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# **Ontological Foundations for Cognitive Robotics Systems**

Mihai Pomarlan  
Stefano De Giorgis  
Nikolaos Tsiogkas

JOWO 2025 - 08/09/2025

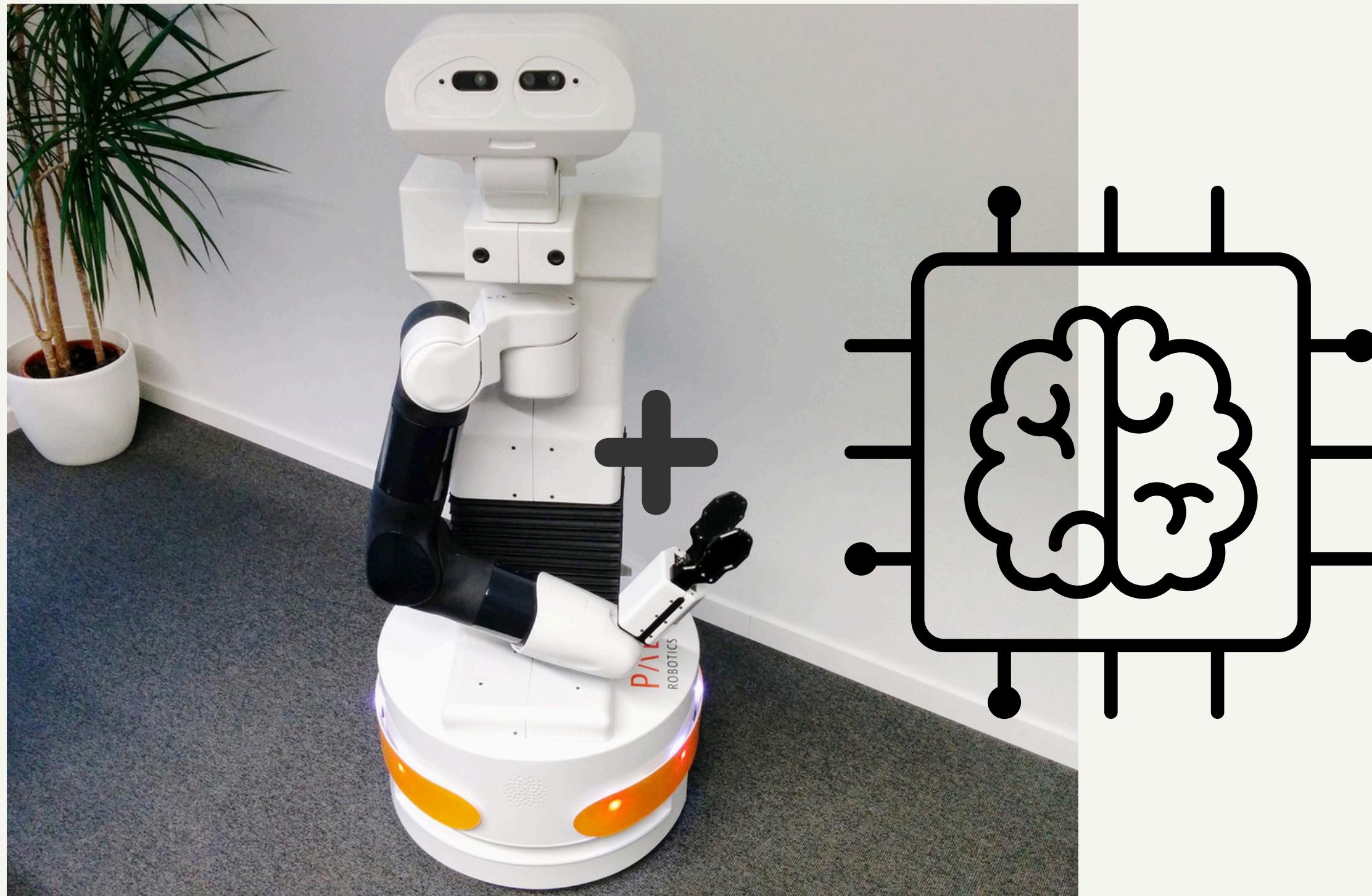
Sensors

Robots in a nutshell

Control software

Actuators





Embodied agent

Source: DFKI

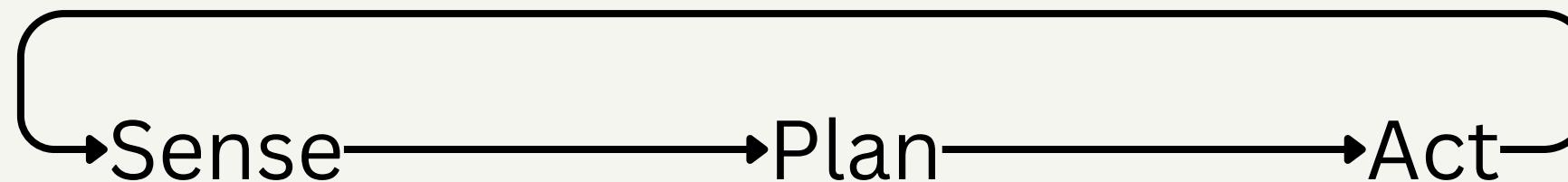
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# Why care?

- Autonomy
- No need for experts
- Safety
- Explainability

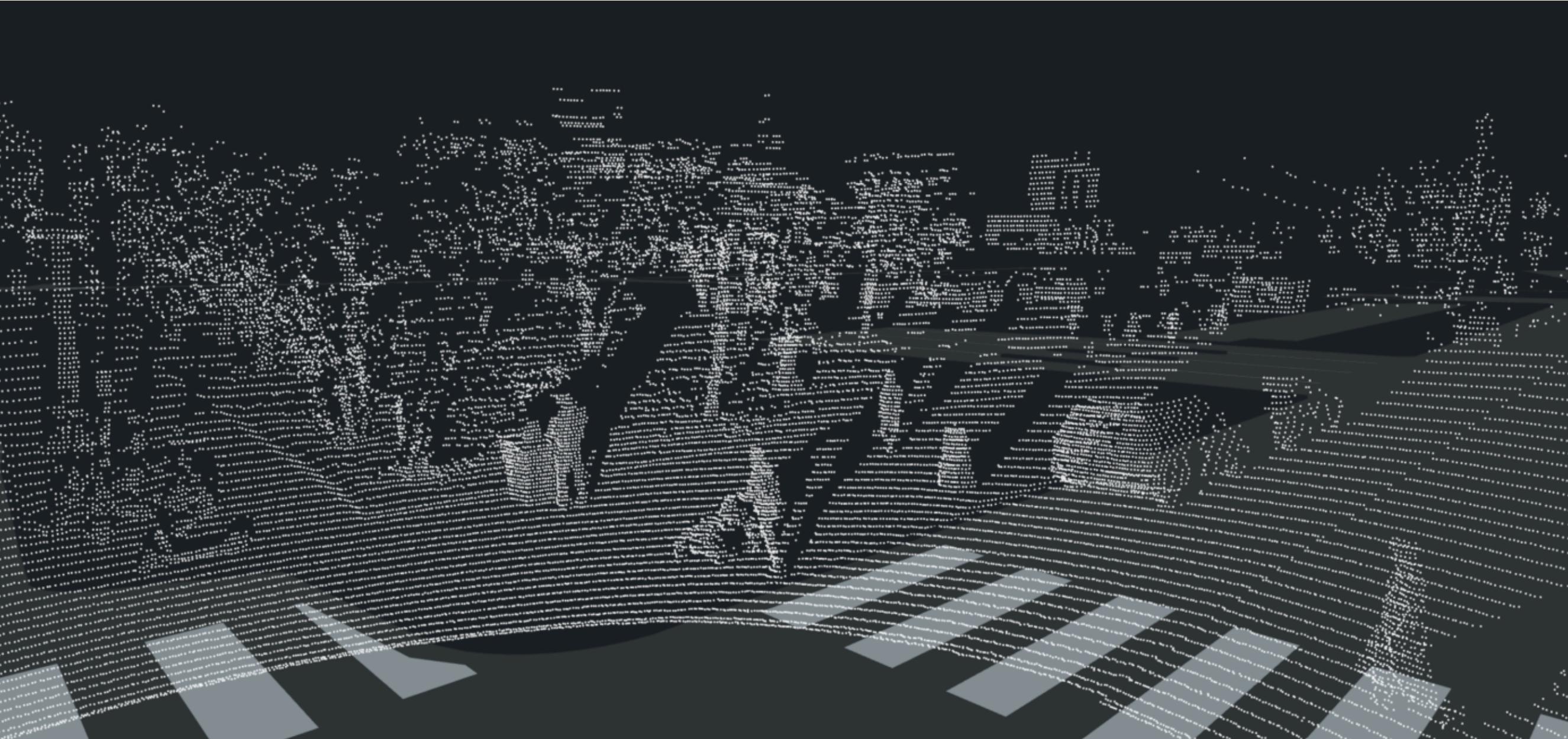
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# SotA in Robotics



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# Sense



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# Plan

- Task
- Path
- Trajectory/Control

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# Act

- Mainly feedback control
- Best case optimal control
- Hardcoded constraints

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# Execution

- Hardcoded monitoring
- Usually caring about the “happy path”
- Exceptions handled only if human has thought of it

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# **Our goals (Kind of a wish-list for now)**

- Increase autonomy
  - Generic task description to execution
  - Automatic exception handling without human intervention
- No (or minimal) reliance on experts
  - Self-configuring agents
  - No need to manually write code for new tasks
- Safety
  - Monitor the execution
  - Understand what is safe and what is not
- Explainability
  - Trust from end-users
  - Know what went wrong

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## **But...**

- No actual robot :(
- Focus on perception, interpretation, and understanding
- Reasoning on future states
- Improving knowledge based on observation and commonsense information

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# Knowledge Driven Affordance Recognition

Previously On...

