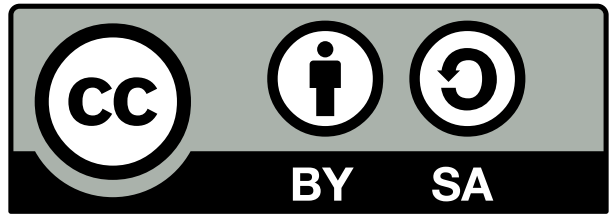
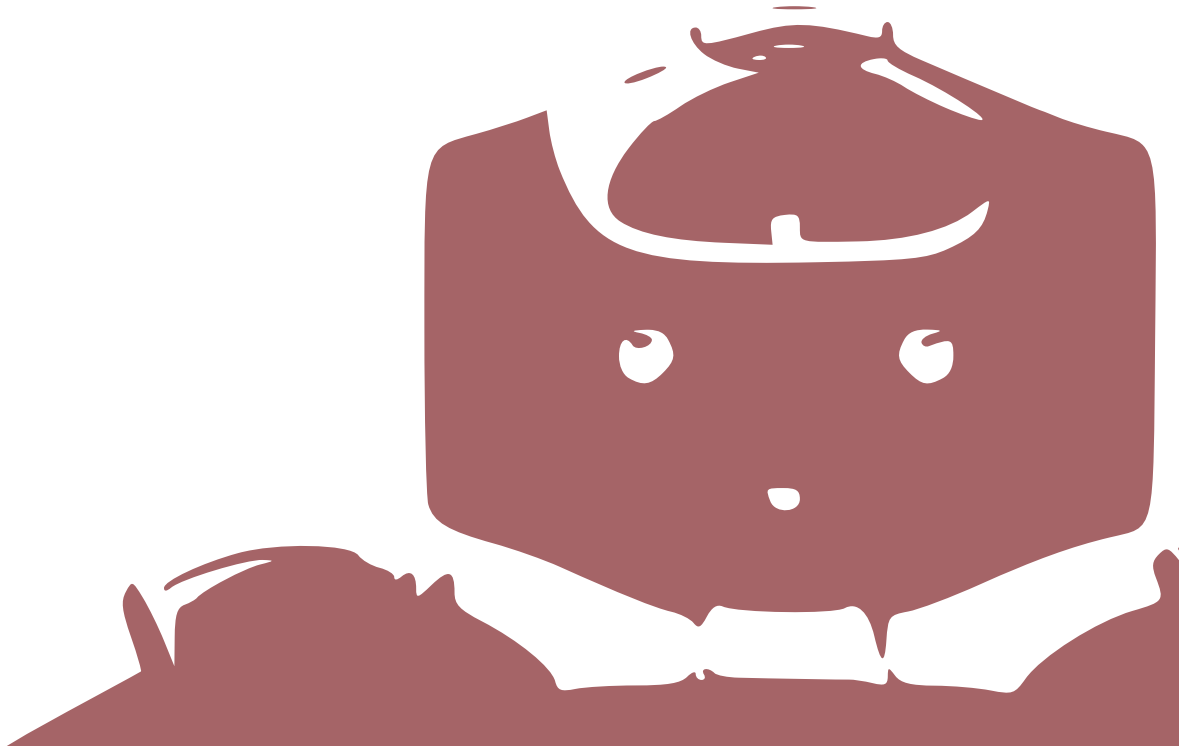


Symbolic Reasoning for HRI



Séverin Lemaignan

Bristol Robotics Lab
University of the West of England

IN THIS LECTURE

- Last week: NLP down to syntax parsing

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- Today: **meaning** (both semantics and pragmatics)

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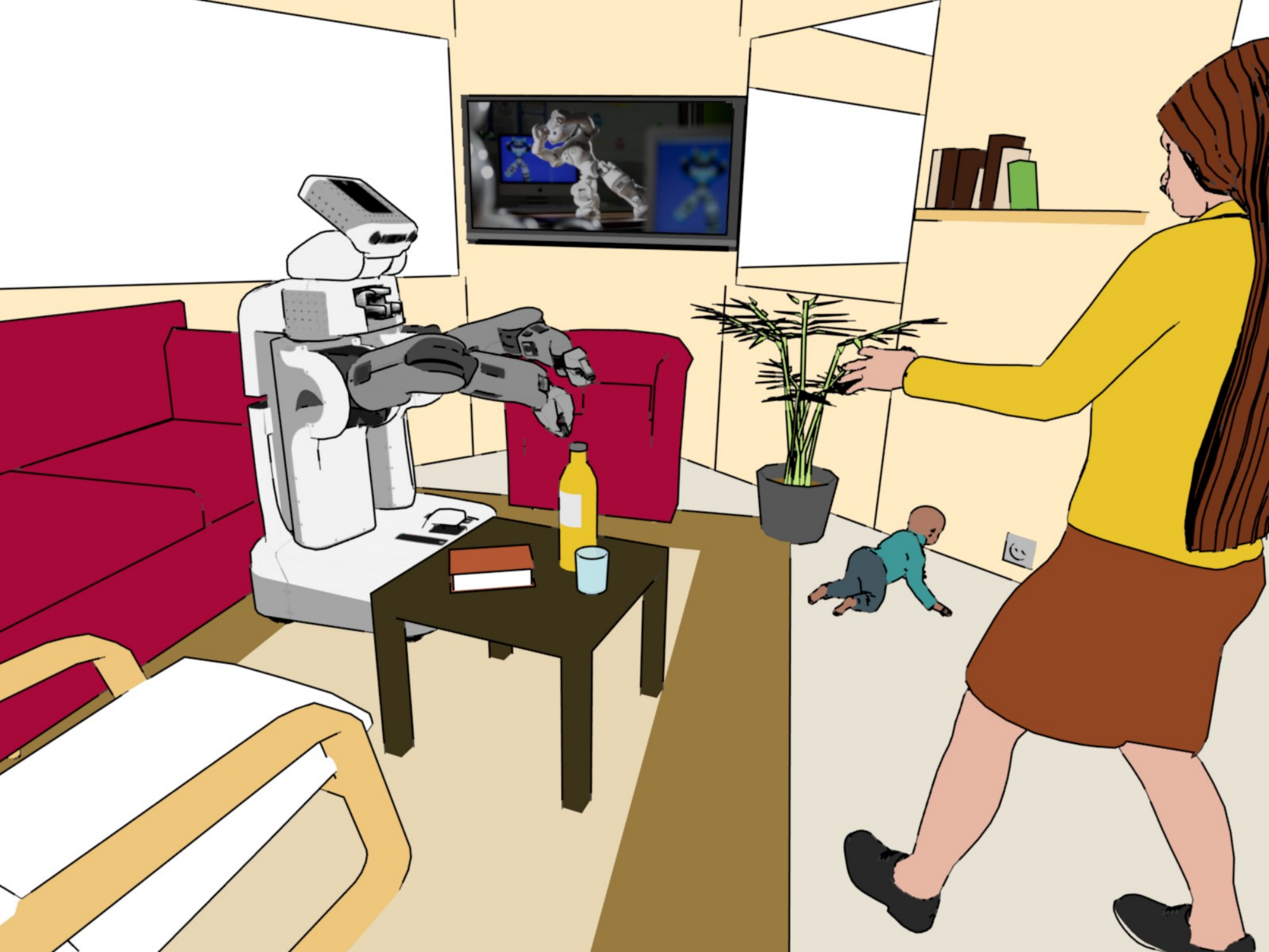
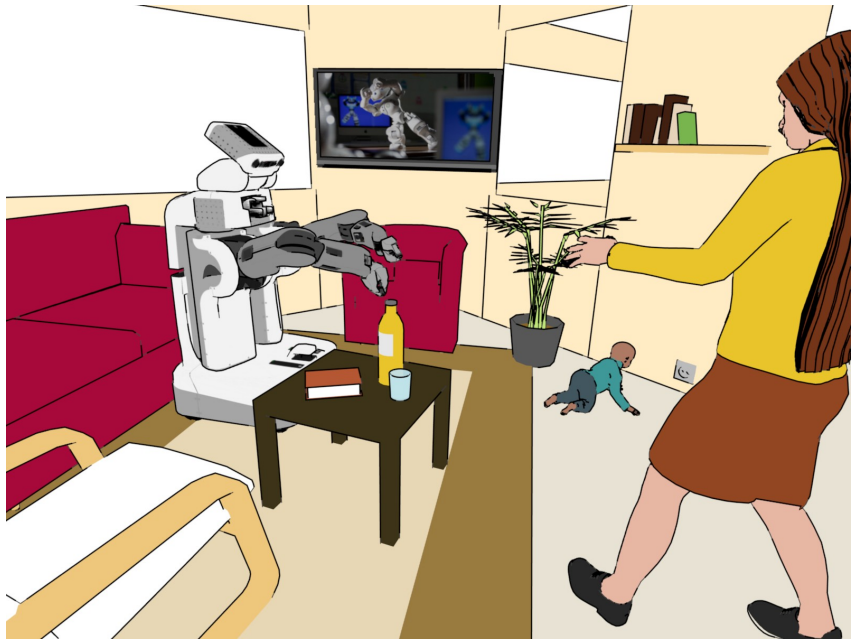
- Last week: NLP down to syntax parsing
- Today: **meaning** (both semantics and pragmatics)
- How to attach *meaning* to natural language?
- What are ontologies?
- How is ‘meaning’ represented and used within the robot?
- How does it relate to *mental models*?



Situated dialogue effectively evidences the challenges

How can the robot make sense of and act upon a command like:

“Can you give me that book?”



