

Tutorial: Everyday Activity Robot Manipulation in an Interactive Learning Environment

Time	Session
8.30 - 8.45	Opening: Michael Beetz & Jörn Syrbe
8.45 - 10.00	Introduction - Michael Beetz
10.00 - 11.00	COFFEE BREAK
11.00 - 12.30	Hands-on Robot Control in CRAM – Arthur Niedźwiecki
12.30 - 1.30	LUNCH
1.30 - 3.00	Hands-On Robotics Simulation in Multiverse – Giang Nguyen
3.00 - 4.00	COFFEE BREAK
4.00 - 5.30	Hands-On Knowledge openEASE – Sascha Jongebloed
5.30	End

IROS 2023 Tutorial

Knowledge Representation and Reasoning for Cognitive
Robots

Sascha Jongebloed
October 5, 2023



IROS 2023



Tutorial: KR&R for Cognitive Robots





Generative Models of Everyday Activity

The Robot Household Marathon

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



openEASE Demo

 openEASE

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[Query](#)

[NEEMs](#)

[Tutorials](#)

[User](#)


Collaborative Research Center

URoboSim-Tablesetting 

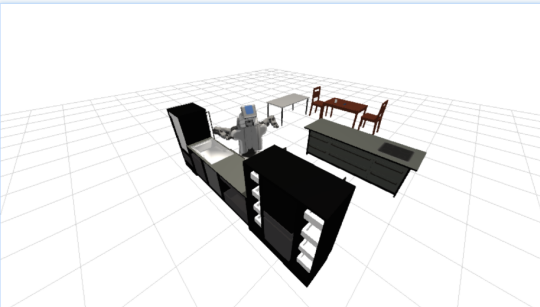

Michael Neumann, 07/18/22 16:47
[Neem-Description](#)
Episodic memories of a PR2 robot setting a table in a simulated laboratory kitchen environment at the University of Bremen.
[Homepage](#)
[Contact](#)

Associated Projects



This work was supported by the German Research Foundation (DFG) as part of the Collaborative Research Center #1320 EASE - Everyday Activity Science and Engineering

Replay of event

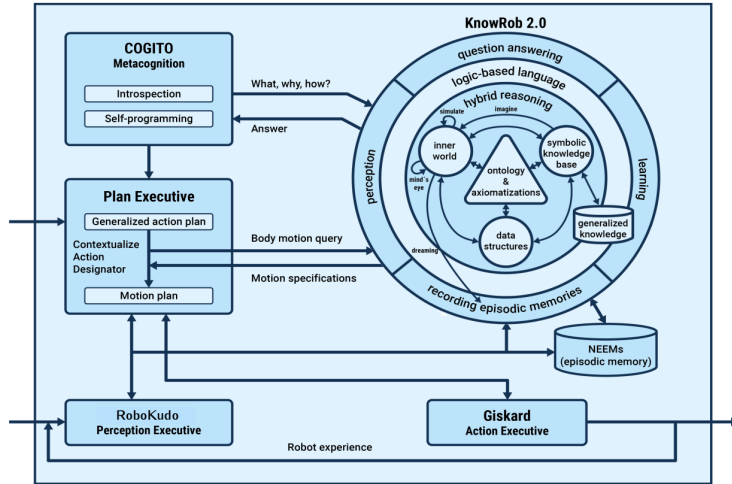

9:55:24 AM

Graph of event participation

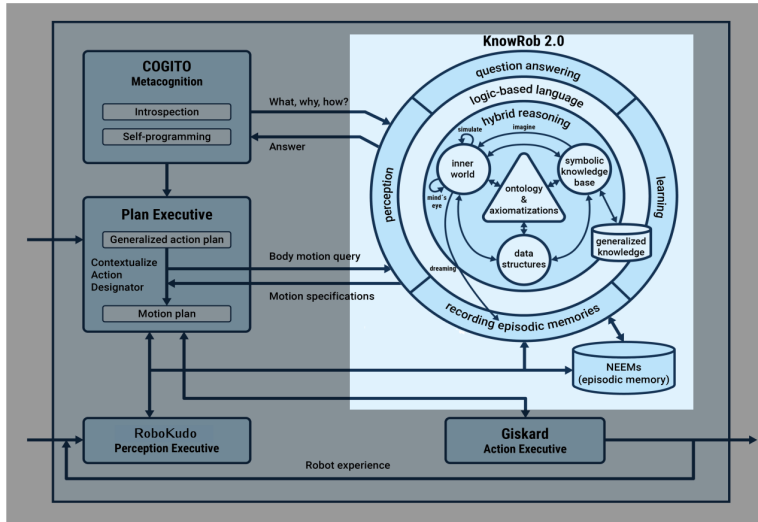


```
graph LR; A((Action_GTLSUMWO)) -- hasParticipant --> B((PR2_0)); B -- hasRole --> C((AgentRole_IPUGJHBKGetActionGrippingEffort_VUBOLYSH)); C -- hasTask --> D(( ));
```

CRAM Architecture



CRAM Architecture



Agenda

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

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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	Possible Questions:
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?

