Comment les robots assistants et coéquipiers prennent-ils des décisions ?

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Humain et numérique en interaction

31 janvier 2019, Paris

Depuis 80 ans, nos connaissances

Les robots parmi nous

- Robot d'assistance ou de service
- Robot équipier en usine, en chantier ou à la ferme

- Besoin d'étudier le rôle et les capacités d'un robot lui permettant de mener une activité conjointe avec des humains

Ecche robot

- Vue d’un roboticien ..

  sensibilisé à l’importance de la pertinence à l’acceptabilité par l’humain de l’activité du robot

- Pas de solutions définitives ni de leçons

- Partage d’un questionnement et présentation de quelques avancées

Robots autonomes

- un rêve
- un défi

- Le robot est (tout) seul
  - Très agile
  - Très intelligent
  - On lui donne un but/une tâche
  - Il fait le « boulot »
  - … et il est prêt pour une nouvelle aventure

un héros

New questions: operating in human environments

- A new area of inquiry
- Understanding the Social Side of Robots
- From robot tools that do things for us…
to robot partners that do things *with* us.

→ Bien plus “subtile”

Depuis 80 ans, nos connaissances

En ce qui concerne l'Interaction Humain-Machine

Nous avons un précurseur

7

« Les temps modernes »

- Tournage : Début 1932 jusqu’au 30 août 1935
- Première : 5 février 1936

- Interaction proximale
- Initiative
- Adaptation à l’homme
- Pertinence des choix
- Fiabilité

Une approche intégrative du problème

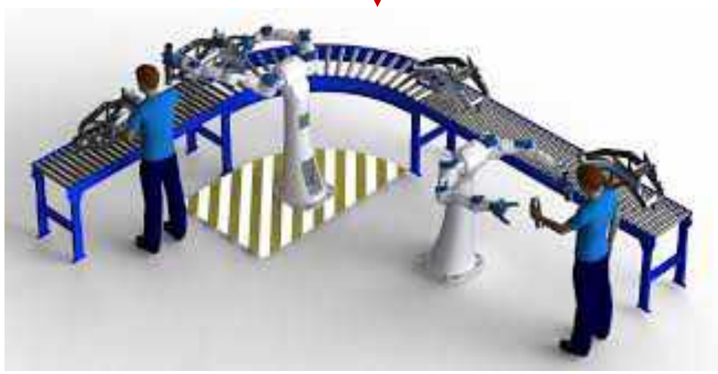
- Contributions sur l’action jointe, la réalisation de tâches coopératives
  - Études sur l’action jointe homme-homme (psychologie, philosophie, ergonomie)
  - Systèmes multi-agents: Joint activity / Teamwork
  - Concrétisées sous la forme de capacités cognitives

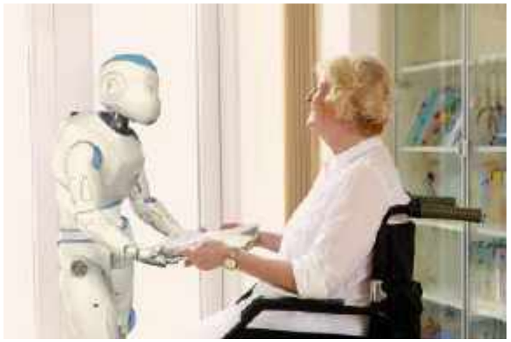
- Aller progressivement vers une maitrise de **l’action conjointe** *(joint action)* **Homme-Robot**

“Joint action can be regarded as any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment.” [Sebanz]

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. Trends in cognitive sciences.

Decisional issues during Human-Robot Joint Action

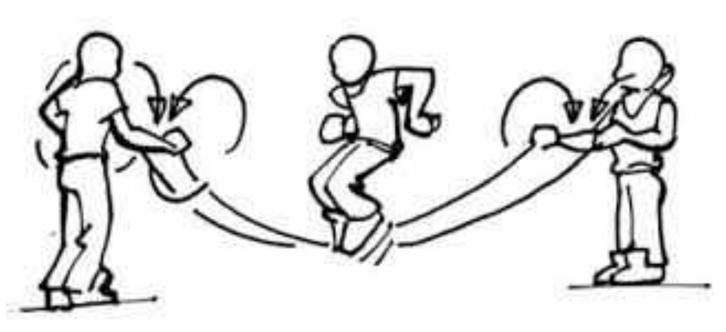




Decisional issues during Human-Robot Joint Action

How are we able to collaborate successfully?

What is necessary to be a good partner?



"Joint action can be regarded as any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment." [Sebanz]

Un travail de recherche multidisciplinaire autour de l'action conjointe Humain-Robot

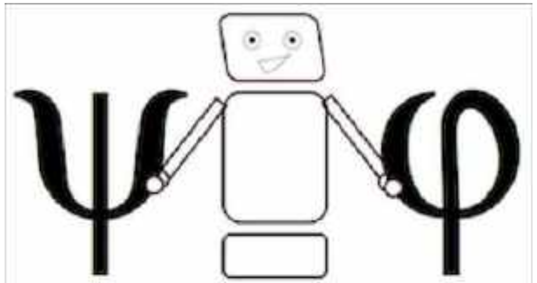
Series of Workshops (10) on Human-Robot Joint Action

- The last ones:
  - July 2018 - RSS – Pittsburg, USA http://fja.sciencesconf.org/ ,
  - Septembre 2018, CNRS

- A two-days workshop : Toulouse, April 2016

  From Human-Human Joint Action to Human-Robot Joint Action and vice-versa !

  http://hrja.sciencesconf.org/ (*Slides available for download)*



Bring together Psychologists, Philosophers, Roboticists on a common topic Joint Action: ANR JointAction4HRI

Approche

- Elaboration d'une Architecture: composants / ingrédients et leur articulation
- Etude / Elaboration de modèles (représentations, schémas) et comment ils peuvent être acquis
- Elaboration de Processus Décisionnels et Interactifs

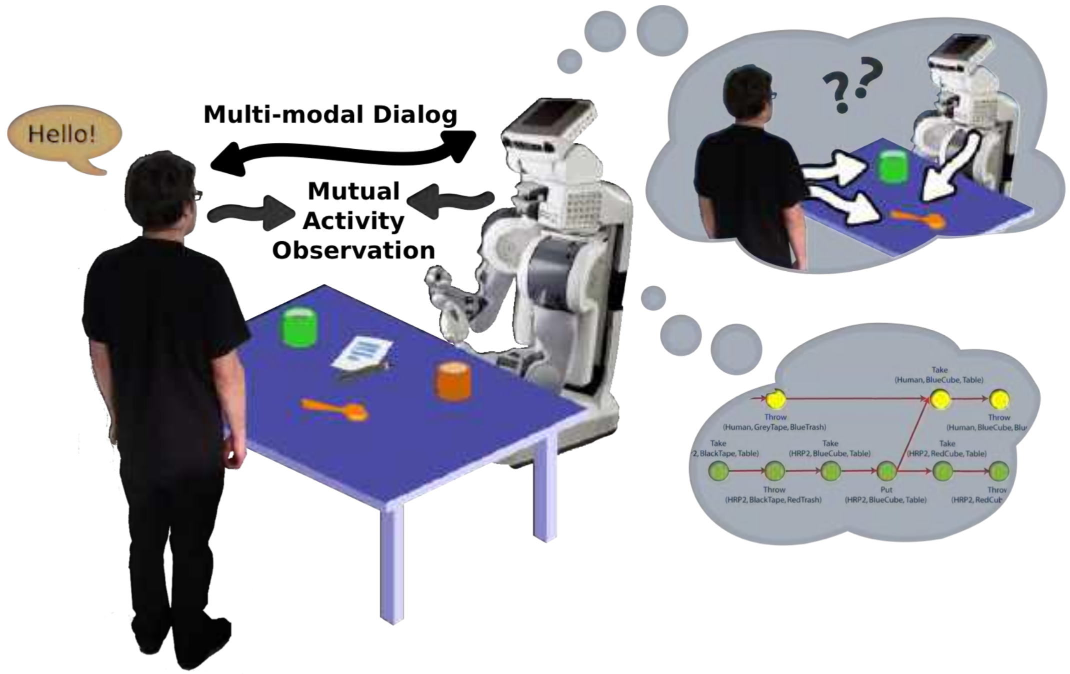
Un fonctionnement orienté tâche pour un robot interactif

H&R Partage de l'Espace et de la Tâche

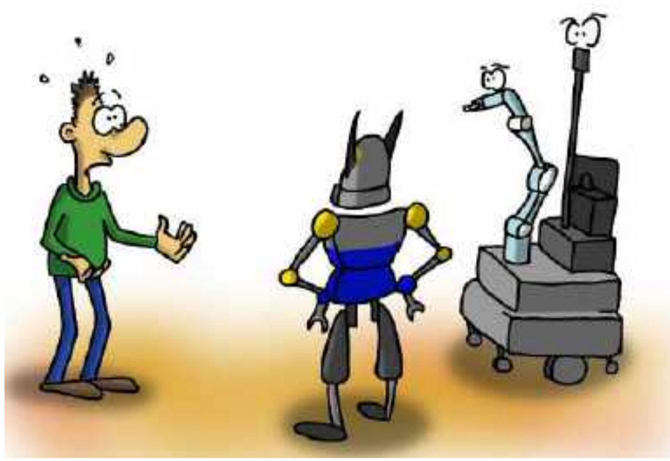
- **Orienté-tâche:** comment réaliser la tâche demandée, en présence de l'homme, et <u>au mieux</u>
  - Efficacité
  - Sûreté
  - Acceptabilité
  - Intentionalité

- **Délibération:** Prise de décision en-ligne et planification
  - Raisonnement
  - Anticipation
  - Comportement Pro-actif

- **Théorie de l'Esprit** – Raisonner et prédire l'état mental de son partenaire

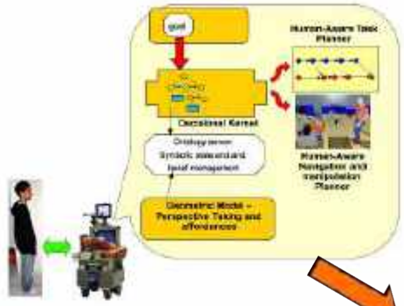


Questions pour un robot assistant un humain: quoi, qui, où, quand, comment?... et pourquoi ?.



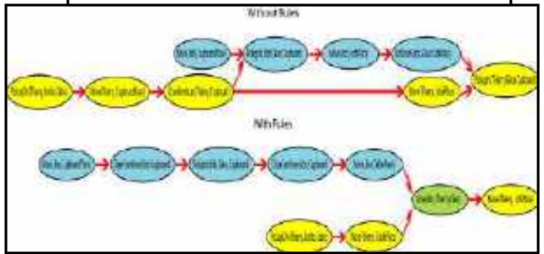
Decisional ingredients for an Interactive Autonomous Assistants

A Control Architecture for a Cognitive Assistant



SHARY: Cooperative Task Achievement

Human Aware Task Planning



Human Aware Navigation

Affordances- Mightabilities

Human Aware Manipulation

Perspective Taking

Soft Motion

Quelques exemples

1. Interprétation de situation, théorie de l’esprit, Perspective-Taking et les affordances
2. Elaboration d’un plan fondée sur les capacités de chacun des partenaires
3. Réalisation d’une action en fonction des préférences et besoins du paratenaire humain
4. Gestion de l’engagement dans la réalisation d’une activité conjointe

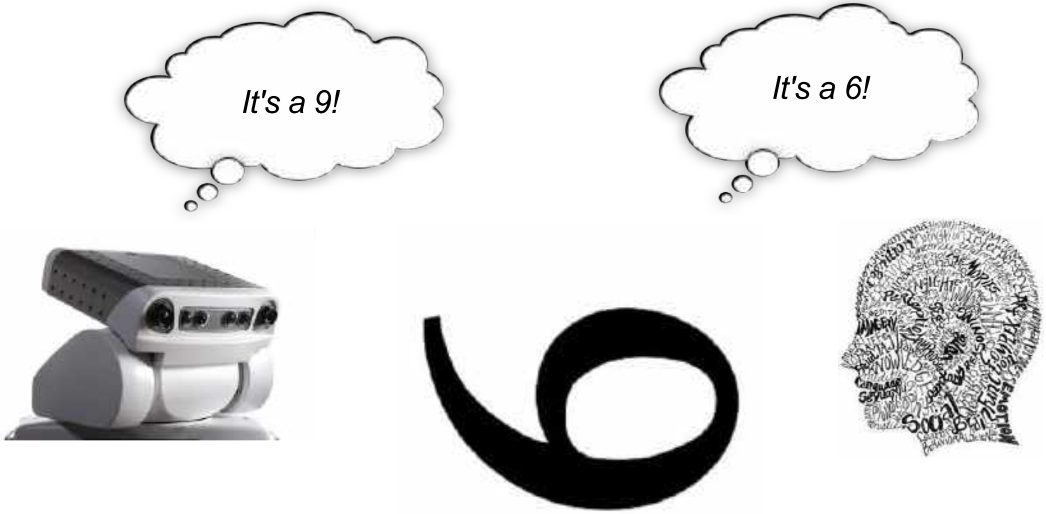
Artificial Cognition for Social Human-Robot Interaction: An Implementation
Séverin Lemaignan, Matthieu Warnier, Emrah Akin Sisbot, Aurélie Clodic, Rachid Alami
Artificial Intelligence, Elsevier, 2017, 247, pp.45-69.

1 - Perspective-taking and affordances in interactive contexts

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

Theory of Mind

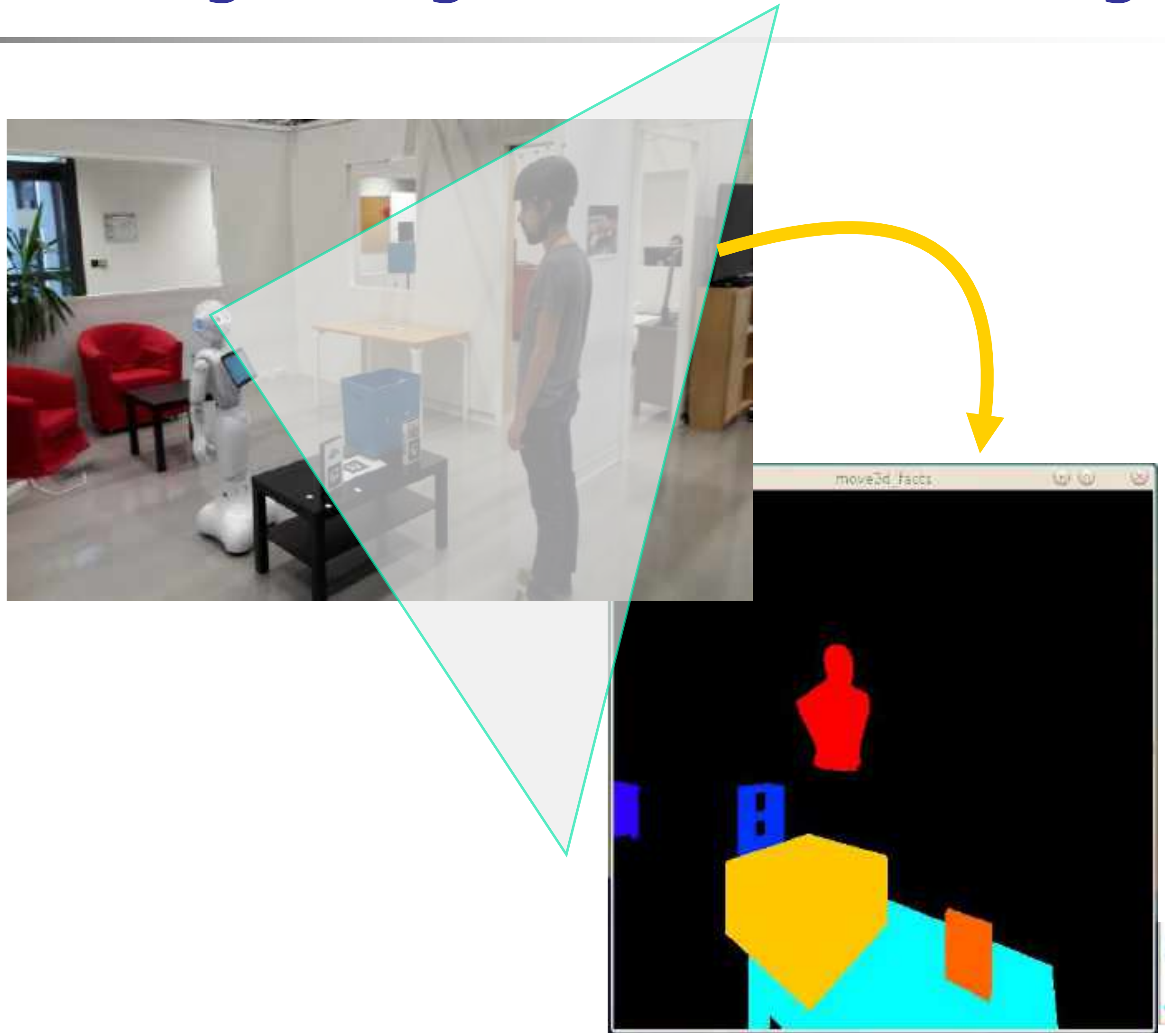


The ability to attribute mental states to oneself and others and to understand that others have beliefs, desires, intentions, and perspectives that are different from one's own.