...just another good reason  
to scroll funny cats reels

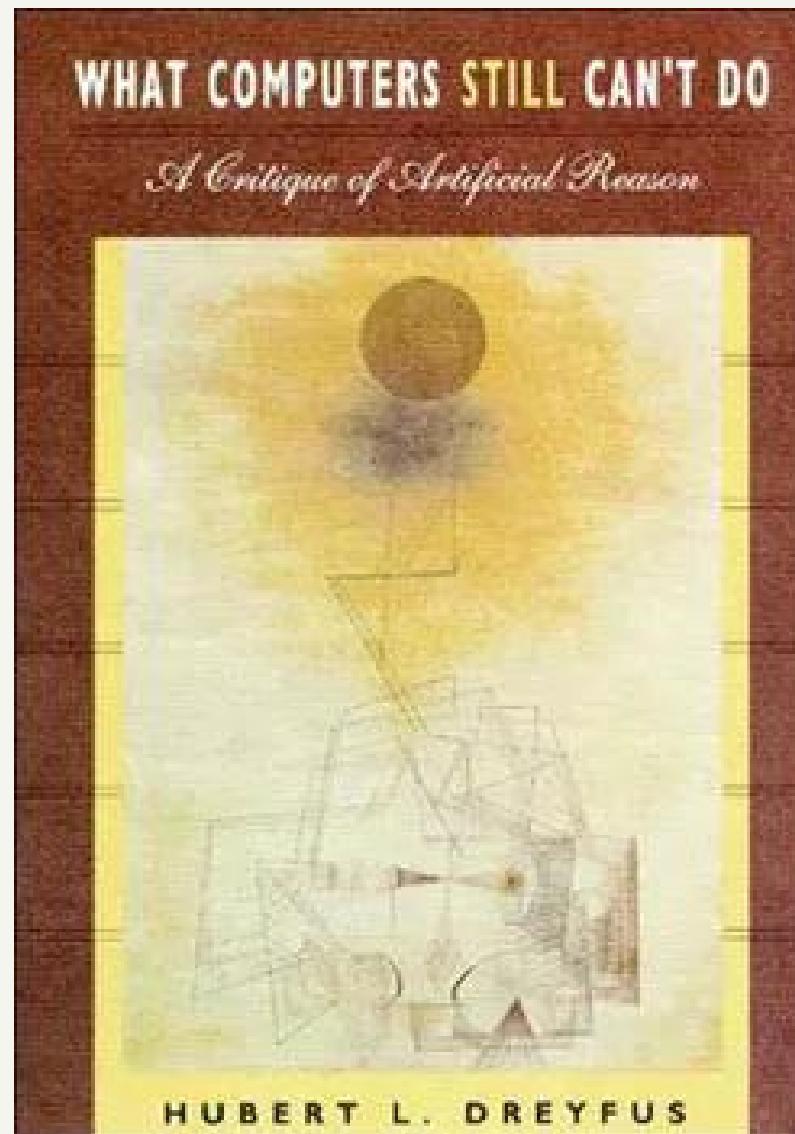
Image Schematic Relation Detection from Videos



Mihai Pomarlan  
Stefano De Giorgis  
Nikolaos Tsiogkas

Image Schema Day 8 - 28.11.2024  
AI\*IA - Bolzano

# Initial Inspiration – Functional Parts



"in Wittgenstein's Tractatus, ... **the world is defined in terms of a set of atomic facts which can be expressed in logically independent propositions**. This is the purest formulation of the ontological assumption, and the necessary precondition of all work in AI as long as researchers continue to suppose that **the world must be represented as a structured set of descriptions which are themselves built up from primitives**."

"[according to Heidegger results in] the exclusive concern with beings (objects) and the concomitant **exclusion of Being (very roughly our sense of the human situation which determines what is to count as an object)**"

# In a World, One Agent



- containment, support, movement, contact etc.
- Support requires a Supporter and a Supported
- <https://github.com/heideggerian-ai-v5/fois2024>

TurtleBot  
It **gathers information**  
from the environment  
and interprets it in **image schematic** terms.



# contact q: ask whether x contacts q

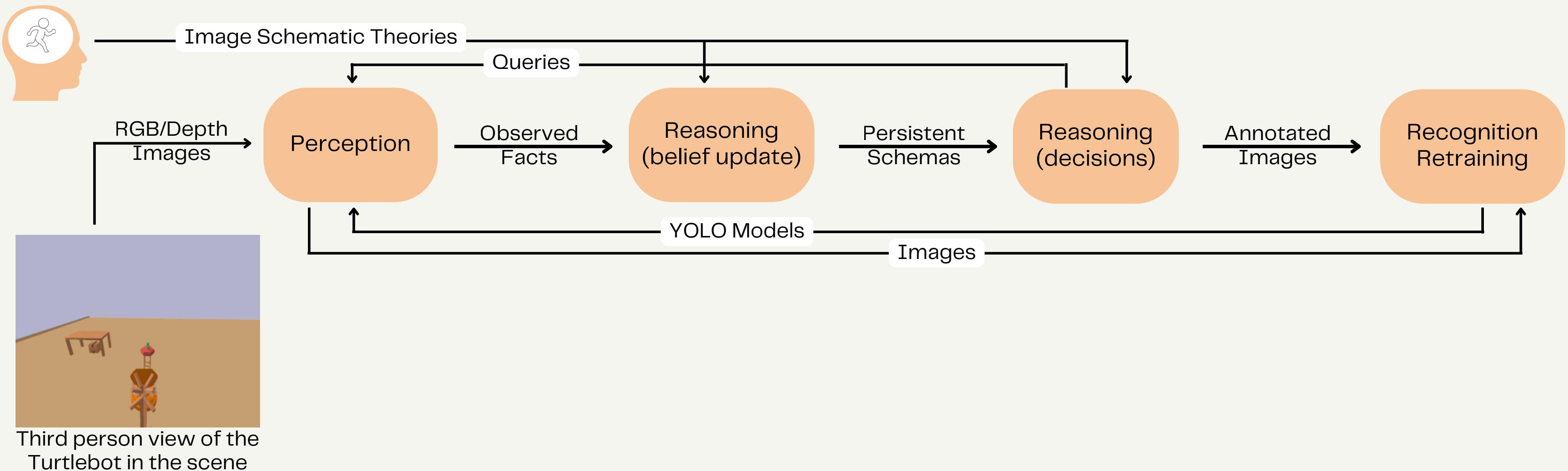
```
isA(?g, PG_G), isA(?g, CheckSupport),  
hasParticipant(?g,?r),  
hasParticipant(?g,?e),  
isA(?r,Supporter),  
isA(?e,Supportee),  
classifies(?r,?y),  
classifies(?e,?x)  
  
=> reliable_contact(?x,?y)
```

## Image Schemas

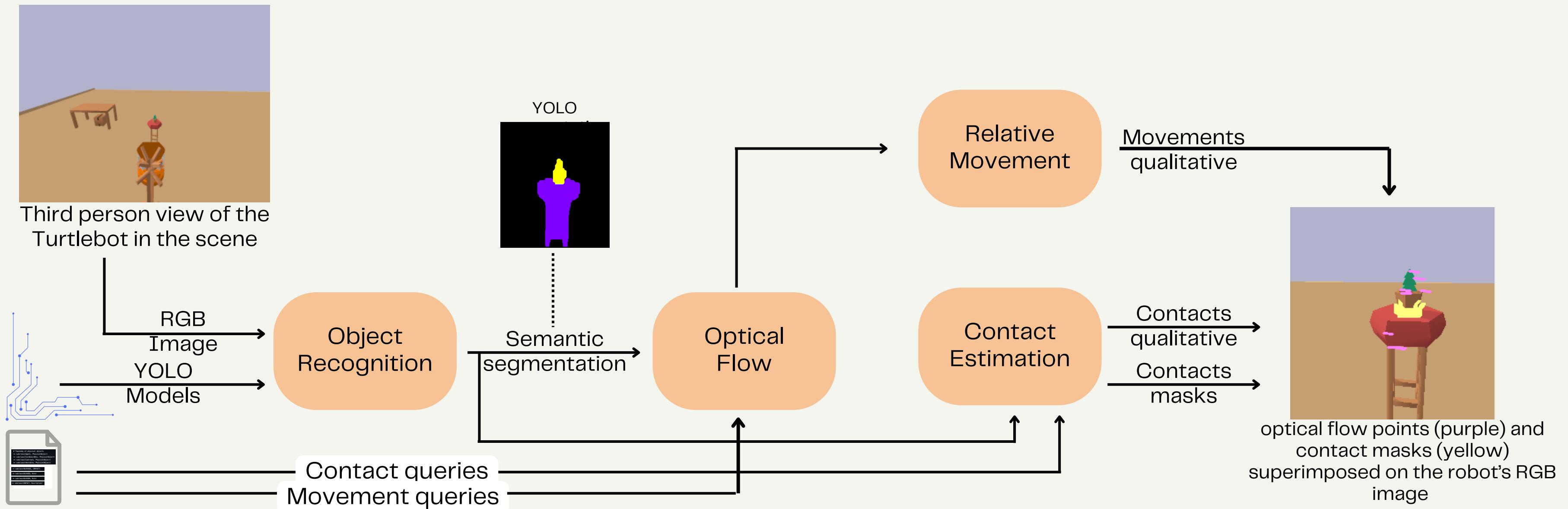
Sensorimotor cognitive patterns grounding human conception in bodily perception.