Terminologies

Male	$\doteq$	$\neg \text{Female}$
Human	$\sqsubseteq$	Living_entity
Woman	$\doteq$	$\text{Human} \sqcap \text{Female}$
Man	$\doteq$	$\text{Human} \sqcap \text{Male}$
Mother	$\doteq$	$\text{Woman} \sqcap \exists \text{ has-child.Human}$
Father	$\doteq$	$\text{Man} \sqcap \exists \text{ has-child.Human}$
Parent	$\doteq$	$\text{Father} \sqcup \text{Mother}$
Grandmother	$\doteq$	$\text{Woman} \sqcap \exists \text{ has-child.Parent}$
Mother-without-daughter	$\doteq$	$\text{Mother} \sqcap \forall \text{ has-child.Male}$
Mother-with-many-children	$\doteq$	$\text{Mother} \sqcap (\geq 3 \text{ has-child})$

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

DIANA: Woman

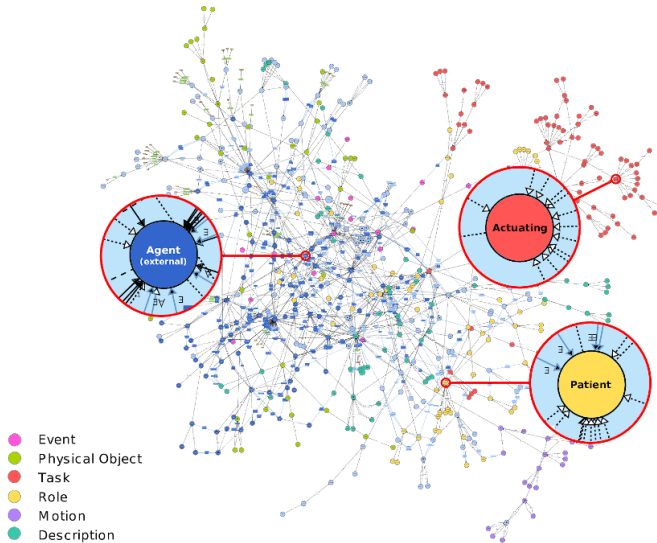
ELIZABETH: Woman

Web Ontology Language (OWL)

A knowledge representation language based on description logics.

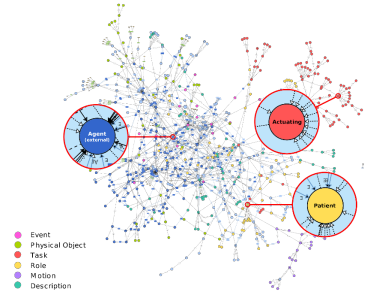
- W3C recommendation since 2004
- Three variants:
 $\text{OWL Lite} \subset \text{OWL DL} \subset \text{OWL Full}$
- OWL Lite a restricted, not very expressive language that allows for rather fast reasoning
- OWL DL is more expressive, though still decidable and equivalent to the SHOIN(D) description logic
- OWL Full includes OWL Lite and OWL DL and but is not decidable any more

Socio-physical Model of Activities (SOMA)



Socio-physical Model of Activities (SOMA)

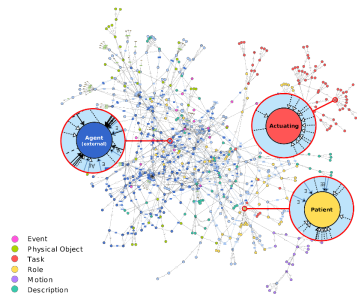
- an ontological model of activity context



Daniel Beßler et. al., "Foundations of the Socio-physical Model of Activities (SOMA) for Autonomous Robotic Agents", In Formal Ontology in Information Systems - Proceedings of the 12th International Conference, FOIS 2021, Bozen-Bolzano, Italy, September 13-16, 2021, IOS Press, 2021.

