## Tutorial: Everyday Activity Robot Manipulation in an Interactive Learning Environment

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tr>
<td>8.30 - 8.45</td>
<td>Opening: Michael Beetz &amp; Jörn Syrbe</td>
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<td>8.45 - 10.00</td>
<td>Introduction - Michael Beetz</td>
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<td>10.00 - 11.00</td>
<td>COFFEE BREAK</td>
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<td>11.00 - 12.30</td>
<td>Hands-on Robot Control in CRAM – Arthur Niedźwiecki</td>
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<td>12.30 - 1.30</td>
<td>LUNCH</td>
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<td>1.30 - 3.00</td>
<td>Hands-On Robotics Simulation in Multiverse – Giang Nguyen</td>
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<td>3.00 - 4.00</td>
<td>COFFEE BREAK</td>
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<td>4.00 - 5.30</td>
<td><strong>Hands-On Knowledge openEASE – Sascha Jongebloed</strong></td>
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<td>5.30</td>
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IROS 2023 Tutorial

Knowledge Representation and Reasoning for Cognitive Robots

Sascha Jongebloed
October 5, 2023
Motivation

Generative Models of Everyday Activity

The Robot Household Marathon

Gayane Kazhoyan, Simon Stelter, Ferenc Bálint-Benczédi, Franklin Kenghagho Kenfack, Sebastian Koralewski, Michael Beetz

Universität Bremen
openEASE Demo

URoboSim-Tablesetting
Michael Neumann, 07/18/22 16:47
Neum-Description
Episodic memories of a PR2 robot setting a table in a simulated laboratory kitchen environment at the University of Bremen.
Homepage
Contact
Associated Projects

Replay of event

Graph of event participation

IROS 2023 Tutorial: KR&R for Cognitive Robots
CRAM Architecture
Agenda

1. Knowledge Representation
2. KnowRob
3. Narrative-Enabled Episodic Memories (NEEMs)
4. Ongoing Work
5. Hands-On
Agenda

1. Knowledge Representation
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What is an Ontology?

A **formal definition** was provided by Gruber (1998):

“An ontology is a **formal, explicit** specification of a **shared conceptualization**”

- **formal**: endowed with formal semantics
- **explicit**: concepts, relations and axioms are defined explicitly
- **shared**: consensual knowledge
- **conceptualization**: abstract model of some phenomena of the world
Informal Example: Family relations

Male is: the opposite of female
A human is: a kind of: living entity
A woman is: a human and a female
A man is: a human and a male
A mother is: a woman with at least one child that is a human
A father is: a man with at least one child that is a human
A parent is: a mother or a father
A grandmother is: a woman, with at least one child that is a parent
A mother-wod is: a mother with only male children

Elizabeth is a woman
Elizabeth has the child Charles Is a grandmother a parent?
Charles is a man Is Diana a parent?
Diana is a mother-wod Is William a man?
Diana has the child William Is Elizabeth a mother-wod?

Possible Questions:
Terminologies

\[ \text{Male} \equiv \neg \text{Female} \]
\[ \text{Human} \sqsubseteq \text{Living\_entity} \]
\[ \text{Woman} \equiv \text{Human} \sqcap \text{Female} \]
\[ \text{Man} \equiv \text{Human} \sqcap \text{Male} \]
\[ \text{Mother} \equiv \text{Woman} \sqcap \exists \text{has\_child.Human} \]
\[ \text{Father} \equiv \text{Man} \sqcap \exists \text{has\_child.Human} \]
\[ \text{Parent} \equiv \text{Father} \sqcup \text{Mother} \]
\[ \text{Grandmother} \equiv \text{Woman} \sqcap \exists \text{has\_child.Parent} \]
\[ \text{Mother\_without\_daughter} \equiv \text{Mother} \sqcap \forall \text{has\_child.Male} \]
\[ \text{Mother\_with\_many\_children} \equiv \text{Mother} \sqcap (\geq 3 \text{has\_child}) \]
Assertions

CHARLES: Man
EDWARD: Man
ANDREW: Man
DIANA: Mother-without-daughter
(ELIZABETH, CHARLES): has-child
(ELIZABETH, EDWARD): has-child
(ELIZABETH, ANDREW): has-child
(DIANA, WILLIAM): has-child
(CHARLES, WILLIAM): has-child
Web Ontology Language (OWL)

A knowledge representation language based on description logics.

