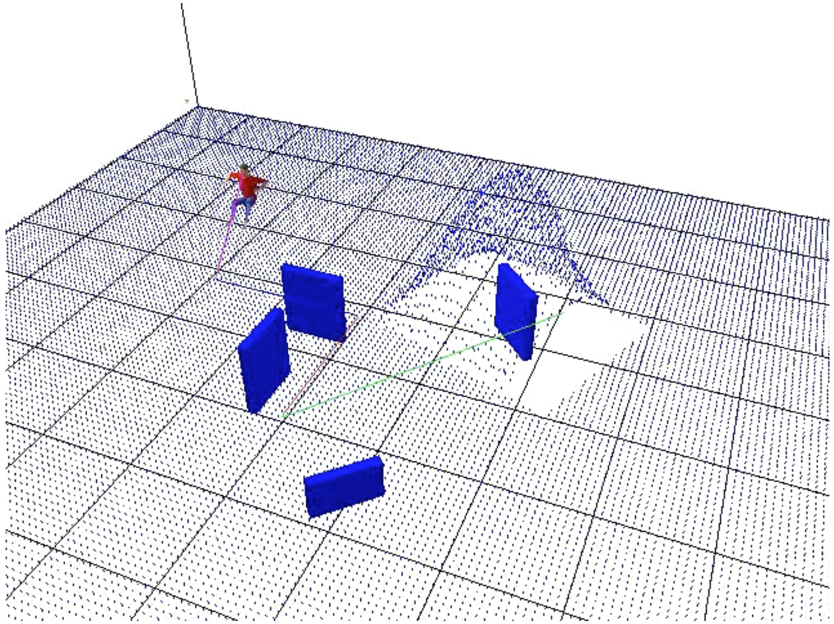


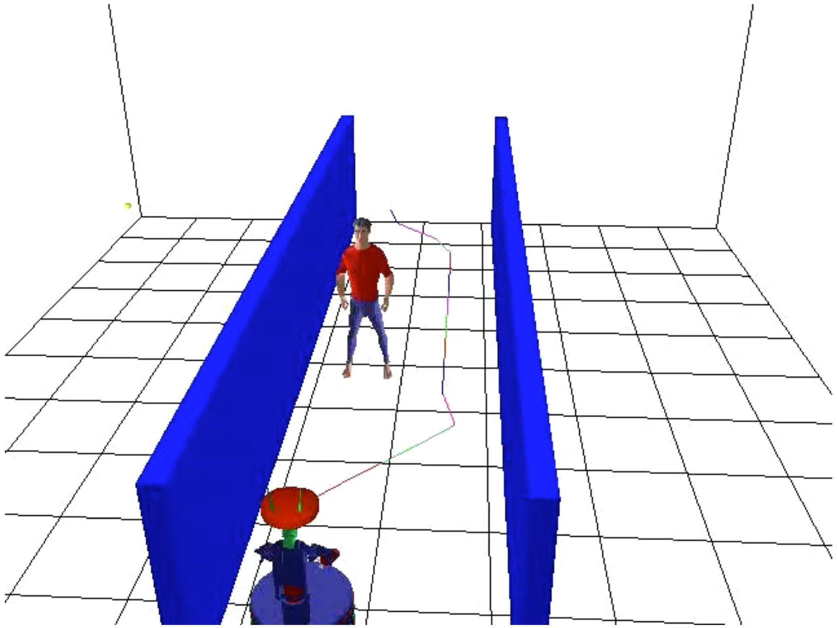




Real-time cost evaluation:
distance, posture, visibility

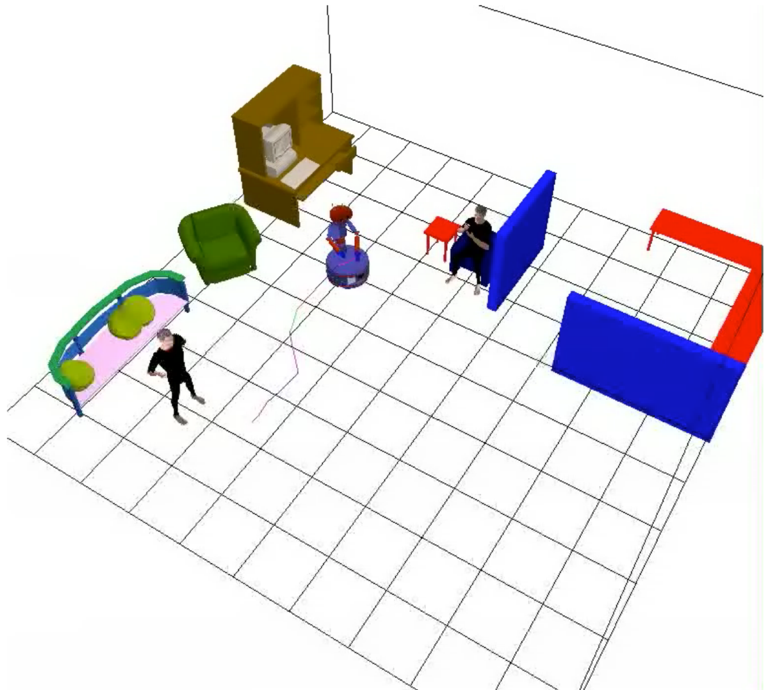
E.A.Sisbot , L. F.Marin Urias , R.Alami , T.Simeon
"A human aware mobile robot motion planner" ,
IEEE Transactions on robotics, Vol.23,N° 5, 2007





Hallway Crossing

Well known Catenary-like trajectory