THE SYMBOL GROUNDING PROBLEM

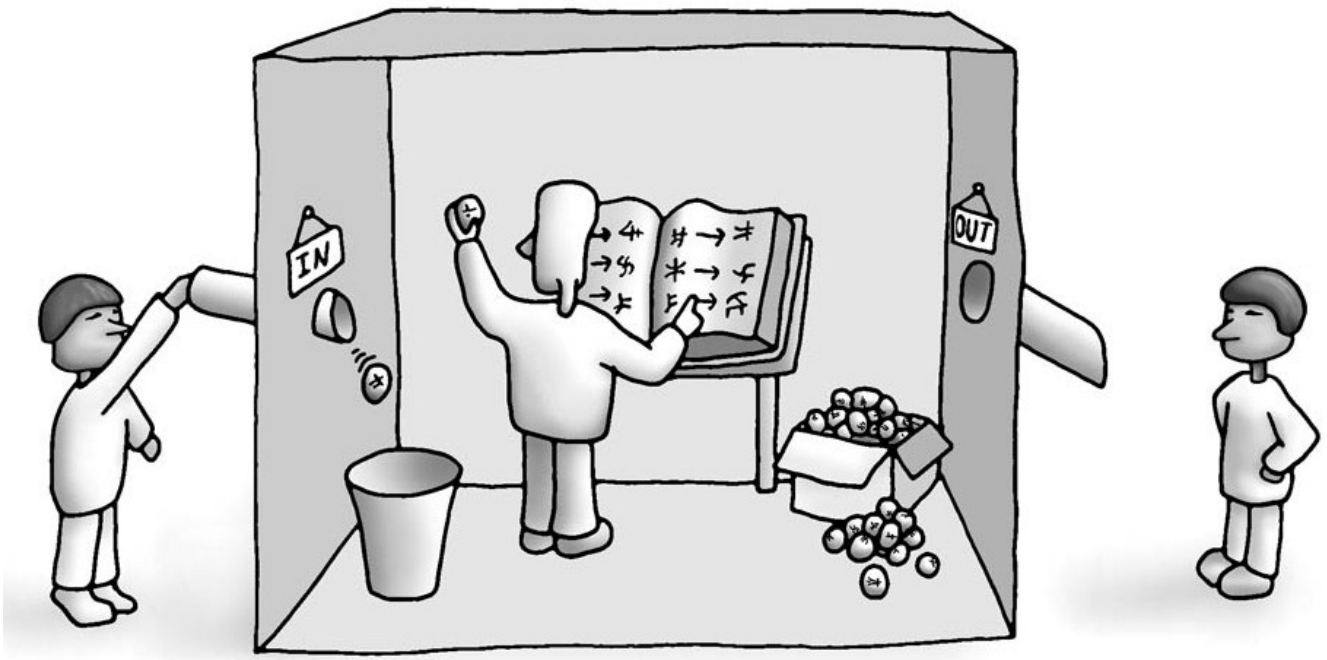
How to attach meaning to a symbol?

[Harnad, ***The Symbolic Grounding Problem***, 1990]

THE SYMBOL GROUNDING PROBLEM

How to attach meaning to a symbol?

Searle's **Chinese Room Argument**



Read more on Wikipedia

[Harnad, ***The Symbolic Grounding Problem***, 1990]

THE SYMBOL GROUNDING PROBLEM

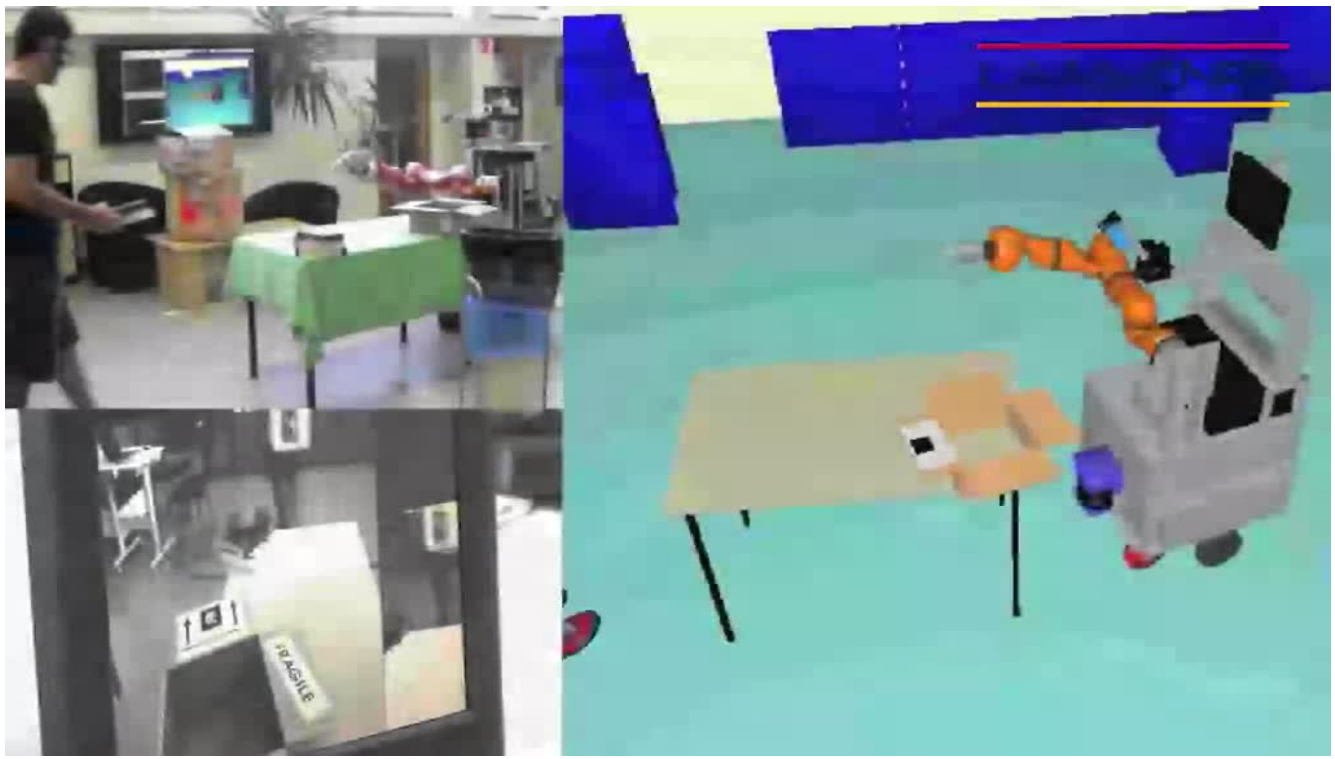
How to attach meaning to a symbol?

Is it possible at all?

[Harnad, ***The Symbolic Grounding Problem***, 1990]

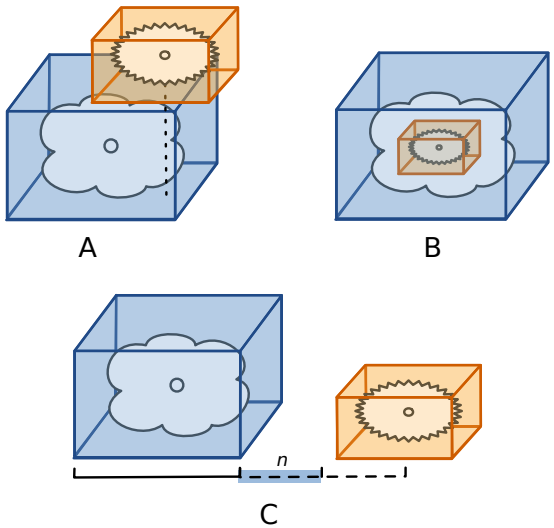
SYMBOLIC SOCIAL COGNITION

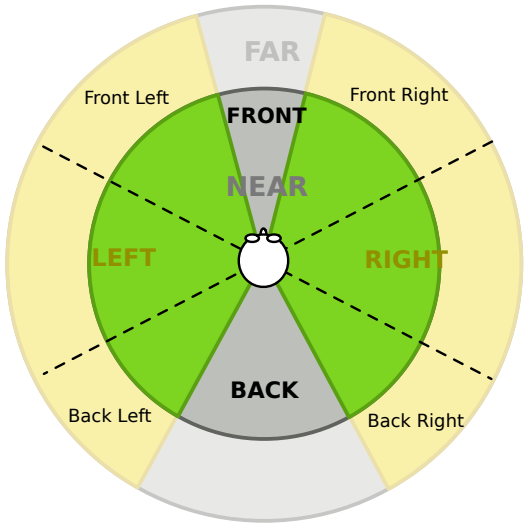
SITUATION ASSESSMENT

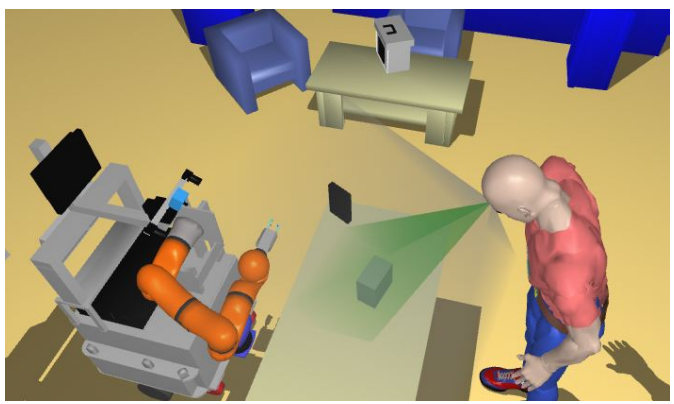


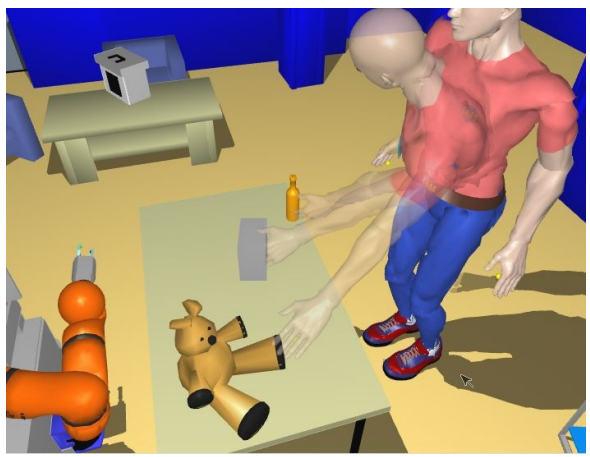
[Lemaignan et al., *Artificial Cognition for Social Human-Robot Interaction: An Implementation*, Artifical Intelligence, 2017]