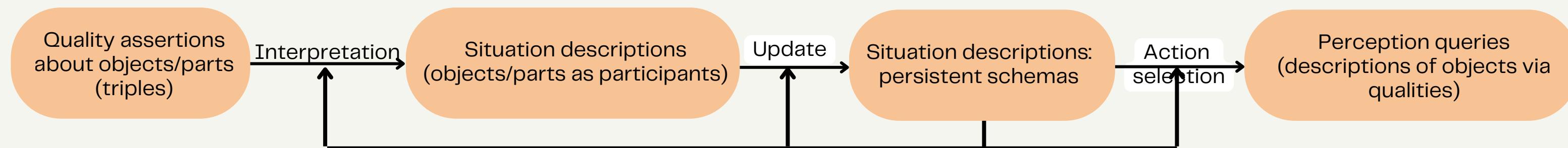
# The Agent - overview



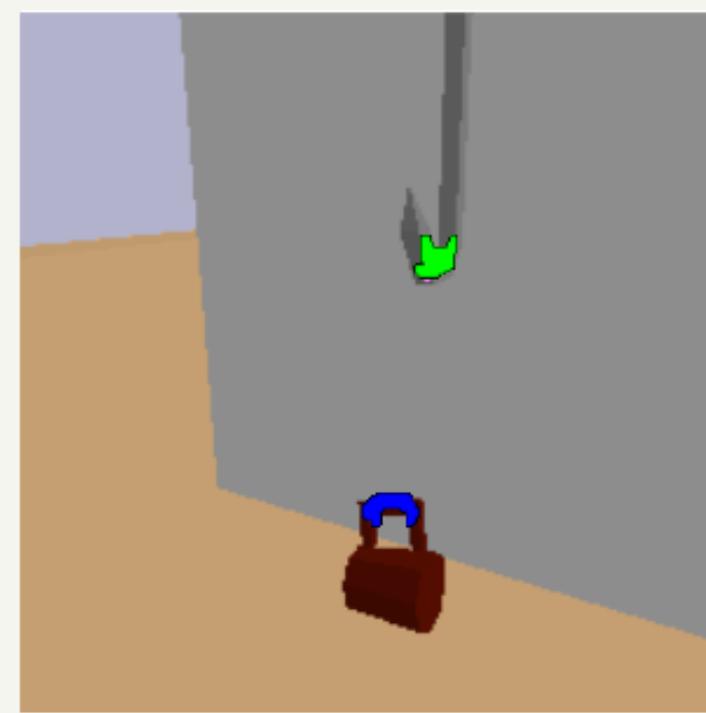
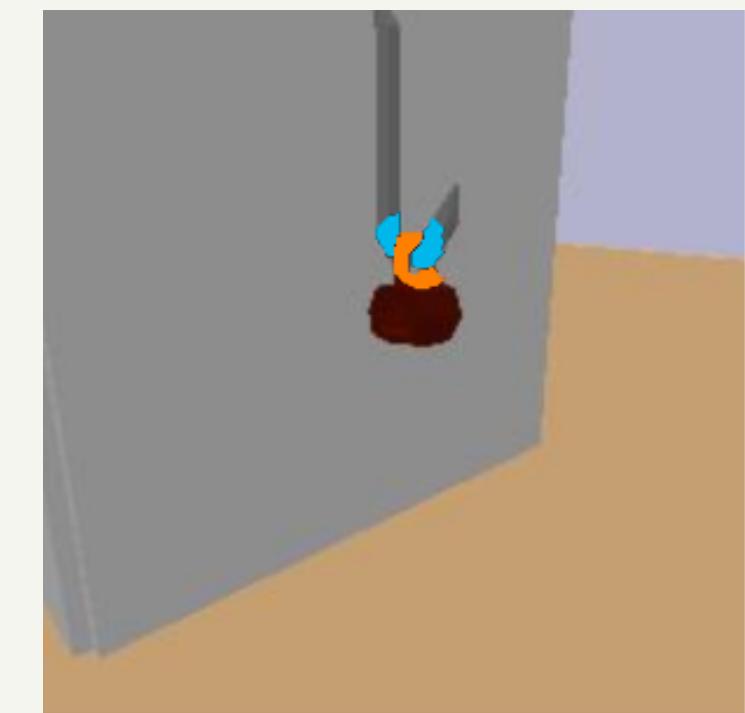
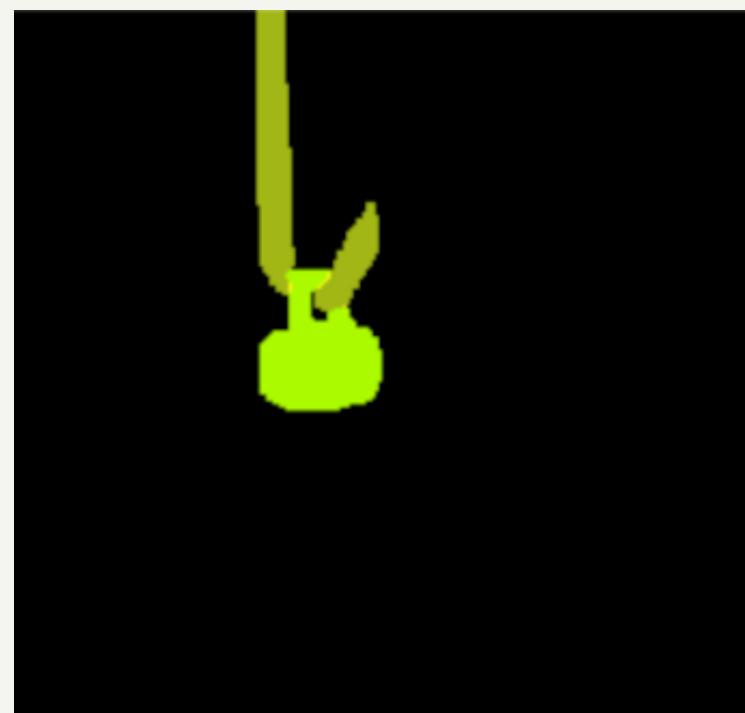
# Perception



# Reasoning



Inference in defeasible logic (rule based)  
... with some hacks: reification

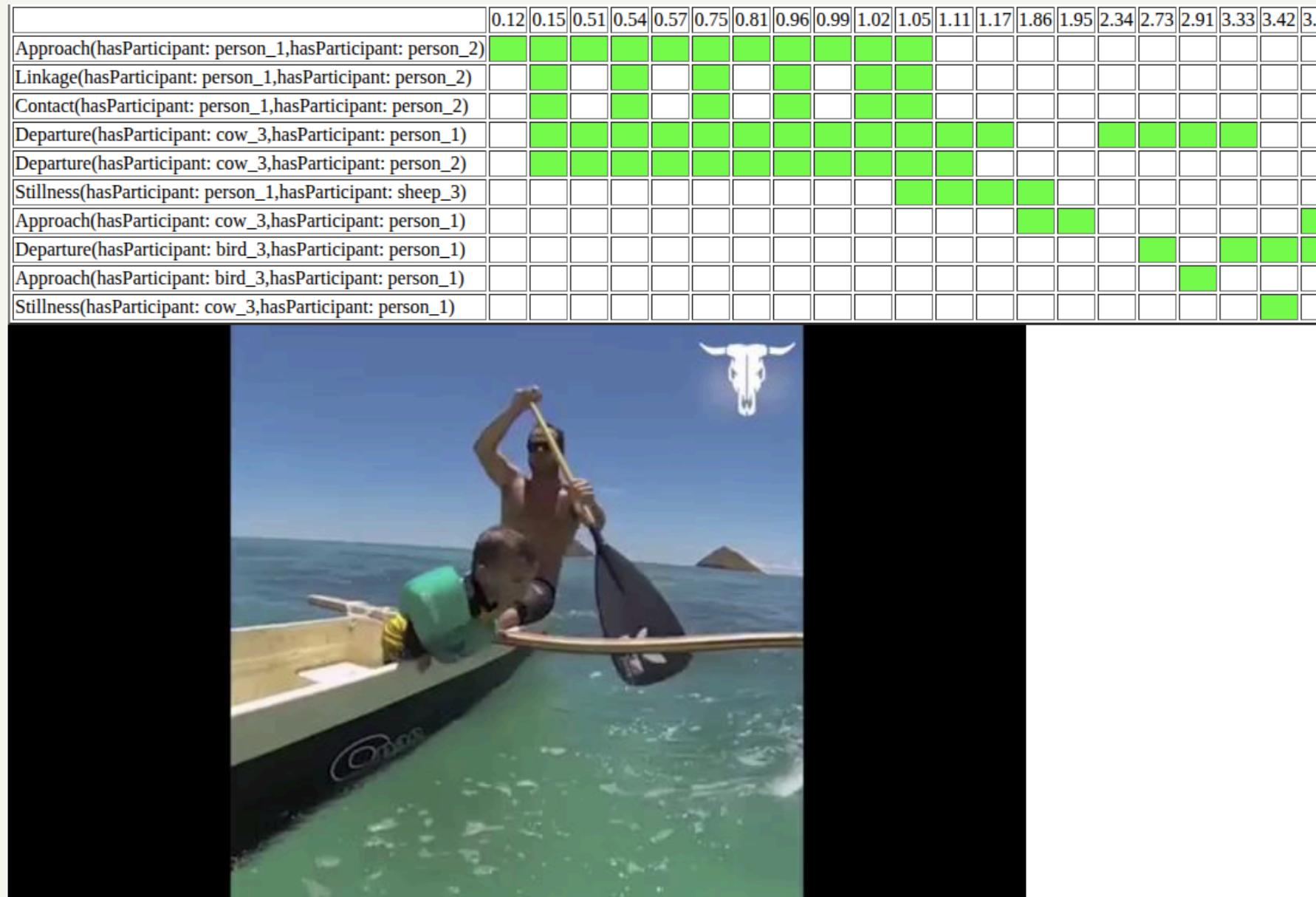


From training to automatic recognition of functional parts.