Socio-physical Model of Activities (SOMA)

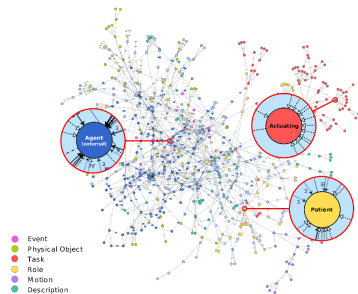
- an ontological model of activity context
- 6.195 axioms, 563 classes, 352 properties



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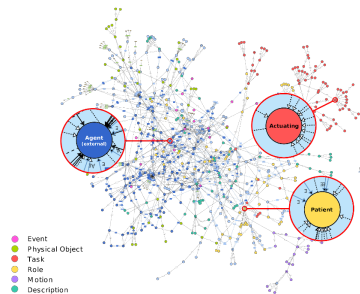
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- aligned with DOLCE+DnS Ultralite (DUL) foundational ontology



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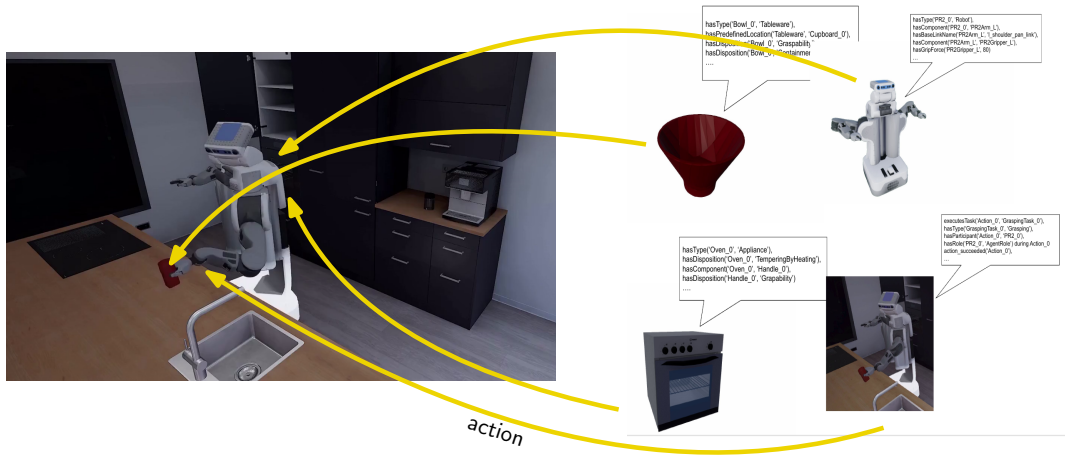
Socio-physical Model of Activities (SOMA)

- an ontological model of activity context
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- aligned with DOLCE+DnS Ultralite (DUL) foundational ontology
- <https://ease-crc.github.io/soma/>



Daniel Beßler et. al., "Foundations of the Socio-physical Model of Activities (SOMA) for Autonomous Robotic Agents", In Formal Ontology in Information Systems - Proceedings of the 12th International Conference, FOIS 2021, Bozen-Bolzano, Italy, September 13-16, 2021, IOS Press, 2021.

Knowledge Representation



Knowledge Representation

```
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)  
...
```

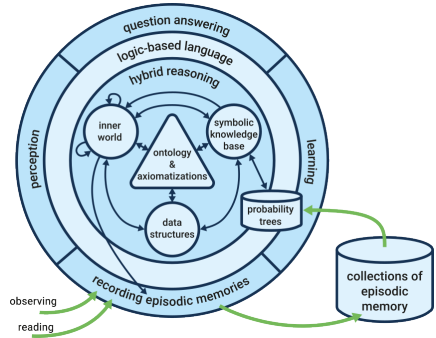


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KnowRob

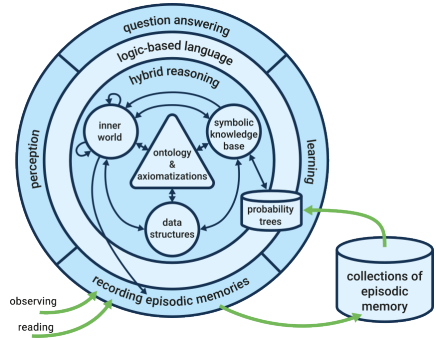
- knowledge processing system designed for robots



KnowRob 2.0 – A 2nd Generation Knowledge Processing Framework for Cognition-enabled Robotic Agents (Michael Beetz, Daniel Beßler, Andrei Haidu, Mihai Pomarlan, Asil Kaan Bozcuoglu and Georg Bartels), In International Conference on Robotics and Automation (ICRA), 2018.