VISUAL PERSPECTIVE TAKING





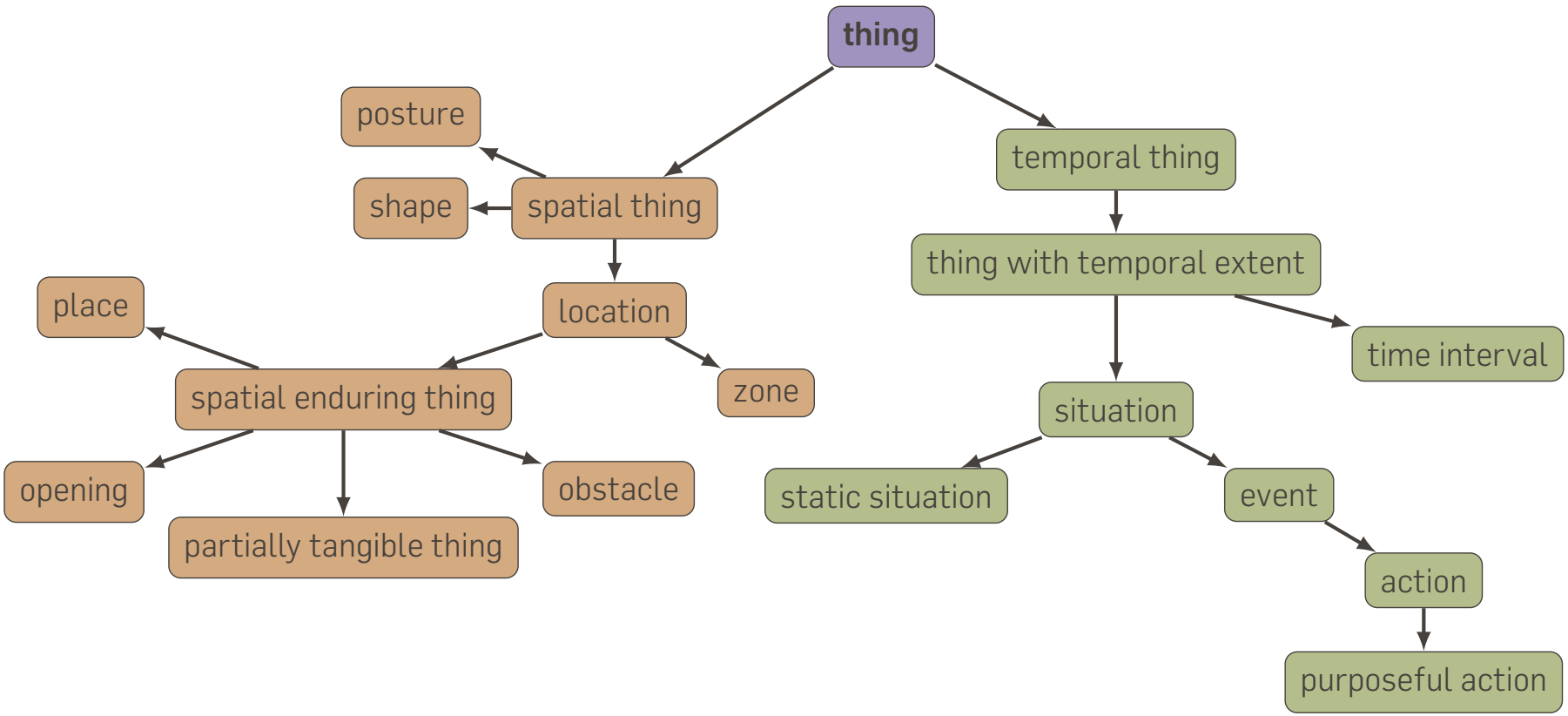




Subject	Predicate	Object
Location	isAt	Location
	→ isOn	
	→ isIn	
	→ isNextTo	
Location	isAbove	Location
Location	isBelow	Location
Location	hasRelativePosition	Location
	→ behind	
	→ inFrontOf	
	→ leftOf	
	→ rightOf	
Object	farFrom	Agent
Object	near	Agent
Agent	looksAt	SpatialThing
Agent	sees	SpatialThing
SpatialThing	isInFieldOfView	xsd:boolean
Agent	pointsAt	SpatialThing
Agent	focusesOn	SpatialThing
Agent	seesWithHeadMovement	SpatialThing
Agent	canReach	Object

[Lemaignan et al., *Artificial Cognition for Social Human-Robot Interaction: An Implementation*, Artifical Intelligence, 2016]

FROM SPATIAL MODEL TO SYMBOLIC MODEL



[Lemaignan et al. *ORO, a Knowledge Management Module for Cognitive Architectures in Robotics*, IROS 2010]

ONTOLOGIES

An **ontology** encompasses a representation, formal naming, and definition of the categories, properties, and relations between the concepts, data, and entities that substantiate one, many, or all domains.

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Ontologies often have close relationships with **first-order logic (FOL)** – more about that later.

ONTOLOGIES

- **T-box** statements: the ***conceptualisation*** of the domain, for instance in terms of ***categories*** (classes): `Dog rdfs:subClassOf Animal`
- **A-box** statements: (T-box compliant) statements about ***individuals*** (instances) in the ontology: `SPOT rdf:type Dog`

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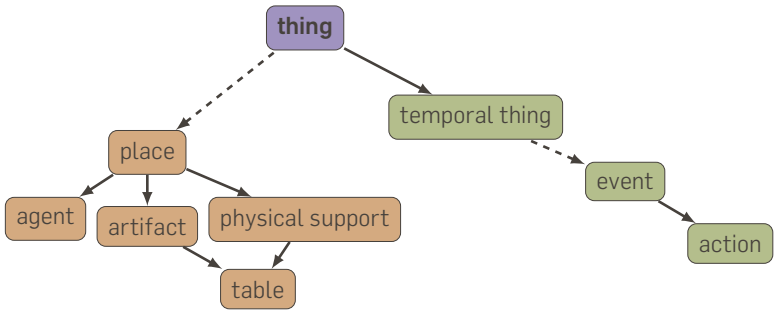
Ontologies are represented using a **knowledge description** language. The **Web Ontology Langage (OWL)** is a very common choice that uses a XML encoding.

ONLINE INSTANCIATION



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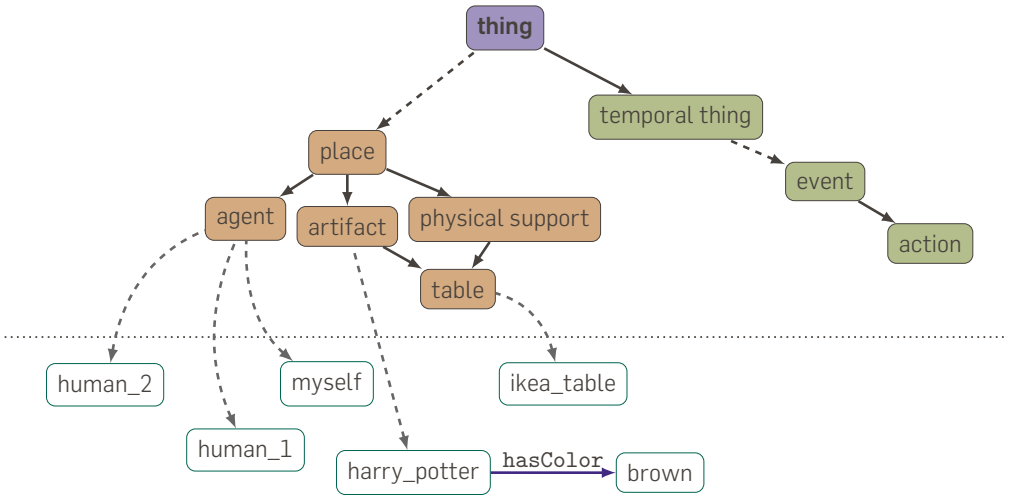

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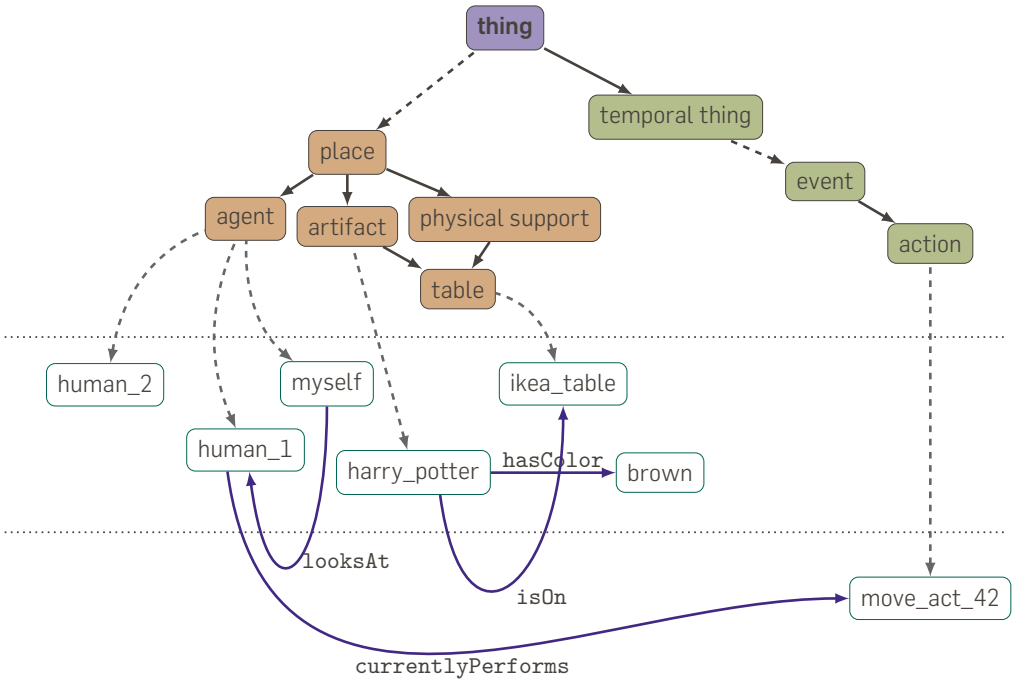
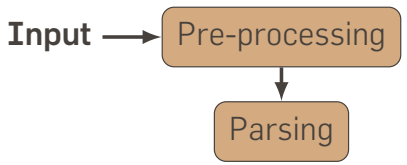


DIALOGUE GROUNDING



[Lemaignan et al. *Grounding the Interaction: Anchoring Situated Discourse in Everyday HRI* – Intl. J. of Social Robotics 2011]