3.61 fps | 0% dbg drop



# Image-schematic Event Segmentation



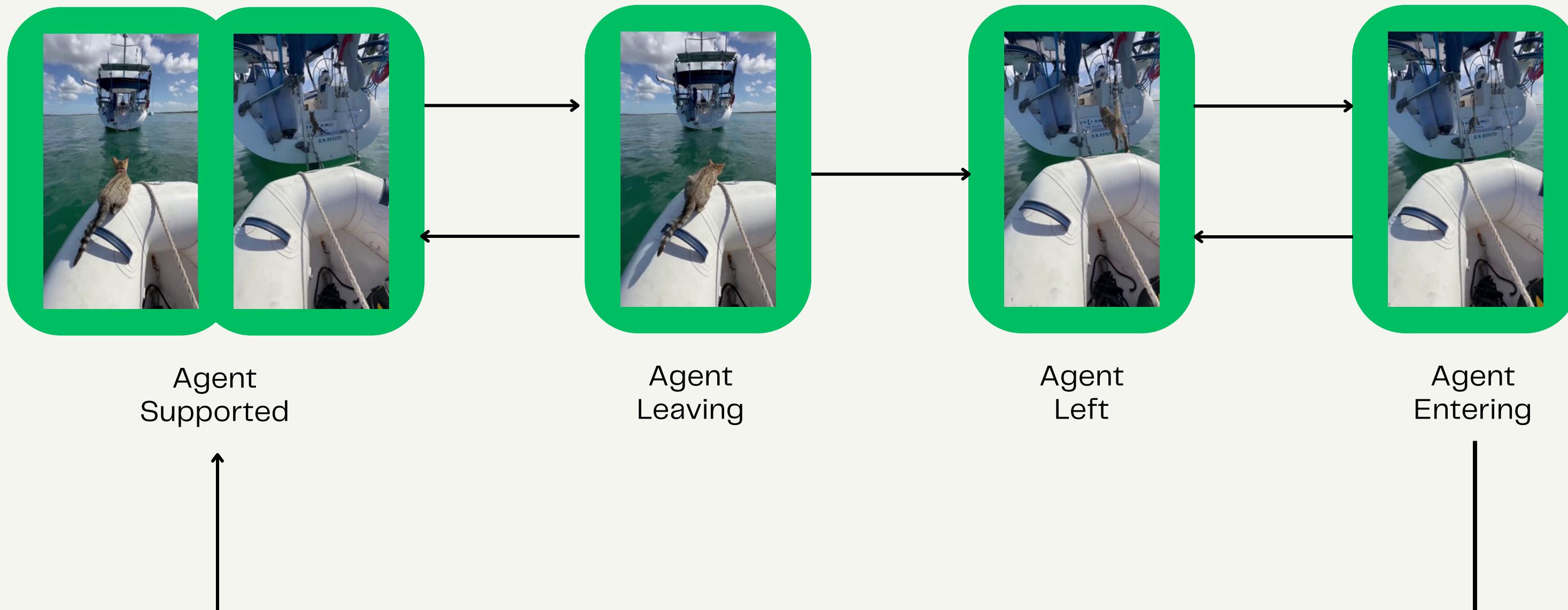
```
log:hasParticipant rdf:type owl:ObjectProperty .  
log:hasId rdf:type owl:DatatypeProperty .
```

```
log:image_0  
    rdf:type owl:NamedIndividual ;  
    rdf:type log:Image ;  
    log:hasId "0.12"^^xsd:string .
```

```
log:schematicRelation_1  
    rdf:type owl:NamedIndividual ;  
    log:hasParticipant log:person_1 ;  
    log:hasParticipant log:person_2 ;  
    rdf:type log:Approach ;  
    log:eventMode log:Started .
```

```
log:person_1 rdf:type owl:NamedIndividual ;  
    rdf:type log:person .  
log:person_2 rdf:type owl:NamedIndividual ;  
    rdf:type log:person .
```

# Example: Agent (support) Transfer



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# Knowledge Enrichment



photo by Evan Vucci/The Associated Press



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*The assassination attempt on Donald Trump.*

photo by Evan Vucci/The Associated Press



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photo by Evan Vucci/The Associated Press

*The assassination attempt on Donald Trump.*

(Without Background Knowledge)

A political figure or leader, doing a victory gesture, surrounded by guards / agents protecting him. Some blood spilling from his ear, an American flag on the background.



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*The assassination attempt on Donald Trump.*

(Without Background Knowledge)

A political figure or leader, doing a victory gesture, surrounded by guards / agents protecting him. Some blood spilling from his ear, an American flag on the background.

(Scene Description Only)

A man in an elegant suit in the center, with a raised arm, surrounded by some people gathering around his body. Some blood spilling from his ear, an American flag on the background.

photo by Evan Vucci/The Associated Press



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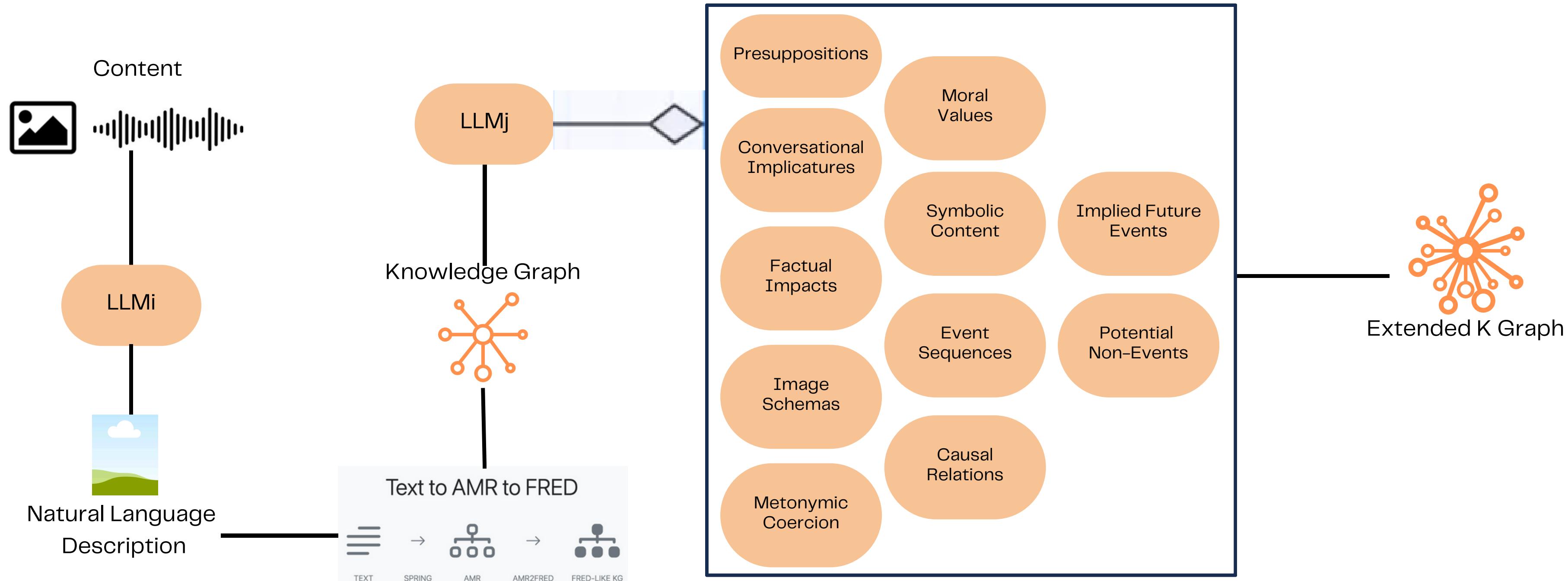


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# Knowledge Extension Pipeline



Off-the-shelf formal graph extensions from automated LLM prompting (11 implicit motifs)



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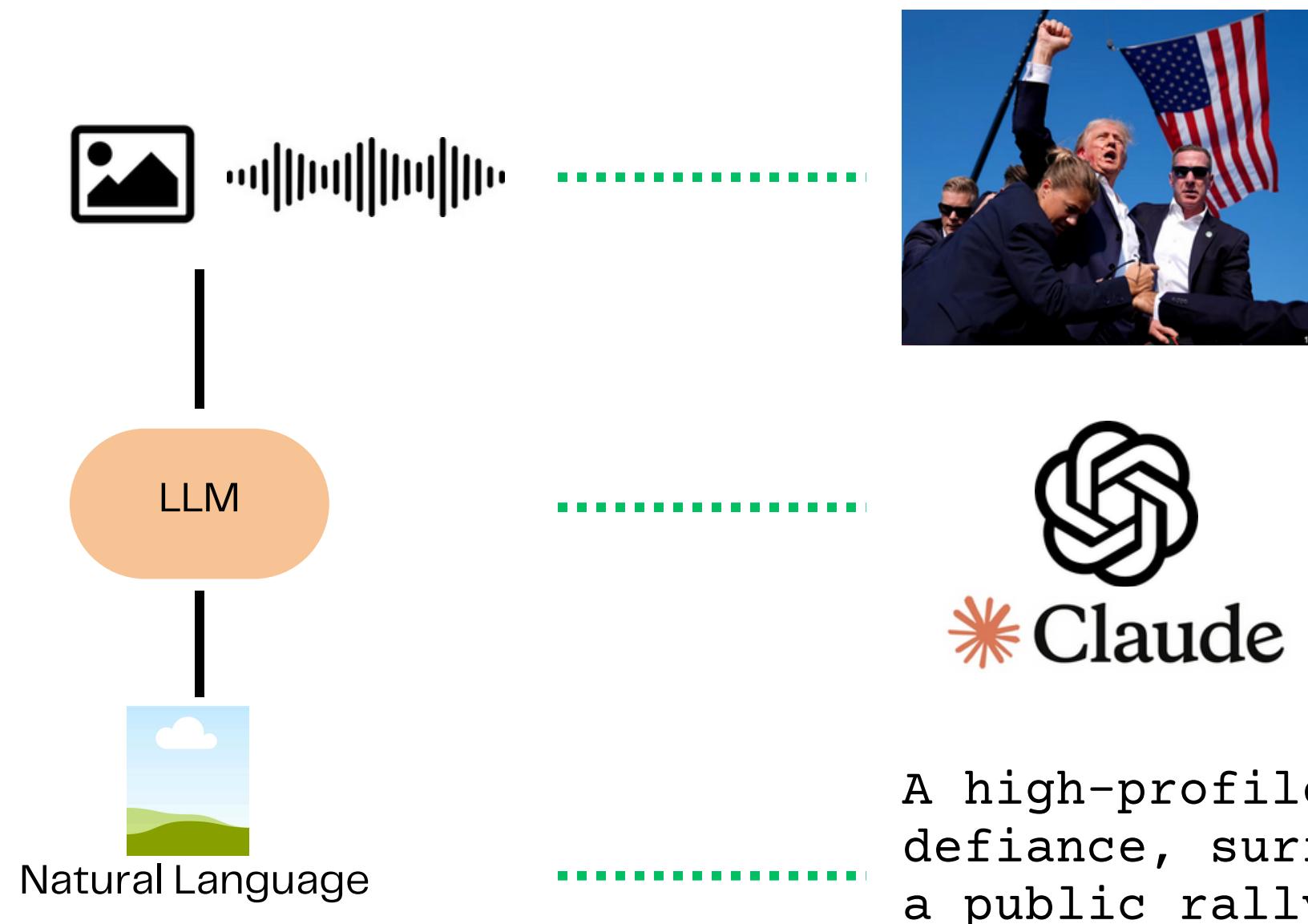


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# Knowledge Extension Pipeline - 2



Possible Clever Prompts:

1. *Describe the overt, implicit and symbolic content of the attached image.*
2. *Describe this photo in detail, including gestures, participants, public roles, situations, bodily position, and general implied meaning.*
3. ...