Replanning in dynamic environment

SPENCER robot at Schiphol

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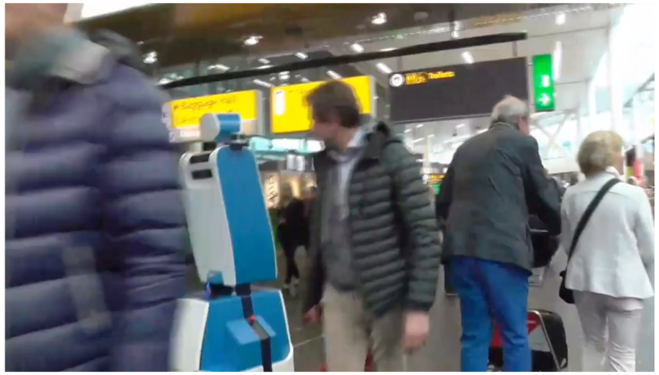
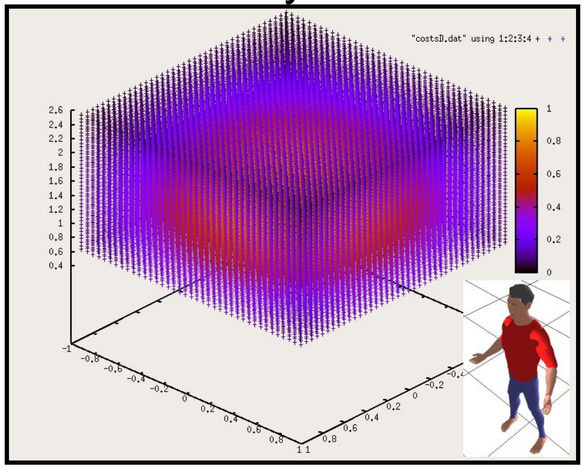


Handing an object to person

The object should be placed in a safe and comfortable position.

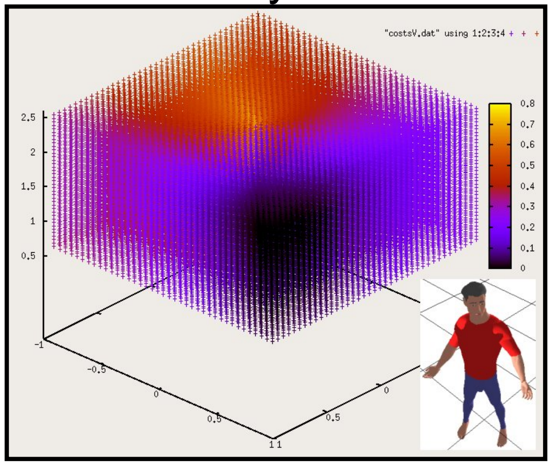
3 different HRI properties are defined and represented as 3D cost grids around the human