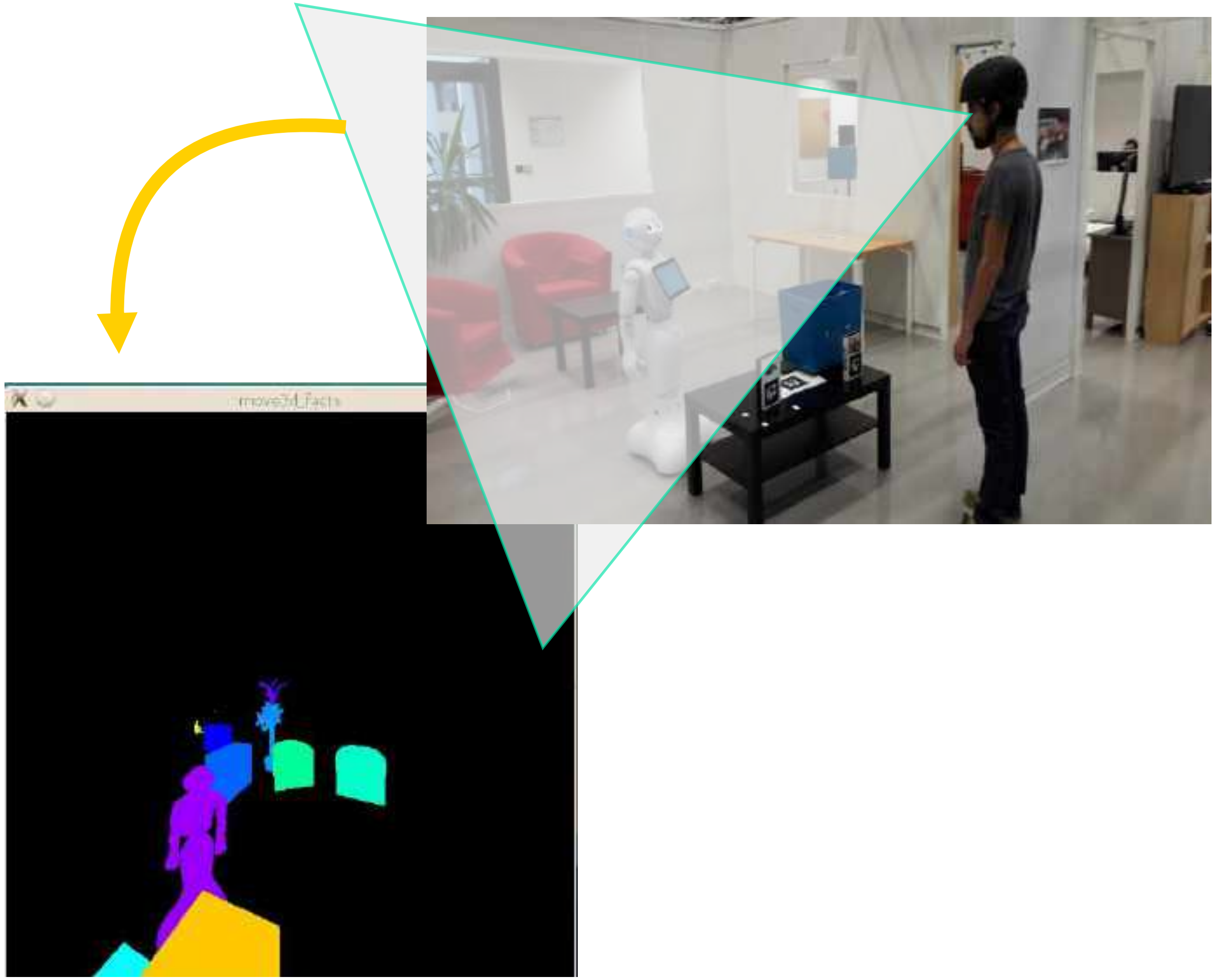
Perspective-taking used for Pointing

- what they see, what they have seen, what is hidden to them in the current situation

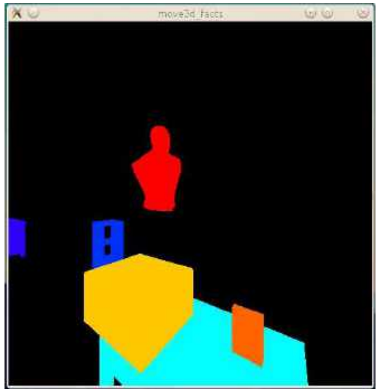
Perspective-taking and geometric reasoning

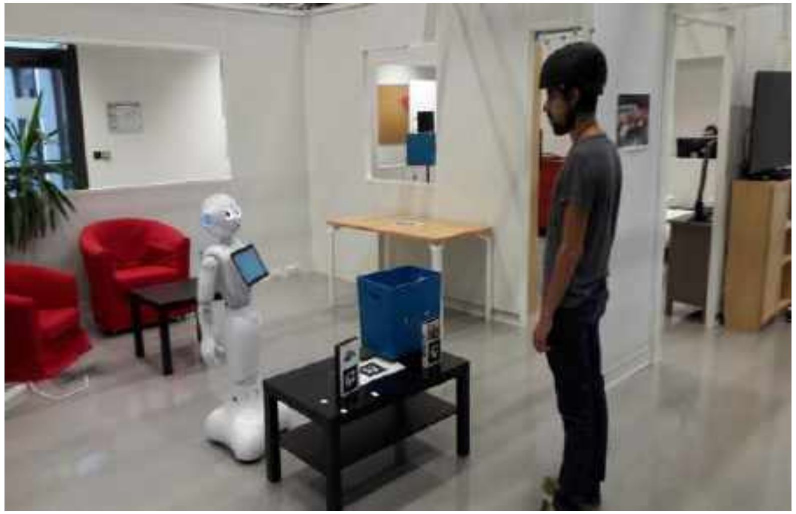


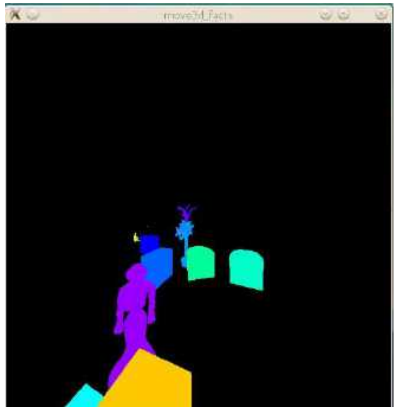
Perspective-taking and geometric reasoning



Perspective-taking and geometric reasoning







the robot

- Enumerates object(s) and human(s) seen by the robot
- Estimates the object(s) and agent(s) seen by its human partners

Perspective-taking used for Pointing

Mind reading for Robot's Social Intelligence

- Theory of mind
- Developing means to estimate mental state
  1. Situation assessment
  2. Comfort, Acceptability of robot behaviour
  3. State of Joint Goals and Shared Plans

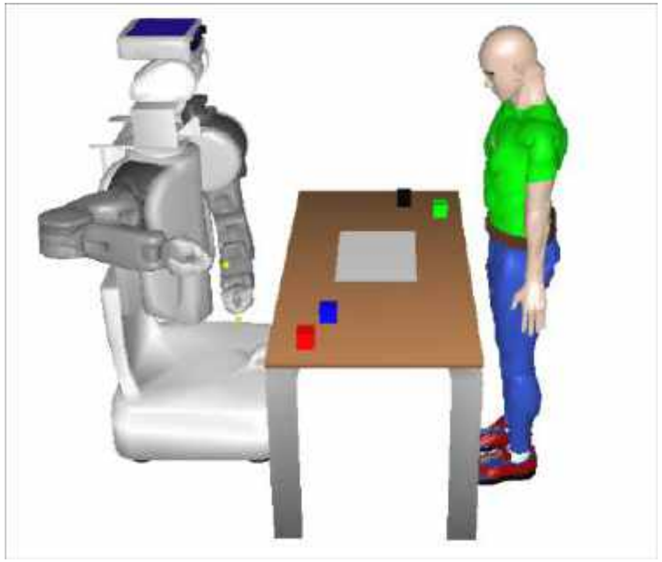
-> Perspective taking based on geometric and temporal reasoning, Affordances estimation

Situation assessment

perception

Situation assessment

perception



robot position
robot arm position
robot head position

human position
human hand position
human head orientation

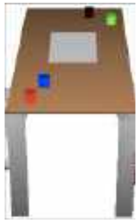


table position

game board position

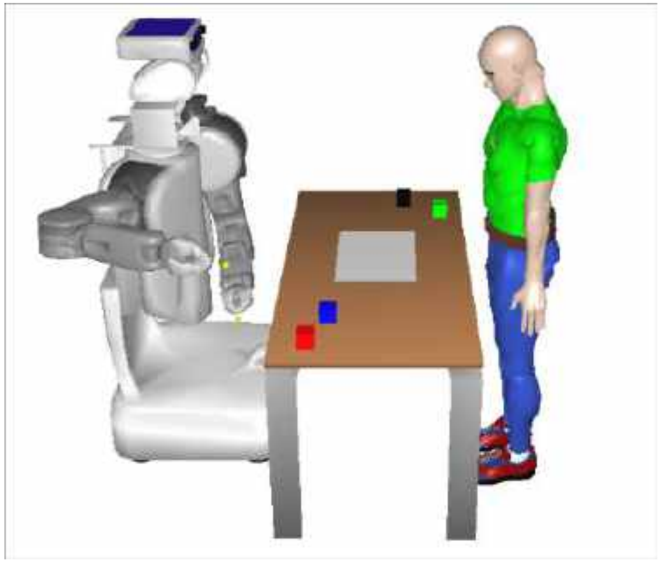
green cube position
red cube position
blue cube position
back cube position

Situation assessment

perception

green cube position ???

- frame base_link
  x -0.5
  y 0.75
  z 0.9
  theta 0.0

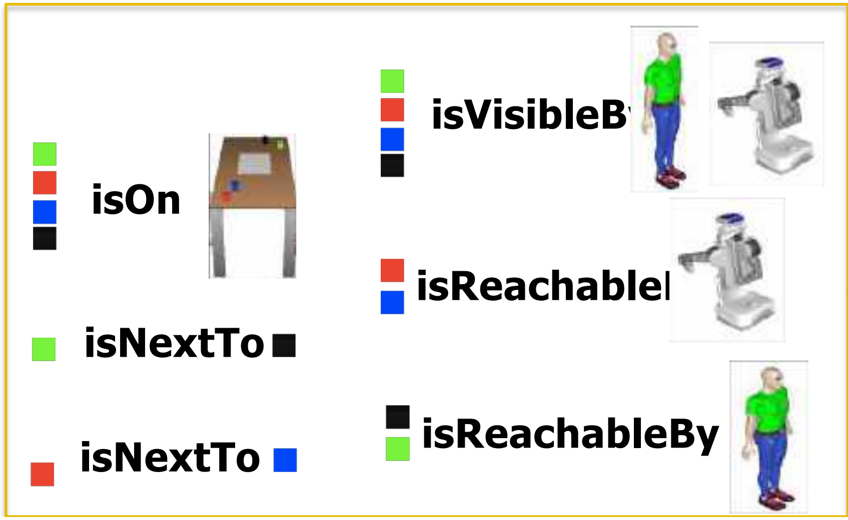


- is on the table

Situation assessment

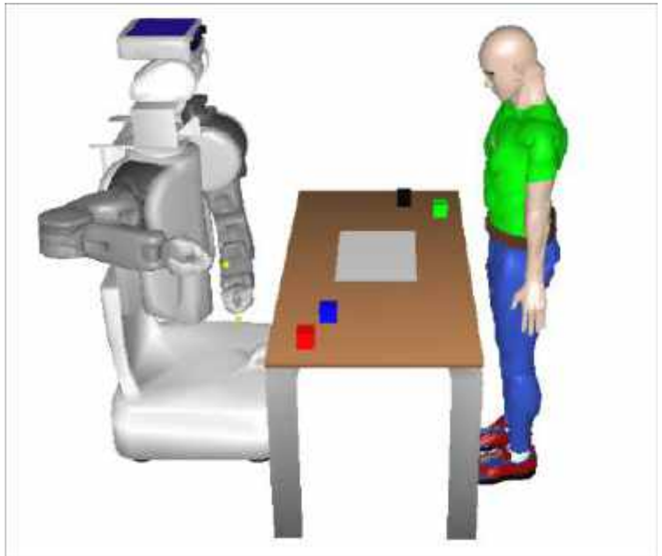
perception

spatial reasoning



Situation assessment

spatial-reasoning



isOn

isNextTo

isNextTo

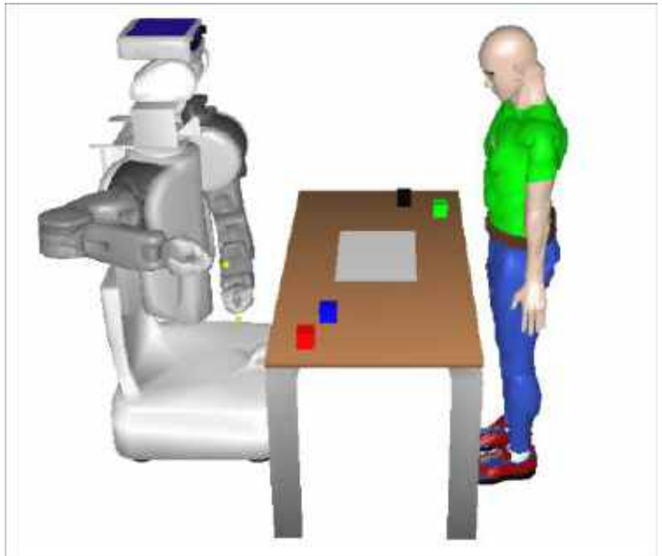
isReachableBy

isReachableBy

isVisibleBy

Situation assessment

spatial-reasoning



isOn 

isNextTo

isNextTo

isReachableBy 

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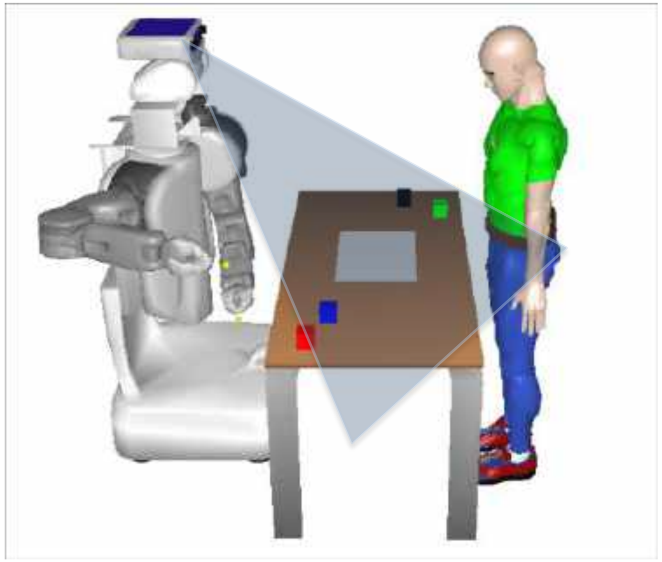
Situation assessment