KnowRob

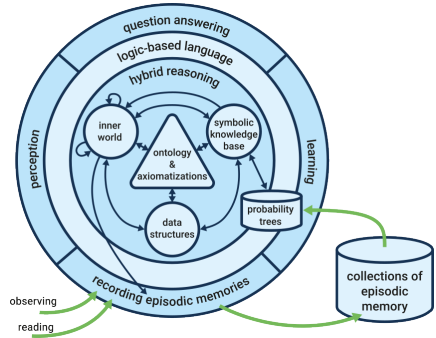
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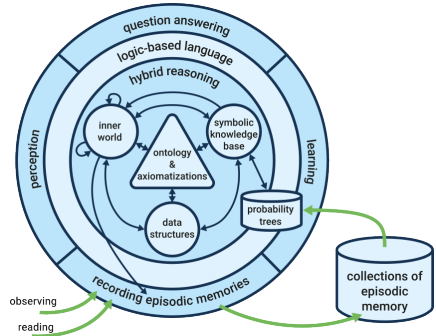
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- KnowRob 3.0 is on the way!



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KnowRob

- knowledge processing system designed for robots
- maintained since 2013
- KnowRob 3.0 is on the way!
- <https://www.knowrob.org>

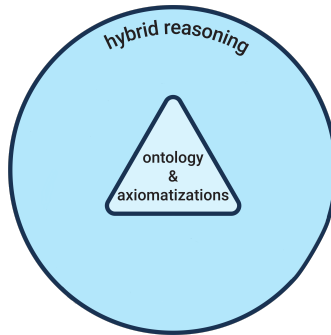


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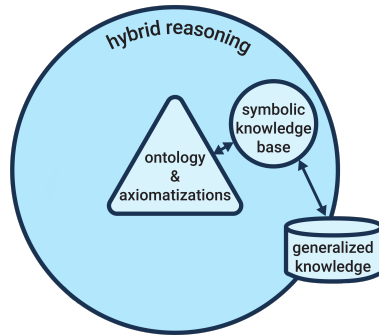
KnowRob - Architecture



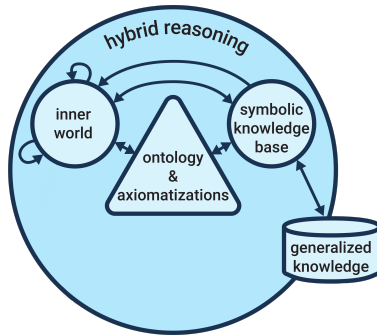
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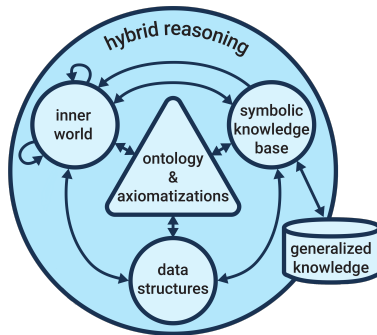
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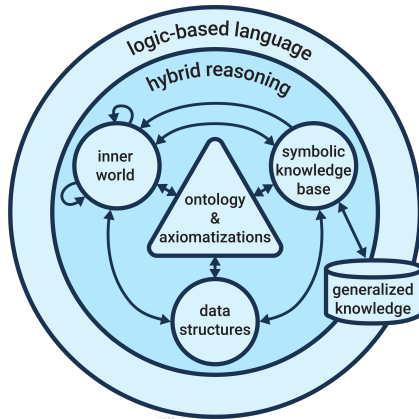
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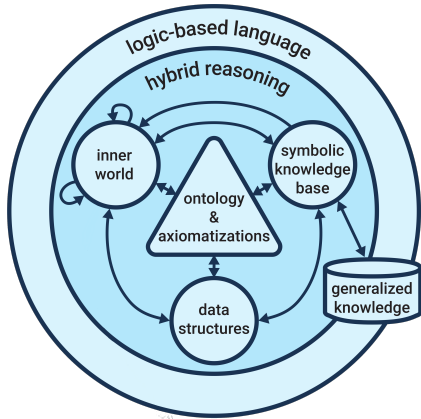
KnowRob - Architecture



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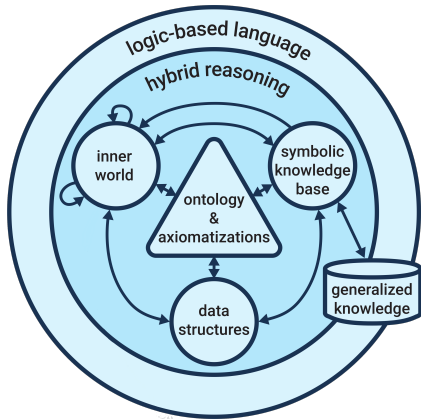


