Task Planning for Human-Robot Interaction

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Smart Objects & Ambient Intelligence conference (sOc -EuSAI), 12th-14th October 2005, Grenoble, France

The COGNIRON Project

- **the COGNItive Robot companiON**

The Personal Robot Assistant

- Interaction is not limited to an interface
- The robot should be able to operate in an environment which has been essentially designed for humans.
- The robot will have to perform its tasks in the presence of humans and to interact with them.

Robot Decisional Issues for HRI

- We have to re-visit some of the robot decisional capabilities:
  - Explicit reasoning on its abilities (reflexivity)
  - Explicit reasoning on interactive task performance
- Besides design choices, it is necessary to endow the robot with the ability to take explicitly into account the presence of humans.

Our first studies in this way

- Design of the robot supervisor
  - How to represent humans in the supervisor of the robot ?
  - How to make decisions with this representation ?
- Human Aware Task Planning (HATP)
  - How to consider human preferences and social rules in the task planning system ?
- Human Aware Motion Planning (HAMP)
  - How to make the robot move in a comfortable way for humans ?

I. Design of the robot supervisor

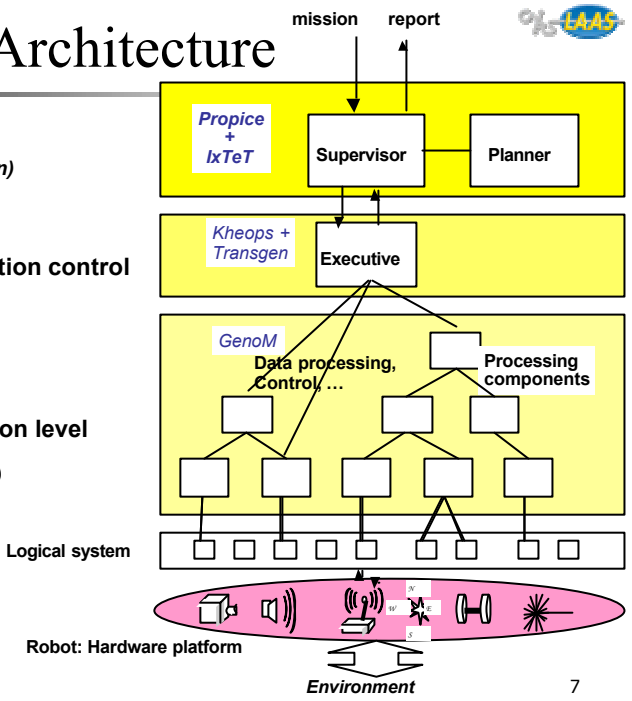
- How to represent humans in the supervisor of the robot ?
- How to make decisions with this representation ?

A Control Architecture

1. **Decision level**
   (planning and supervision)

2. **Validation and execution control**
   (action coordination)

3. **Functional and execution level**
   (action execution; dynamic organization)



What is specific in our problem ?

- **We want a framework that allows the robot:**
  - **To acquire its goals.**
  - **To accomplish its tasks.**
  - **To produce behaviors that support its engagement vis-à-vis its humans partner and interpret similar behaviors from him.**
  - **To follow human task performance.**
  - **To monitor and influence human commitment to the common goal.**

InterAction Agent (IAA)

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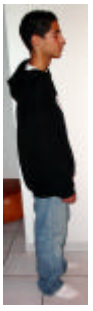


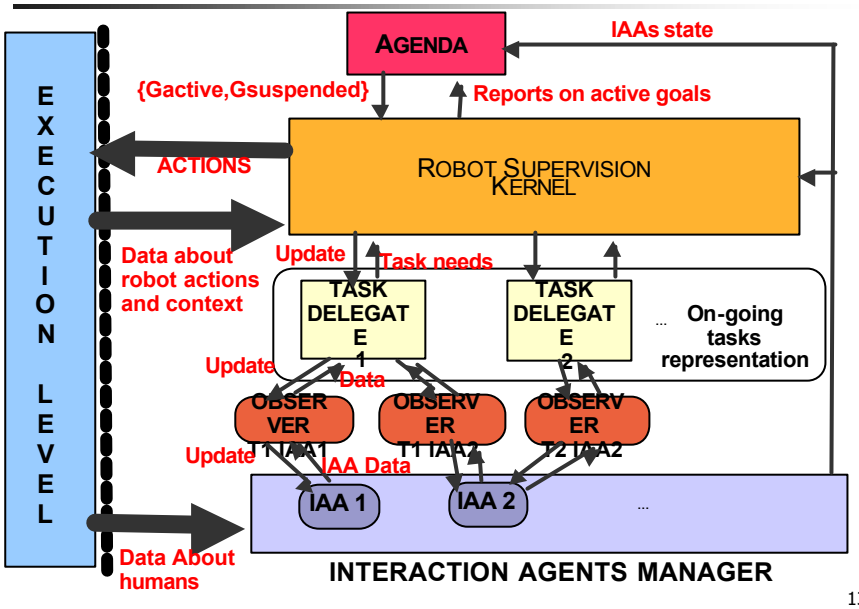
InterAction Agent (IAA)