mental state management



isOn 

isNextTo

isNextTo

isReachableBy 

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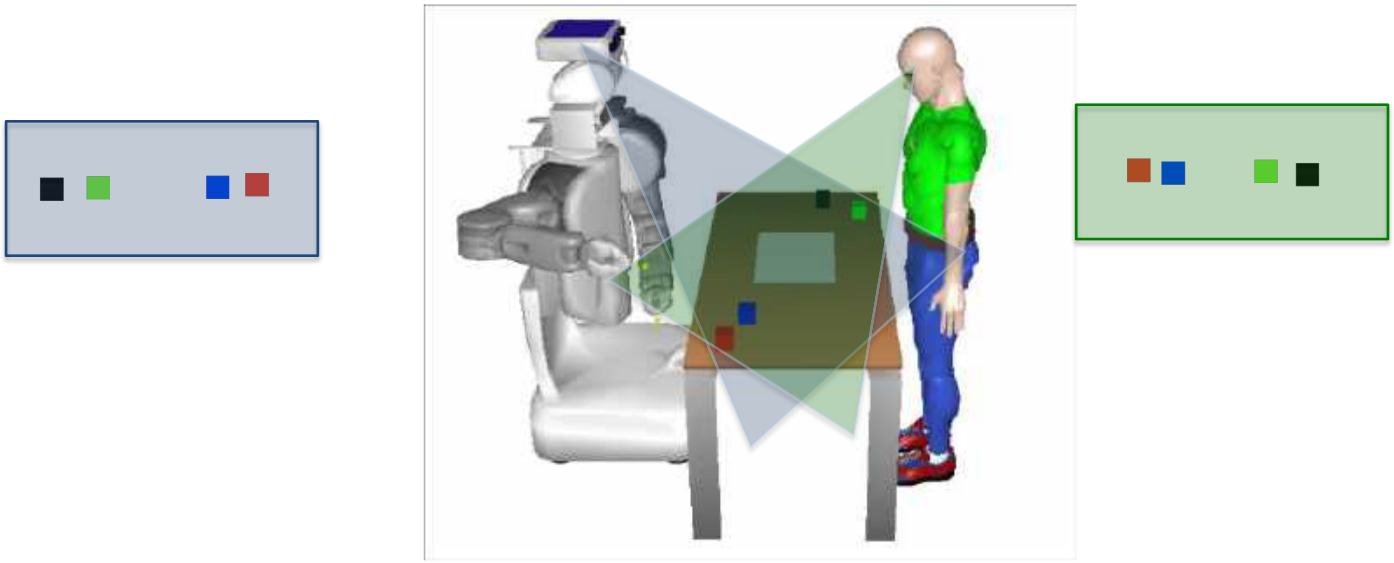
isVisibleBy  

Situation assessment

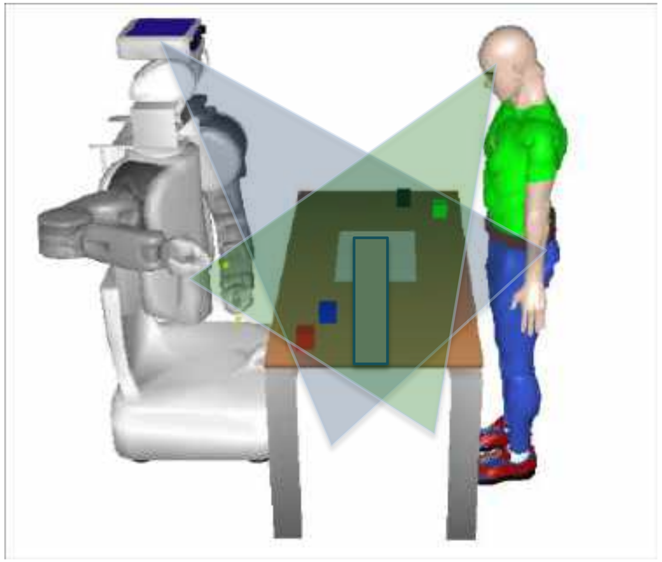
mental state management

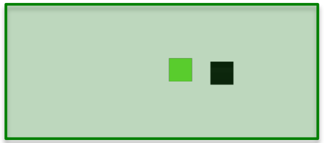


set of the cubes on the table ???

Situation assessment

mental state management

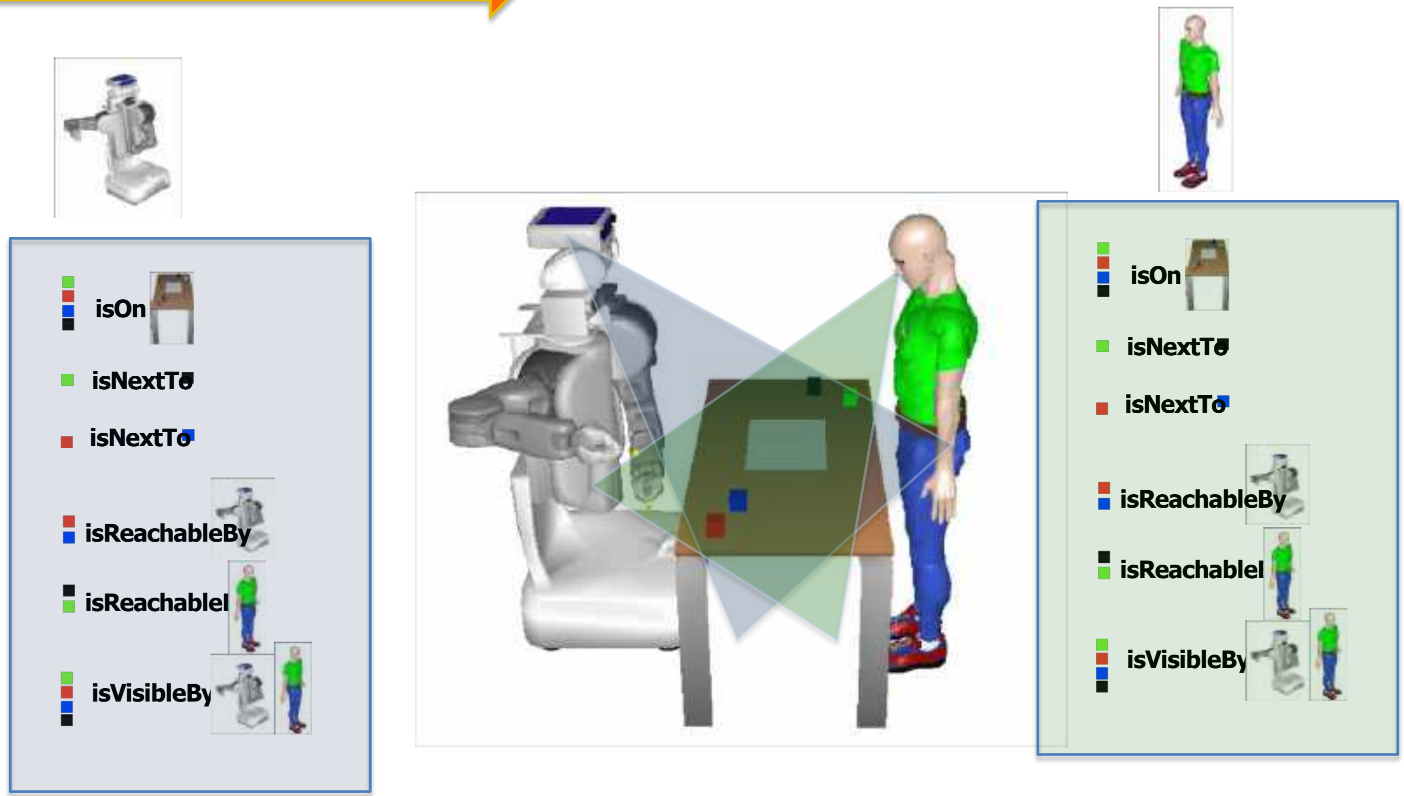




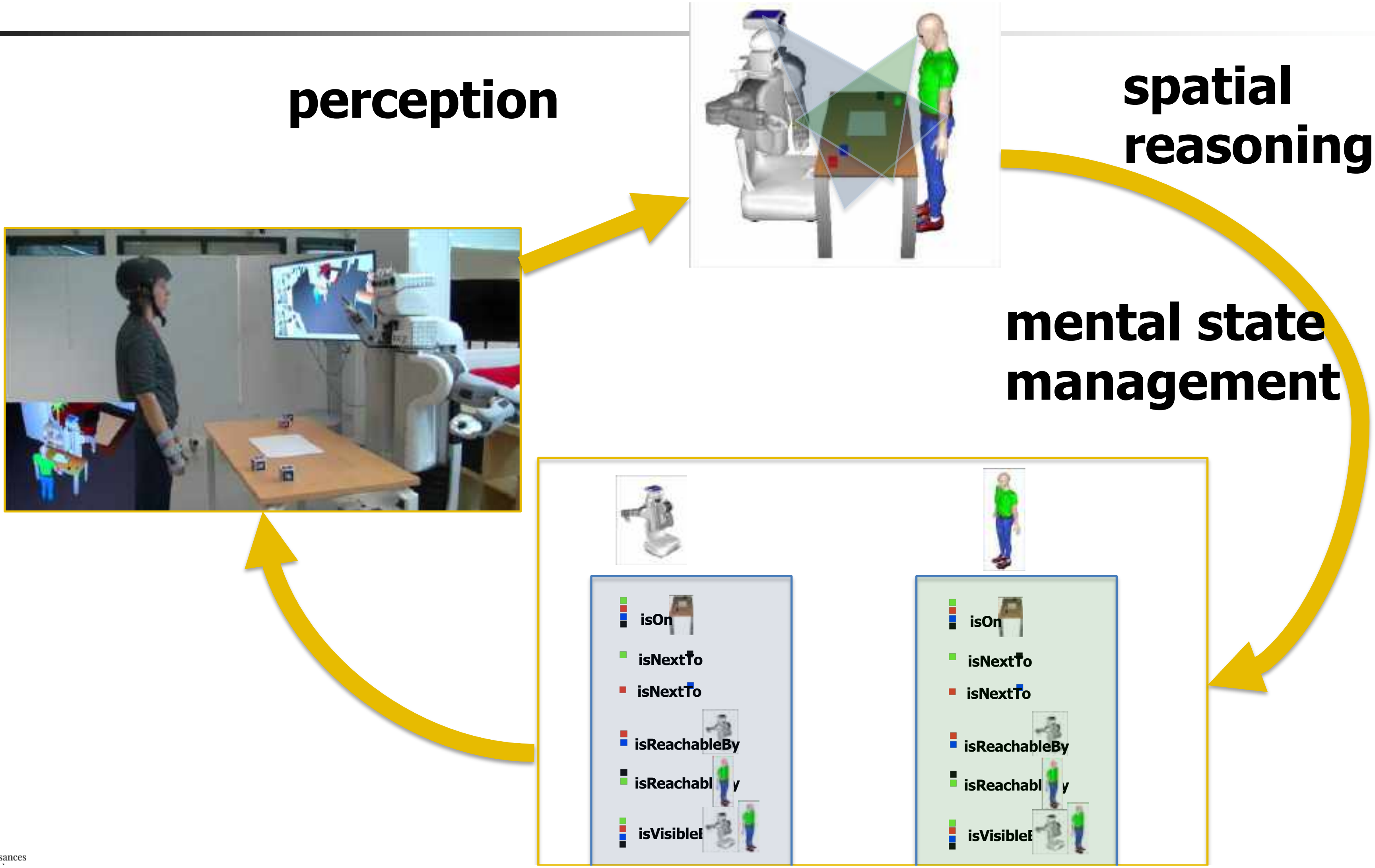
set of the cubes on the table
what if something is hidden ?

Situation assessment

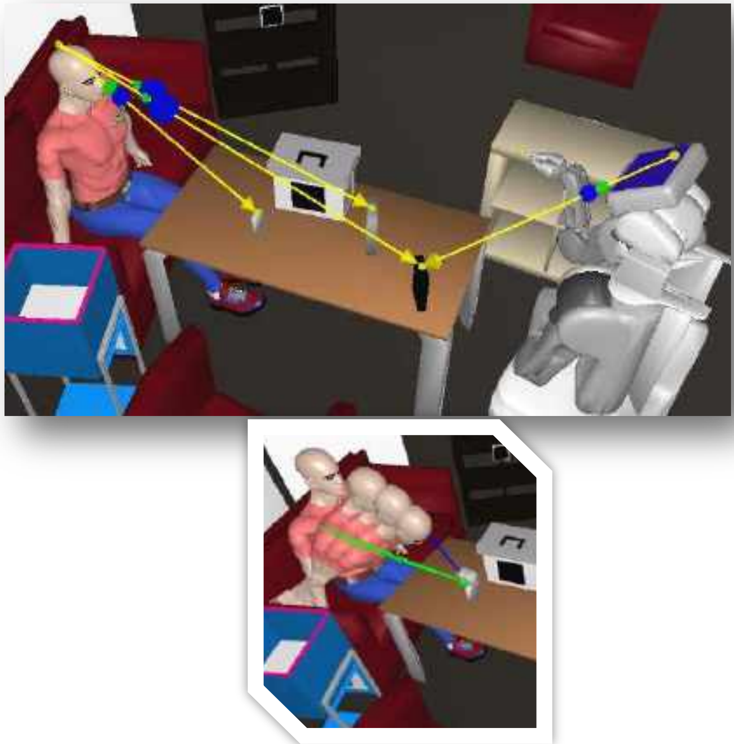
mental state management

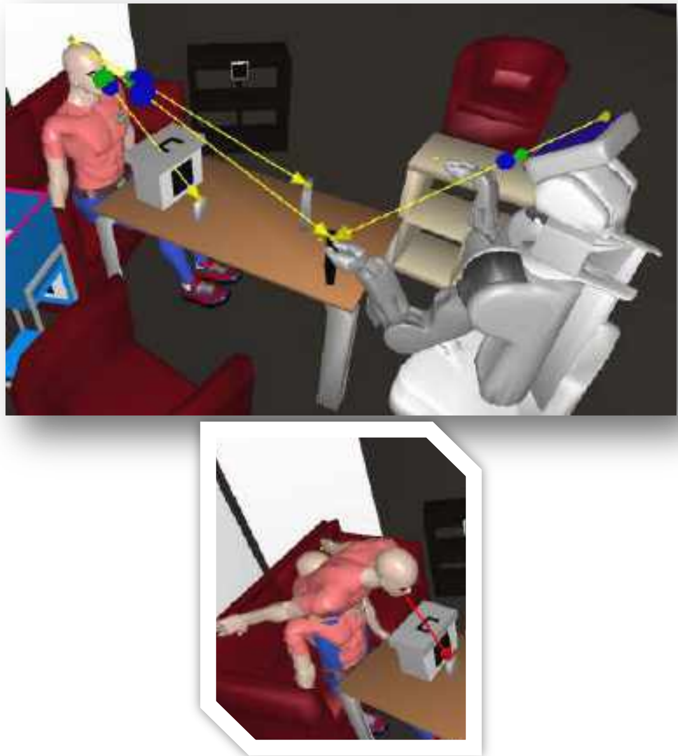


Situation assessment



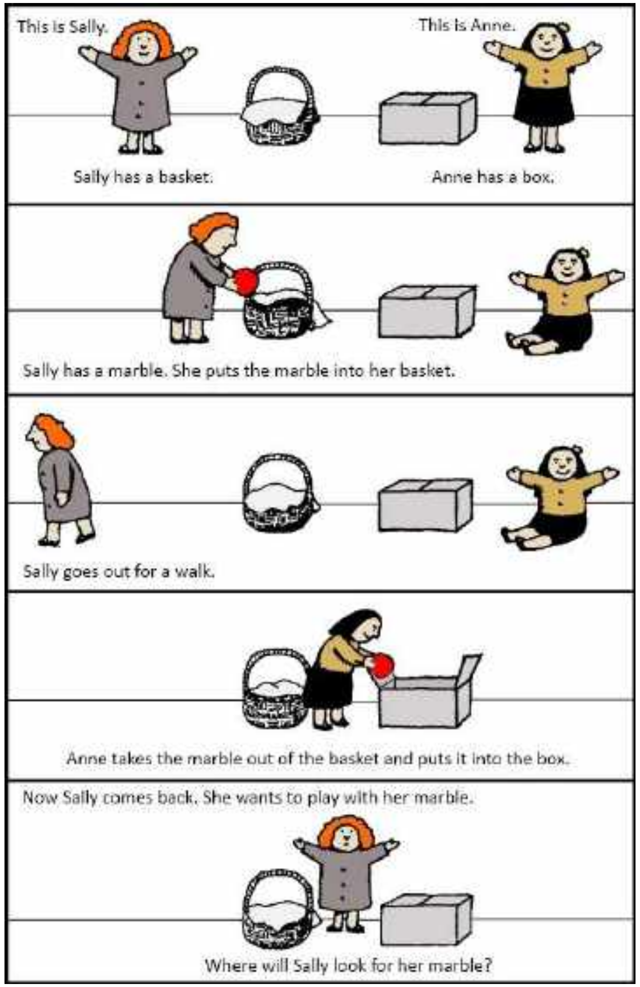
Situation assessment





Pandey, A. K. (2012). *Towards Socially Intelligent Robots in Human Centered Environment*.