KnowRob - Query Language



- 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

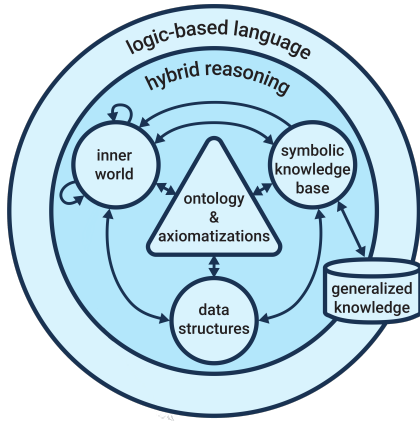
KnowRob - Query Language



Example:

has_type('PR2_0', 'Robot')

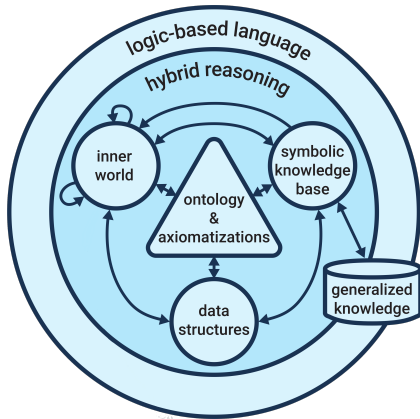
KnowRob - Query Language



Example:

has_type($R, Robot'$)

KnowRob - Query Language

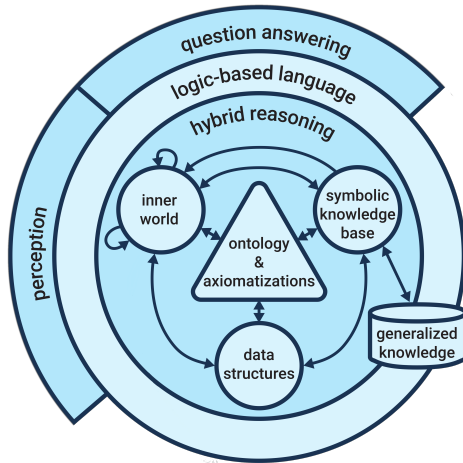


Example:

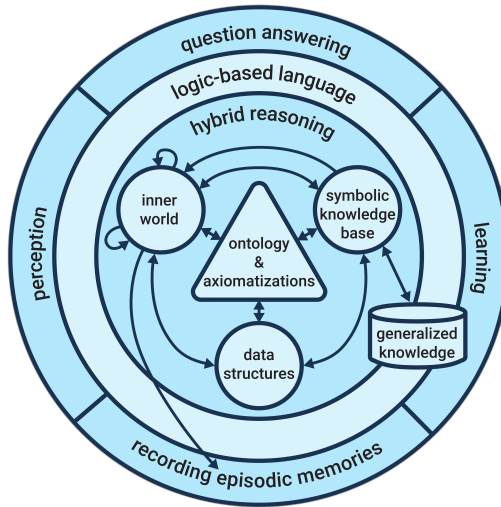
has_type(Act, 'Action'), (1)

has_subevent(Act, Sub) (2)

KnowRob - Architecture



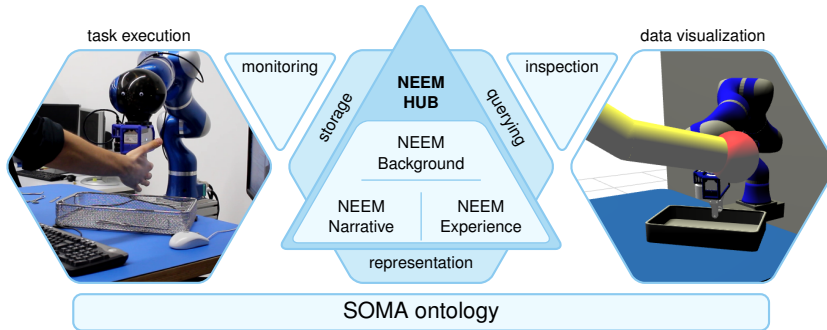
KnowRob - Architecture



Agenda

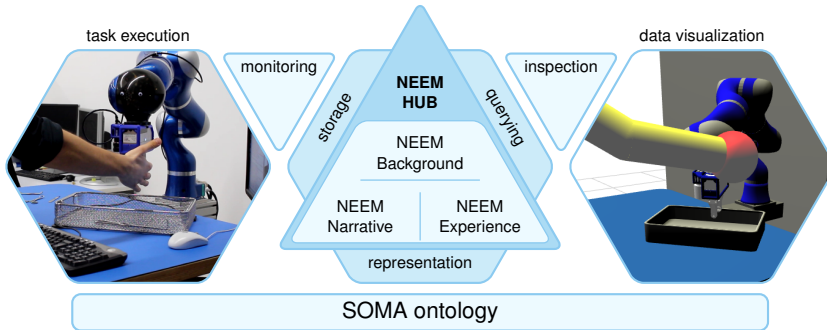
- 1 Knowledge Representation
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Monitoring and Inspection of Experience Knowledge