"InterAction Agents" (IAAs), similar to proxies, implemented on the robot side as a representative of a human agent

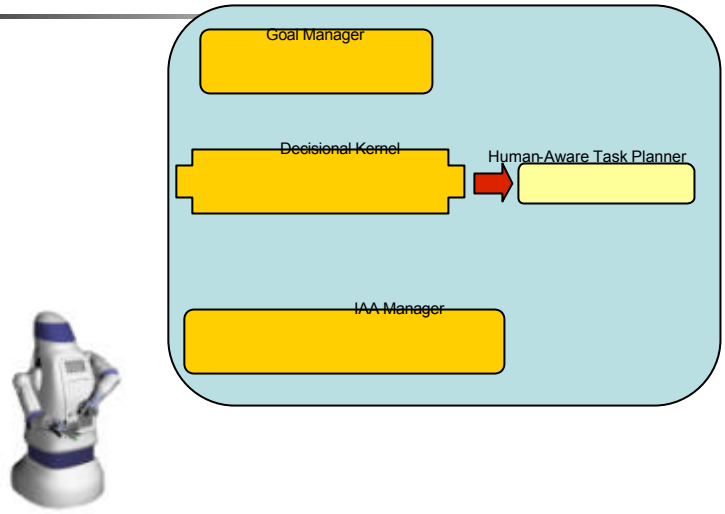
IAA Manager

- IAA Manager:
  - An IAA (InterAction Agent) is created dynamically and maintained by the "IAA Manager"
  - Several types of IAA (various abilities)
    - Actions
    - Needs, preferences
    - Determines how the robot behave with respect to the IAA

Our framework



Simulation



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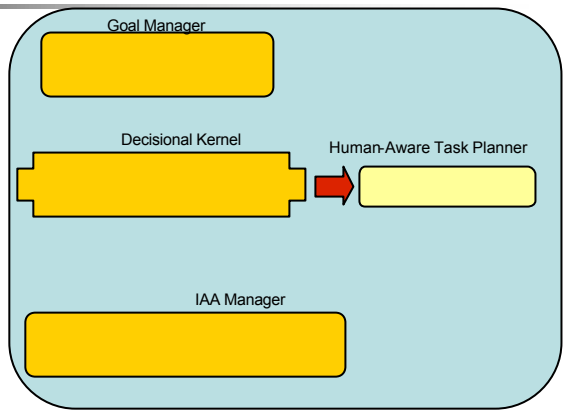

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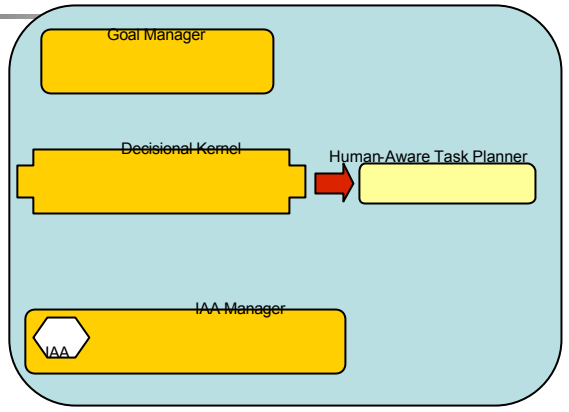

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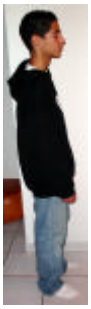