Safety



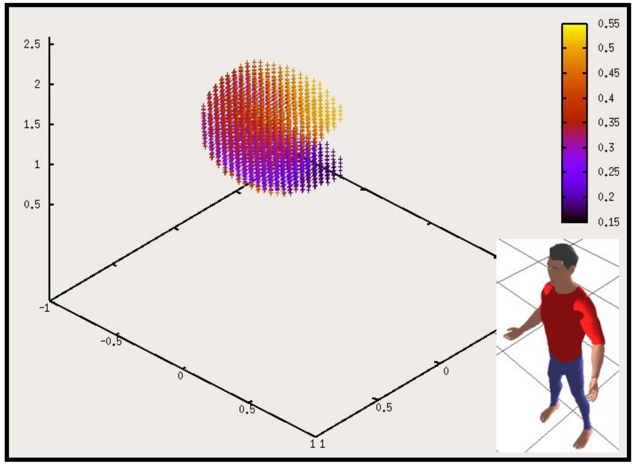
Proportional to the distance to human

Visibility



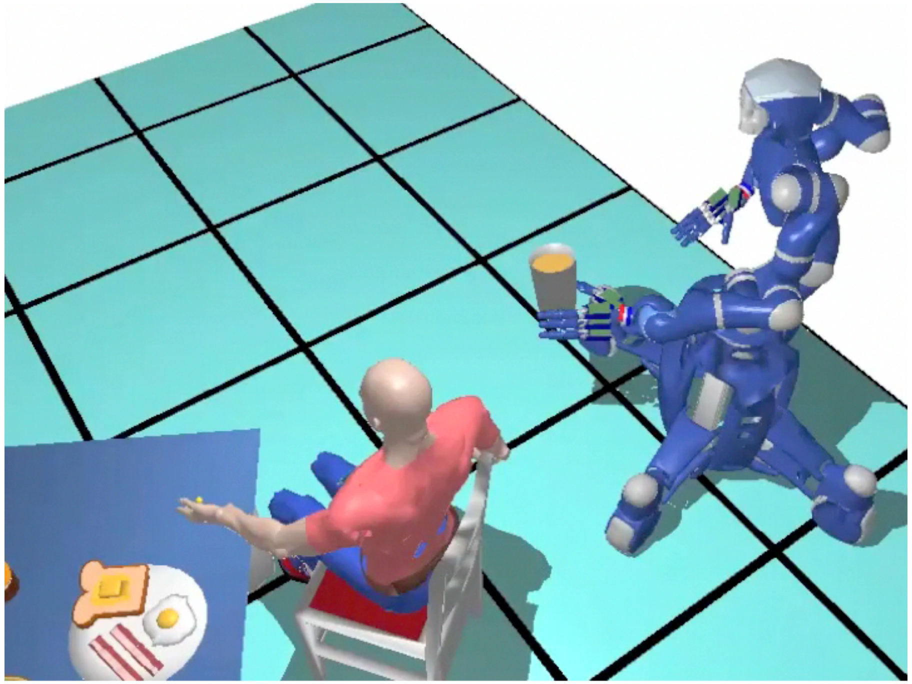
Reflects the effort to see a point

Arm Comfort(right/left)