Sally and Anne



Detecting and Managing Divergent Beliefs

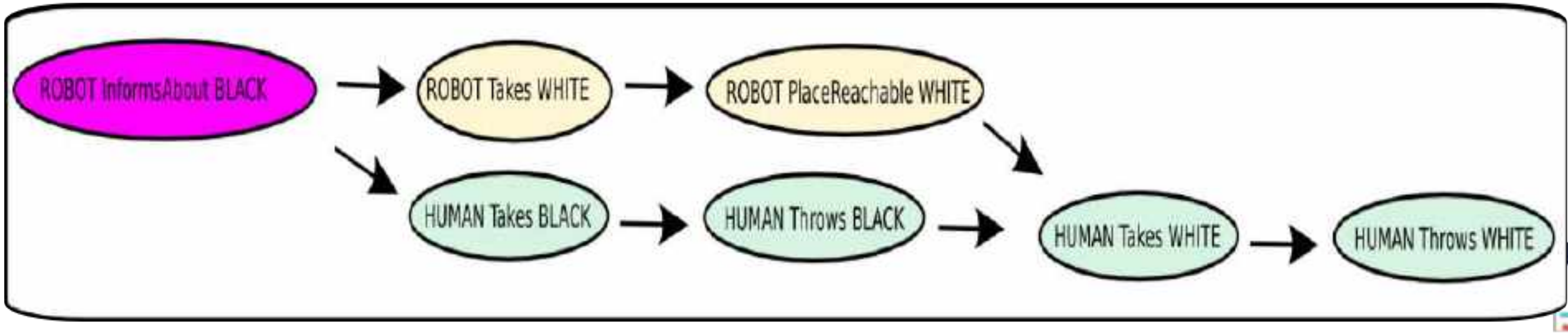
If the goal is « to clean the table »….

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**



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)

Depuis 80 ans, nos connaissances

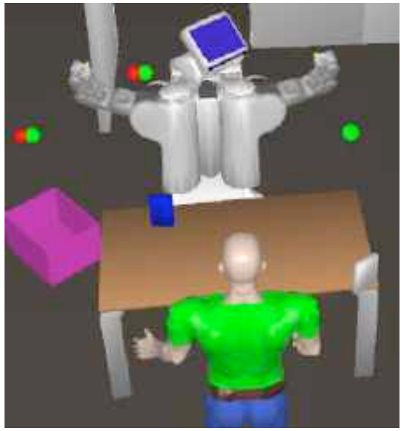
From Shared Cooperative Activity

- From a (shared) goal to a (shared) plan
- Need to elaborate and agree on how to achieve a goal: the plan (also called « recipe »)

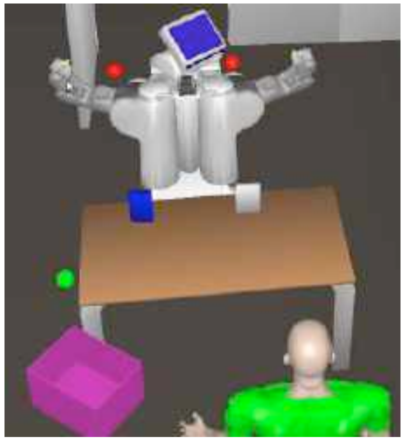
- Robot selects a stereotypical or known plan / build a plan based:
  - on the goal to satisfy
  - on the current state (as it is perceived and inferred)
  - on its knowledge of the capacities of each agent (itself and the human)
  - on its estimation of the belief of its human partner

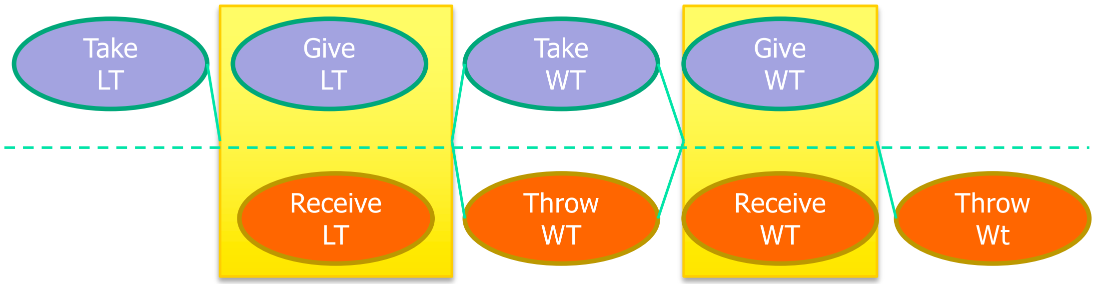
HATP: An HTN Planner for Robotics, Raphaël Lallement, Lavindra De Silva, Rachid Alami
2nd ICAPS Workshop on Planning and Robotics, Jun 2014, Portsmouth, United States

Human Aware Planning

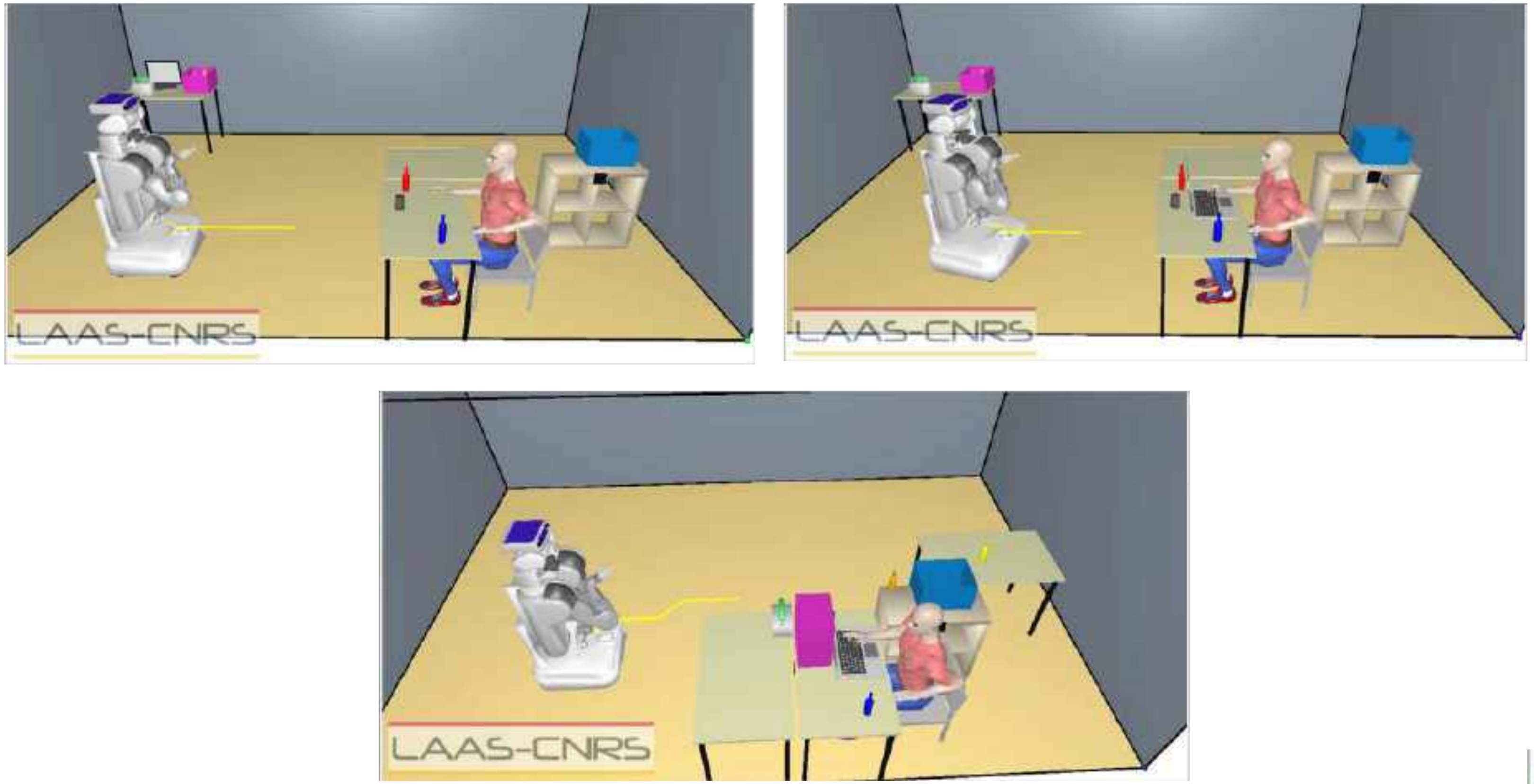


Meshing sub-plans

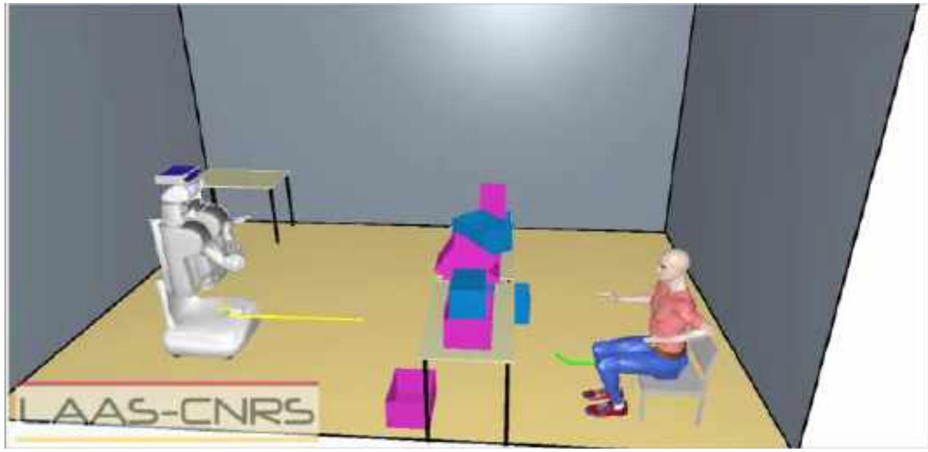




Planning for human and robot

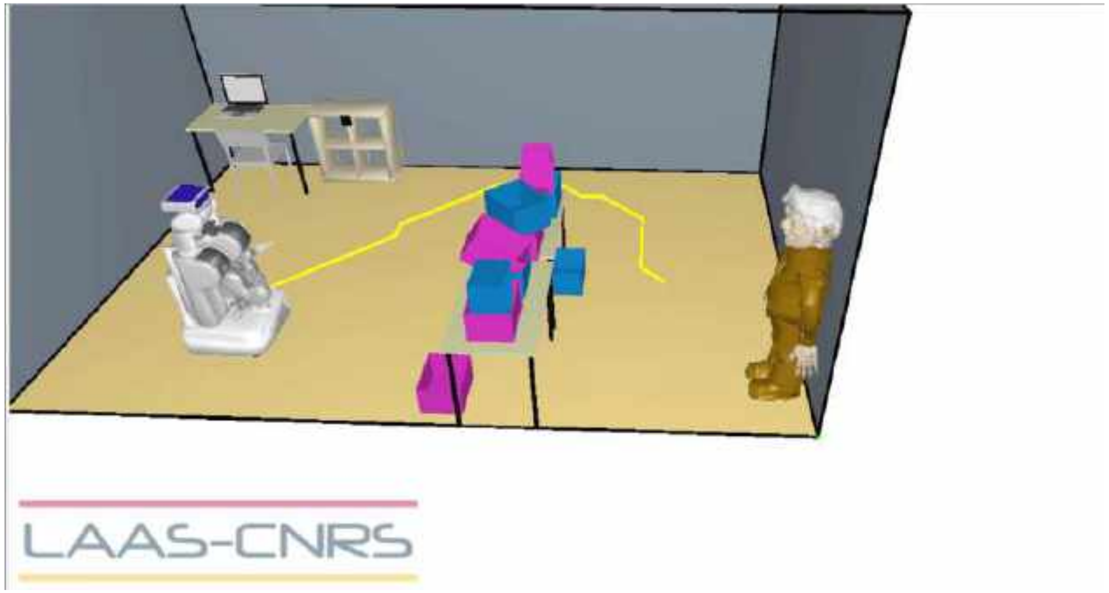


Planning for human and robot



Robot behaviour can be tuned and adapted to human preferences

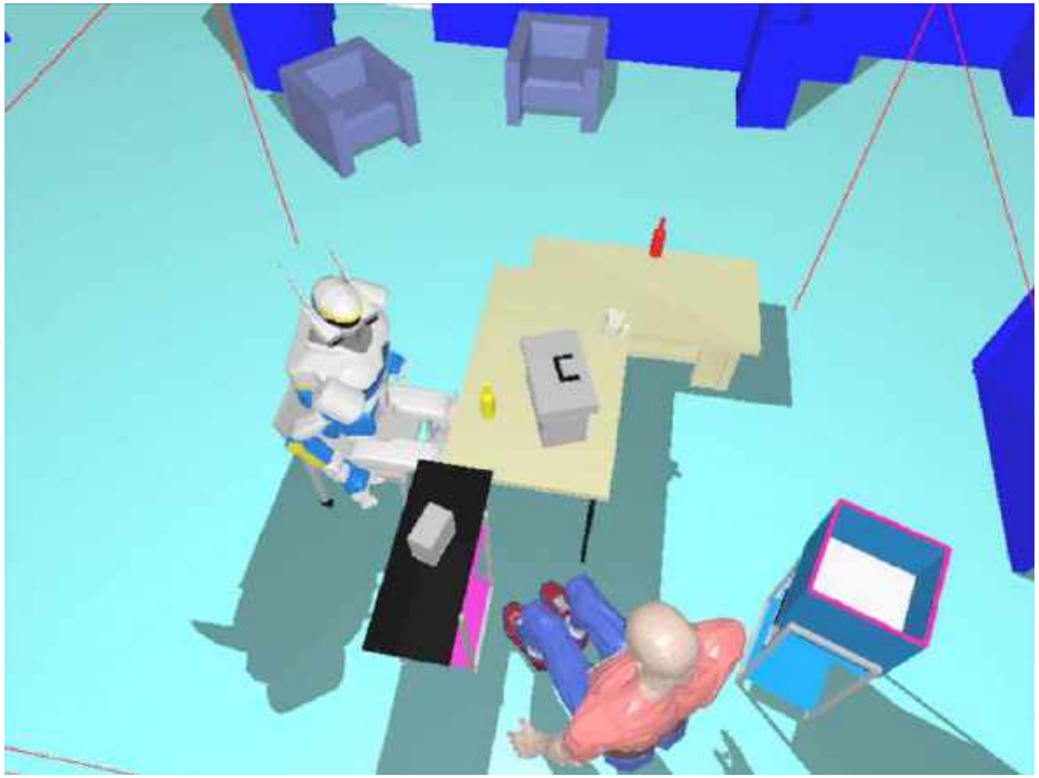
Sharing the load for efficiency :
Human needs the task to be achieved quickly



Sharing the load for convenience:
Elderly people prefer the robot to do more

Sharing effort in planning human-robot handover tasks
Jim Mainprice, Mamoun Gharbi, Thierry Siméon, Rachid Alami
IEEE RO-MAN: 2012, Paris, Francea

Put for human



Raisonnement sur la visibilité et l'accessibilité

Towards Human-Level Semantics Understanding of Human-Centered Object Manipulation Tasks for HRI: Reasoning About Effect, Ability, Effort and Perspective Taking
Amit Kumar Pandey, Rachid Alami
nternational Journal of Social Robotics,
Springer, 2014, 6 (4), pp.593 - 620.