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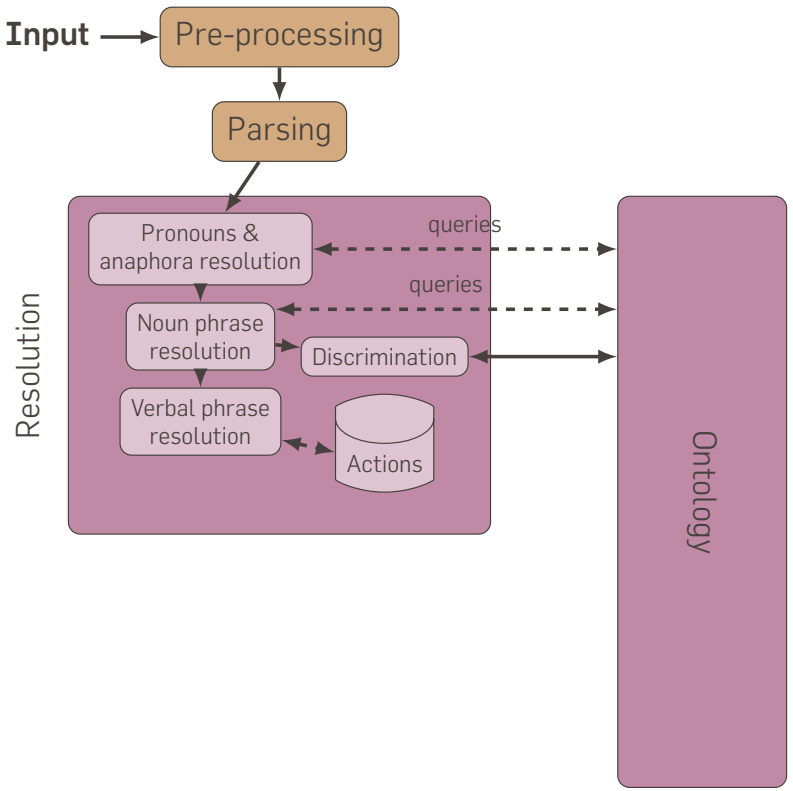

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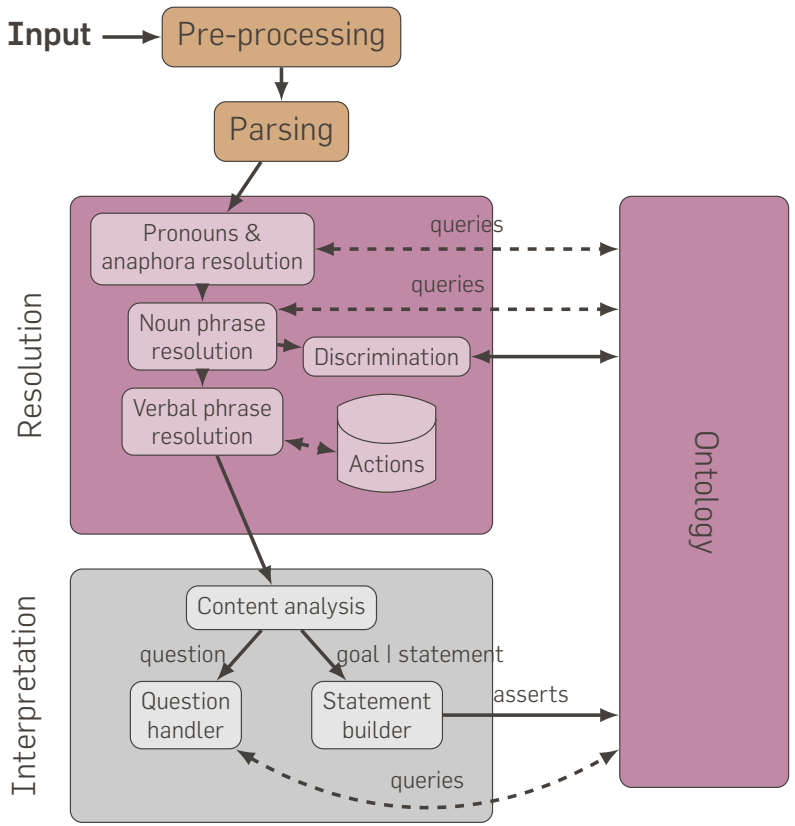

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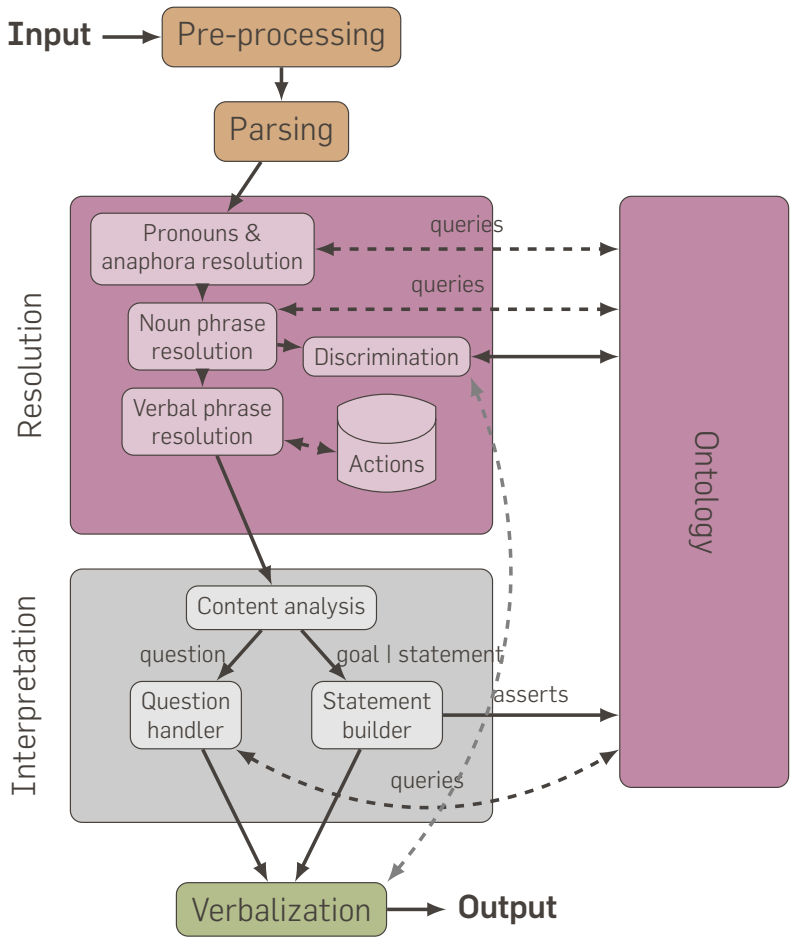

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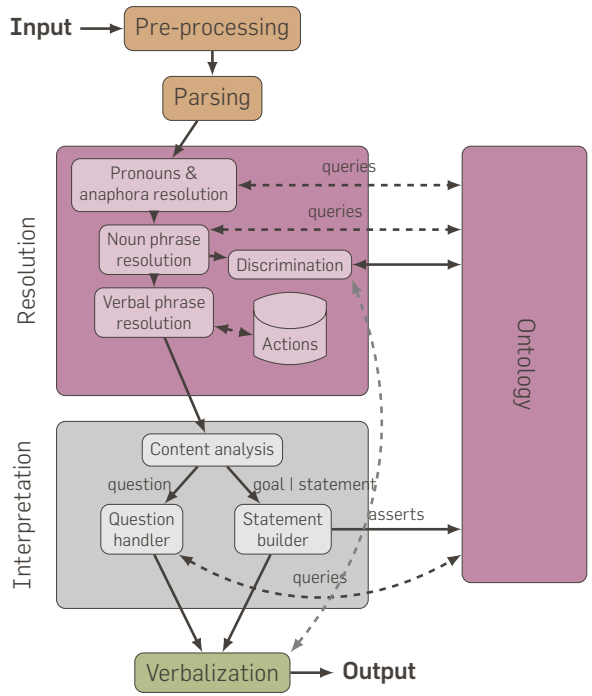
DIALOGUE GROUNDING

“Give me the book on the table”



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DIALOGUE GROUNDING

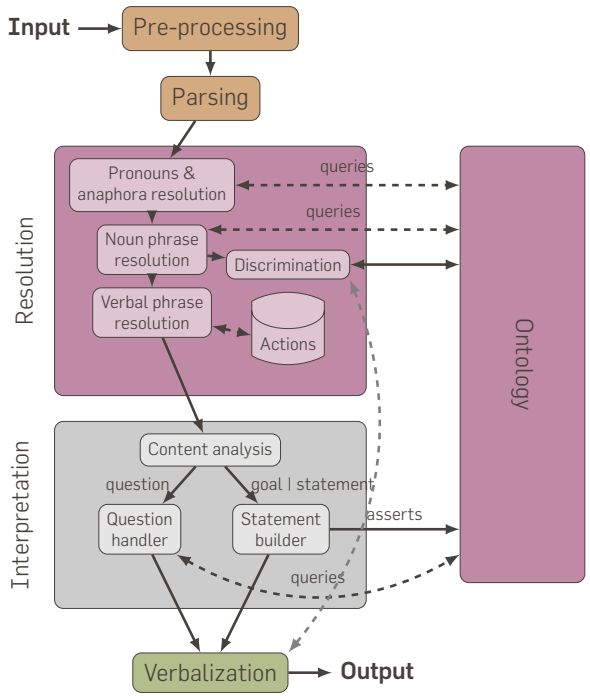
“Give me the book on the table”

$$\downarrow$$

$$\texttt{me} \rightarrow \texttt{human\_1}$$

$$\text{find}(\texttt{?obj type table}) \rightarrow \texttt{ikea\_table}$$

$$\text{find}(\texttt{?obj type book, ?obj isOn ikea\_table}) \rightarrow \texttt{harry\_potter}$$



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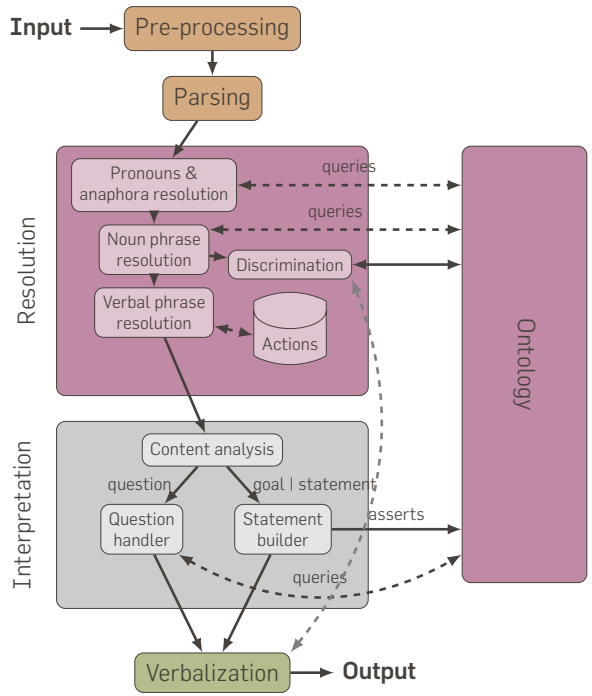
```
human_1 desires give_act_1,
    give_act_1 type Give,
give_act_1 performedBy myself,
give_act_1 actsOnObject book,
give_act_1 receivedBy human_1
```



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MULTI-MODAL INTERACTION

What about
“Give me that book”?
(or even: **“Give me that!”**)

[Lemaignan et al., **Artificial Cognition for Social Human-Robot Interaction: An Implementation**, Artifical Intelligence, 2017]


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EXAMPLE OF FIRST-ORDER LOGIC REASONING

"Where is the other tape?"