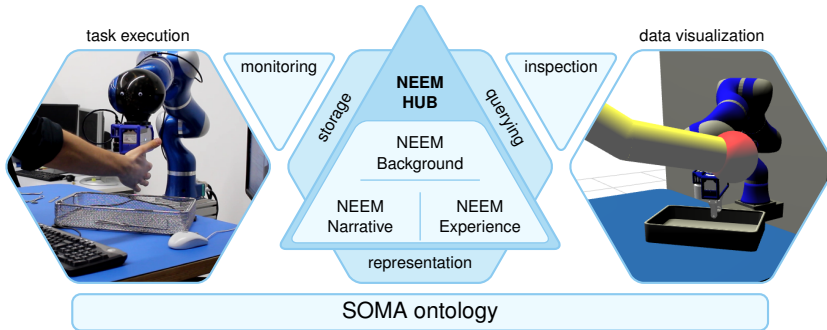
- a robot creates an ABox ontology of an activity

Monitoring and Inspection of Experience Knowledge



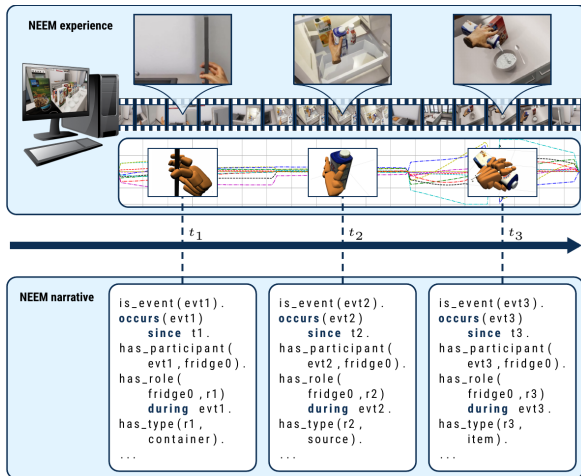
- a robot creates an ABox ontology of an activity
- the subsymbolic experience data can be logged additionally

Monitoring and Inspection of Experience Knowledge



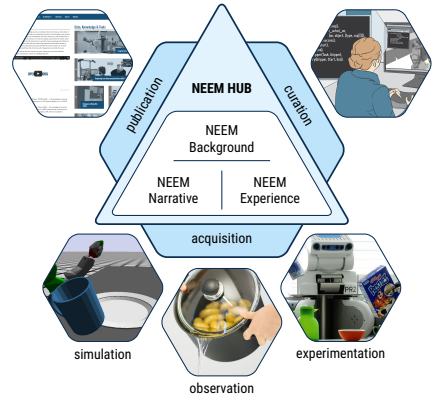
- a robot creates an ABox ontology of an activity
- the subsymbolic experience data can be logged additionally
- it also reasons about the activity using the same ontology

Narrative-enabled Episodic Memories (NEEMs)



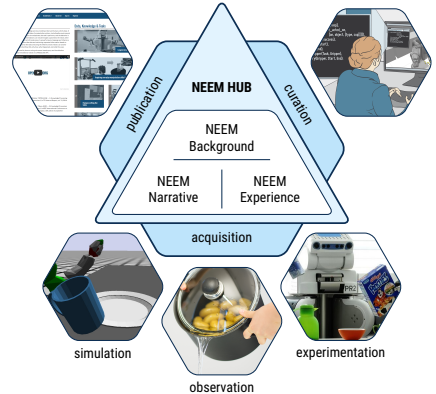
NEEM-hub

- Hadoop-based infrastrutrure



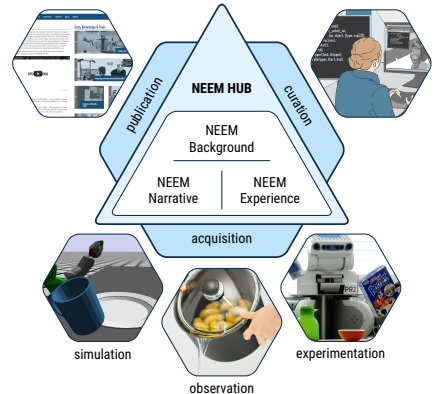
NEEM-hub

- Hadoop-based infrastructure
- data versioning using DVC



NEEM-hub

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



- describes data formats, representation and logging software



NEEM Handbook

Michael Beetz, Daniel Beller, Sebastian Koralewski, Mihai Pomarlan, Abhijit Vyas, Alina Hawkin, Kaviya Dhanabalachandran, Sascha Jongebloed