A high-profile political figure raises his fist in defiance, surrounded by vigilant security personnel during a public rally, with a large American flag prominently displayed in the background, emphasizing themes of patriotism and protection.



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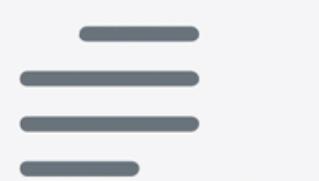


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# Text to AMR to FRED



TEXT



SPRING



AMR



AMR2FRED

FRED-LIKE KG

Test it!



Given some text as input, this tool will parse it into an [AMR](#) (Abstract Meaning Representation) graph, using [SPRING](#). The AMR graph is then converted into an RDF/OWL knowledge graph that follows [FRED](#)'s knowledge representation patterns, using [AMR2FRED](#).

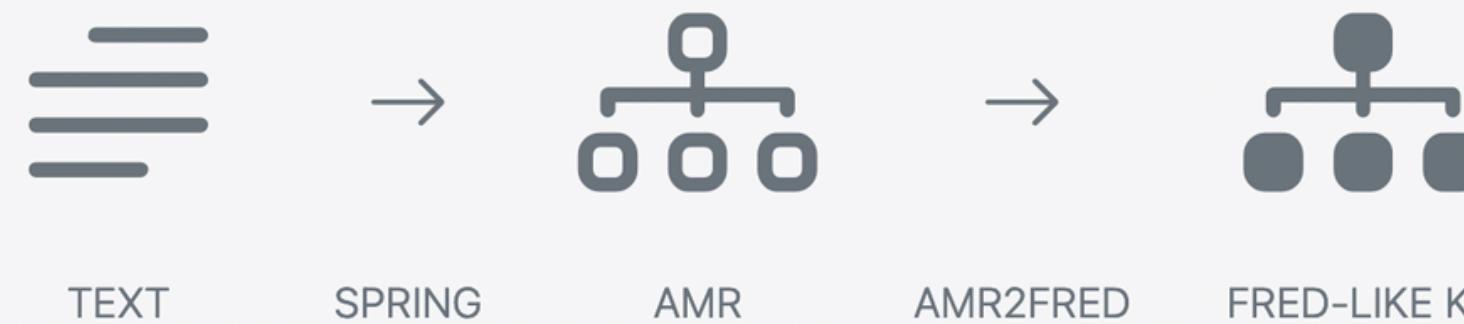
A high-profile political figure raises his fist in defiance, surrounded by vigilant security personnel during a public rally, with a large American flag prominently displayed in the background, emphasizing themes of patriotism and protection.

⚙️ [Settings](#)

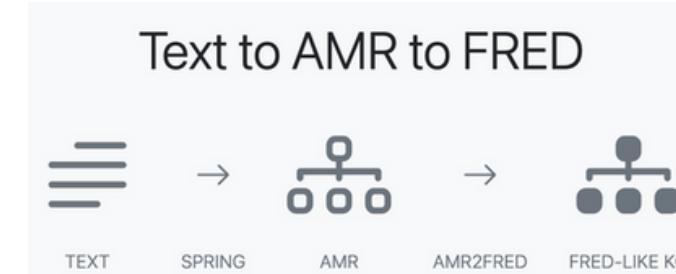
<https://arco.istc.cnr.it/itaf/>

≡ Convert text

# Text to AMR to FRED



A high-profile political figure raises his fist in defiance, surrounded by vigilant security personnel during a public rally, with a large American flag prominently displayed in the background, emphasizing themes of patriotism and protection.



(z0 / raise-01  
:ARG0 (z1 / figure  
:mod (z2 / politics)  
:mod (z3 / profile  
:ARG1-of (z4 / high-02))  
:ARG1-of (z5 / surround-01  
:ARG2 (z6 / personnel  
:mod (z7 / security)  
:ARG0-of (z8 / vigilant-01)))  
:ARG0-of (z9 / have-03  
:ARG1 (z10 / flag  
:mod (z11 / large)  
:mod (z12 / country  
:wiki "United\_States"  
:name (z13 / name  
:op1 "America"))  
...

AMR excerpt due to its dimension



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## Text to AMR

Your text

PENMAN

Graph

This is the result of converting your text to AMR using SPRING. The AMR graph is serialized using the [PENMAN notation](#).

```
(z0 / raise-01
  :ARG0 (z1 / figure
    :mod (z2 / politics)
    :mod (z3 / profile
      :ARG1-of (z4 / high-02))
    :ARG1-of (z5 / surround-01
      :ARG2 (z6 / personnel
        :mod (z7 / security)
        :ARG0-of (z8 / vigilant-01)))
    :ARG0-of (z9 / have-03
      :ARG1 (z10 / flag
        :mod (z11 / large)
        :mod (z12 / country
          :wiki "United_States"
          :name (z13 / name
            :op1 "America")))
```

## Text to AMR

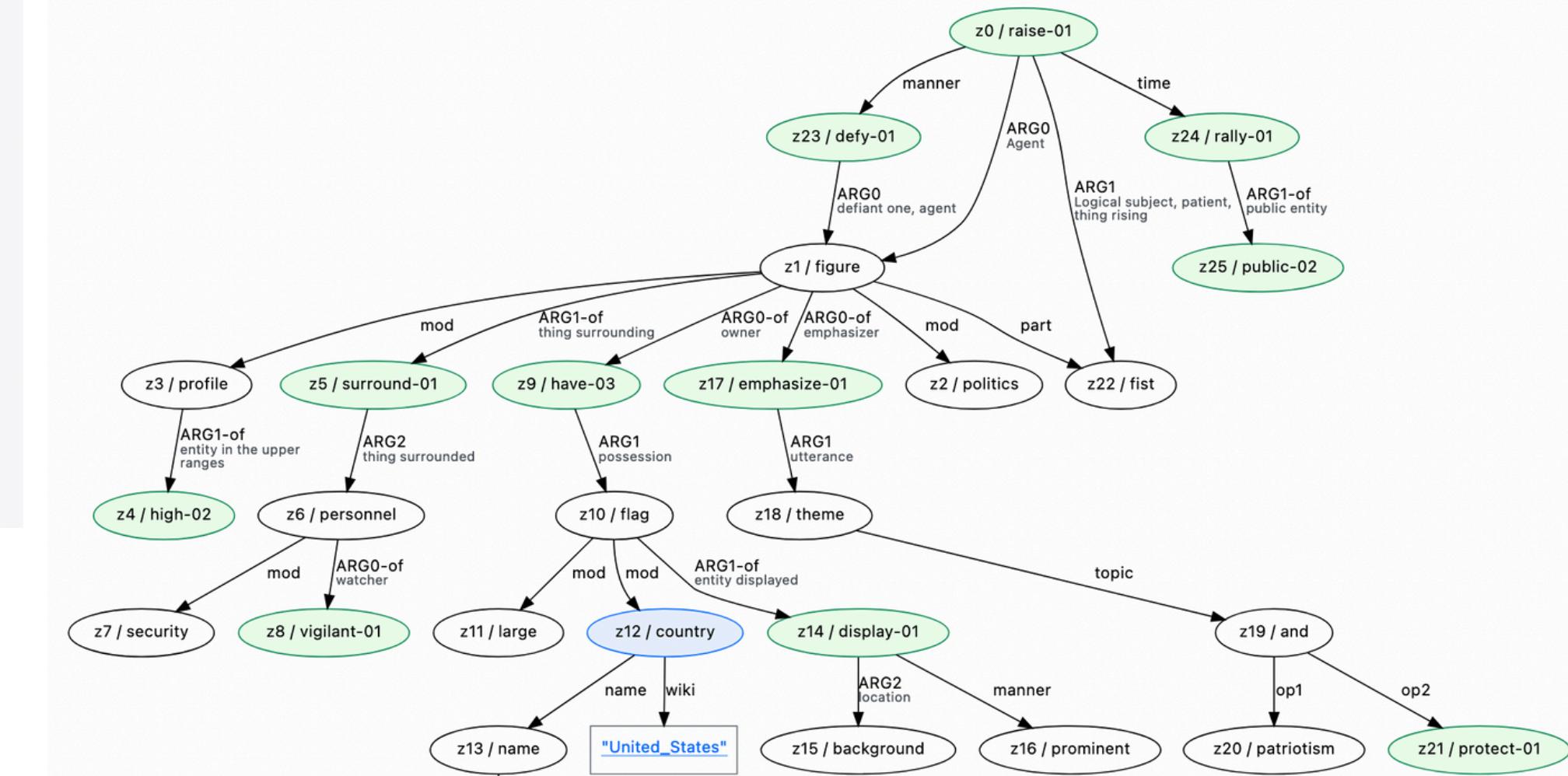
Your text

PENMAN

Graph

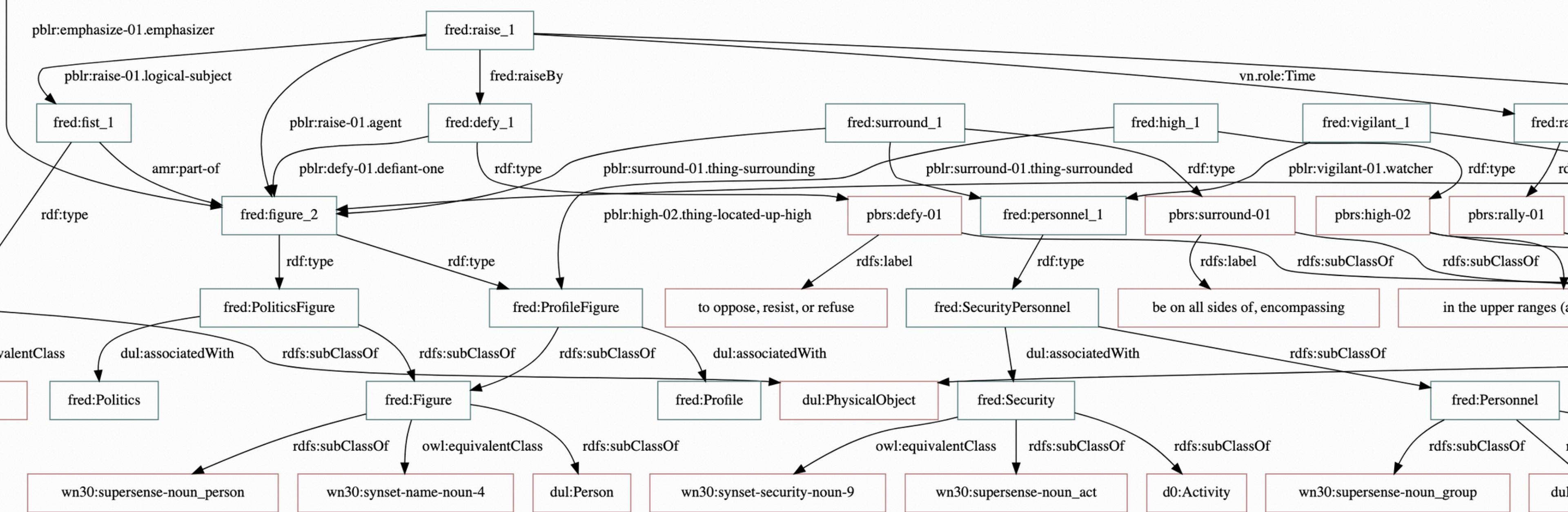
Zoom: double-click to zoom-in and Shift + Double-click to zoom-out, or use Shift + Scroll

