Learning Through Coaching in Cooperative Side-by-Side Human-Humanoid Interaction

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Objectives:

- Humanoid robot ‘apprentice’
  - Establish base-line tasks(s)/scenario(s)
  - Set of sensory-motor primitives
  - Mechanism for composing new behavior from these primitives
  - Demonstrate generalization to a set of tasks

- Side by side interaction
  - Spoken language
  - Vision
  - Automatic learning and anticipation

- Representation Shared intentional plans
Demonstrate these capabilities on standard humanoid platforms

iCub – FP6 IST RobotCub
IIT Genoa

HRP-2 n°14 AIST-CNRS JRL
LAAS Toulouse
The Robot Apprentice

- The robot works with the human to assemble the table
- And learns about the shared task
- To progressively acquire skill
- The robot should have:
  - Some Basic Skills
  - Ability to Learn from the Expert
  - Ability to use language to guide action, including learning
  - Notion of Shared Plans
Spoken Language Programming: Composing primitives into behaviors

Table 1. Action Commands

<table>
<thead>
<tr>
<th>Motor Command</th>
<th>Resulting Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepare</td>
<td>Move both arms to neutral position, rotate chest to center, elevate left arm, avoiding contact with the work surface (5 DOF)</td>
</tr>
<tr>
<td>OpenLeft</td>
<td>Open left hand (1 DOF)</td>
</tr>
<tr>
<td>CloseLeft</td>
<td>Close left hand (1 DOF)</td>
</tr>
<tr>
<td>Give it to me</td>
<td>Rotate hip to pass the object in left hand to user on the right (1 DOF)</td>
</tr>
<tr>
<td>Hold</td>
<td>Center hip, raise right arm preparing to hold table top (5 DOF)</td>
</tr>
<tr>
<td>Right open</td>
<td>Open right hand (1 DOF)</td>
</tr>
<tr>
<td>Right close</td>
<td>Close right hand (1 DOF)</td>
</tr>
</tbody>
</table>

Table 2. Learning and Control Commands

<table>
<thead>
<tr>
<th>Commands</th>
<th>Correspondence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn</td>
<td>Begin encoding subsequent commands</td>
</tr>
<tr>
<td>OK</td>
<td>Store encoded command sequence in macro</td>
</tr>
<tr>
<td>Macro</td>
<td>Execute the stored macro</td>
</tr>
<tr>
<td>Wait</td>
<td>Interrupt command execution until a spoken “continue” command is issued</td>
</tr>
<tr>
<td>Continue</td>
<td>Terminate the “wait” pause and resume execution</td>
</tr>
</tbody>
</table>

Table Assembly and Disassembly
Teaching a Generalized Sensorimotor Behavior

- Give me the *green* leg
  - Take the *green* leg
  - Turn right
  - Open right hand
- Training with one example
  - *Green* is passed as an argument to TAKE
  - Learned procedure generalizes over (yellow, rose, green, orange)
  - Powerful learning capability with procedures that take variables
- Embodiment of lexical categories
  - Verbs – procedures
  - Nouns – arguments
- Requires more sophisticated skills
  - Vision
  - Inverse kinematics

Part of Joint Robotics Laboratory project, CNRS LAAS Toulouse, Dominey, Mallet, Yoshida (2007) IEEE Int. Conf. On Humanoid Robotics
Performance Evaluation

Primitive Completion Times

No Vision | With Vision*
---|---
E1 Cmd | E1 Prg | E3 Cmd | E3 Prg
Completion Time

*and improved motion trajectories
Automatic Learning, and Anticipation

- On-line Learning of complex cooperative behavior via continuous interaction history monitoring
- Yields Anticipation for
  - Speech recognition
  - Action propositions
  - Action initiative taking

Automatic Learning, and Anticipation

- If current subsequence is in interaction history
  - L1 – anticipate speech
  - L2 – propose next action
  - L3 – take initiative
- Else get next command
- Execute
- Update interaction history

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Table 1. iCub Specific Action Commands

<table>
<thead>
<tr>
<th>Motor Command</th>
<th>Resulting Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach</td>
<td>Position left hand next to closest table leg</td>
</tr>
<tr>
<td>Grasp</td>
<td>Close left hand</td>
</tr>
<tr>
<td>Lift</td>
<td>Raise left hand</td>
</tr>
<tr>
<td>Pass</td>
<td>Turn trunk and left shoulder towards user</td>
</tr>
<tr>
<td>Open</td>
<td>Open left hand</td>
</tr>
<tr>
<td>Hold</td>
<td>Bimanually coordinated holding</td>
</tr>
<tr>
<td>Release</td>
<td>Place both hands in upward safe position</td>
</tr>
<tr>
<td>Wait</td>
<td>Suspend until OK signal</td>
</tr>
</tbody>
</table>

Progressive effects of Learning

Speech anticipation
With leg 2

Action proposition
With leg 3

First experience
With leg 1

Robot initiative
With leg 4
Shared Intentions & Situated Simulations

Tomasello et al. Behavioral and Brain Sciences, 2005
Implementing Shared Plans

[Diagram showing the process of implementing shared plans, with labels for actions, intentions, world state, and control systems.]
Putting it all together:

- Primitives (perceptual and motor)
  - ‘Innate’ set
  - Ability to create new primitives

- Composition
  - On-line sequence detection
  - Explicit ‘spoken language programming’
  - Observation

- Anticipation
- Naming of new sequences – increasing the behavior repertoire
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Situated Simulation Architecture