↓

find(`?obj isAt ?loc, ?obj type VideoTape, ?obj differentFrom WALL_E_TAPE`)

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"Where is the other tape?"

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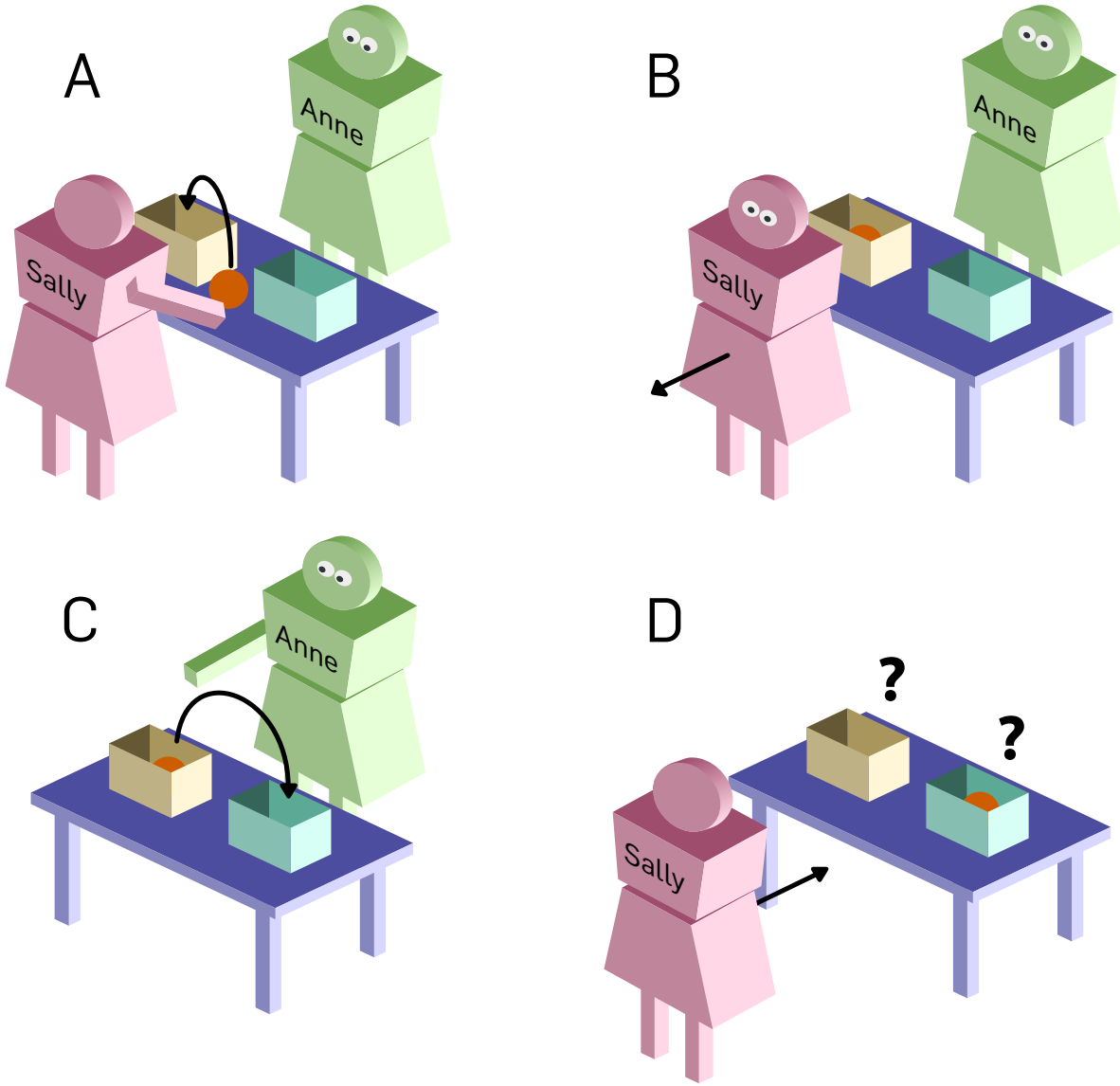
Symbolic approaches effective at dealing with this kind of constraints

ONE STEP FURTHER: THEORY OF MIND

1ST ORDER TOM: THE FALSE-BELIEF EXPERIMENT



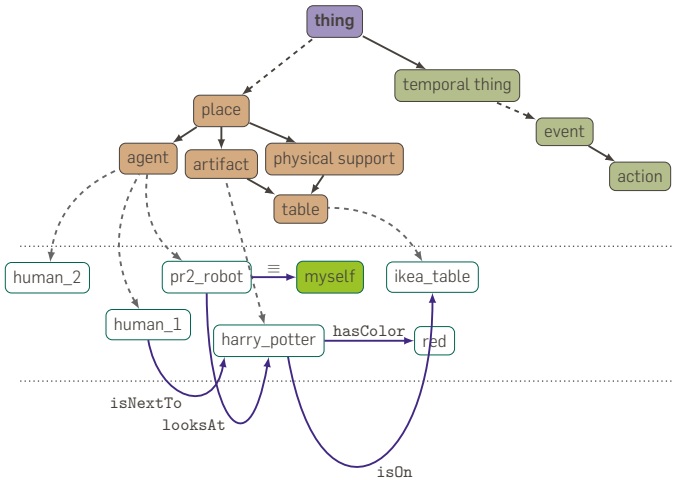
[Wimmer and Perner, **Beliefs about beliefs: Representation and constraining function [...]**, Cognition, 1983]]

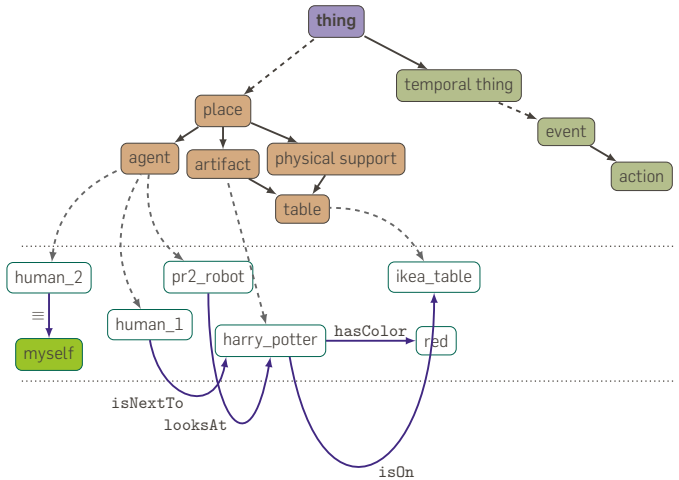
What if I ask for the video tape in the box, but the robot previously moved it somewhere else?

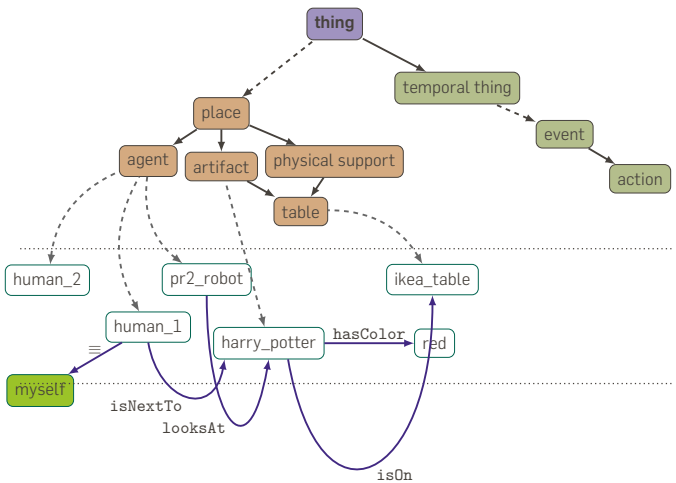
What if I ask for the video tape in the box, but the robot previously moved it somewhere else?

False-belief situation

PARALLEL MODELS: TOWARDS THEORY OF MIND







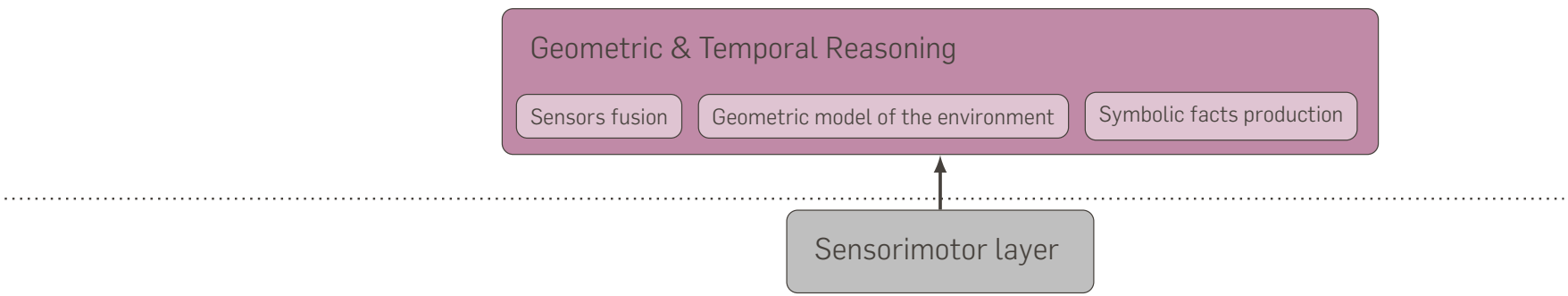
...