Pan: drag left mouse button



**Penman and Graph**  
notation for Text to AMR

# FRED graph





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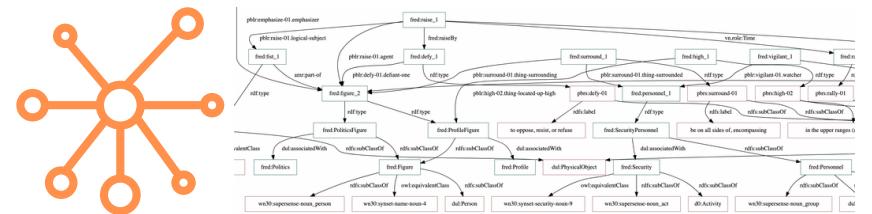
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# Knowledge Extension Pipeline - 3

Knowledge Graph



## Task:

Your goal is to extend KG with more knowledge that can be assumed from T, but it is not explicit.

Using the elements of KG, and PropBank and WordNet elements as linking points, add any further elements you need to extract implicit knowledge about: Conversational implicatures.

Conversational implicatures, in the sense of Grice's pragmatics.

Here are natural language inference examples:

1) She won't necessarily get the job -> She will possibly get the job

...

## "Clever Prompting" Techniques

Semantic Layers for knowledge enrichment

You receive a text "**T**" and a frame-based knowledge graph "**KG**" that is the extraction of factual knowledge from **T**.

**T:**  
&lt;&lt; Text &gt;&gt;

**KG:**  
&lt;&lt; KG &gt;&gt;

Your goal is to extend **KG** with more knowledge that can be assumed from **T**, but it is not explicit.

conversational\_implicatures.prompt



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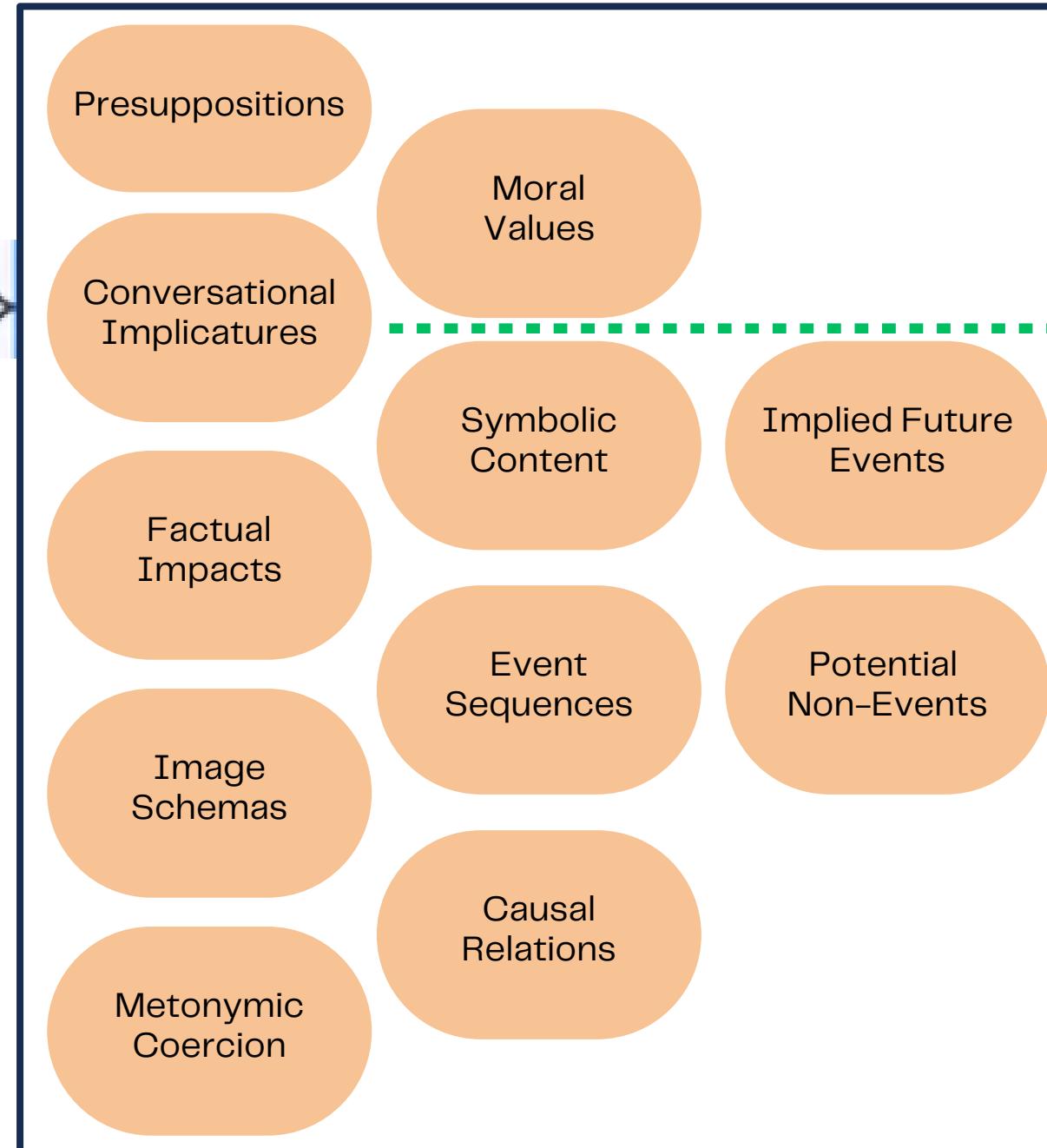
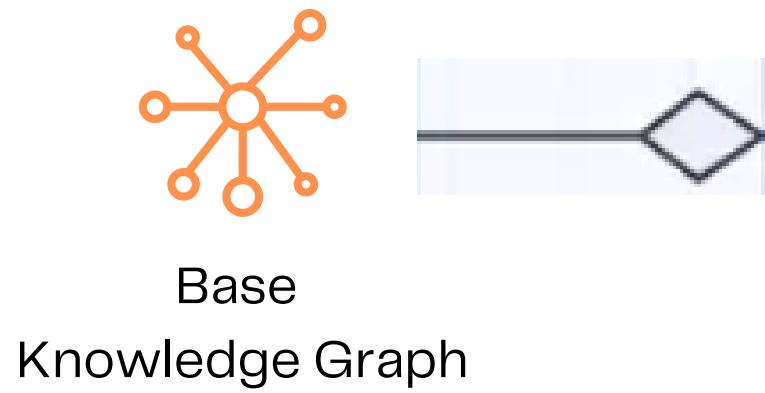


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# Knowledge Extension Pipeline - 4



“Clever Prompting” Techniques

Semantic Layers for  
knowledge enrichment

You receive a text  
"**T**"  
and a frame-based  
knowledge graph  
"**KG**"  
that is the extraction of  
factual knowledge from **T**.  
  
**T**:  
{{ **Text** }}  
  
**KG**:  
{{ **KG** }}  
  
Your goal is to extend **KG**  
with more knowledge that  
can be assumed from **T**, but  
it is not explicit.

conversational\_implicatures.prompt



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## BASE GRAPH

```
fred:raise_1 a ptrs:raise-01 ;
  pblr:raise-01.agent fred:figure_2 ;
  pblr:raise-01.logical-subject fred:fist_1 .
```

```
fred:surround_1 a ptrs:surround-01 ;
  pblr:surround-01.thing-surrounded fred:personnel_1 ;
  pblr:surround-01.thing-surrounding fred:figure_2 .
```

**The figure has a raised fist. The personnel surrounds the figure.**

```
fred:fist_1 coerce:coercedType
  mor:Resistance, mor:Strength .
```

```
fred:flag_1 coerce:coercedType
  mor:NationalIdentity, mor:Patriotism .
```

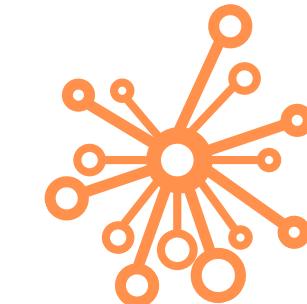
**The fist is a symbol of Resistance and strength.  
The flag is a symbol of national identity and patriotism.**

## SYMBOLIC COERCION

```
fred:figure_2 impact:hasExpectedEmotion impact:Defiance ;
  impact:hasExpectedSocialImpact impact:IncreasedPublicSupport .
```

```
fred:personnel_1 impact:hasExpectedEmotion impact:Tension ;
  impact:hasExpectedMentalState impact:Alertness .
```

**The figure has expected social impact an increased public support.  
The personnel has expected mental state alertness.**



Extended K Graph

```
fred:assert_1 a ptrs:assert-02 ;
  mor:evokes mor:PowerDemonstration ;
  pblr:assert-02.agent fred:figure_2 ;
  pblr:assert-02.topic fred:power_1 .
```