3 - Synthesizing a good / pertinent behavior

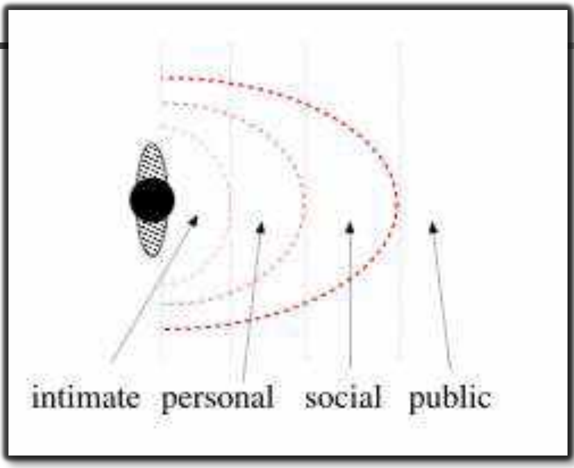
Building a « good » plan

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

Constraints on robot plans

Sharing space

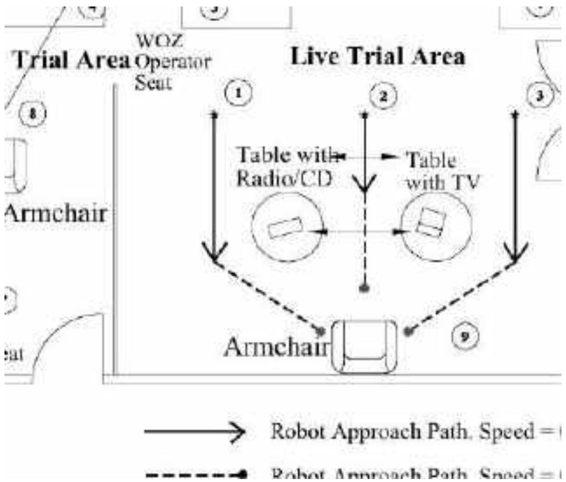
Robot motion and placement deduced from user trials

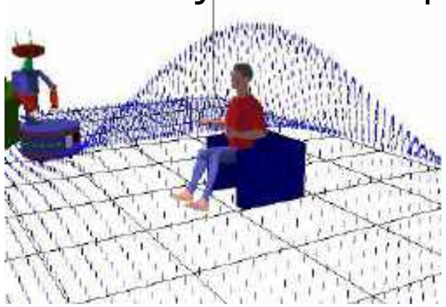


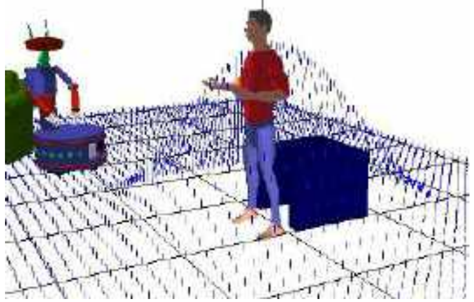
Proxemics (Hall 66)

User trials performed at Univesity of Hertfordshire

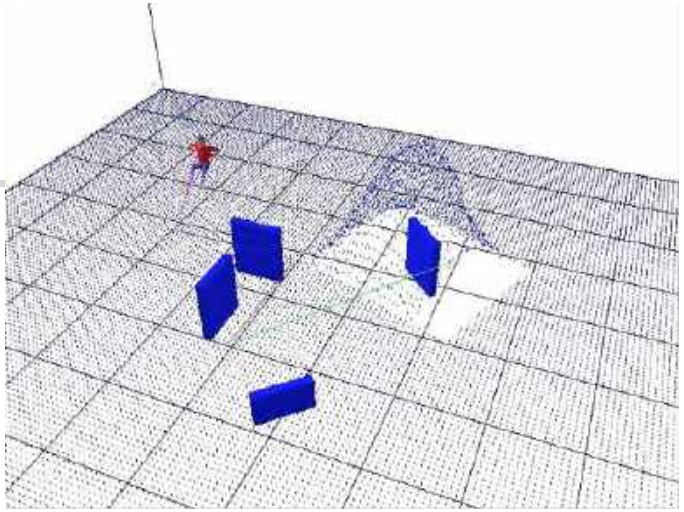
K.L.Koay et Al "Exploratory Studies of a Robot Approaching a Person in the Context of Handing Over an Object »AAAI Spring Symposium - 2007



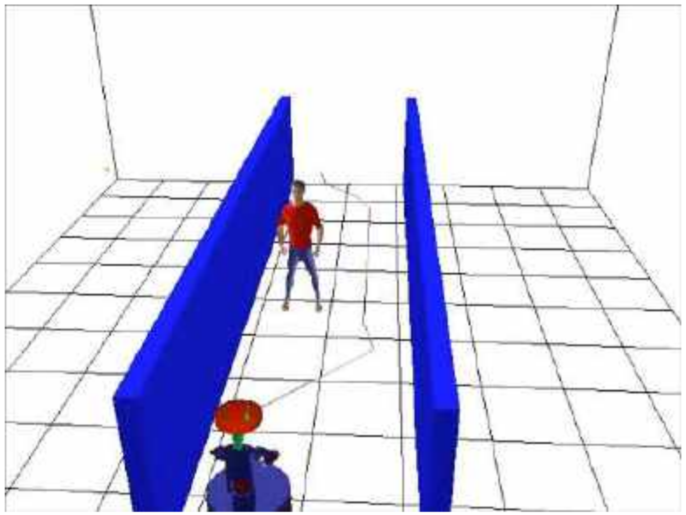




Real-time cost evaluation: distance, posture, visibility

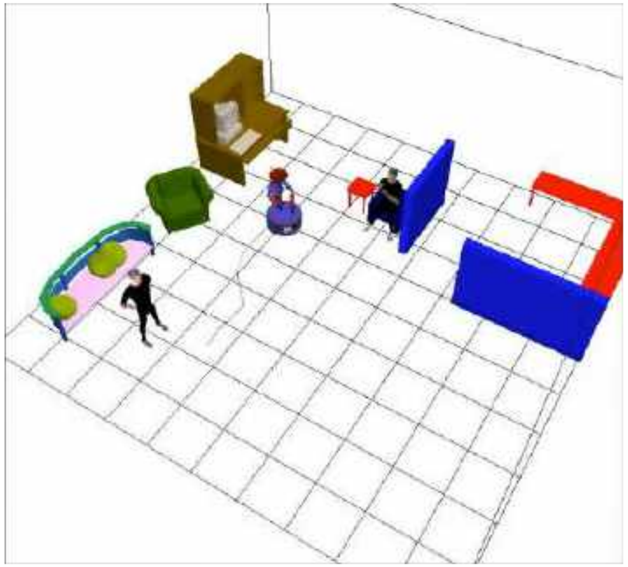


E.A.Sisbot , L. F.Marin Urias , R.Alami , T.Simeon
"A human aware mobile robot motion planner" ,
IEEE Transactions on robotics, Vol.23,N°5, 2007



Hallway Crossing

Catenary-like trajectory

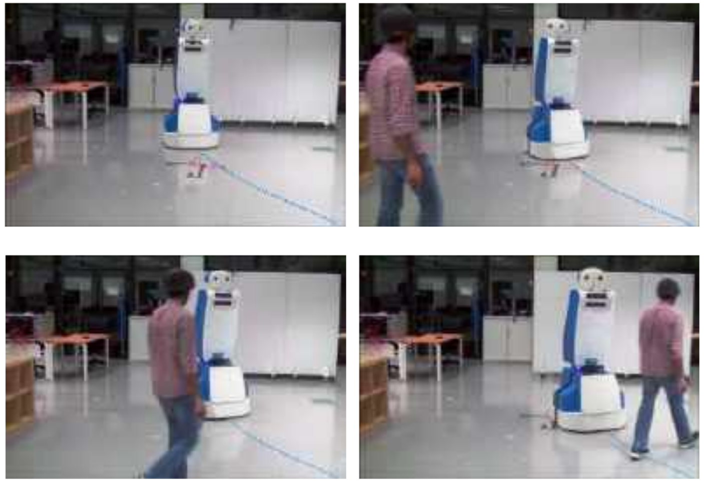


Replanning in dynamic environment

Depuis 80 ans, nos connaissances

Making robot intent legible

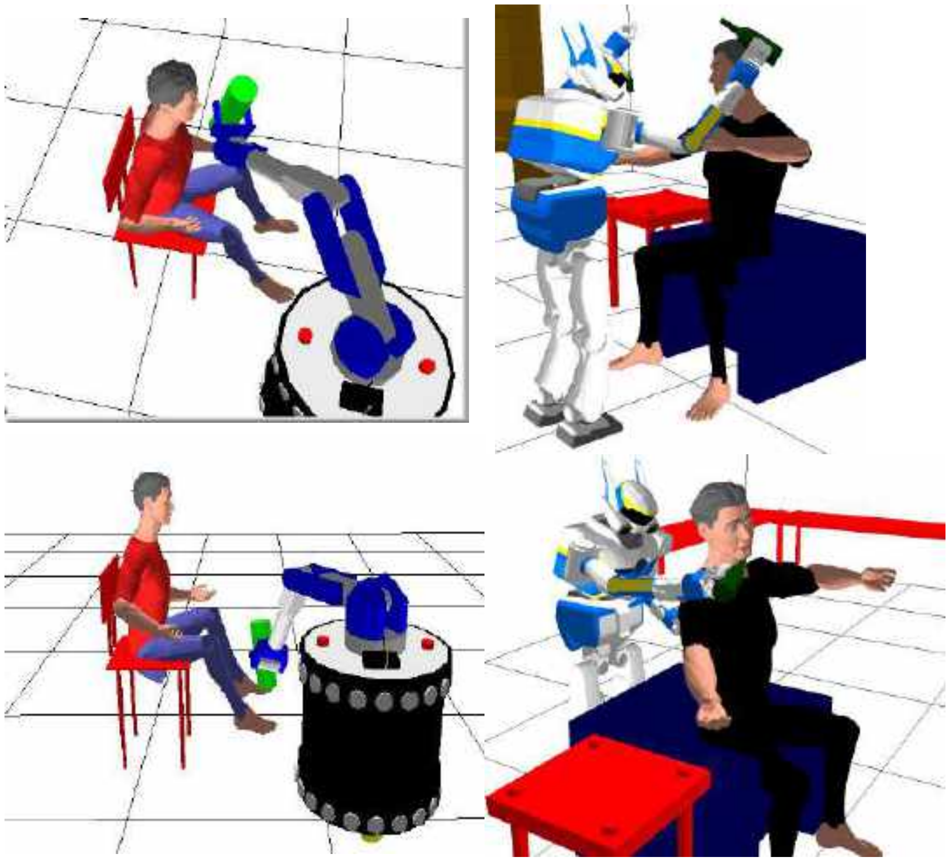
- We have proposed a multi-criteria decision-making based approach for head pan-tilt motion control.
- A head-behavior module have been developed that exhibits ***look-at-path*** and ***glance-at-human*** behaviors for **legibility of robot intent**



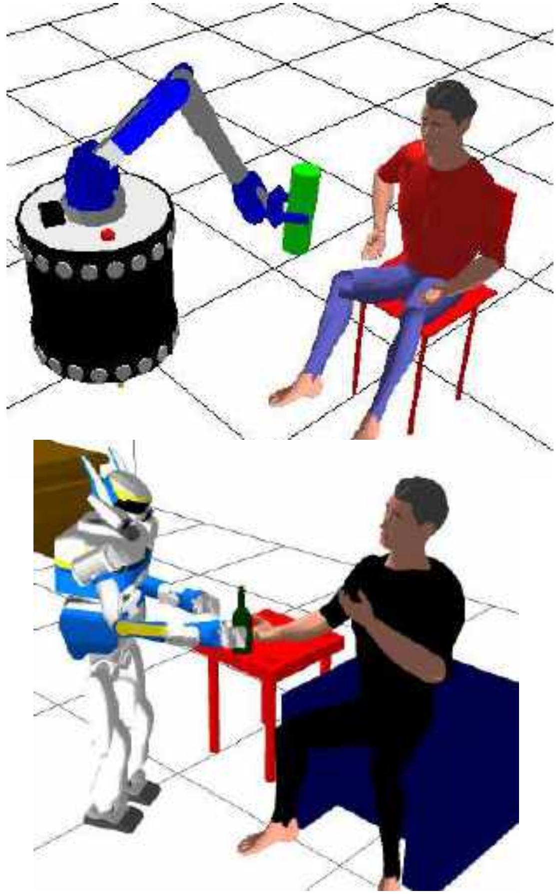
SPENCER robot at Schiphol

Take the mug … and Give it to me
or (simply)
Give me the mug

How to hand an object to a person?