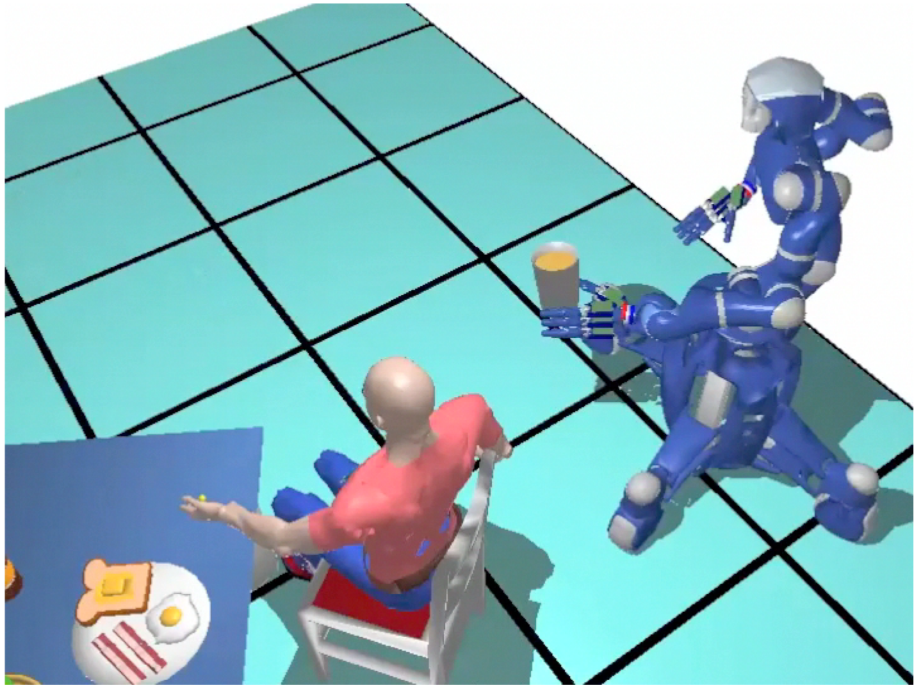


Combination of d.o.f difference and potential energy

Intrusive



Better



A human-aware manipulation planner. E. A. Sisbot and R. Alami, IEEE Transactions on Robotics, vol. 28, no. 5, pp. 1045-1057, 2012.

