Robot Learning from Human Teachers

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Quiz (10 point)

- Do you still remember the LfD framework? Fill in these blocks
Quiz (10 point)

- LfD framework
Review: LFD framework
The Framework of LfD

- Feedback loop
- Assumption:
  - There exists a Human Teacher who demonstrates execution of a desired behavior

What if the assumption breaks?
Social learning mechanisms used by humans, particularly children
The Framework of LfD

Common modes of human-robot interaction that are used to provide demonstrations
The Framework of LfD

How to reproduce, generalize and refine a learned motion/skill
Conduct experiment to evaluate the learning results

The Framework of LfD
All the possible names for the same thing

Learning by Demonstration (LbD)
Programming by Demonstration (PbD)
Learning from Demonstration (LfD)
Learning by Experienced Demonstrations
Assembly Plan from Observation
Learning by Showing
Imitation (learning)
Learning from Observation
Learning by Watching
mimicry
behavioral cloning
Human Social Learning
Overview

• Human psychology that affects the design of robot learning
  • Situated learning
  • Teacher’s role
  • Learner’s role
  • Coupling in learning process

• Compare LfD to
  • Machine learning, reinforcement learning
Human motivation for learning
Intrinsic vs extrinsic motivation

- **Intrinsic motivation** → **Self-motivated learning**
- **Extrinsic motivation** → **Situated learning**
Children are motivated to interact

- What enables a children to interact?
  - Being able to recognize, seek proximity to, and interact with (caregivers)

- A big assumption
  - Children assume that the caregiver has their best interest

- Assisted imitation
  - A dynamic **turn-taking** activity
One recent HRI focus

- Modeling engagement and turn-taking dynamics in interaction

Examples

- Partner robot – Generate connection event [1]
- Social robot – Control multimodal dialog [2]
- Conversational service robots – Controls task-based dialog [3]
Generating connection event

• Engagement between a human and a humanoid robot

• Assume both human and robot can perform
  • Look at the other’s face, objects on the table or “away”
  • Point at objects on the table
  • Nod the head (up and down)
  • Shake the head (side to side)
  • Speech (not available for now)
Generating connection event

- Connection events include
  - Directed Gaze
  - Mutual Facial Gaze
  - Adjacency Pair
  - Backchannel
Generating connection event

Robot generates non-verbal behavior that contributes to HRI engagement
Generating connection event

Process human-initiated CE

engagement recognition

human-initiated CE’s
robot-initiated CE’s
turn fragments
gaze/point inhibit

engagement statistics

symbolic vision

speech & gestures
## Evaluation

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1) Melvin seemed more like a human than a robot.</td>
<td>3.43</td>
<td>2.27</td>
<td>.55</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>2) Melvin looked at the table and the puzzle pieces at appropriate times.</td>
<td>6.21</td>
<td>4.47</td>
<td>.73</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>3) Melvin always looked at me in a natural way.</td>
<td>4.57</td>
<td>2.73</td>
<td>.58</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>4) Melvin looked at me at appropriate times.</td>
<td>6.21</td>
<td>2.40</td>
<td>.46</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>5) I always knew what object Melvin looked at.</td>
<td>6.07</td>
<td>3.80</td>
<td>.83</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>6) I could easily tell which objects Melvin looked at.</td>
<td>5.71</td>
<td>3.40</td>
<td>.72</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>7) I looked at Melvin’s face often.</td>
<td>6.07</td>
<td>5.00</td>
<td>.50</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>8) I made eye contact with Melvin frequently.</td>
<td>5.43</td>
<td>4.00</td>
<td>.62</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>9) I always knew what object Melvin pointed at.</td>
<td>6.57</td>
<td>3.13</td>
<td>.72</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>10) I could easily tell the object that Melvin pointed to.</td>
<td>6.43</td>
<td>3.07</td>
<td>.70</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
Switch between multiple situated modules
Switch between multiple situated modules

- Bottom-up method
Implementing interaction dynamics

- The basic strategy of implementing interaction dynamics
  - Develop situated modules for various situations.
  - Define episode rules for sequential transition.
  - Modify implemented episode rules (rules of negation) to suppress execution of the situated modules for a particular long-term context.
Switch between expert models