SEMANTICS-AWARE ARCHITECTURE

INTO AN CONTROL ARCHITECTURE

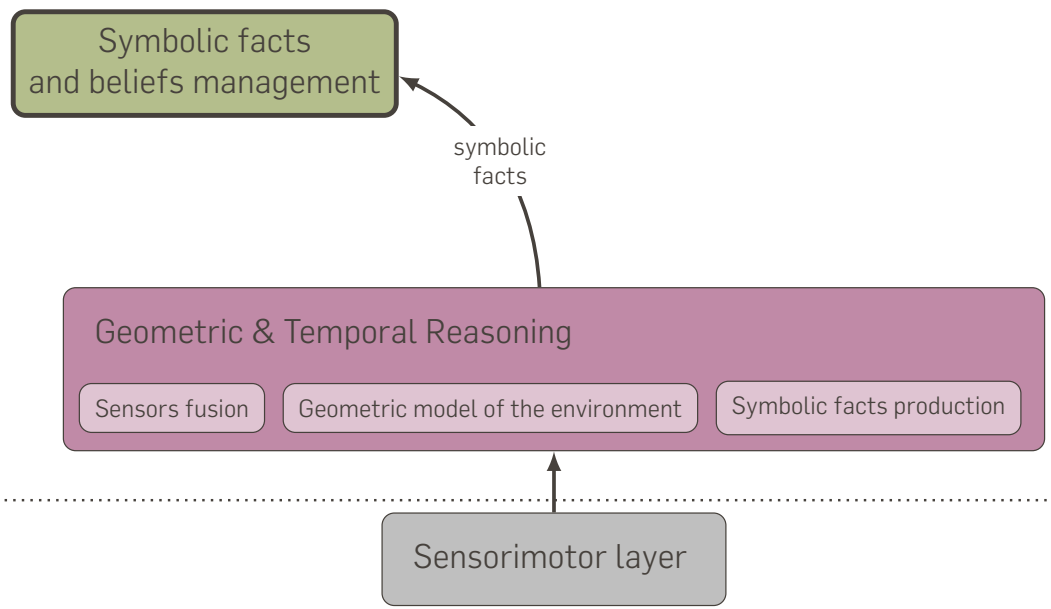
Sensorimotor layer

INTO AN CONTROL ARCHITECTURE



[Lemaignan et al., **Artificial Cognition for Social Human-Robot Interaction: An Implementation**, Artifical Intelligence, 2017]

INTO AN CONTROL ARCHITECTURE



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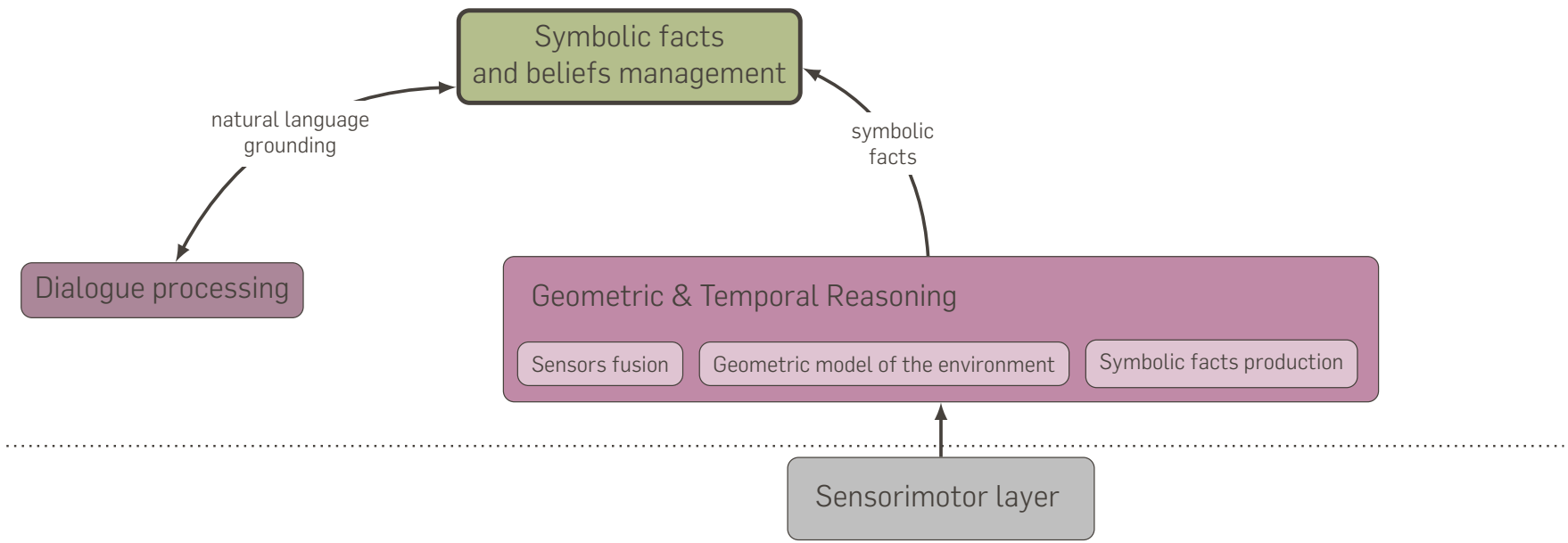

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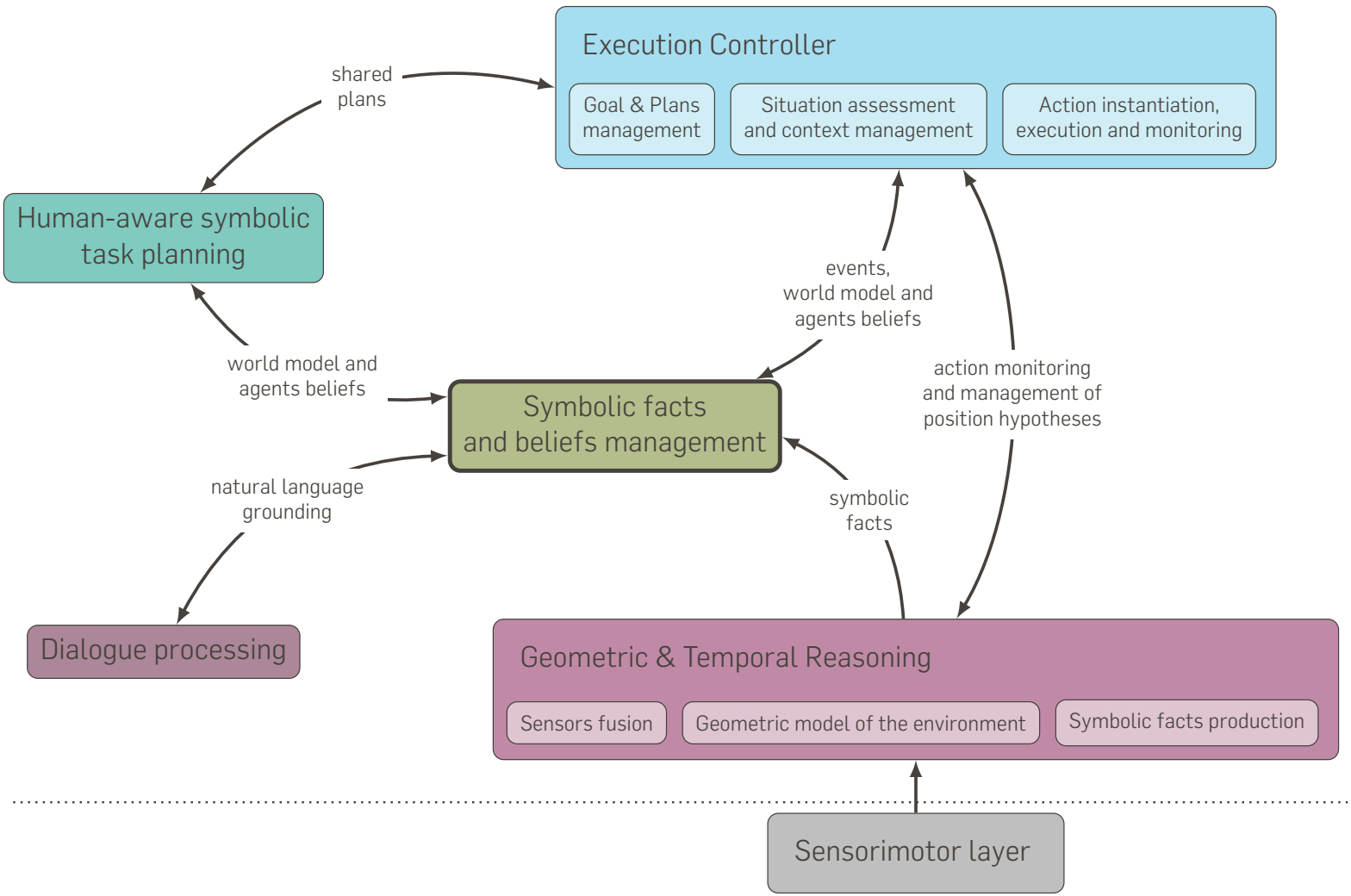