Task-Based Motion Planning

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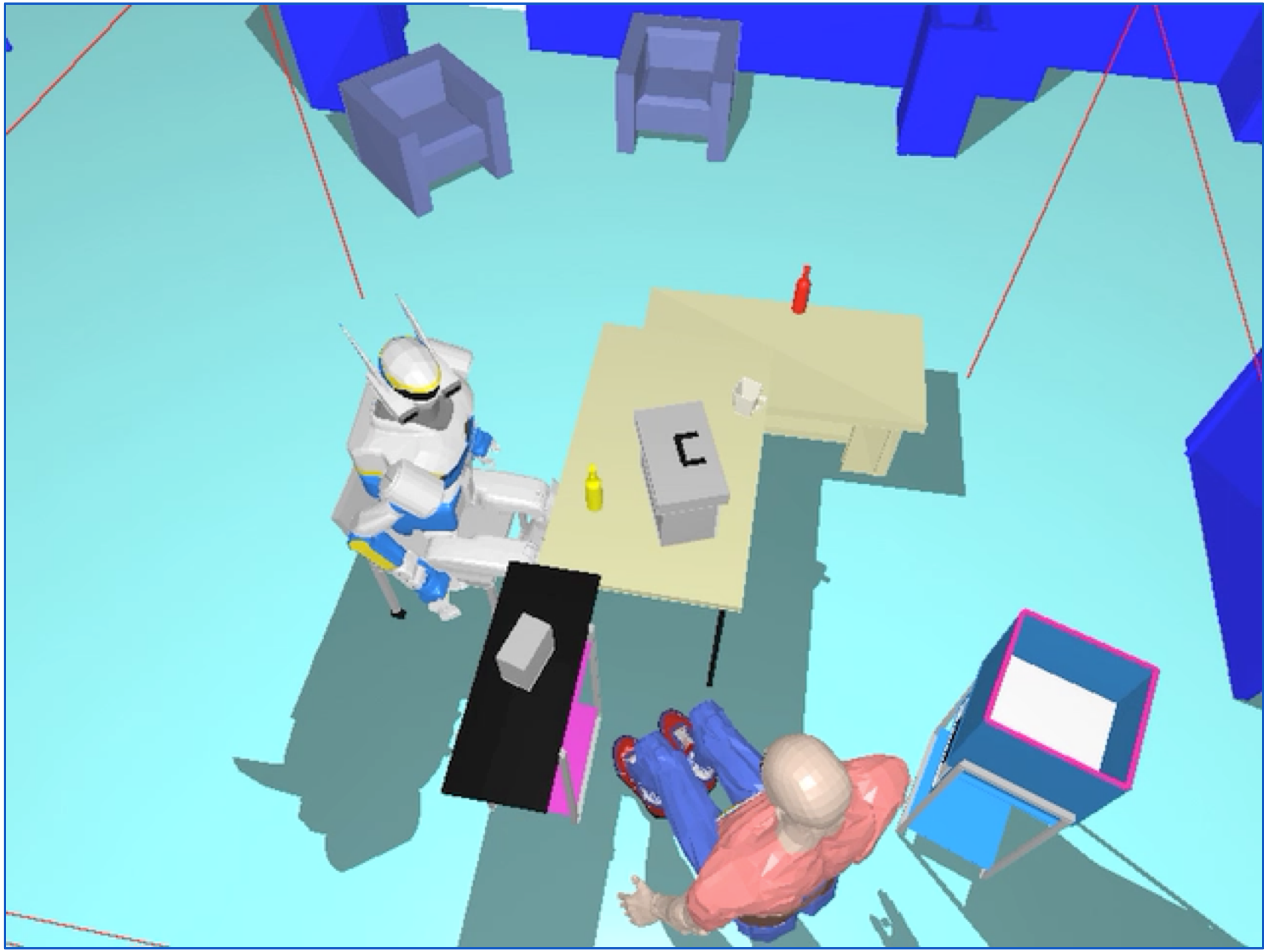
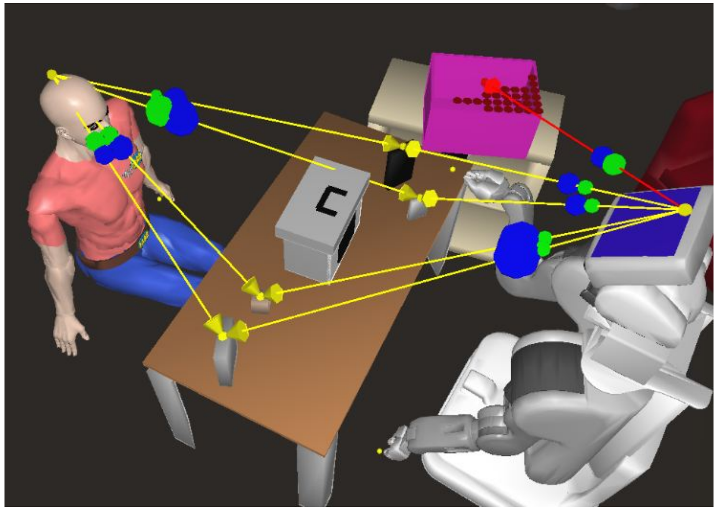
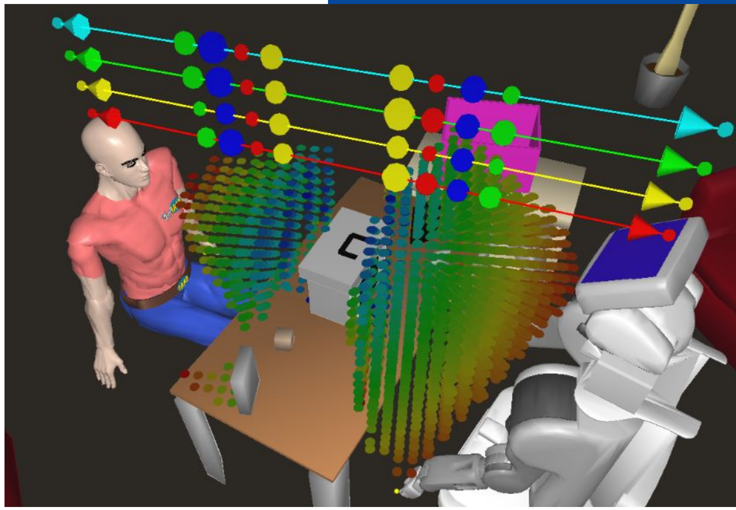


Whole day of assembly work! Now let us clean the table (or put the tools in the box)