Undesirable Placements /Motions

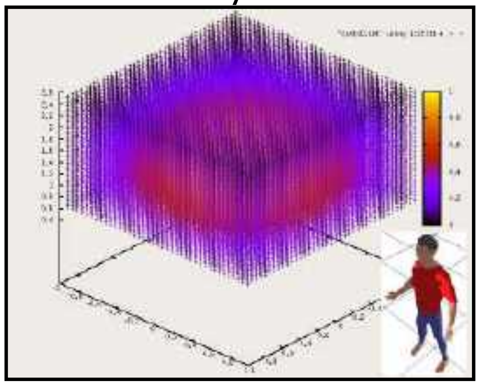


“acceptable” placements

Handing an object to person

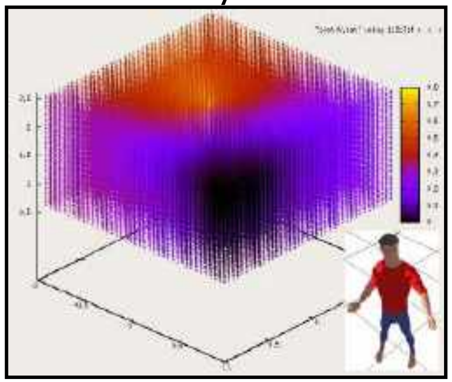
- The object should be placed in a safe and comfortable position.
- 3 different HRI properties are defined and represented as 3D cost grids around the human

Safety



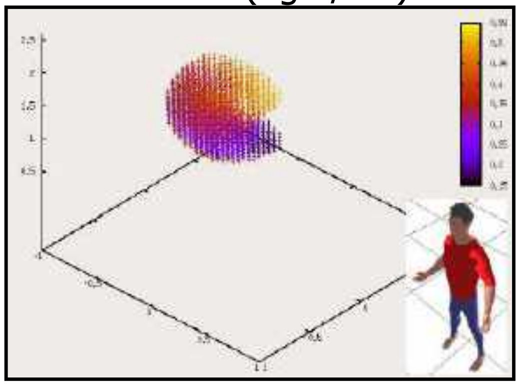
Proportional to the distance to human

Visibility



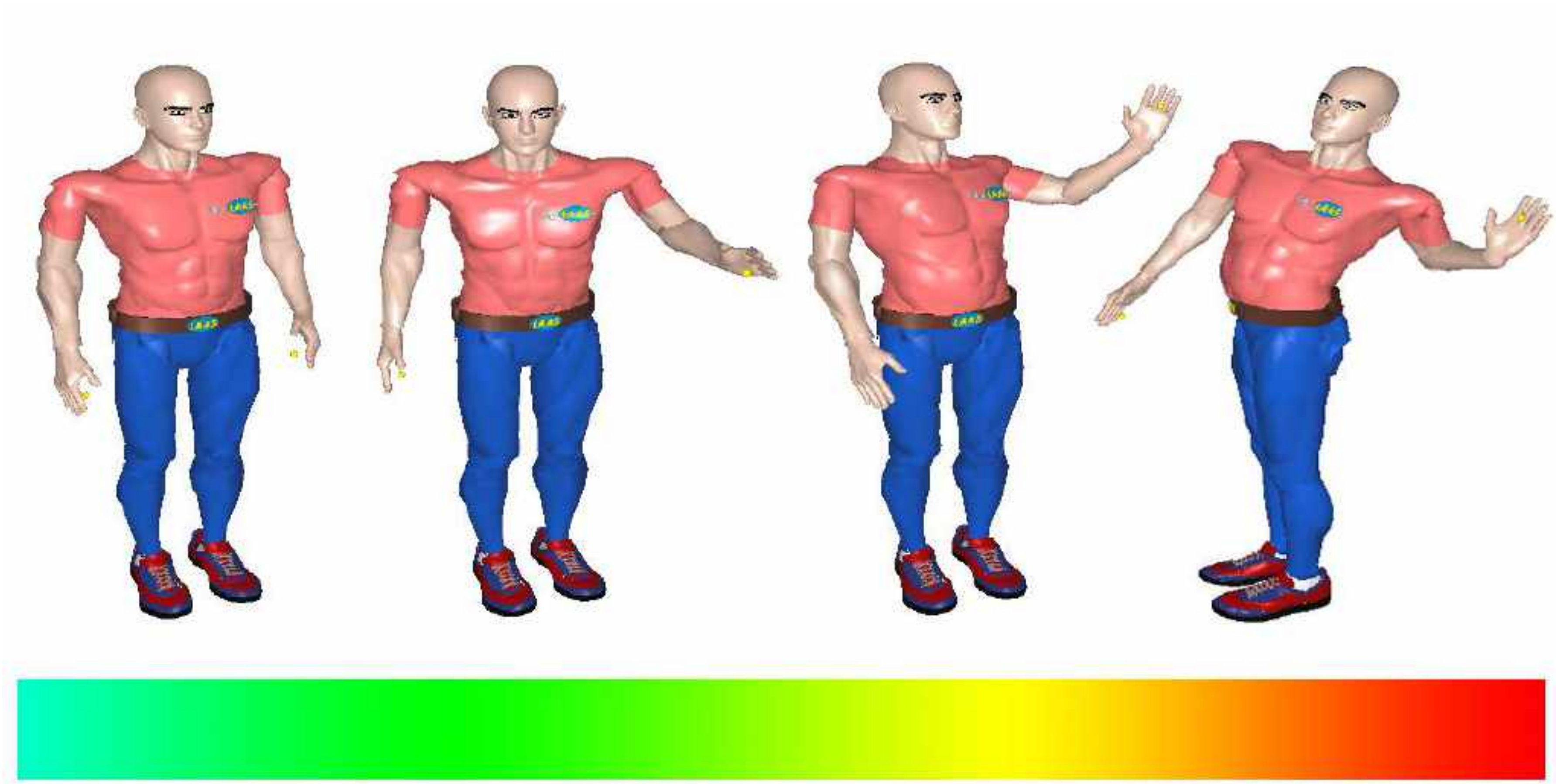
Reflects the effort to see a point

Arm Comfort(right/left)



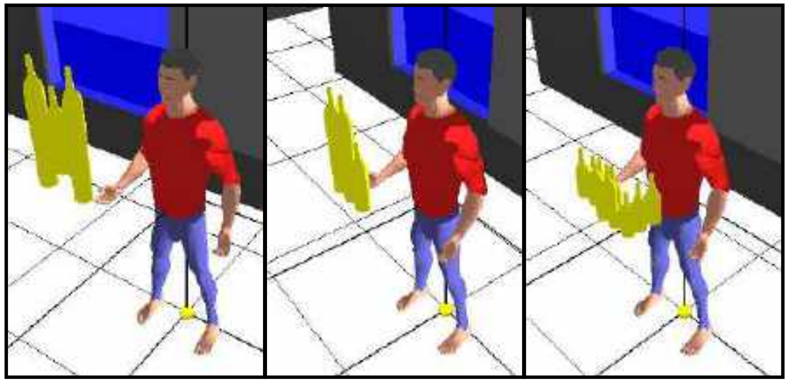
Combination of d.o.f difference and potential energy

The comfort criteria

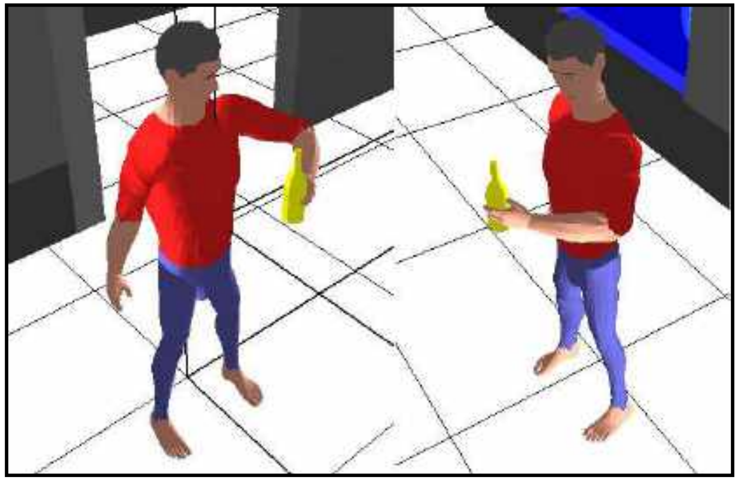


Calculating object transfer position

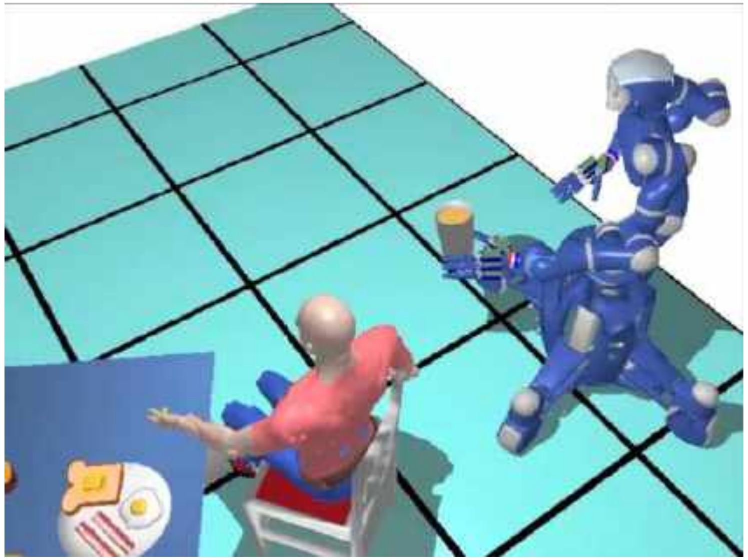
- 3 grids are combined to form a final grid that merges all these properties.
- The cell with minimum cost is chosen to be the place where robot will place the object.



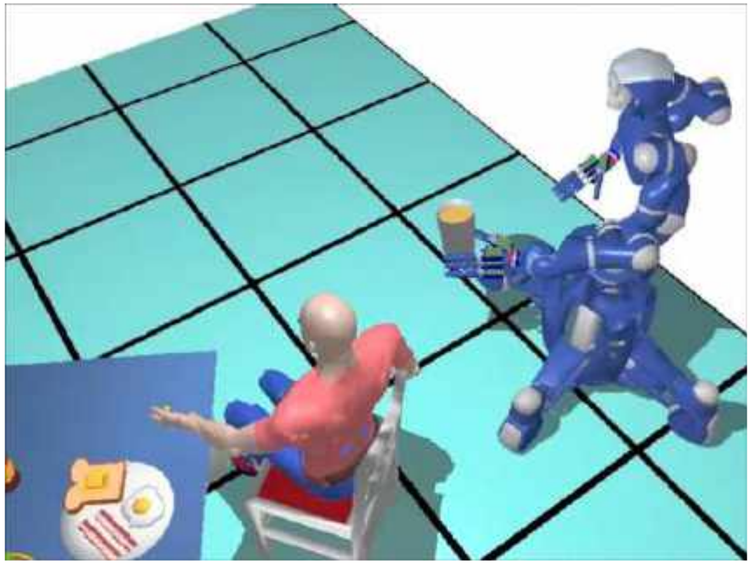
Dist > Vis >AC   Vis > Dis > AC   AC > Vis > Dis



Intrusive



Better



E.A.Sisbot , L. F.Marin Urias , R.Alami , T.Simeon "A human aware manipulation planner" , IEEE Transactions on robotics, 2012, 28 (5), pp.1045 - 1057.

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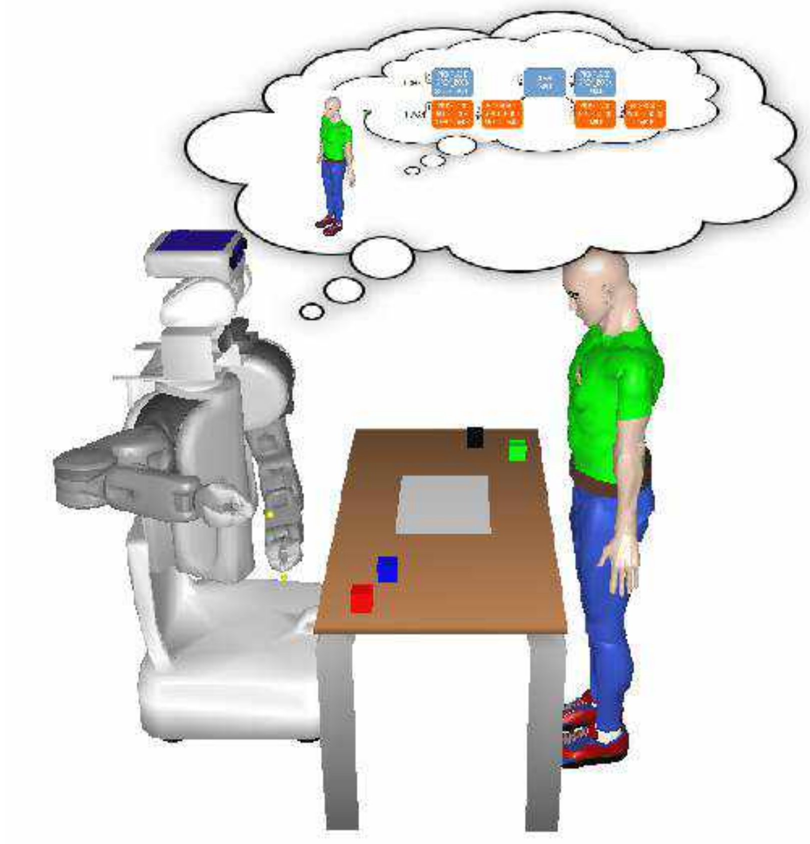
4 – Managing Commitment in Joint task achievement

Theory of Mind to Improve Human-Robot Shared Plans Execution



S. Devin and R. Alami : An Implemented Theory of Mind to Improve Human- Robot Shared Plans Execution. ACM HRI 2016

Use of mental states to solve divergent beliefs

- **Before humans actions**

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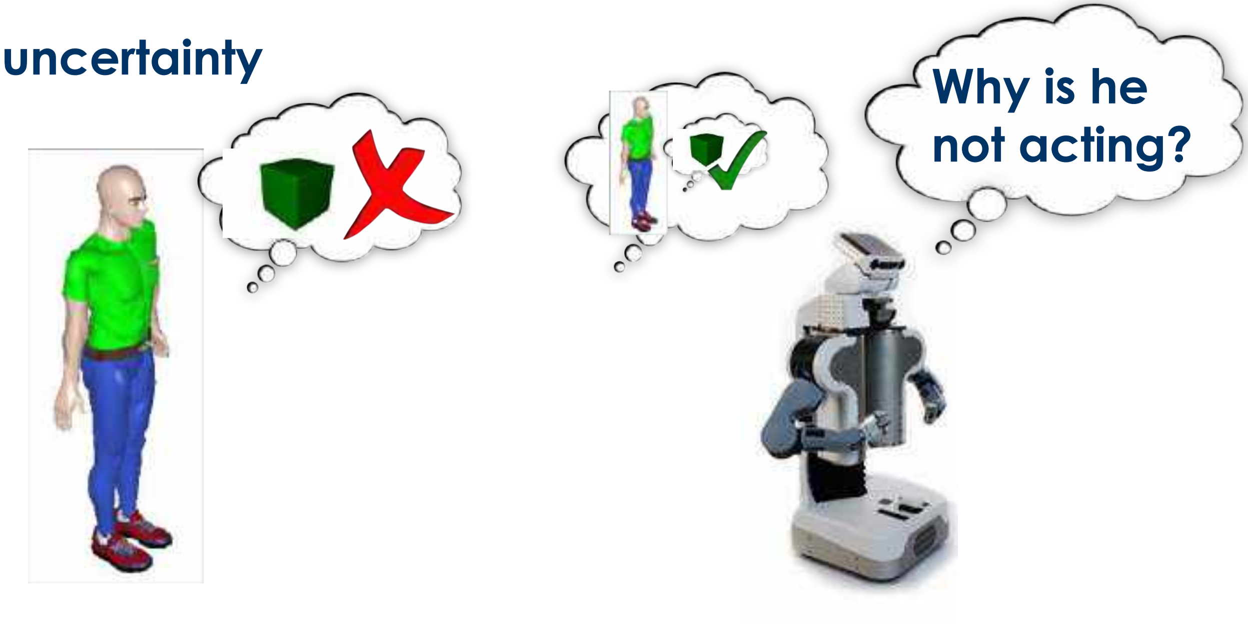
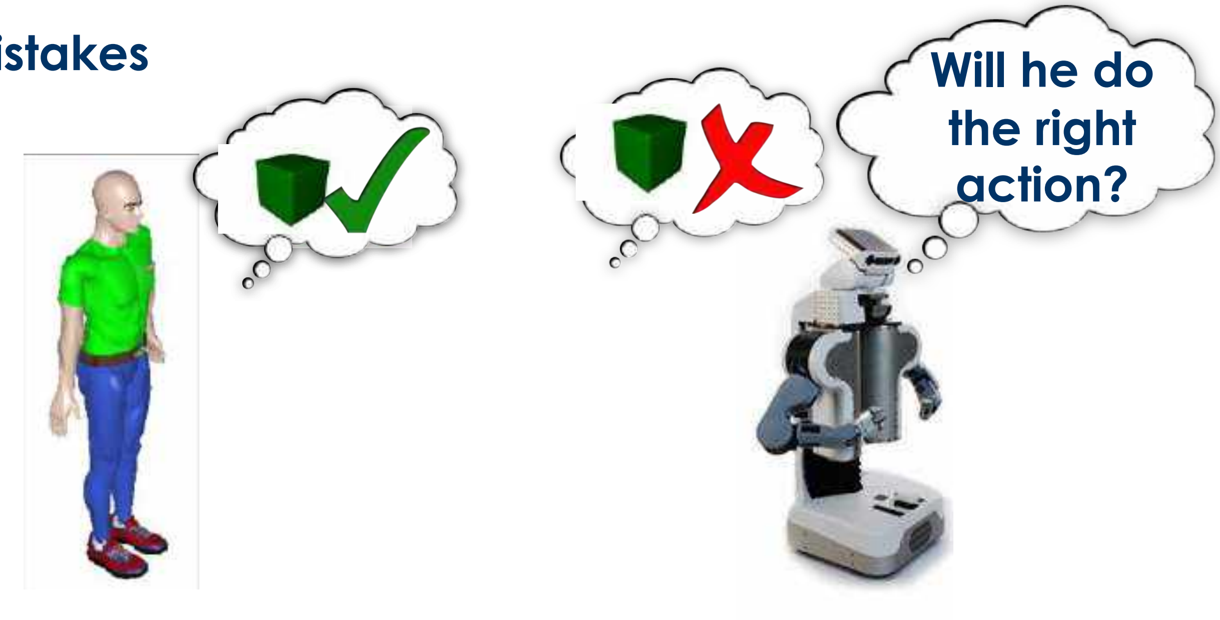
Use of mental states to solve divergent beliefs

