Towards the Grounding of Abstract Categories in Cognitive Robots

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Outline

1. Overview
   - Task Description

2. Approaches to the Problem
   - Symbolic Models
   - Connectionist and Embodied Models

3. Experiments
   - Starting Point
   - Experiment I
   - Experiment II
   - Initial Work

4. Conclusion
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Towards the Grounding of Abstract Categories in Cognitive Robots

**GOAL** To answer the following questions:
Towards the grounding of abstract categories in cognitive robots

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**Abstract Concepts**

truth?  democracy?  happiness?  justice?

accept?  reject?  give?  use?
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- How can the symbol grounding mechanism be extended to generate and ground abstract categories?
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- democracy?
- happiness?
- justice?
- accept?
- reject?
- give?
- use?

**Symbol Grounding Problem**

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Symbolic Models

“The mind is a symbol system and cognition is symbol manipulation” (Harnard, 1990).

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Latent Semantic Analysis (LSA, Landauer and Dumais).
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- Chinese Room Argument (Searle, 1980).

Illustration from http://www.macrovu.com/CCTMap4ChineseRm.html.

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Connectionist and Embodied Models

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- Mental processes are deeply influenced by the structure of the body and its interaction with the environment (Embodiment) (*Sandini et al.*, 2007).

- Linguistic abilities are developed through the direct interaction between the cognitive agents and the social and physical world they interact with (*Cangelosi, Riga*, 2006).
Insights from Psychology and Neuroscience

In psychology (Glenberg, Kaschak, 2002), (Andrews et al., 2009) and neuroscience (Perani et al., 1999) different theories have been proposed in which embodiment plays an important role in representing abstract concepts.
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Bayesian models of abstract words (from left to right: experiential, distributional and combined models).
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Action-Sentence Compatibility Effect.

Bayesian models of abstract words (from left to right: experiential, distributional and combined models).

Regions of the brain specifically associated with the processing of verbs (C) and abstract words (D).

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- Two simulated agents (**teacher** and **learner**).
- Set of basic actions to be learnt.
Starting Point

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- Two simulated agents (teacher and learner).
- Set of basic actions to be learnt.

Training Mechanism:

- The learner acquires basic actions by observing the teacher. It then learns the basic action names (direct grounding).
- The learner uses the linguistic symbols that were grounded in the previous learning stage to acquire new higher-order actions (symbol grounding transfer).

Cangelosi, Riga, 2006. *Cognitive science.* Cangelosi et al., 2006. *IJCNN.*
Training Stages:

1. **BASIC GROUNDING (BG):** The robot learns, via imitation, to perform basic action primitives and their corresponding names (e.g. “CLOSE_LEFT_ARM”, “CLOSE_RIGHT_ARM”, “MOVE_FORWARD”).

2. **HIGHER-ORDER GROUNDING 1 (HG1):** The robot learns a higher-order action word combining two basic action primitives (BG+BG e.g. “GRAB” [is] “CLOSE_LEFT_ARM” [and] “CLOSE_RIGHT_ARM”).

3. **HIGHER-ORDER GROUNDING 2 (HG2):** The robot learns a higher-order behavior consisting of the combination of one basic action primitive and one higher-order action word (BG+HG1 e.g. “CARRY” [is] “GRAB” [and] “MOVE_FORWARD”).
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GOAL To train iCub:

- To perform a series of action primitives (e.g. “PUSH”, “PULL”, “GRASP”, “RELEASE”).

- Subsequently, by correlating higher-order action words (e.g. “KEEP”, “GIVE”, “RECEIVE”) with basic action primitives, the robot will acquire more abstract concepts (e.g. “PICK”, “ACCEPT”, “REJECT”).

- Verbs chosen from ITALK report.
Experiment I

Possible Behaviour: “ACCEPT”
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“GRASP”, “RELEASE”, “SMILE”, “FROWN”, “STOP”..

“KEEP”
Experiment I

Possible Behaviour: “ACCEPT”

“GRASP”, “RELEASE”, “SMILE”, “FROWN”, “STOP”.