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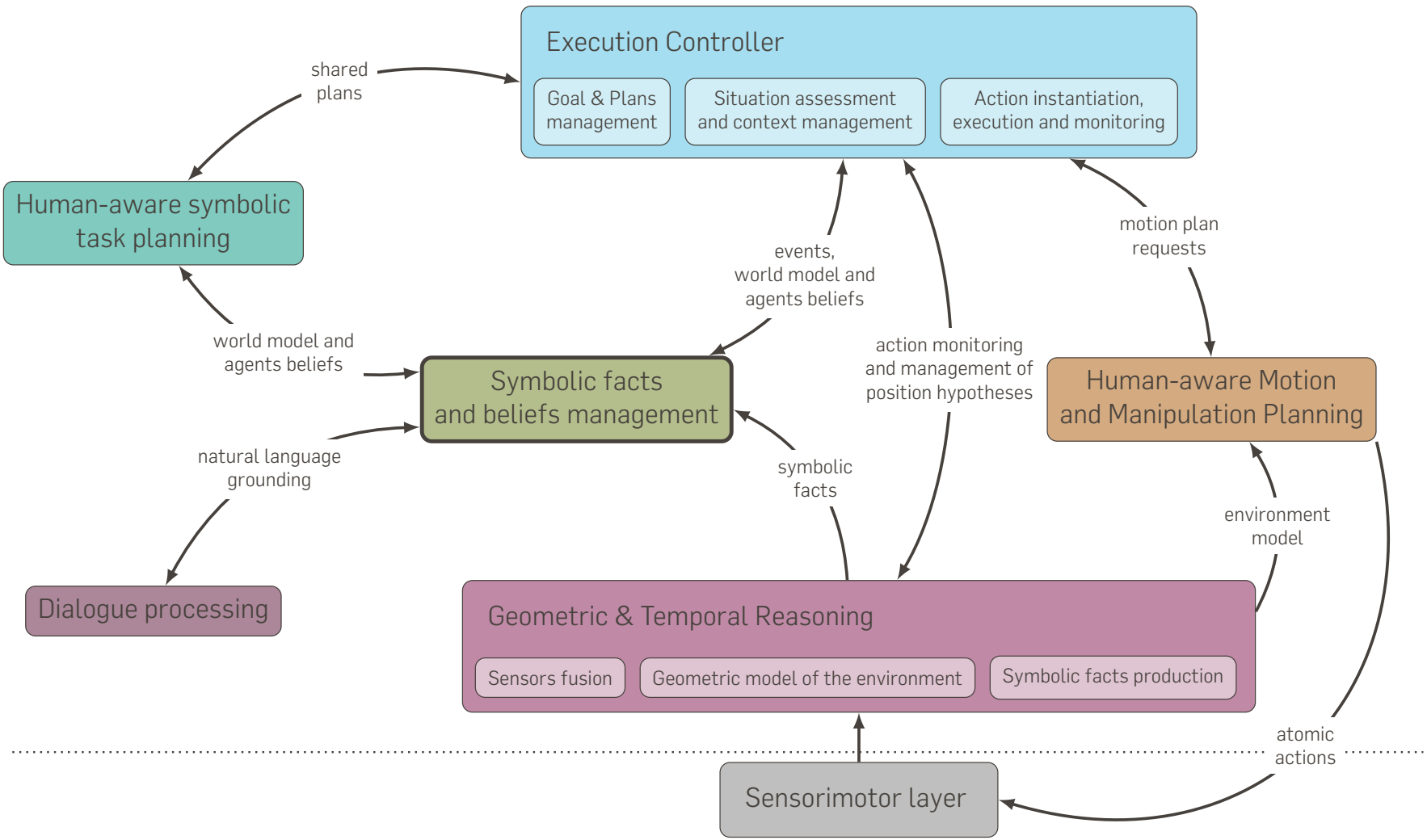

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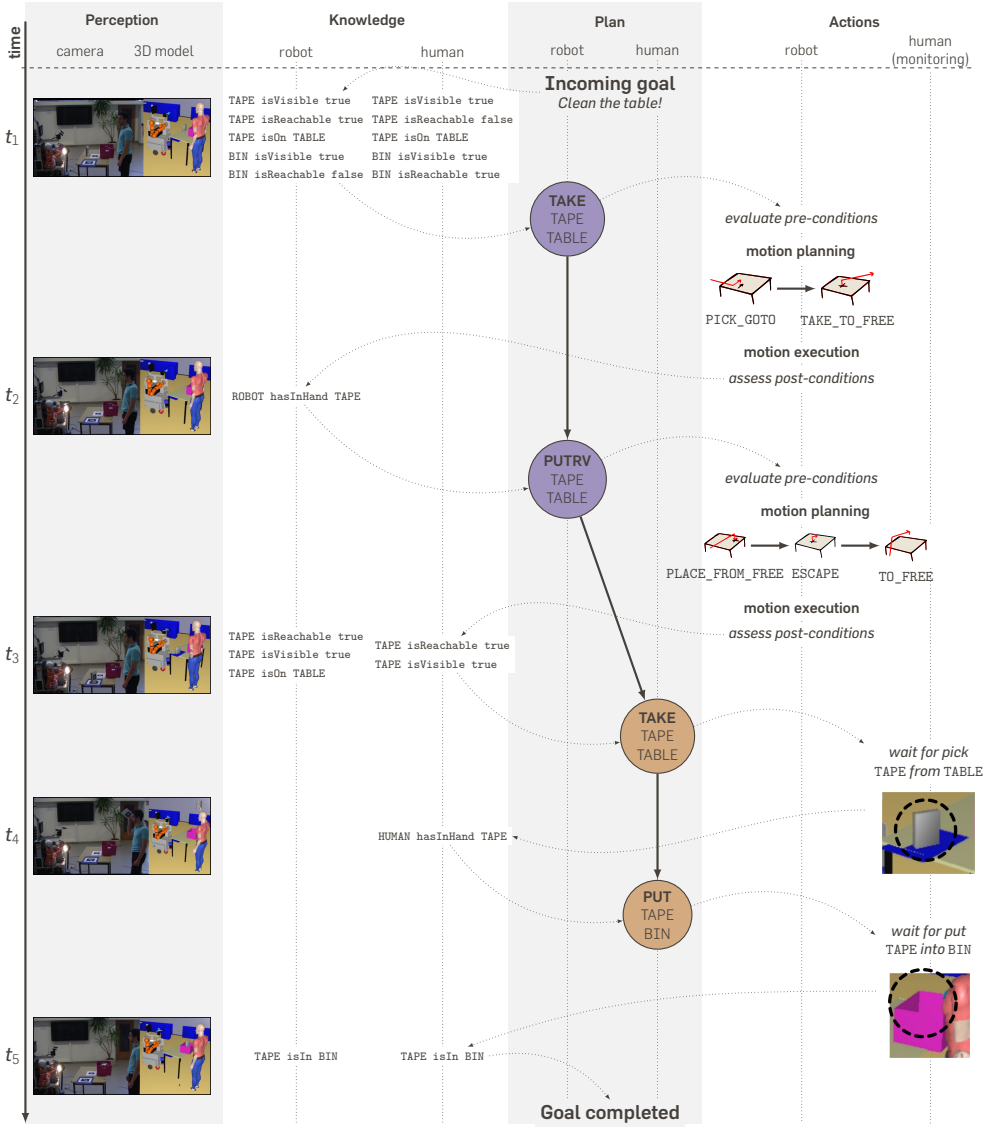
FULL SOCIAL & AUTONOMOUS INTERACTION: ONE EXAMPLE



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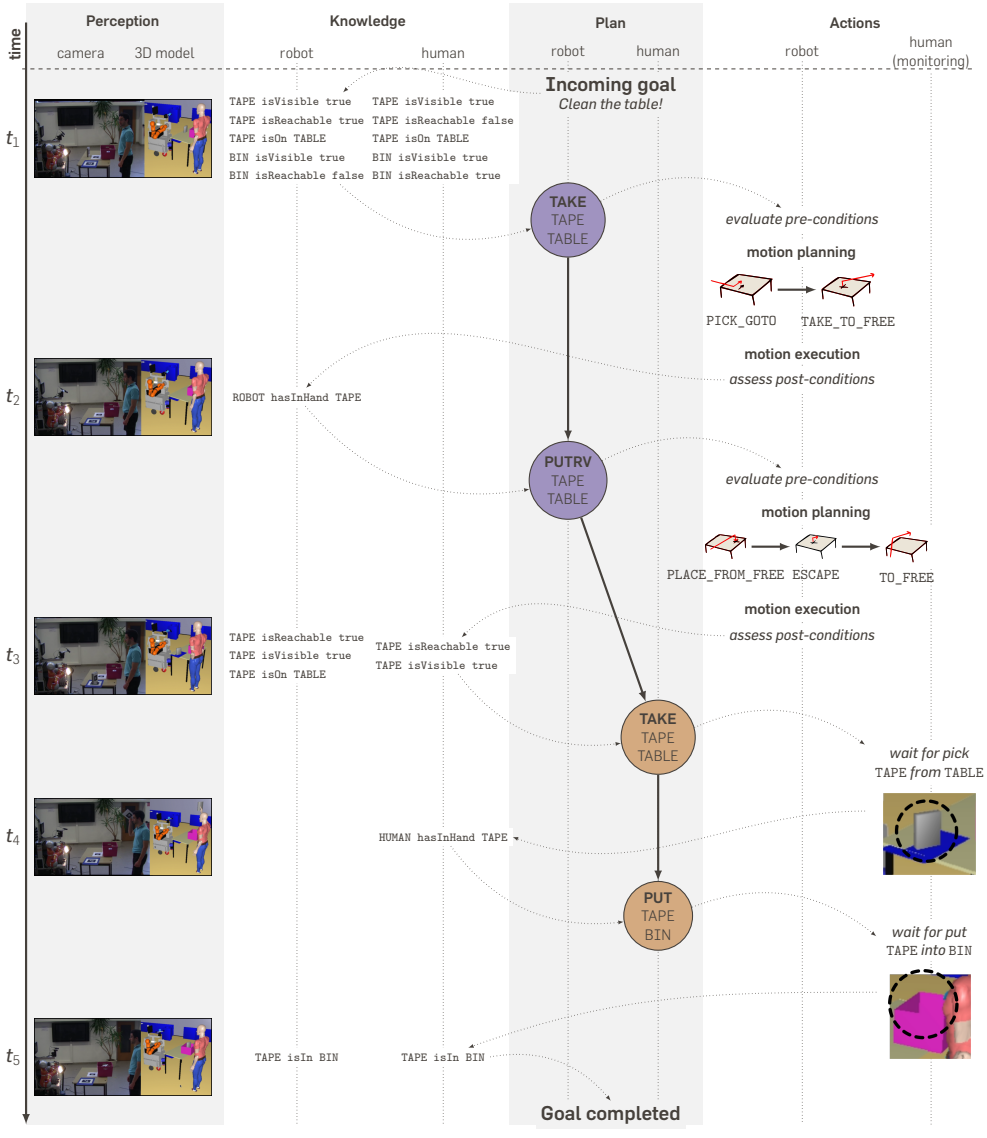
"CLEANING THE TABLE"...