- **Inaction and uncertainty**



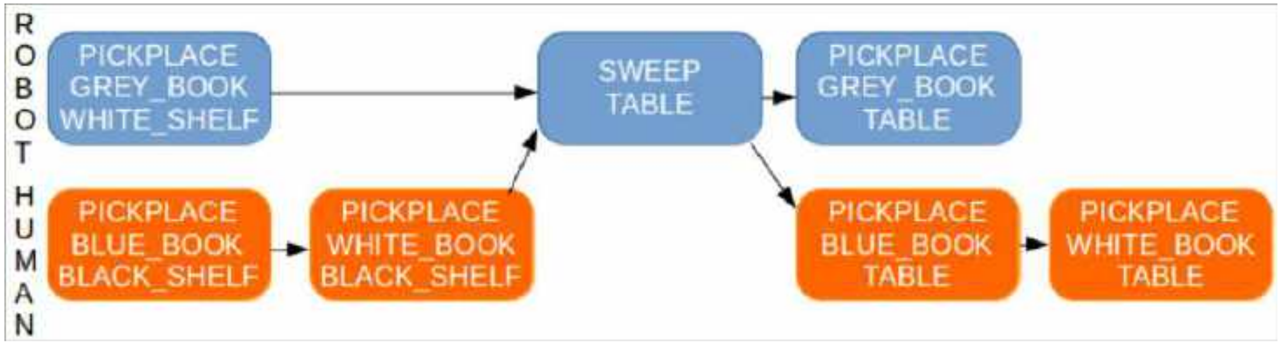
Use of mental states to solve divergent beliefs

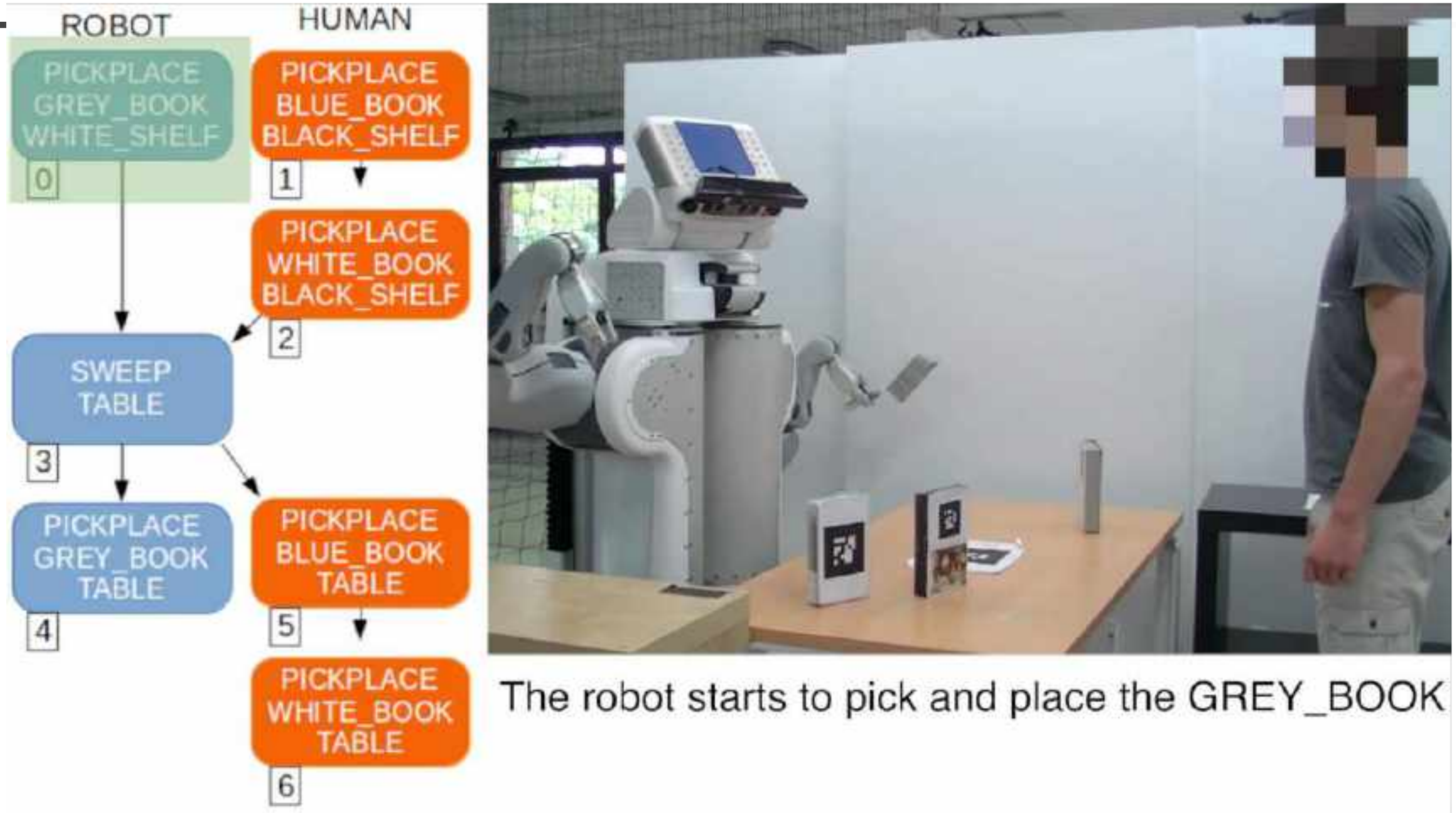
- **Preventing mistakes**



Example

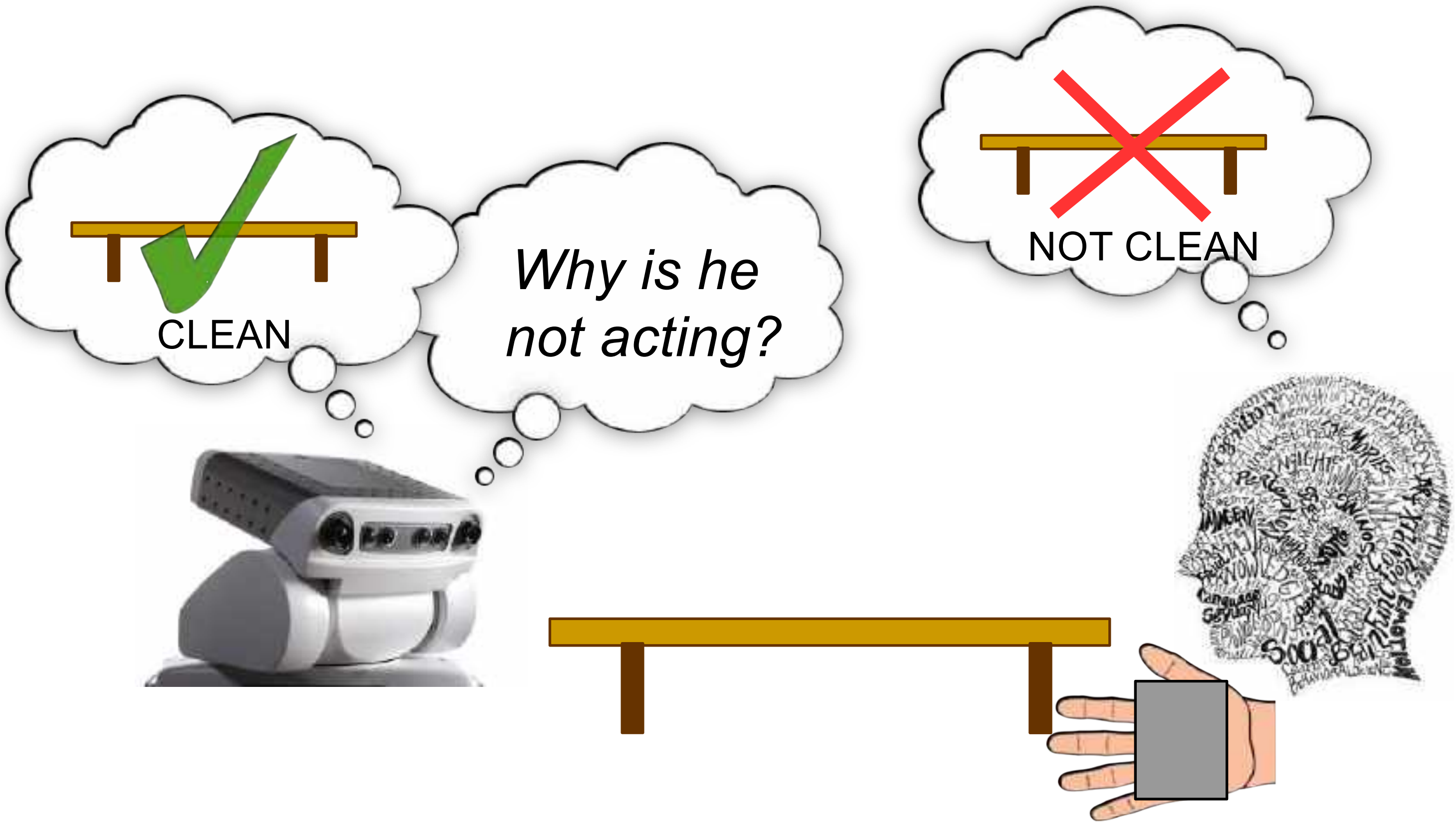
✓ Already established shared plan



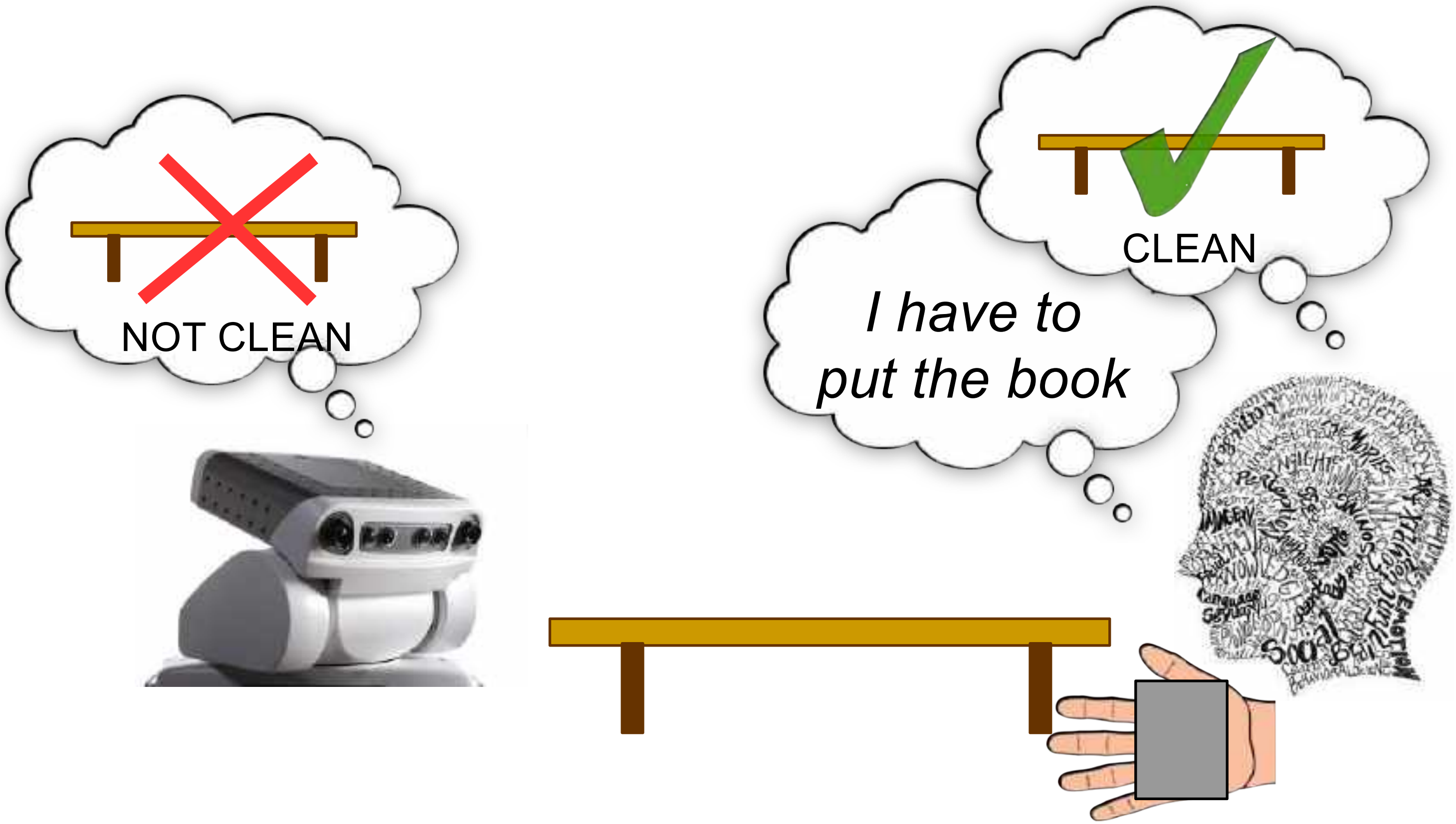


What should the robot do?