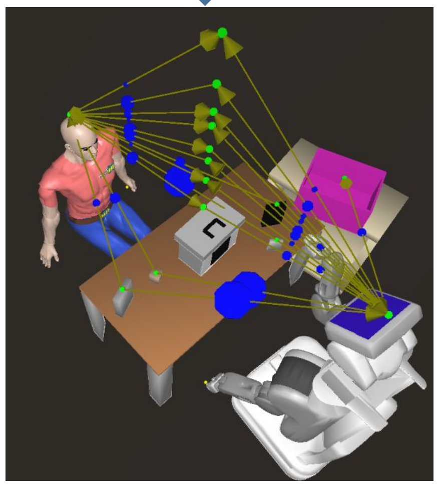


Who can do what with which object with which effort.

+



Who can do what for whom, with which effort and where.



Affordance Graph

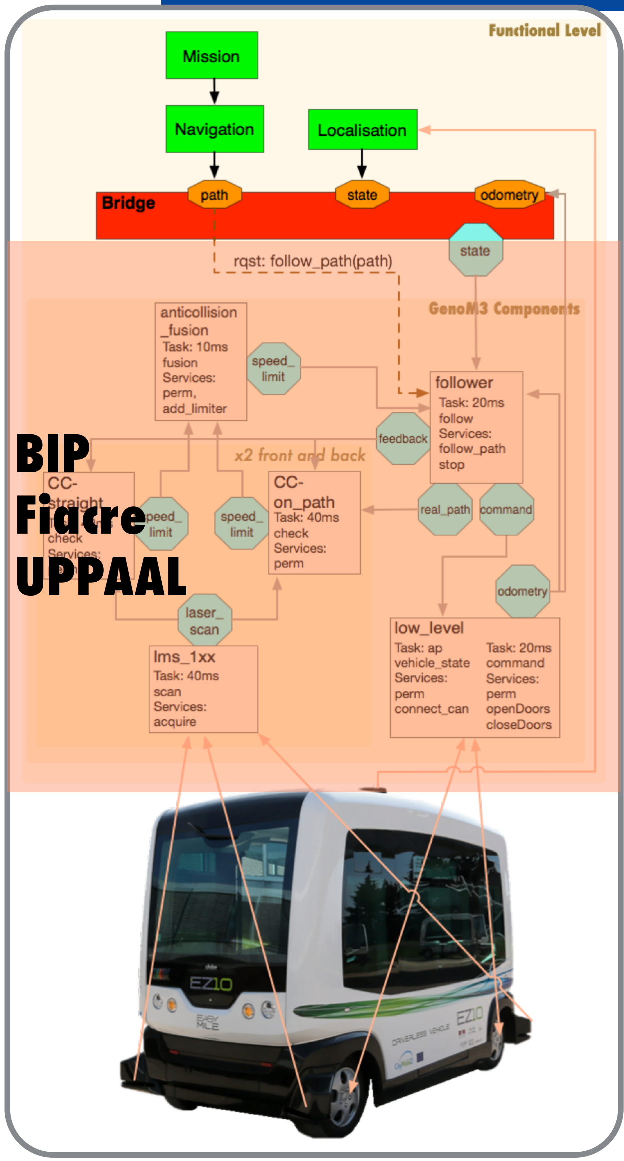
Verification &Validation Robotic Software Architecture

- Functional level : GenoM
- Modules
  - Services (control flow)
  - Ports (data flow)

Model-Driven Software Engineering

- BIP (Verimag)
- Fiacre/TINA (LAAS/VerTICS)
- UPPAAL (UPPsala & AALborg University)

Formal Methods/ Frameworks



Temporal Task Planning and Acting

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Rich temporal representation (ANML)