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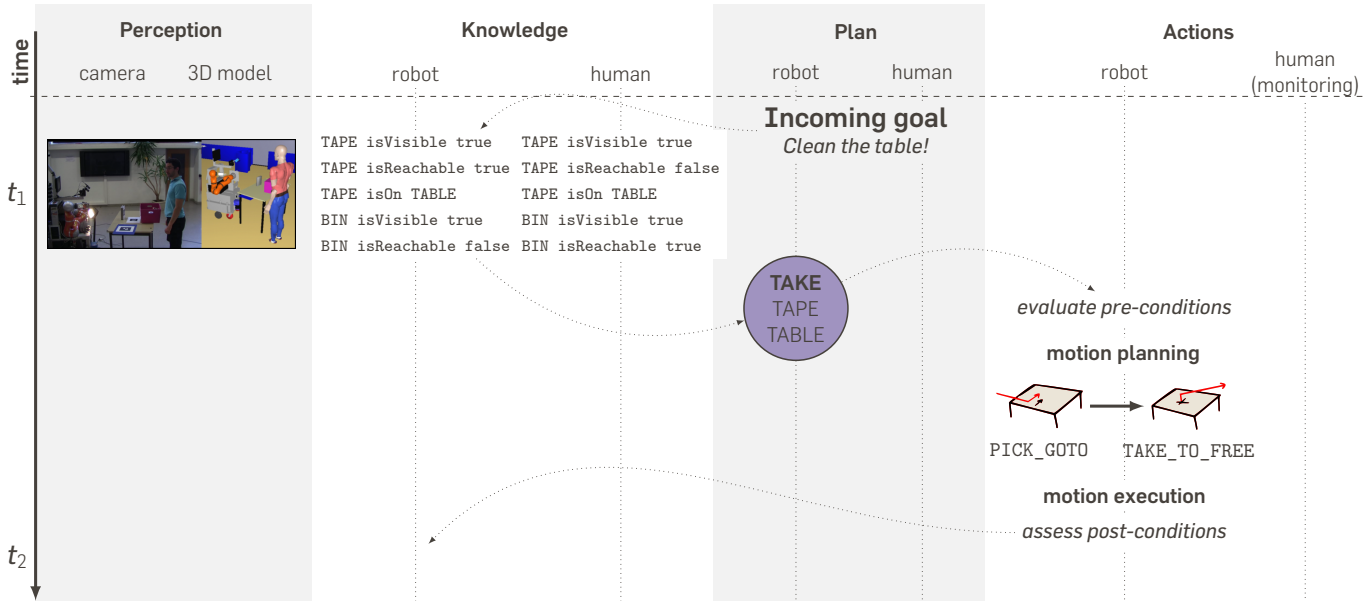

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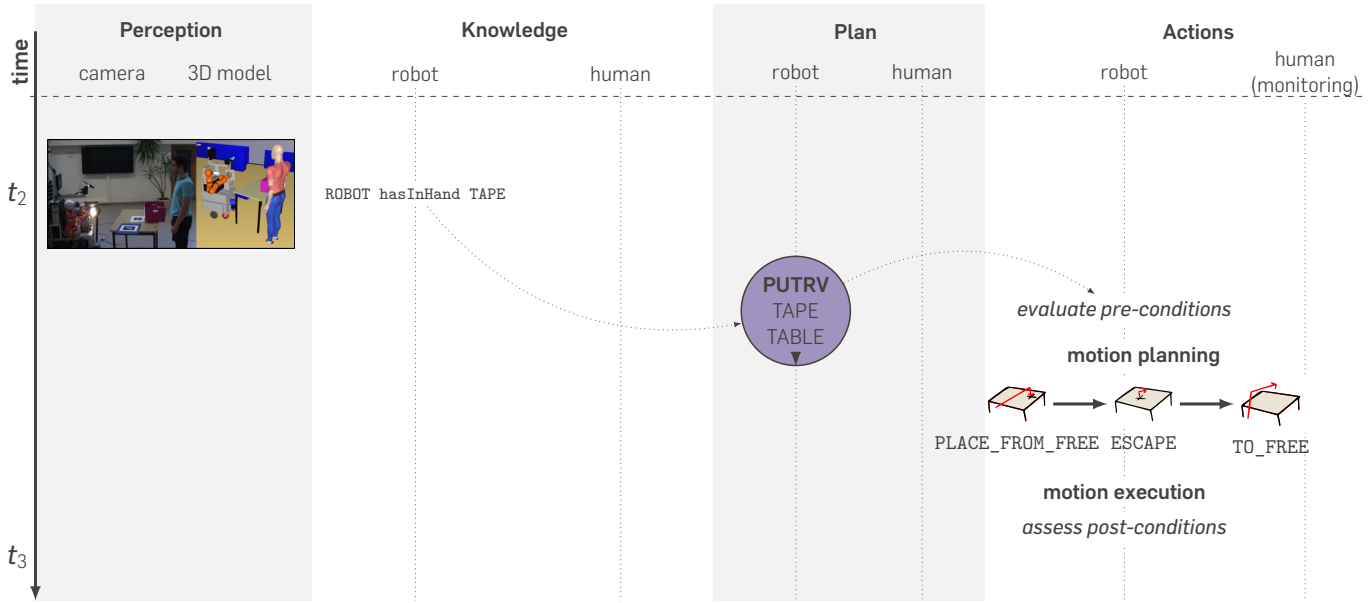

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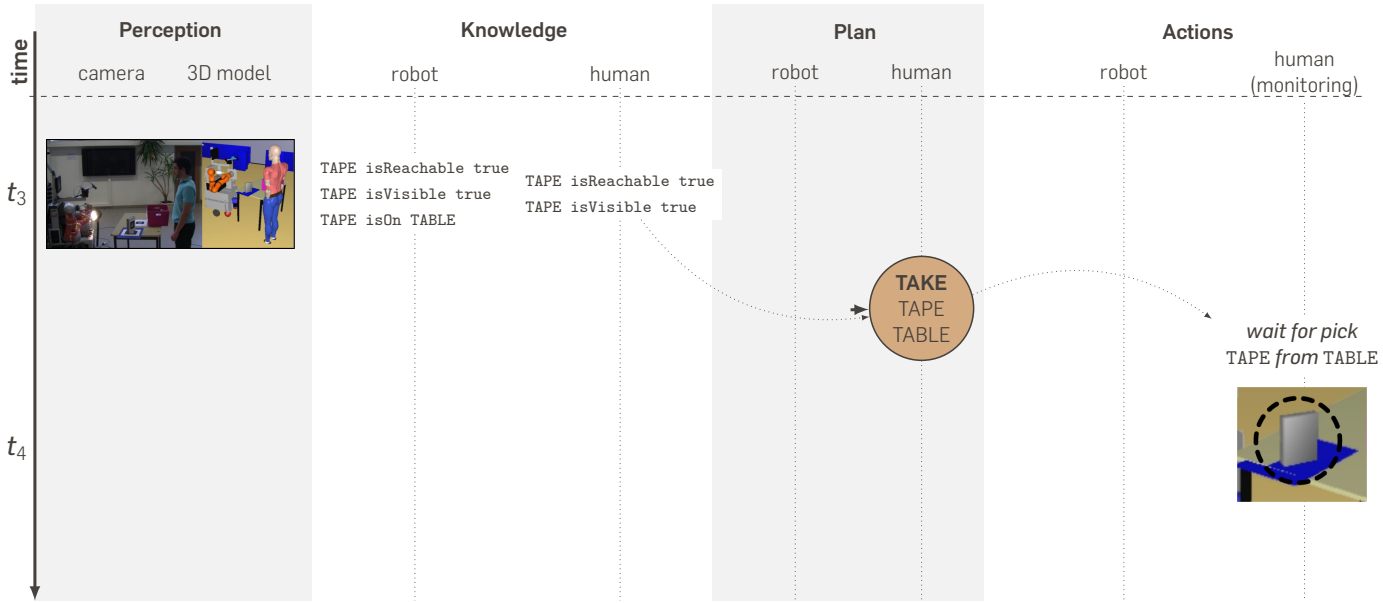

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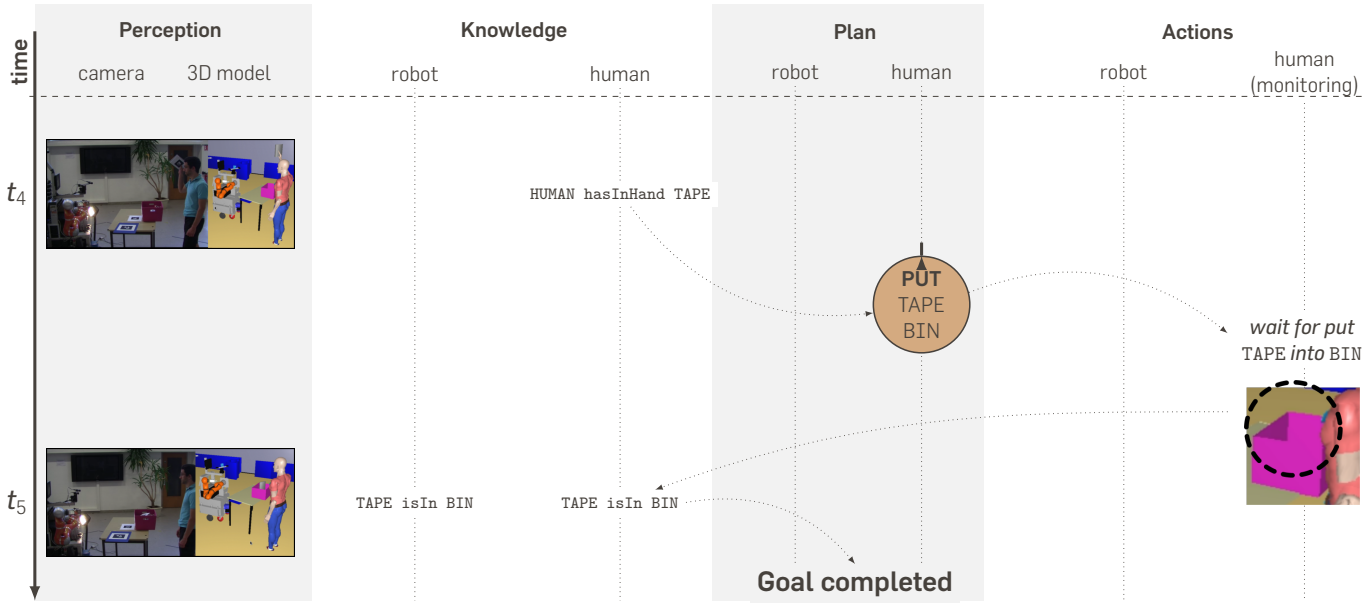


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That's all for today, folks!

Questions:
severin.lemaignan@brl.ac.uk

Slides:
github.com/severin-lemaignan/lecture-symbolic-reasoning