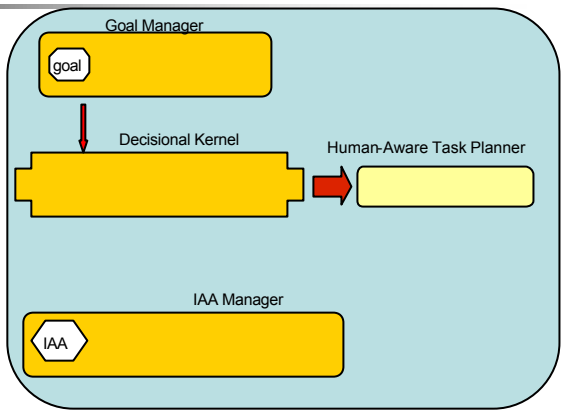

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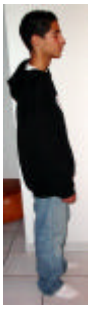

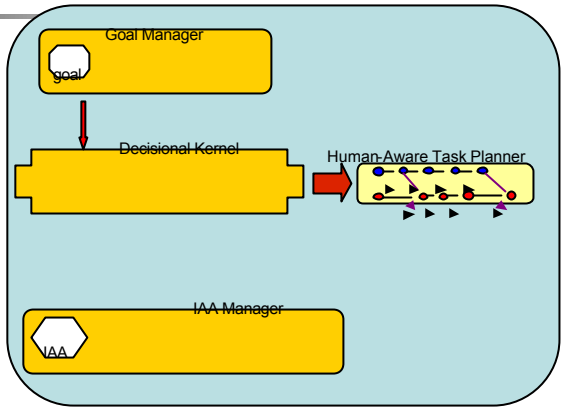

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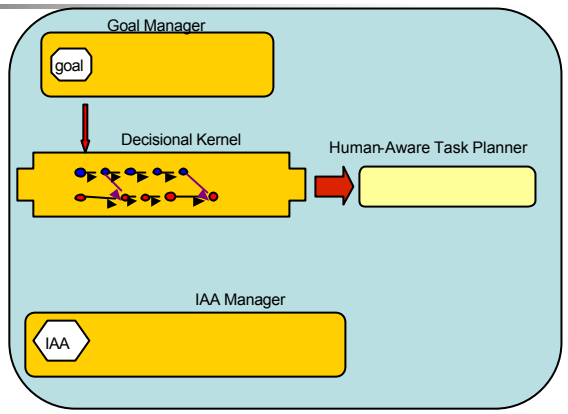

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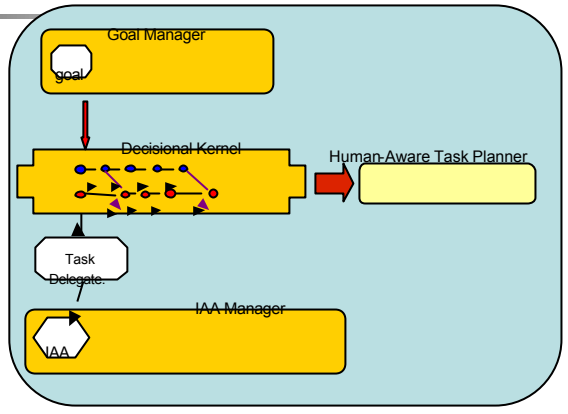


Observing human activity

Estimating human commitment level to a joint goal

…

II. Human Aware Task Planning (HATP)

- How to consider human preferences and social rules in the task planning system ?

To plan with human preferences

- **Model of an actor a_i (human or robot) :**
  - $M_{ai} = \{<A_i, C_i(ctxt)>\}$
  - A_i = an action (operator)
  - $C_i(ctxt)$ = context-dependent cost associated to A_i.
- **Costs meaning**
  - For a robot: difficulty to realize the action (slowness, computational time needed, etc...)
  - For a human: mix between difficulty to realize the action and gratification/pleasure to do it.
- Idea $\Rightarrow$ Make a plan with the least cost

Operator example (in SHOP2)

```
(:operator (!put ?name ?thing)
  ;; precondition
  ((actor ?name) (thing ?thing) (place ?place)
(has ?name ?thing) (at ?name ?place)
(drop_cost ?name ?cost))
  ;; delete list
  ((has ?name ?thing))
  ;; add list
  ((on ?thing ?place))
  ;; cost
  ?cost
)
```


To plan with social rules

- **Undesirable states:**
  - $P_{states} = \{<S_j, C_j(ctxt)>\}$
  - If the plan implies a passage by S_j, the corresponding context-dependent cost $C_j(ctxt)$ is added to the total plan cost.
- Undesirable sequences:
  - $P_{sequences} = \{<S_k, CO_k, C_k(ctxt)>\}$
  - If the plan contains an undesirable sequence of actions S_k under the conditions CO_k, the corresponding context-dependent cost $C_k(ctxt)$ is added to the total plan cost.