“ACCEPT”  “KEEP”  “SMILE”
Experiment I

Model of Experiment I

Object Features

<table>
<thead>
<tr>
<th>Shape</th>
<th>Color1</th>
<th>Color2</th>
<th>Color3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape3</td>
<td>0.5</td>
<td>0</td>
<td></td>
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</tbody>
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HG2

- **“PICK”**
  1. RECEIVE
  2. NEUTRAL
  3. STOP

- **“ACCEPT”**
  1. KEEP
  2. SMILE
  3. STOP

- **“REJECT”**
  1. GIVE
  2. FROWN
  3. STOP

HG1

- **“KEEP”**
  1. GRASP
  2. STOP

- **“RECEIVE”**
  1. GRASP
  2. PUSH
  3. PULL
  4. STOP

- **“GIVE”**
  1. GRASP
  2. PUSH
  3. RELEASE
  4. STOP

BG

- **Naming “NEUTRAL”**
  Initial NEUTRAL Action

- **Naming “SMILE”**
  Initial SMILE Action

- **Naming “FROWN”**
  Initial FROWN Action

- **Naming “STOP”**
  Initial MOVE ARM ACTION

- **Naming “PUSH”**
  INITIAL MOVE ARM ACTION

- **Naming “PULL”**
  INITIAL MOVE ARM ACTION

- **Naming “GRASP”**
  INITIAL MOVE ARM ACTION

- **Naming “RELEASE”**
  INITIAL MOVE ARM ACTION
“GRASP”, “SMILE”, “STOP”...
“GRASP”, “SMILE”, “STOP”...

“KEEP” [is] “GRASP” [and] “STOP”.

Model of Experiment I
"GRASP", "SMILE", "STOP"...

"KEEP" [is] "GRASP" [and] "STOP".

"ACCEPT" [is] "KEEP" [and] "SMILE" [and] "STOP".
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GOAL Further experiments will be carried out to teach iCub:

- To perform a series of action primitives (e.g. “HIT”, “PAINT”, “DRAW”, “STOP”) and to recognize the tools to interact with (e.g. “HAMMER”, “BRUSH”, “PENCIL”).
- Then, by correlating higher-order action words (e.g. “HIT HAMMER”, “DRAW PENCIL”) with basic action primitives, the robot will acquire more abstract concepts (e.g. “USE”, “MAKE”).
- Verbs chosen from ITALK report.
Experiment II

Meaning of: “TO USE”

DRAW [with] PENCIL

PAINT [with] BRUSH

"USE PENCIL", "USE BRUSH"
Experiment II

Meaning of: “TO USE”

DRAW [with] PENCIL

PAINT [with] BRUSH
Experiment II

Meaning of: “TO USE”

DRAW [with] PENCIL

PAINT [with] BRUSH

“USE PENCIL”, “USE BRUSH”
"PENCIL", "DRAW", "STOP"...
"DRAW PENCIL" [is] "DRAW" [and] "PENCIL" [and] "STOP".
"USE PENCIL" [is] "DRAW PENCIL" [and] "STOP".
"USE BRUSH" [is] "DRAW BRUSH" [and] "STOP".
"USE HAMMER" [is] "HIT HAMMER" [and] "STOP".
Model of Experiment II

“PENCIL”, “DRAW”, “STOP”...
“PENCIL”, “DRAW”, “STOP”...


Model of Experiment II

Experiment II

Experiments

Approaches to the Problem

Overview

Conclusion
“PENCIL”, “DRAW”, “STOP”...


“USE PENCIL” [is] “DRAW PENCIL” [and] “STOP”.

Model of Experiment II
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- The **actionPrimitives library** of the iCub repository software is being used.
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- Simulation experiments are being initially developed on a software environment for the **iCub humanoid robot**.

- The **actionPrimitives library** of the iCub repository software is being used.

- Then the **iCub** humanoid will be used for testing the experiments on a **real robotic architecture**.
The robot learn how to behave through interaction with the environment.

**Association Network**
- learning of action primitives.

**Network Control**
- encoding in output robot motors.
Conclusion

- Building intelligent systems that can learn the meaning of abstract words is a challenging task for cognitive developmental robotics.
- The aim of my project is to prove that the grounding of abstract categories can be obtained as a consequence of sensorimotor experiences.
Acknowledgement

- Marie Curie ITN
  - Project RobotDoC
  - Project Number 235065
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- Thank you for your attention!


