Ontologies, Knowledge Graphs, and Neuro-symbolic AI

Knowledge Graphs and Semantic Technologies

Stefano De Giorgis

LEARNING and REASONING

VU UNIVERSITY AMSTERDAM

photo by Evan Vucci/The Associated Press

photo by Evan Vucci/The Associated Press

The assassination attempt on Donald Trump.

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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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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.

(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.

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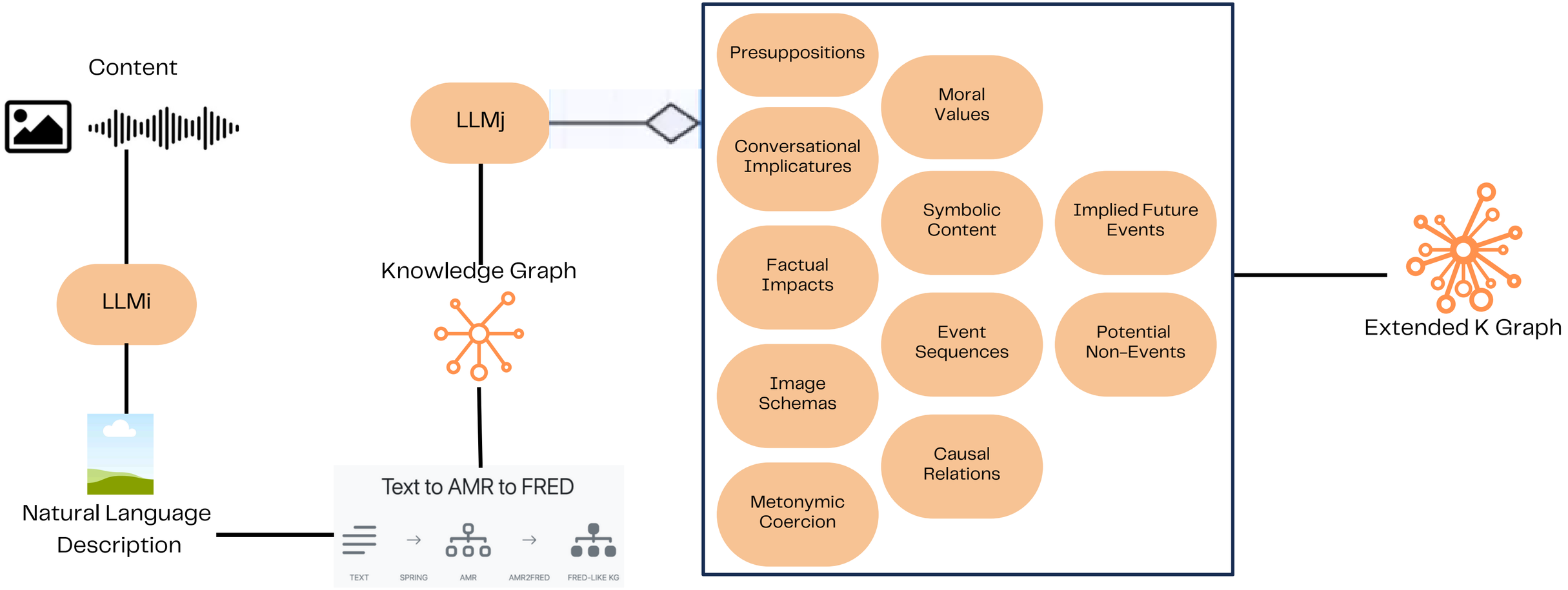
Knowledge Extension Pipeline



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

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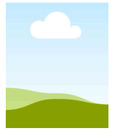
Knowledge Extension Pipeline - 2

LLM



Natural Language Description

Claude

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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Text to AMR to FRED

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.

