Overview

What is needed for a Social Robots to "live" in an environment with humans?

Deep and Specific Knowledge about the environment and the social behaviors

- Incremental building and maintaining of a rich representation of the environment through human-robot interaction
- Explicit representation of human actions and social rules for social behaviors
Motivations

**Rich representation of the environment through human-robot interaction**
Robot perception still very limited to capture specific knowledge about an environment

**Explicit representation of social action and rules**
Hand-coded social behaviors limit scalability to complex situations

Summary

1. **Interactive Incremental knowledge acquisition**

2. **Explicit representation of social rules and actions**
Interactive Knowledge Acquisition

Acquisition of semantic information about the environment through on-board sensors and HRI

System architecture
Example
On-line semantic mapping

KB representation

- Concept Taxonomy
- Instance Signatures
- Semantic Grid Map
- Topological Graph
Multi-modal knowledge acquisition

- Spoken dialogue
- Laser pointer
- Visual object detection and recognition

Speech Recognition

- Grammar-based ASR (Microsoft engine)
- Semantic output (frame) for each rule
- Structured commands for the robot
- Grammars loaded on-line based on context

[Go]_{Motion} [near the chair]_{Goal} [slowly]_{Manner}
Petri Net Plans

Formal model for representation and execution of complex (multi-)robot plans.

[JAAMAS11]

Petri Net Plans execution

Complex interactions modelled with PNP
Object Detection from RGBD

![Images of a fire extinguisher from different angles and with different filters applied.]

KB reasoning

<table>
<thead>
<tr>
<th>User</th>
<th>Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>“Memorize.”</td>
</tr>
<tr>
<td>Robot</td>
<td>“I am ready to memorize an object.”</td>
</tr>
<tr>
<td>User</td>
<td>The user points at the object until an auditory feedback is received.</td>
</tr>
<tr>
<td>Robot</td>
<td>“This is the book cabinet.”</td>
</tr>
<tr>
<td>User</td>
<td>“I already know that a cabinet is here. I’ve updated the label of this object with book cabinet.”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>User</th>
<th>Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>“This is the fire extinguisher.”</td>
</tr>
<tr>
<td>Robot</td>
<td>“I know that a socket is also here. Should I keep it in my memory?”</td>
</tr>
<tr>
<td>User</td>
<td>“No.”</td>
</tr>
<tr>
<td>Robot</td>
<td>“Ok, I have removed the socket and I have memorized the fire extinguisher.”</td>
</tr>
</tbody>
</table>
KB reasoning

<table>
<thead>
<tr>
<th>User</th>
<th>Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Go to the socket.&quot;</td>
<td>&quot;There are many sockets in the environment. Which one do you mean?&quot;</td>
</tr>
<tr>
<td>&quot;The one close to the emergency door.&quot;</td>
<td>&quot;OK. I am going to the socket.&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>User</th>
<th>Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Go to the socket.&quot;</td>
<td>&quot;There are many sockets in the environment. Which one do you mean?&quot;</td>
</tr>
<tr>
<td>&quot;Anyone.&quot;</td>
<td>&quot;OK. I am going to the closest socket.&quot;</td>
</tr>
</tbody>
</table>

[VIDEO] Sockets

Use cases

Multiple robots, multiple environments, multiple users
Some results

<table>
<thead>
<tr>
<th>Distance Thresholds</th>
<th>Average Percentage</th>
<th>Experts Percentage</th>
<th>Non-Experts Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0.1m</td>
<td>18%</td>
<td>20%</td>
<td>16%</td>
</tr>
<tr>
<td>≤ 0.2m</td>
<td>42%</td>
<td>37%</td>
<td>47%</td>
</tr>
<tr>
<td>≤ 0.3m</td>
<td>48%</td>
<td>46%</td>
<td>50%</td>
</tr>
<tr>
<td>≤ 0.4m</td>
<td>76%</td>
<td>72%</td>
<td>80%</td>
</tr>
<tr>
<td>≤ 0.5m</td>
<td>88%</td>
<td>94%</td>
<td>82%</td>
</tr>
</tbody>
</table>

Correct positioning of semantic elements in the map by users using the system

Summary

1. Interactive Incremental knowledge acquisition

2. Explicit representation of social rules and actions
Explicit Representation of KB

KB models:
- Domain description
- Robot actions
- Human actions
- Social rules

Classic Plan-Execution Framework
Social Plan-Execution Framework

Answer Set Programming

ASP Modelling and Reasoning
- common-sense knowledge
- domain knowledge
- social rules
- human and robot actions

Explicit representation vs. implicit (hand-coded) definitions
Use case

- Deliver papers printed by a printer to a location that is behind a closed door.
- Robot cannot take papers or open doors
- **Users are not aware of the robot’s plan**

Example: opening a door

![Diagram of a workflow for opening a door](image)
HR-PNP to executable PNP

Human action is transformed in a PNP sub-plan

Executable PNP

Complex behavior integrating robot actions and human interactions
Video
Executing the social task

Results
70 runs with different combinations of social norms

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful execution of the task with human help</td>
<td>42%</td>
</tr>
<tr>
<td>Unsuccessful execution of the task but user was willing to help</td>
<td>6%</td>
</tr>
<tr>
<td>User answered that s/he was not willing to help</td>
<td>10%</td>
</tr>
<tr>
<td>No answer to robot’s request</td>
<td>42%</td>
</tr>
</tbody>
</table>
References