• Requirements for conversational robot intelligence model
  • Integration of dialogues and physical actions
  • Handling multiple task domains
  • Interruption handling
  • Parallel task execution
  • Extensibility

• Goal
  • Build a dialogue and behavior controller
Architecture for conversational service robots
Change in experts and primitive tasks
Robot Intelligence based on Multiple Experts

RIME
Reference


Assignment 7: Reading – Due Nov 14

• Review paper
Assignment 7: Reading – Due Nov 14

• Refer to “Research paper review guidance”
  • https://docs.google.com/document/d/1oVmjZSjo9YY_PsutFf6UBMm3Ly18_VHOvk_Yno-7k5M/pub

• Prepare 4-6 presentation slides
  • Good presentation slides will be rewarded with additional credit and will have a chance to give a 5-min presentation in coming lecture
  • More opportunity coming soon
Children’s motivation to imitate
Children have motivation to imitate

• Like-me bias
  • An inclination and ability to map self and others’ actions

• Theory of “legitimate peripheral participation”
  • Children want to participate adults’ world
  • Get out of subordinate learner role, and be able to choose what to do
  • Strong motivation for learning
Teacher – Method to impose influence

• Given the motivation of imitate, there are several ways that the teacher can influence the learner
  • Stimulus enhancement
  • Emulation
  • Mimicking
  • Imitation
Teacher – Method to impose influence

• Given the motivation of imitate, there are several ways that the teacher can influence the learner
  • **Stimulus enhancement**
    • Draw and focus the observer’s **attention** on interesting things
  • Emulation
  • Mimicking
  • Imitation
Teacher – Method to impose influence

• Given the motivation of imitate, there are several ways that the teacher can influence the learner
  • Stimulus enhancement
  • **Emulation**
    • After observing a result, the observer uses their *own action repertoire* to produce the result
  • Mimicking
  • Imitation
Teacher – Method to impose influence

• Given the motivation of imitate, there are several ways that the teacher can influence the learner
  • Stimulus enhancement
  • Emulation
  • **Mimicking**
    • Copy *other’s action* without understanding their purposes
  • Imitation
Teacher – Method to impose influence

- Given the motivation of imitate, there are several ways that the teacher can influence the learner
  - Stimulus enhancement
  - Emulation
  - Mimicking
  - Imitation
    - Reproducing both action and result
Teacher – Method to impose influence

• All the four methods benefit self-exploration
  • Particularly when the target goal is rare occurrence

• Which is the “best”?  
  • Depend on the nature of the problem, and the current behavior of social partner
How to create learning motivation for robot?

• Reinforcement Learning
  • Reward novel experience

• Developmental learning [1]
  • Focus on task-independent learning
  • Build a control system to continue to adapt to new problems
  • Integrate self-motivation and curiosity
How to Scaffold the learning process?
Human teacher scaffold robot learner

- Human can help robot with hard problems in learning
  - What to learn, when to learn, what action to try, how to measure success, ...

- Three methods for scaffolding
  - Direct robot attention
  - Dynamic scaffolding
  - Externalize and modeling meta-cognition
Direct robot’s attention

• Effect of social gaze
  • Lots of studies in HRI

• Example
  • Teach a robot as if parenting a baby
  • How to?
Example – Parenting robot

- Parents (human teacher) alter their actions when interacting with infants, compared to when interacting with adults
  - Put longer and more pauses between actions
  - Exaggerate actions
  - Decompose a rounded movement into several linear movements
- Baby (robot learner)
  - Immature attention capability, don’t know where to pay attention to
  - Parental teaching helps a robot to detect significant information of the actions
Parental action demonstration

- Analyze videotaped data of parent-infant/-adult interactions
Apply saliency-based attention model
Experimental comparison of saliency map

• Experimental conditions
  • Partner = infant
  • Partner = adult

• High value in saliency when the partner is infant
  • Suppressing body motion
  • Add motion to the cup
  • Long pause before start and after end of the demonstration
  • Stop and comment on action/show additional emotional facial expression
Demonstrate to robot simulation

• Program robot to look at the most salient part
Reference