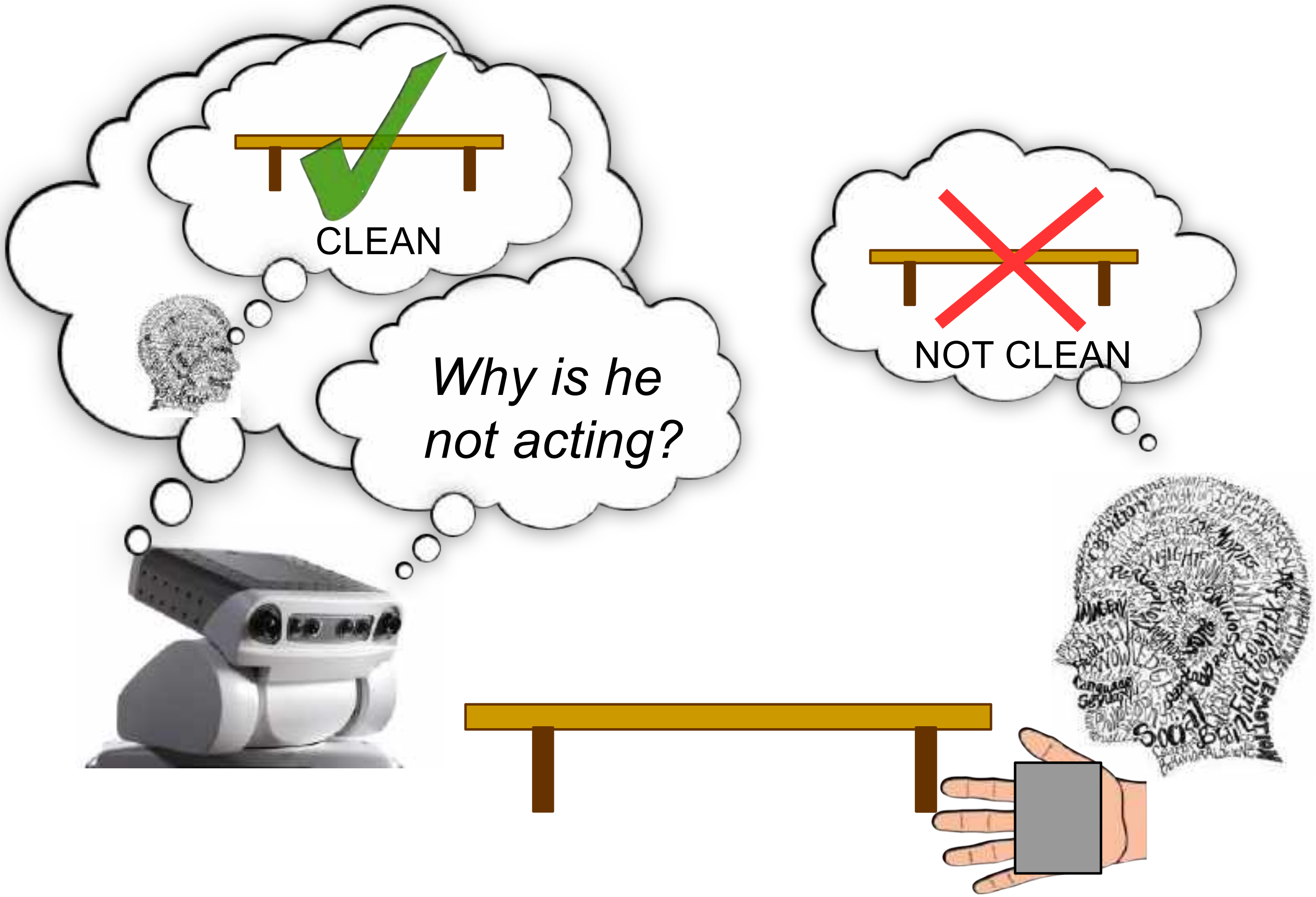
Before humans' actions



Preventing mistakes



Inaction and uncertainty



The human comes back

Managing commitment (extra)

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A robot guide that monitors commitment of its "customers"

Robot Searches for interaction when left alone

Establishes a common task

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

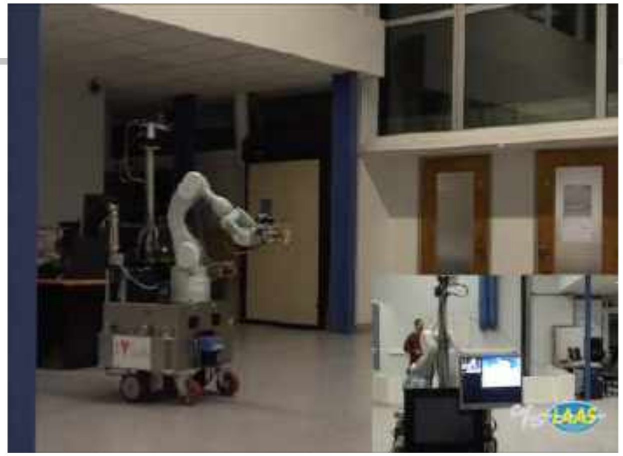
Monitors (and even **tries to influence) human commitment** to the task

Abandons mission if guided person stops following

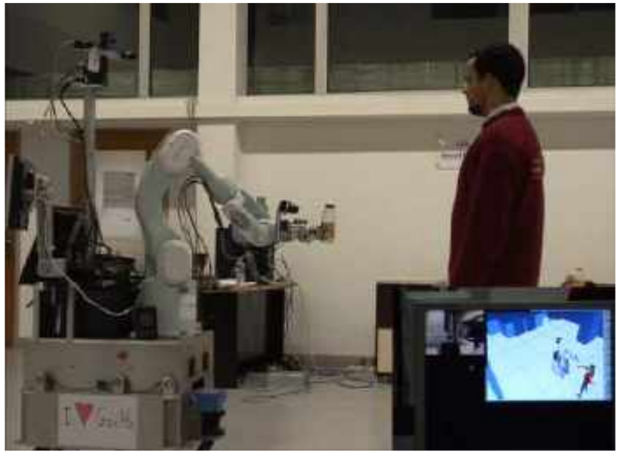
Rackham at « Cité de l'Espace »:

Handing an object to a person / various situations

Tout va bien



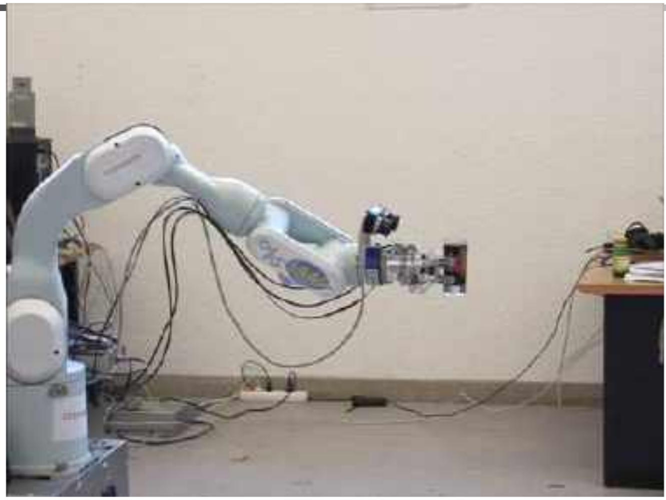
Where is Thierry ?



Thierry does not take the bottle

« Disturbed » attention

Cooperative action: When to release the object ?



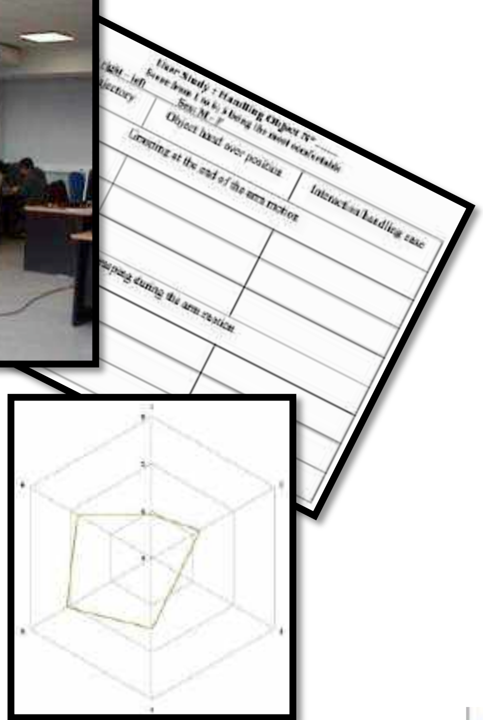
Be responsive.
Always leave the opportunity to the person to act.

Evaluation

Subjective user studies with naive users

With Video Trials
(Cogniron Project)

With a real robot



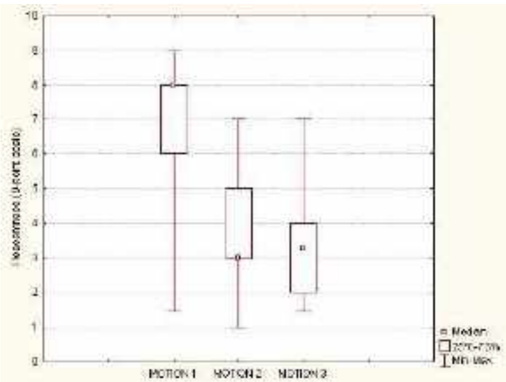
www.cogniron;or
g

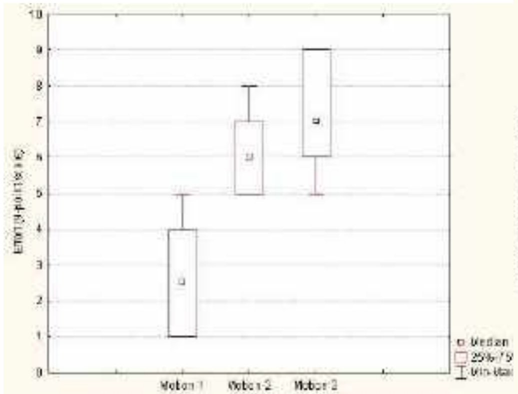
Evaluation: Objective user studies with naive users

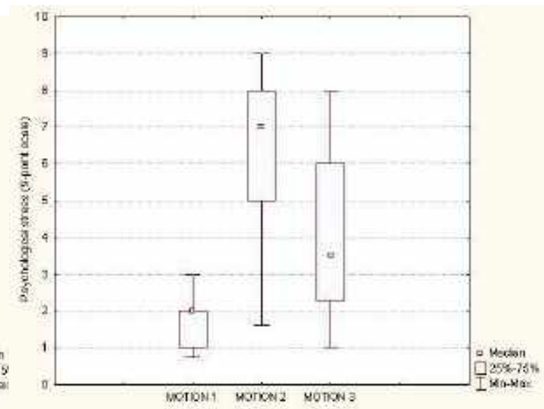
Data from Physilogical sensors

- Skin conductance
- Respiration
- Oculometry
- Electro-myogram

F. Dehais et Al, « Physiological and sub- jective evaluation of a human-robot object hand-over task, Applied Ergonomics , Vol 42, Nr 6, pp 785-791, 2011







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Communication cues involved in a human-robot object transfer

- Variables : Three different variable were used:
  - Giver type: Human - Robot
  - Gaze behavior
  - Movement speed
- 33 volunteers (age range 22–38, M=27, SD = 3.5; 21 males, 12 females)

Variables **Gaze behaviour**

Looking at the **R**eceiver then at the **O**bject and at the **R**eceiver again (**ROR**)

Toward a better understanding of the communication cues involved in a human-robot object transfer
Mamoun Gharbi, Pierre-Vincent Paubel, Aurélie Clodic, Ophélie Carreras, Rachid Alami, Jean-Marie Cellier
24th International Symposium on Robot and Human Interactive Communication, IEEE RO-MAN,, Kobe, Japan. 2015
pp.319-324, 2015,

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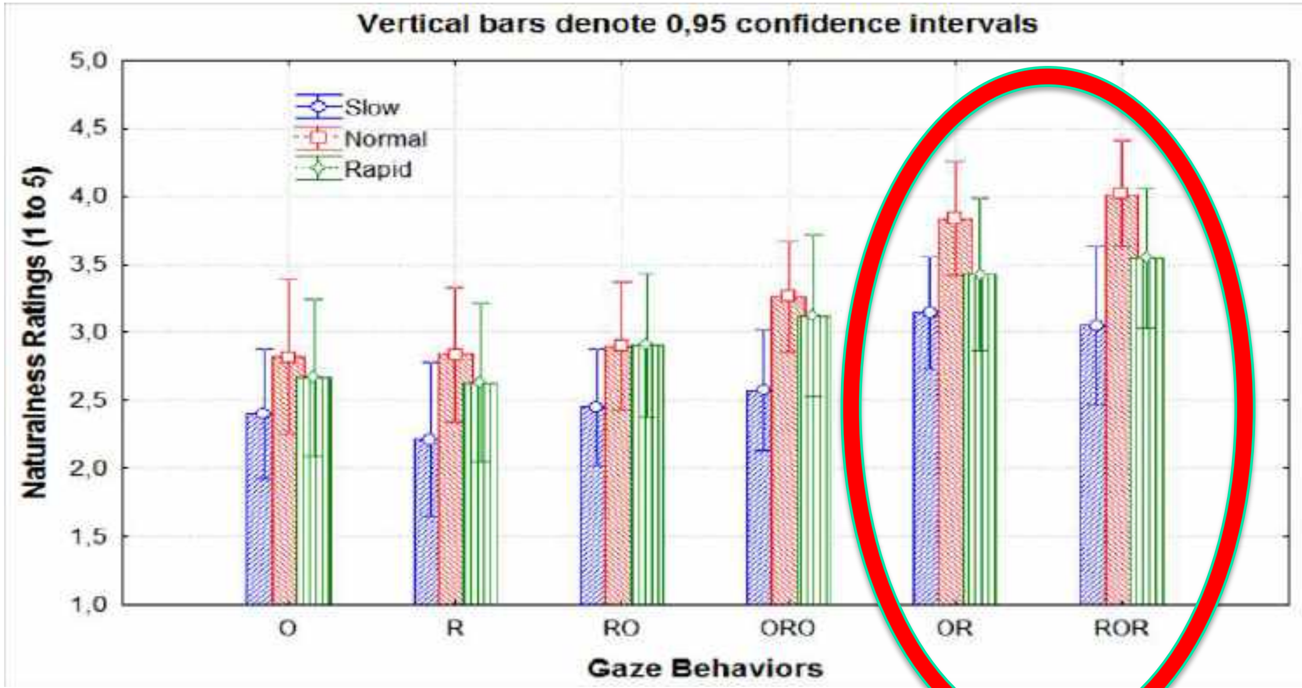
Naturalness ratings



- Main effect of the gaze behaviour
  - OR and ROR gaze behaviour > R, O, RO, ORO
- Main effect of the movement speed
  - normal and rapid speed movement > slow speed movement

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Conclusion

List of co-authors

Rachid Alami, Samir Alili, Gérard Bailly, Michael Beetz, Kathleen Belhasseine, Tony Belpaeme, Ludovic Brethes, Guilhem Buisan, Jonathan Cacace, Riccardo Caccavale, Loic Caroux, Ophélie Carreras, Michael Causse, Ophélie Carreras, Jean-Marie Cellier, Raja Chatila,Mohaled Chetouani, Ricardo-Omar Chavez-Garcia, Maxime Cottret, Aurélie Clodic, Patrick Danes, Kerstin Dautenhahn, Frédéric Dehais, Sandra Devin, Xavier Dollat, Peter Dominey, Frédéric Elisei, Christele Ecrepont, Isabelle Ferrane, Alberto Finzi, Michelangelo Fiore, Sarah Fleury, Malik Ghallab, Mamoun Gharbi, Mokhtar Gharbi, Benoît Girard, Martin Haegele, Matthieu Herrb, Guillaume Infantes, Felix Ingrand, Luca Iocchi, Mehdi Khamassi, Harmish Khambhaita, Ken Koay, Madhava Krishna, Thibaut Kruse, Jens Kubacki, Raphael Lallement, Jean-Paul Laumond, Christian Lemaire, Frédéric Lerasle, Séverin Lemaignan, Efrain Lopez Damian, Jerome Manhes, Philippe Marcoul, Amandine Mayima, Luis Marin, Jim Mainprice, Paulo Menezes, Grégoire Milliez, Vincent Montreuil, Christopher Nehaniv, Christopher Parlitz, Elisabeth Pacherie, Amit Pandey, Pierre-Vincent Paubel, Erwan Renaudo, Jorge Rios-Martinez, Raquel Ros Espinoza, Yoan Sallami, Guillaume Sarthou, Daniel Sidobre Lavindra De Silva, Thierry Siméon, Akin Sisbot, Camille Vrignaud,, Mick Walters, Felix Warneken, Matthieu Warnier, Jules Waldhart, Britta Wrede, Sara Woods.

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HORIZON 2020
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Development and articulation of some abilities involved in shared activity

- 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

Planning - Decisional processes

- **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

But still …

- Besides advances in general robot capabilities …
- We need far more refined models, based on solid grounds, and evaluated in realistic situations

Merci…