Social rules examples (1/2)

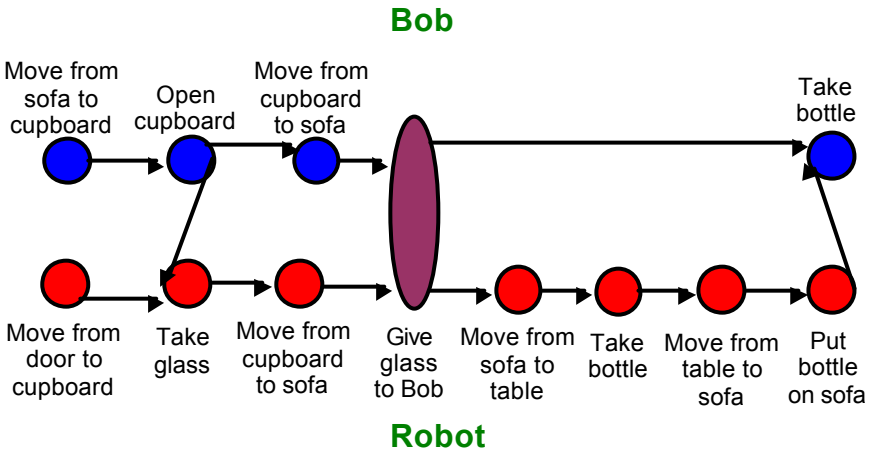
- Undesirable states:
  - Description of the state:
    - S_1 = ((has ?name ?obj1) (has ?name ?obj2) (food ?obj1) (clean_object ?obj2))
  - Cost value:
    - C_1 = 20 if ((mop ?obj2))
      = 10 else

Social rules examples (2/2)

- Undesirable sequences:
  - Description of the sequence:
    - S_k = ((!drop ?name1 ?obj) (!take ?name2 ?obj))
  - Conditions:
    - CO_k = ((robot ?name1) (human ?name2))
  - Cost value:
    - C_1 = 20 if ((= ?name1 BOB))
      = 10 else

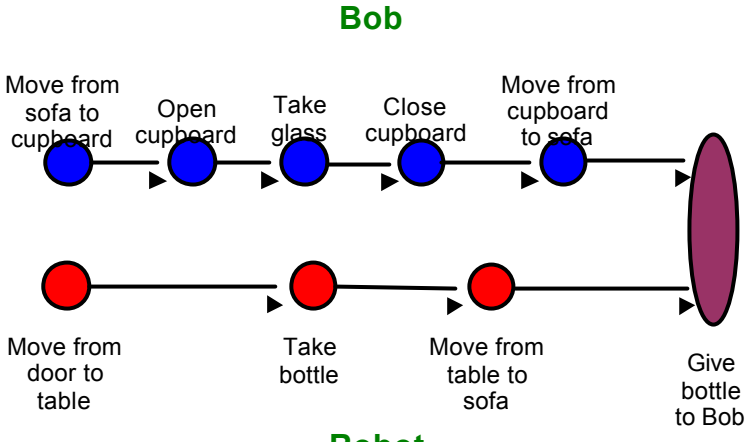
HATP plan example

- A classical plan produced by SHOP2



HATP plan example

- A plan produced by HATP (in SHOP2)



III. Human Aware Motion Planning (HAMP)

- How to make the robot move in a comfortable way for humans ?

Key points for HAMP

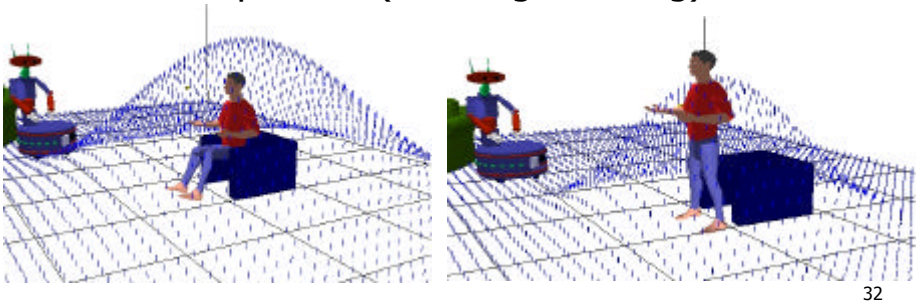
- **Physical safety**
  - **The robot must avoid to injure physically humans:**
    - **At the hardware level: round joints, light and soft material.**
    - **At the software level: control on distance, speed, etc.**
- **Mental safety**
  - **The robot must move in a natural way for humans (constraints on robot head direction, etc…).**
  - **The robot must avoid to surprise**

Environment representation

- Home environment: 2D grid with forbidden zones for static objects.
- The cell (i,j) of the grid is associated with a cost $a_{i,j}$.
- More $a_{i,j}$ is greater, more the robot should avoid the cell (i,j).
- $a_{i,j}$ is computed by merging several criteria.
- Each criterion is represented by a numerical potential field.