• W3C recommendation since 2004
• Three variants:
  OWL Lite ⊂ OWL DL ⊂ OWL Full
• OWL Lite a restricted, not very expressive language that allows for rather fast reasoning
• OWL DL is more expressive, though still decidable and equivalent to the SHOIN(D) description logic
• OWL Full includes OWL Lite and OWL DL and but is not decidable any more
Socio-physical Model of Activities (SOMA)
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- an ontological model of activity context

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- 6,195 axioms, 563 classes, 352 properties

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- https://ease-crc.github.io/soma/

Knowledge Representation

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Knowledge Representation

```python
hasType('PR2_0', 'Robot'),
hasComponent('PR2_0', 'PR2Arm_L'),
hasBaseLinkName('PR2Arm_L', 'l_shoulder_pan_link'),
hasComponent('PR2Arm_L', 'PR2Gripper_L'),
hasGripForce('PR2Gripper_L', 80)
...
```
Agenda

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KnowRob

- knowledge processing system designed for robots

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- KnowRob 3.0 is on the way!
- [https://www.knowrob.org](https://www.knowrob.org)

KnowRob - Architecture

ontology & axiomatizations
KnowRob - Architecture
KnowRob - Architecture
KnowRob - Architecture

- Inner world
- Symbolic knowledge base
- Hybrid reasoning
- Ontology & axiomatizations
- Generalized knowledge
KnowRob - Architecture

IROS 2023 Tutorial: KR&R for Cognitive Robots
KnowRob - Architecture

Diagram of the KnowRob architecture showing:
- Logic-based language
- Hybrid reasoning
- Inner world
- Symbolic knowledge base
- Ontology & axiomatizations
- Data structures
- Generalized knowledge
KnowRob - Query Language

- Prolog-like Query language
- Prolog:
  - Turing-complete subset of Predicate Logics
  - Computation is started by users asking queries
  - Prolog then searches for solutions using the facts and rules
KnowRob - Query Language

Example:

\[ \text{has\_type}('PR2_0', 'Robot') \]
KnowRob - Query Language

Example:

```
has_type(R,'Robot')
```
KnowRob - Query Language

Example:

has\_type(Act,’ Action’), \hspace{1cm} (1)

has\_subevent(Act, Sub) \hspace{1cm} (2)
KnowRob - Architecture
KnowRob - Architecture
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Monitoring and Inspection of Experience Knowledge

- a robot creates an ABox ontology of an activity
• a robot creates an ABox ontology of an activity
• the subsymbolic experience data can be logged additionally
Monitoring and Inspection of Experience Knowledge

- a robot creates an ABox ontology of an activity
- the subsymbolic experience data can be logged additionally
- it also reasons about the activity using the same ontology
Narrative-enabled Episodic Memories (NEEMs)

NEEM experience

NEEM narrative

\[
\begin{align*}
\text{is\_event(evt1).} \\
\text{occurs(evt1) since t1.} \\
\text{has\_participant(evt1, fridge0).} \\
\text{has\_role(fridge0, r1) during evt1.} \\
\text{has\_type(r1, container).} \\
\text{...} \\
\end{align*}
\]

\[
\begin{align*}
\text{is\_event(evt2).} \\
\text{occurs(evt2) since t2.} \\
\text{has\_participant(evt2, fridge0).} \\
\text{has\_role(fridge0, r2) during evt2.} \\
\text{has\_type(r2, source).} \\
\text{...} \\
\end{align*}
\]

\[
\begin{align*}
\text{is\_event(evt3).} \\
\text{occurs(evt3) since t3.} \\
\text{has\_participant(evt3, fridge0).} \\
\text{has\_role(fridge0, r3) during evt3.} \\
\text{has\_type(r3, item).} \\
\text{...} \\
\end{align*}
\]
NEEM-hub

- Hadoop-based infrastructure
NEEM-hub

- Hadoop-based infrastructure
- data versioning using DVC
NEEM-hub

- Hadoop-based infrastructure
- data versioning using DVC
- https://neemgit.informatik.uni-bremen.de/neems

NEEM HUB
observation
eperimentation
simulation
acquisition
curation
publication

NEEM Background

NEEM Narrative

NEEM Experience

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NEEM Handbook

• describes data formats, representation and logging software
NEEM Handbook

- describes data formats, representation and logging software
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Mental Simulation

Ongoing Work

Real World

Queries

Sends request containing Sub-Plan, Worldstate

Simulated Episode

Mental Simulation Reasoner

GISKARD

KnowRob

KnowRob

CRAM

CRAM

Tutorial: KR&R for Cognitive Robots
Introspection: Modelling CRAM

Ongoing Work

- Modelling the CRAM software architecture in SOMA

Introspection: Modelling CRAM

Ongoing Work

- Modelling the CRAM software architecture in SOMA
- Allows introspection of task execution and failures

Introspection: Modelling CRAM

Ongoing Work

- Modelling the CRAM software architecture in SOMA
- Allows introspection of task execution and failures
- First step: Modelling software and communication

Introspection: Modelling CRAM

Ongoing Work
Intropection: Modelling CRAM

Ongoing Work
Introspection: Modelling CRAM

Ongoing Work

How do events relate by cause and composition?
What are the capabilities of an agent, and, in particular, a software controller?
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Thanks for your attention!

If you want to try openEASE:
https://hackmd.informatik.uni-bremen.de/s/lpGPs-9g_
Shortened: https://t.ly/SFJC0

[QR Code]

Artificial Intelligence