Concurrency

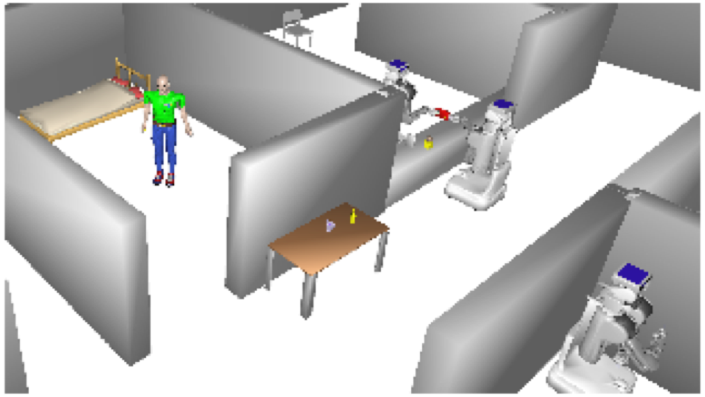
Plan space planning with

- Timelines
- Hierarchical decomposition methods

FAPE

Integrates

- Planning : first ANML-based planner
- Acting: interface with action refinement in PRS
- Plan repair and replanning



concurrency
synchronization

deadlines
domain knowledge

Rich temporal statements:

```
[start+10,end-10] light == on :-> off;
[60,90] contains at(r) == Kitchen;
```

HTN methods:

```
action Exchange(Robot r1, Robot r2,
                Object o, Location l) {
  :decomposition {
    move1 : Move(r1, _, l);
    move2 : Move(r2, _, l);
    Give(ra, rb, o, l);
    end(move2) < end(move1) -2;
  };
}
```

Combining Symbolic and Geometric Planning

Principled approach to link
Symbolic and
Geometric Planning

Geometric Task Planner (GTP)

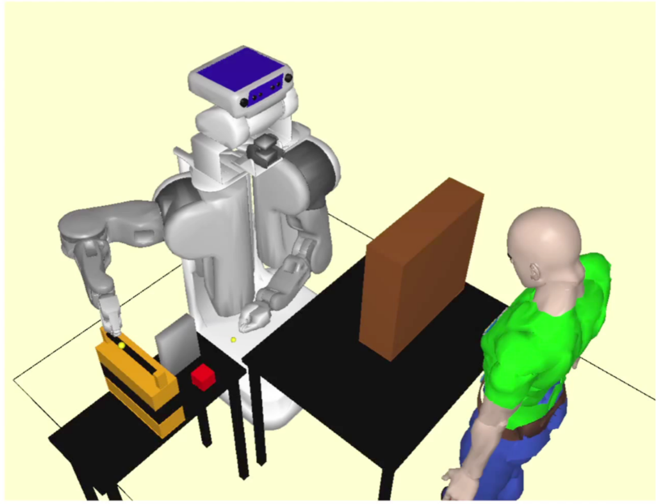
- Computation of H and R affordances
- Manipulation planning: pick-place, hand-over
- Perspective-taking: show, hide, reach
- Motion planning

Symbolic Task Planner (HATP)

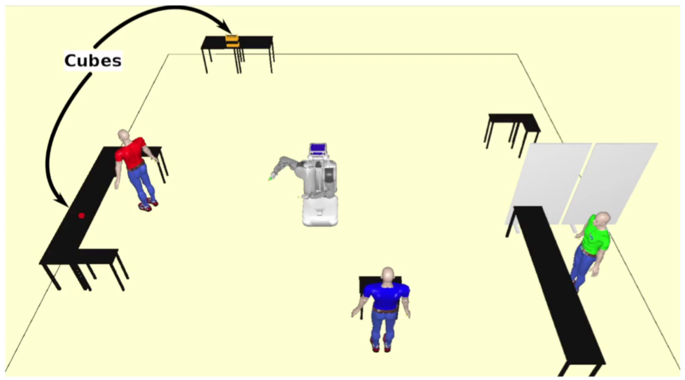
- HTN approach
- Human-Aware Task Planner: modeling actions of the robot and its human partner