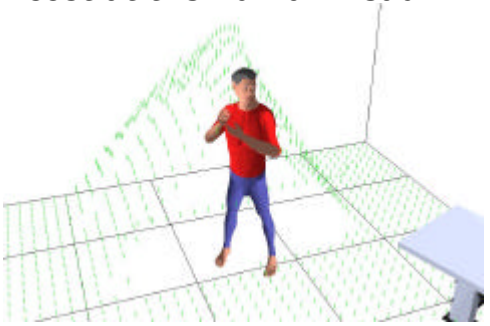
Physical Safety of humans

- Safety criterion: control on the distance between the robot and humans.
- Costs for safety criterion:
  - Inversely proportional to the distance.
  - Human position (standing or sitting).



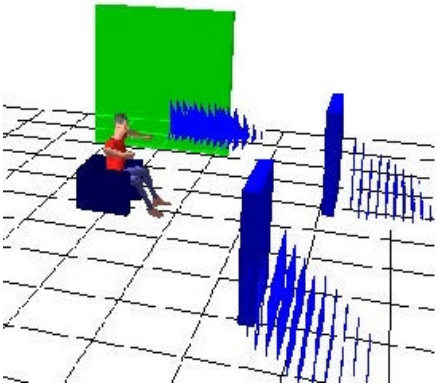
Mental Safety of humans

- Visibility criterion: keeping the robot in the human field of view.
- Costs for visibility criterion:
  - Inversely proportional to the distance with the higher cost at the human head.



Mental Safety of humans

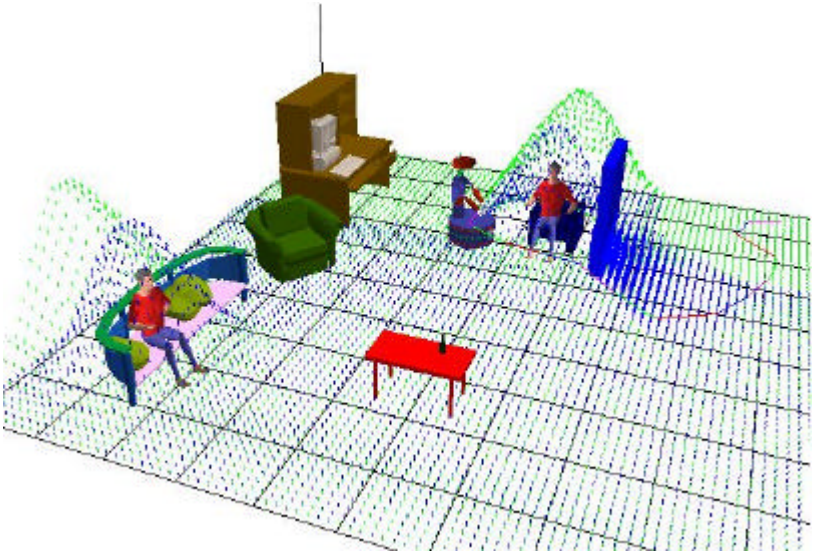
- Hidden zones: to prevent the robot to be hidden behind obstacles.
- Costs for visibility criterion:
  - Based on the human head direction and position of the obstacles.
  - Inversely proportional to the distance.