**The figure assertion is a demonstration of power.**

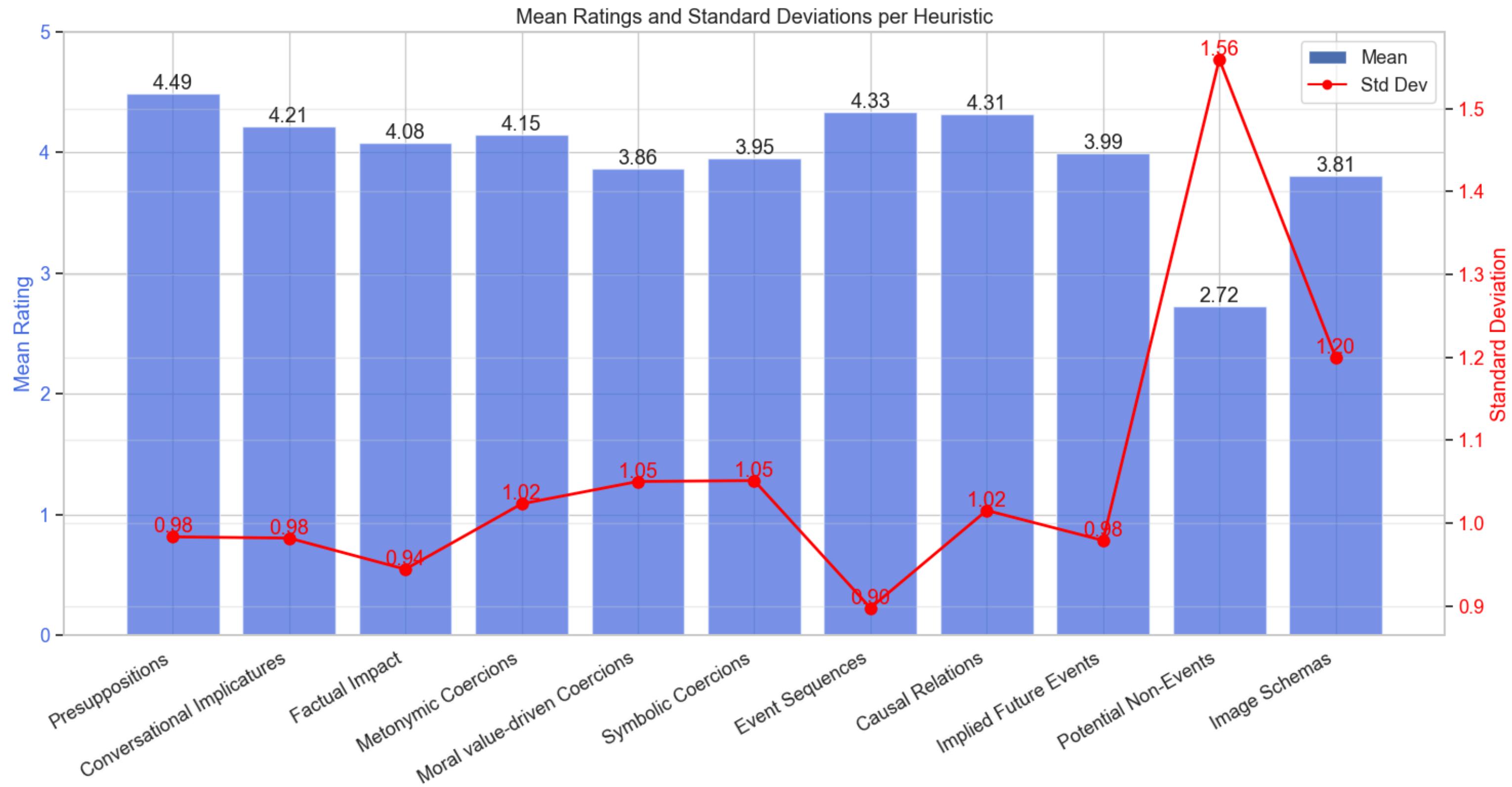
```
fred:support_1 a owl:ObjectProperty,
  ptrs:support-01 ;
  pblr:support-01.supported fred:figure_2 ;
  pblr:support-01.supporter fred:audience_1 .
```

**We can expect a raise in the support from the audience.**

## IMPLIED FUTURE EVENTS

## FACTUAL IMPACT

## MORAL VALUES



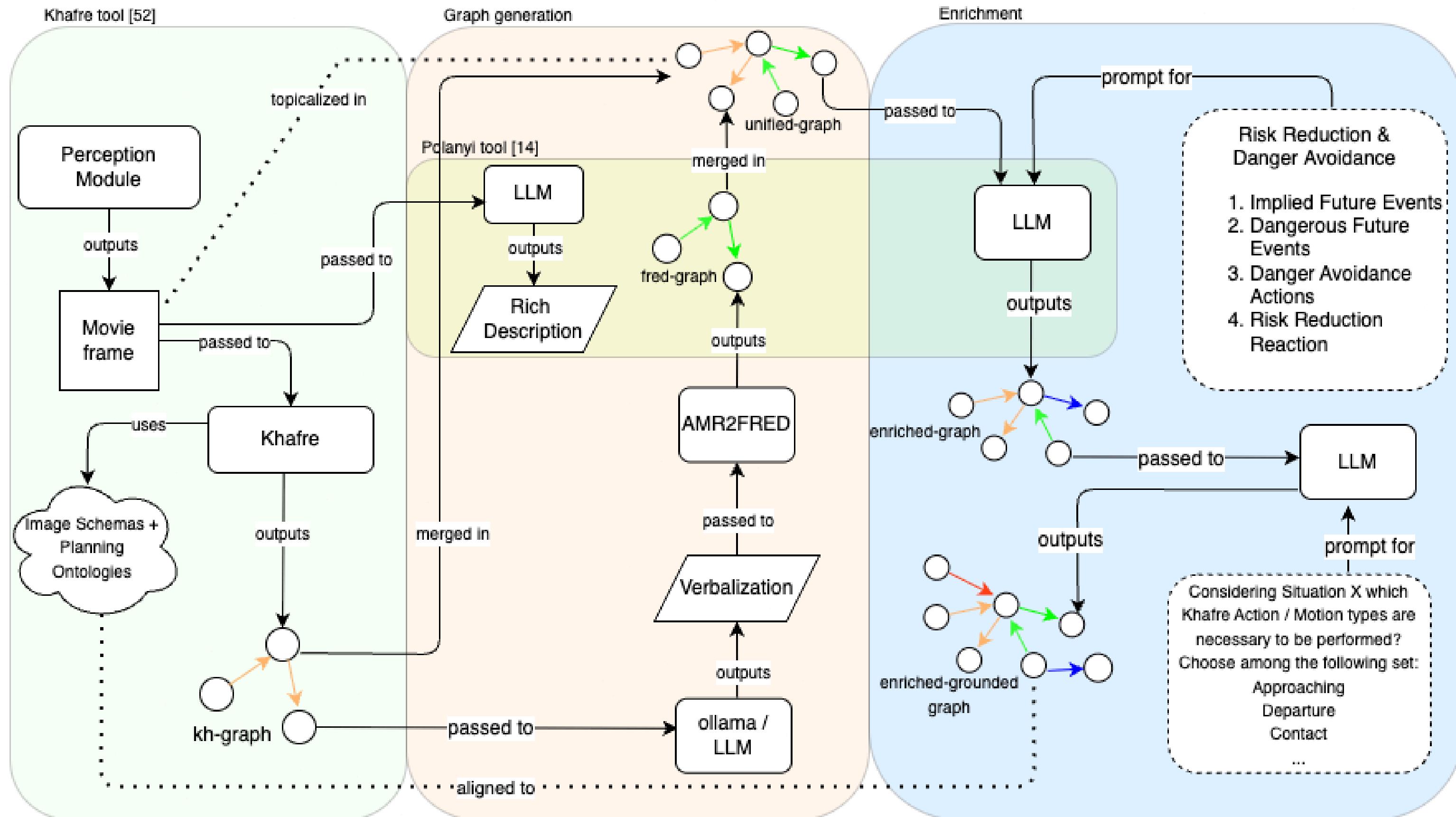
Stefano De Giorgis, Aldo Gangemi, and Alessandro Russo. "Neurosymbolic graph enrichment for grounded world models." *Information Processing & Management* 62.4 (2025): 104127.