CRC Everyday Activity Science and Engineering (EASE)
University Bremen, Am Fallturm 1, 28359 Bremen
ai-office@cs.uni-bremen.de

Summary. The Collaborative Research Center EASE is an interdisciplinary research initiative at the University of Bremen that attempts to advance our understanding of how human-scale manipulation tasks can be mastered by robotic agents. The challenge is that the same task needs to be executed by the robot in different ways depending on, for example, what tools are available, and how the environment is shaped. The key to solve this issue is generalization. However, the robot needs to know more than what step it needs to execute next – it further needs to decide on how the next step is carried out through motions of its body, and interactions with its environment. In this document, we will describe how these types of information are represented in the EASE system, how such data-sets are acquired, and how they are stored, maintained, and curated using a centralized web-service. The goal of this effort is to establish representations and infrastructure for a shared experience storage with associated data-sets of agents performing everyday activities, and to use these data-sets as ground truth data to find generalizations that do not abstract away from movements, and naive physics.



NEEM Handbook

- describes data formats, representation and logging software
- <https://ease-crc.github.io/soma/files/current/NEEM-Handbook.pdf>

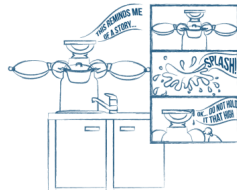


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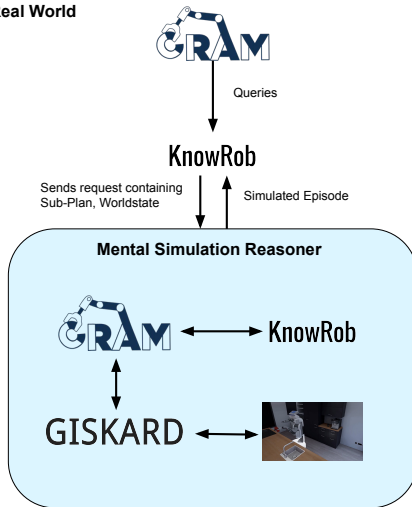
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Mental Simulation

Ongoing Work

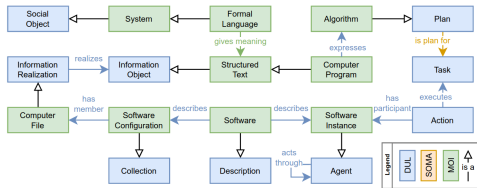
Real World



Introspection: Modelling CRAM

Ongoing Work

- Modelling the CRAM software architecture in SOMA

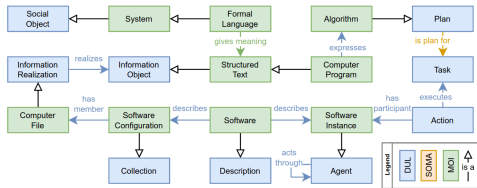


Robin Nolte, Mihai Pomaral, Daniel Beßler, et al. Towards an Ontology for Robot Introspection and Metacognition. Accepted for FOIS 2023.

Introspection: Modelling CRAM

Ongoing Work

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

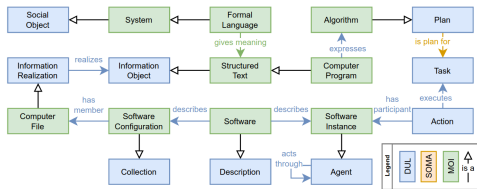


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Introspection: Modelling CRAM