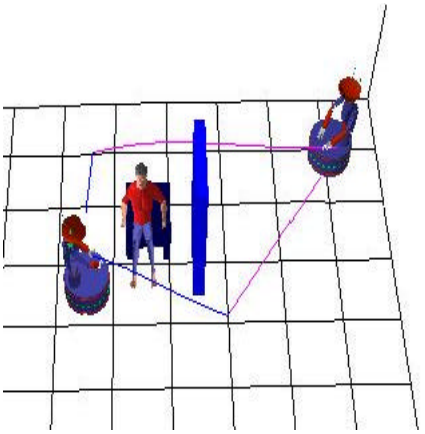
Merging the criteria

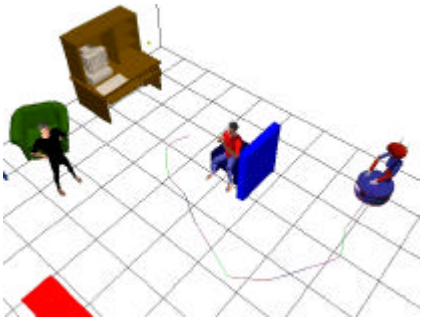
- With the 3 criteria we compute a final grid:
  - For visible zones: $a_{i,j} = Cost_{merged}(i,j)$.
  - $Cost_{merged}(i,j)$ can be computed in 2 ways:
    - $Cost_{merged}(i,j) = \max(Cost_S(i,j) , Cost_V(i,j))$
    - $Cost_{merged}(i,j) = w_1 * Cost_S(i,j) + w_2 * Cost_V(i,j))$
  - For hidden zones: $a_{i,j} = w_3 * Cost_{HZ}(i,j)$.
- Algorithm A* to find a path in the final grid.

Example of a final grid

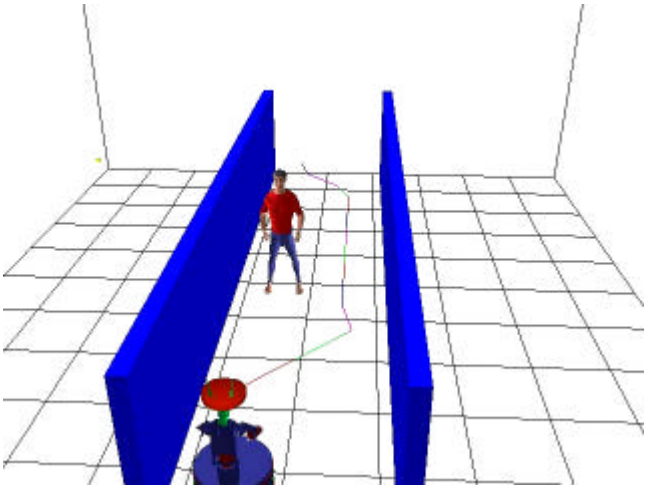


Comparison with a classical path planner

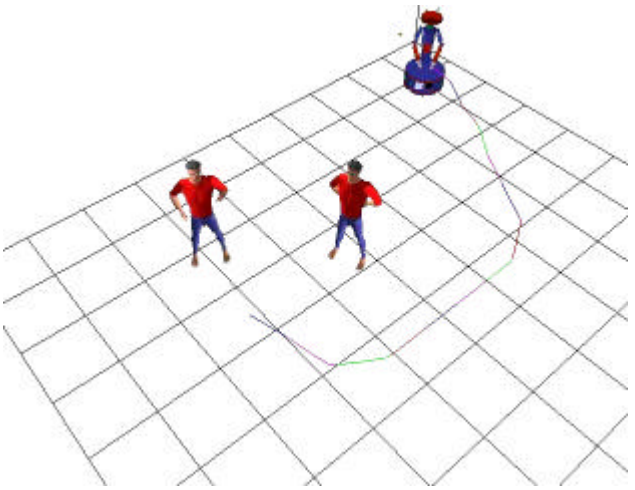




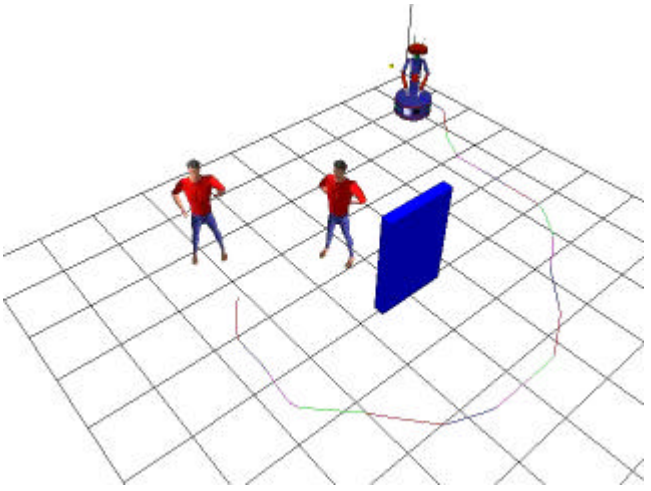
Other results (1/3)



Other results (2/3)



Other results (3/3)



Future Work

- Refinement of the framework
  - Dialogue
  - Learning
- Improvement of HATP: introduce uncertainty
- Improvement of HAMP: conversion to a 3D-planner
- Implementation on a tour-guide robot