PR2 puts objects reachable to human

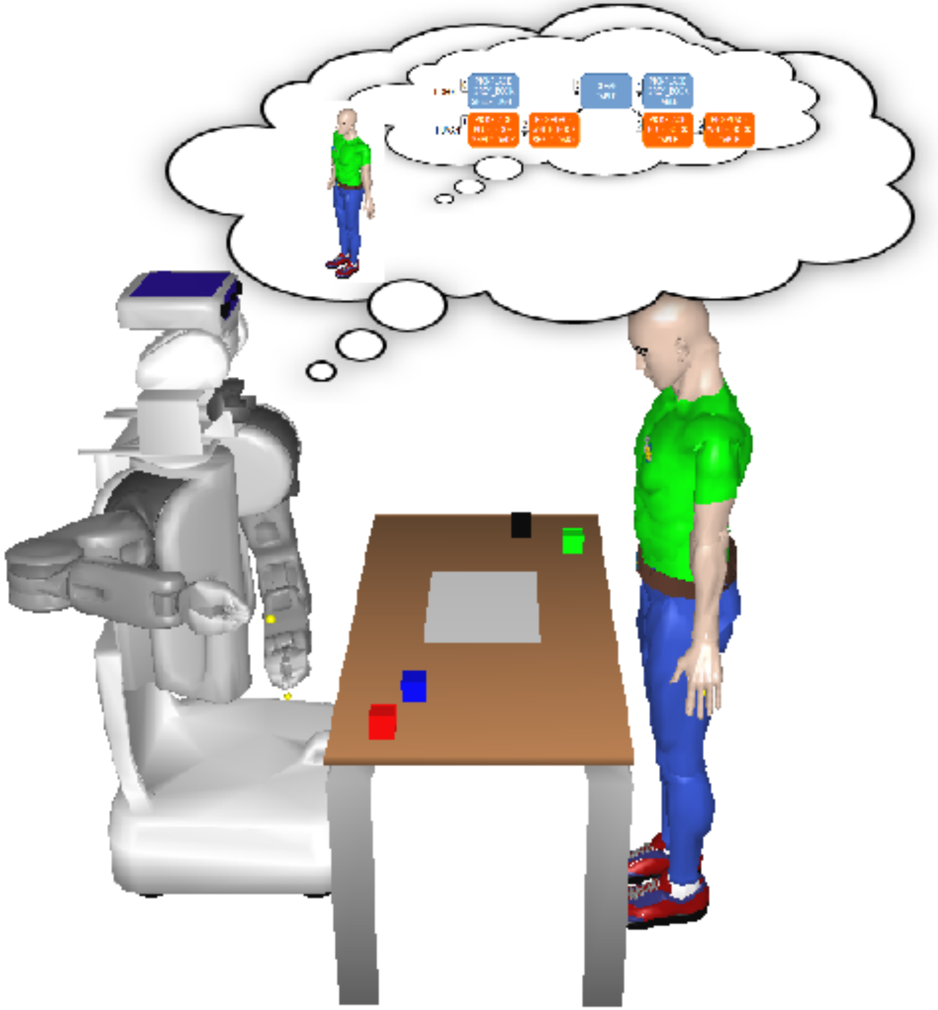
Illustrates the ramification problem



- Multi-agent task:
  robot (PR2),
  a client (green)
  a co-worker (blue)
  a worker (red)
- Choose a cube



Theory of Mind to Improve Human-Robot Shared Plans Execution



Sandra Devin - HRI16

Planning / Decisional processes

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Cost based search

- Proxemics
- Visibility
- Effort

Constraints

- Relative placements
- Postures
- Grasps
- Reach
- Mutual visibiilty

Properties that a plan should satisfy

- Protocols
- Standard / known procedures
- Interaction modalities, social signals
- Rhythms
- « social » rules
- Compliance to social norms

Criterias

- Comfort
- Acceptability
- Legibility
- Intentionality
- Predictability
- Robustness
- Efficiency
- Time

Development and articulation of some abilities involved in shared activity

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Architecture and decisional components for a robot to participate in collaborative activities with shared goals and intentions

Robot « tries » to do its « share » in the process

- Mutual responsiveness -- behavioral coordination
- Elaboration of a shared plan to satisfy a shared goal
- Commitment to the shared goal – mutual support
- Consideration of Human needs and preferences (Human-aware behavior synthesis)

Specific, limited context: fetch&carry, interactive manipulation and associated tasks

But still …

Besides advances in general robot capabilities …

We need far more refined models, based on solid grounds, and evaluated in realistic situations