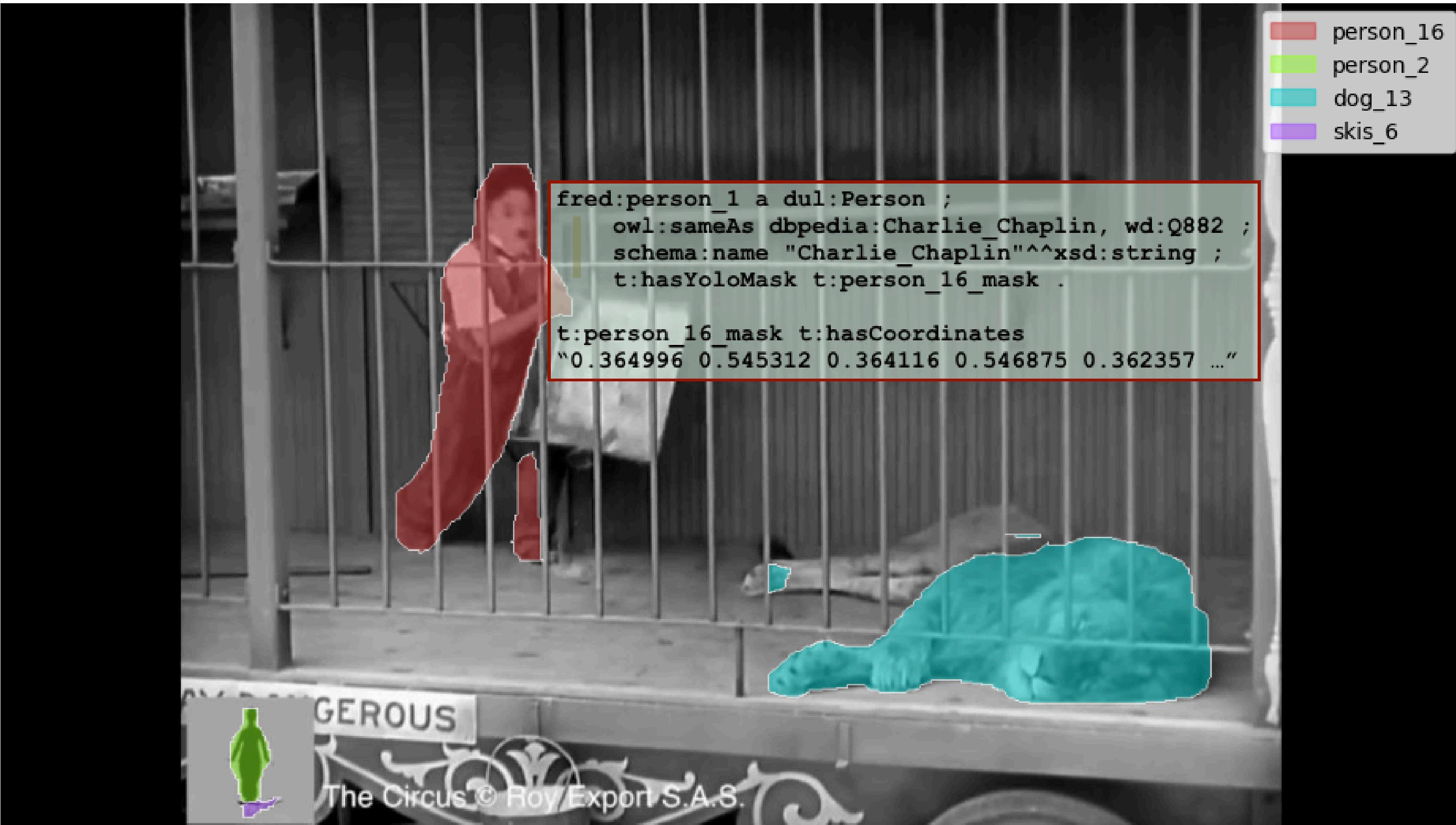


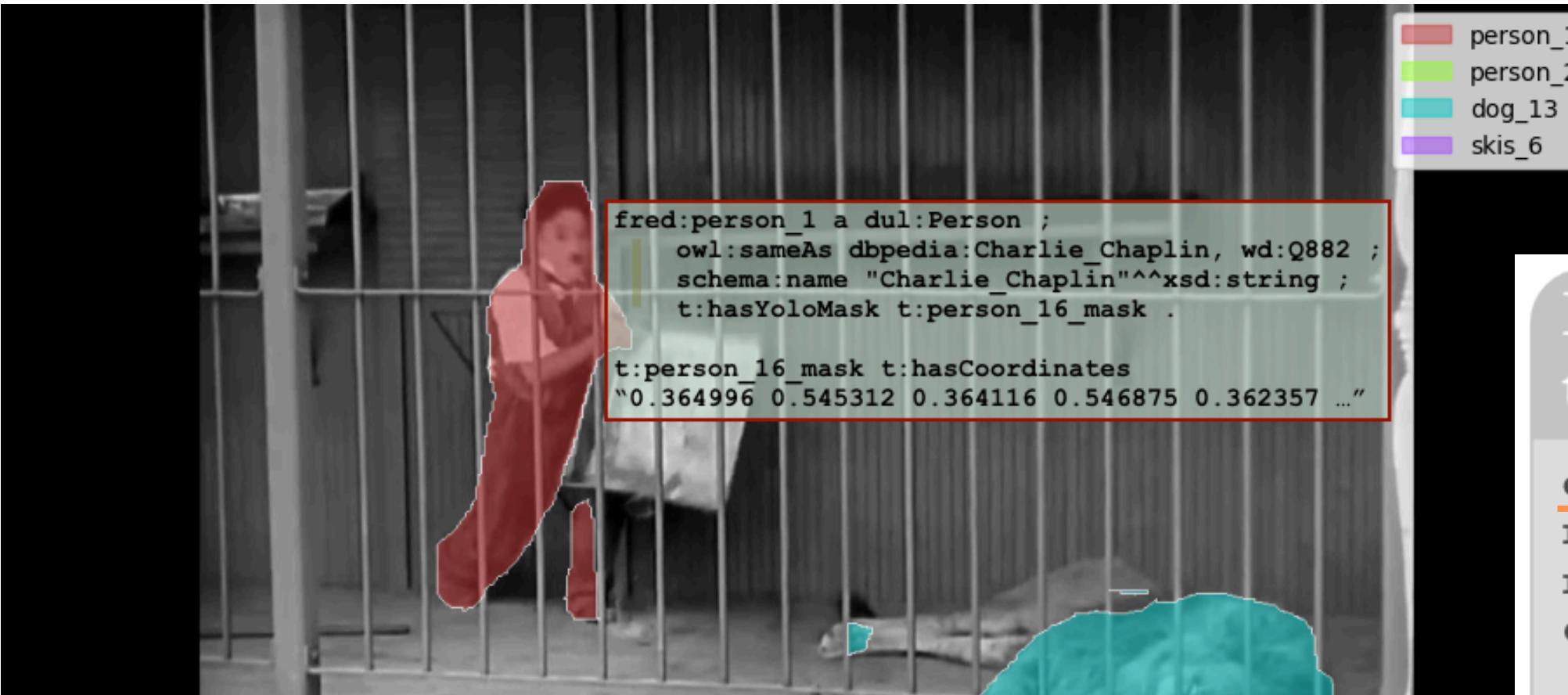
De Giorgis S., Pomarlan Hawkins M., Tsiogkas N.,  
Righetti G., Hedblom M. Leemhuis M., Kutz O. - ongoing

# NEURAL COMPONENT - OBJECT RECOGNITION

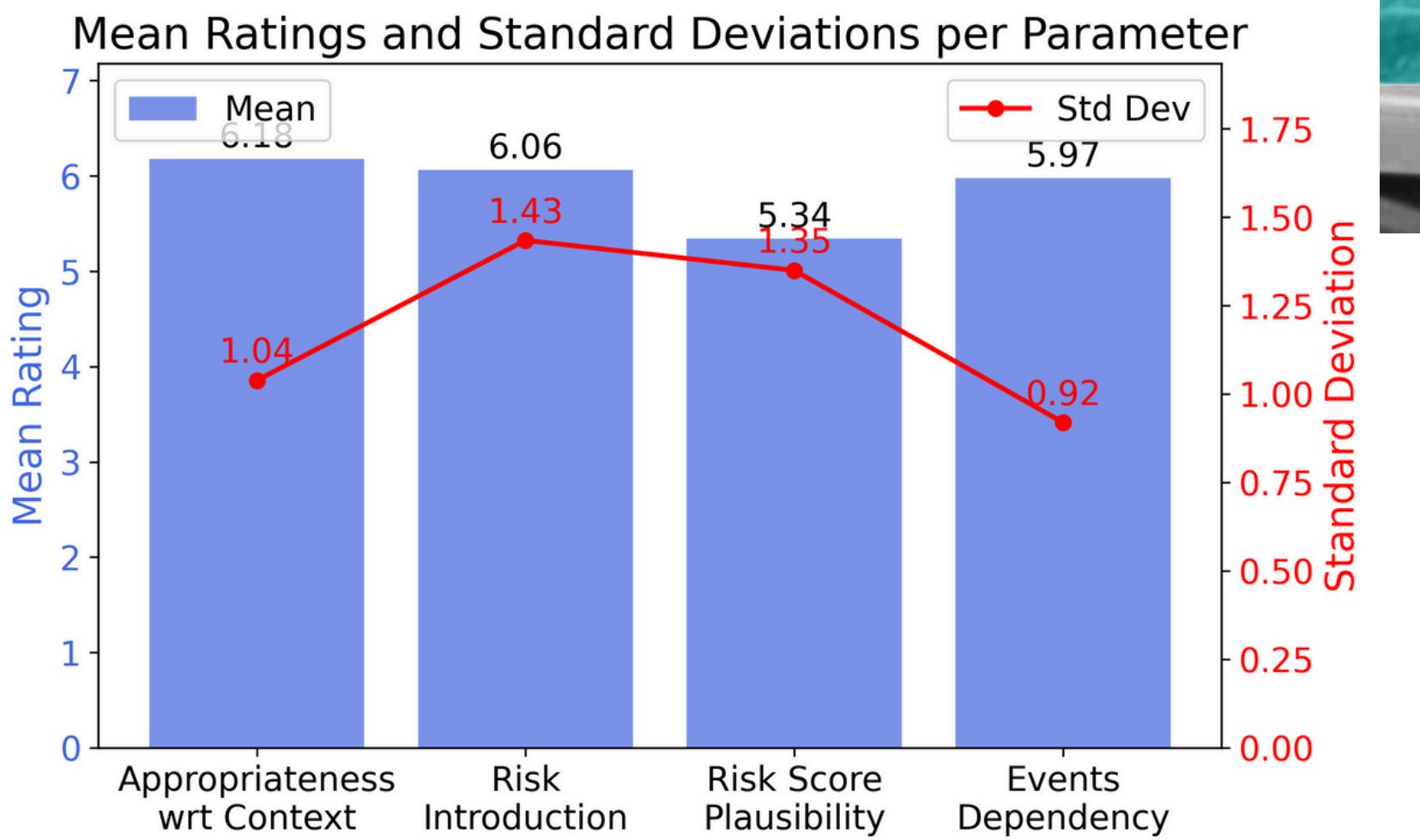








person\_16  
person\_2  
dog\_13  
skis\_6



## Box 6 - Recommended Action / Motion types

en:manExitingCageCarefully a dul:Situation ;  
rs:requires kh:Movement, kh:Departure ;  
rdfs:comment "The man should exit the cage carefully without making sudden movements" .

kh:person\_16 dul:hasRole kh:Mover, kh:Deporter .

en:manStumblingBackward a dul:Situation ;  
rs:requires kh:Movement, kh:Departure,  
kh:Falling ;  
rdfs:comment "The man might stumble while moving backward, drawing the lion's attention" .

kh:person\_16 dul:hasRole kh:Mover, kh:Deporter,  
kh:Faller .

kh:person\_16 dul:hasRole kh:Mover, kh:Deporter .  
kh:dog\_13 dul:hasRole kh:ReferencePoint .

---

# **Now, up to you: playground session!**

---

# Now, up to you: playground session!

1. Ontological needs to get a more comprehensive representation of specific phenomena (scene recognition, affordances, object usage optimization, etc.)
2. KG enrichment with focus on the agent embodied needs: what do we need to focus on in order to perform a specific task, given restricted/specific motor abilities?
3. KG enrichment in a broader sense: applications in other domains, kg alignment with foundational ontologies like DOLCE, BFO, UFO, etc.