Ongoing Work

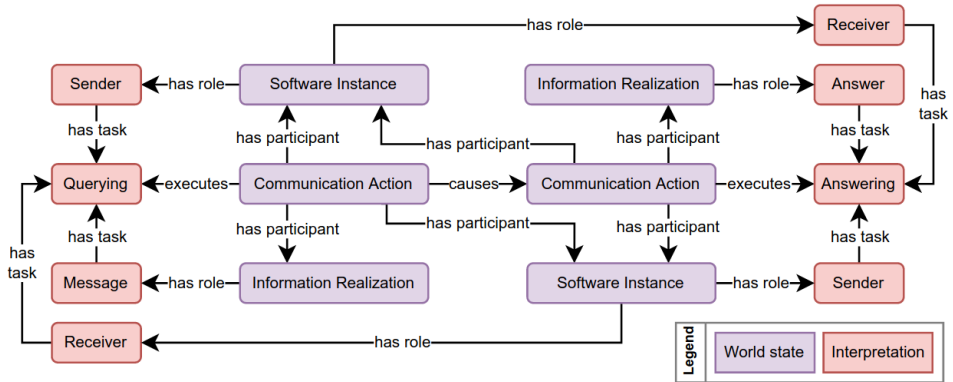
- Modelling the CRAM software architecture in SOMA
- Allows introspection of task execution and failures
- First step: Modelling software and communication



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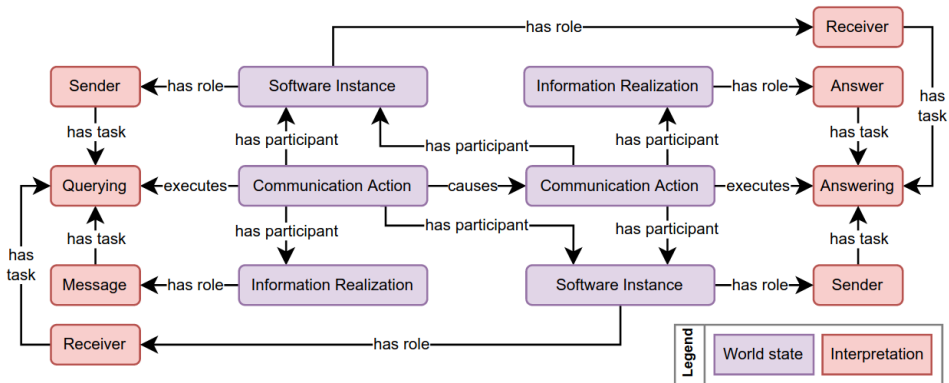
Introspection: Modelling CRAM

Ongoing Work



Introspection: Modelling CRAM

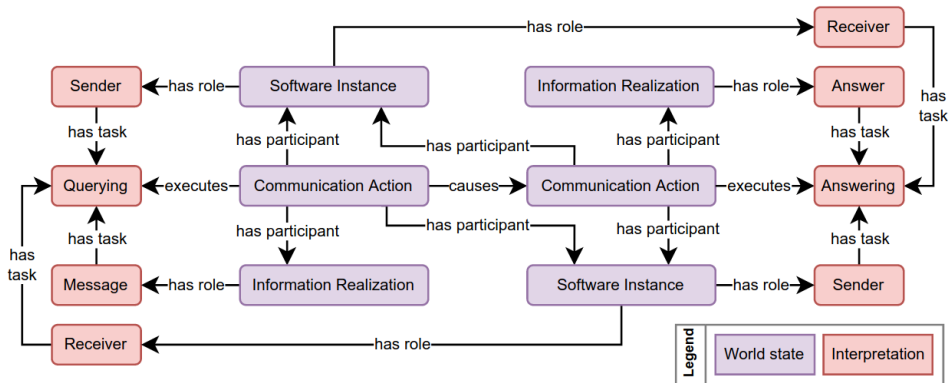
Ongoing Work



Introspection: Modelling CRAM

Ongoing Work

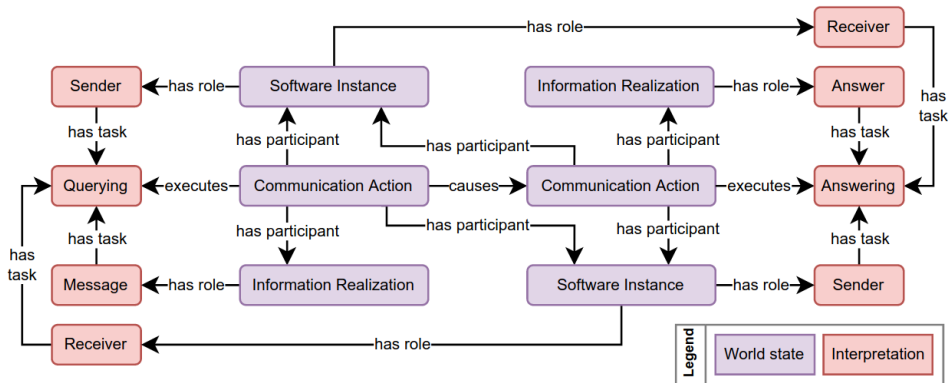
How do events relate by cause and composition?



Introspection: Modelling CRAM

Ongoing Work

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>