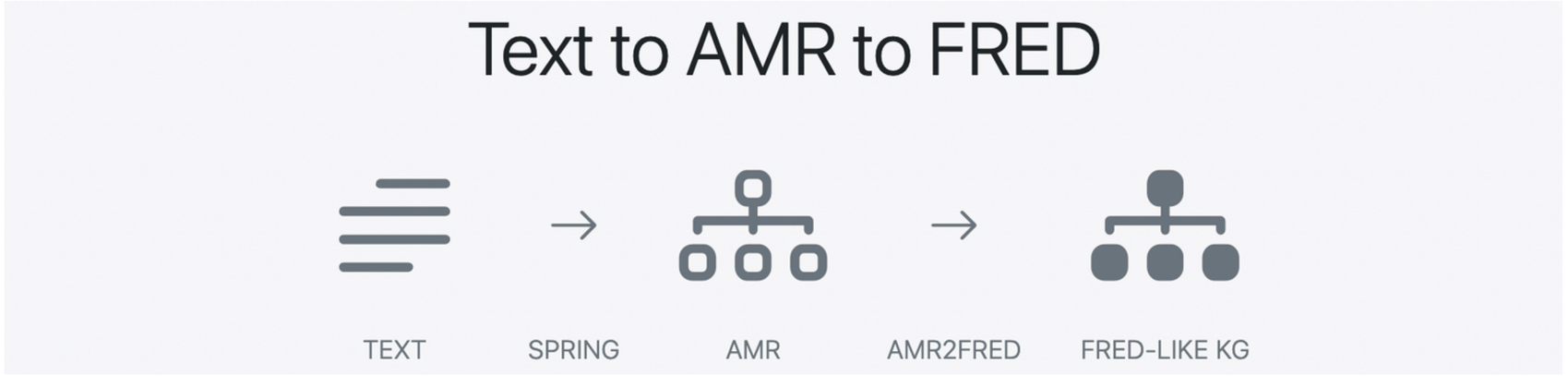
A high-profile political figure raises his fist in defiance, surrounded by vigilant security personnel during a public rally, with a large American flag prominently displayed in the background, emphasizing themes of patriotism and protection.

Settings

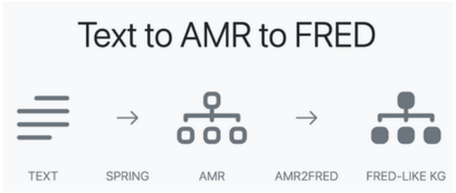
Convert text

Test it!

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



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.



AMR excerpt due to its dimension

```
(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"))
                                                ...
```

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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"))
```

Penman and Graph notation for Text to AMR

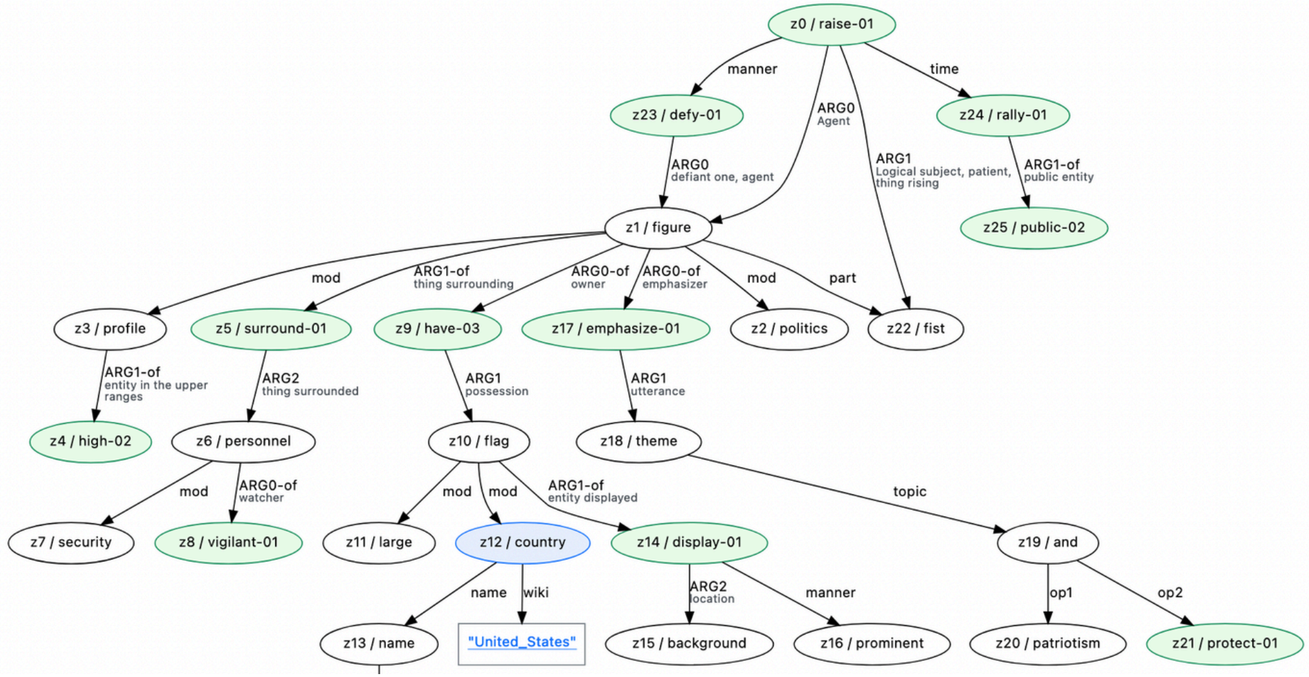
Text to AMR

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**



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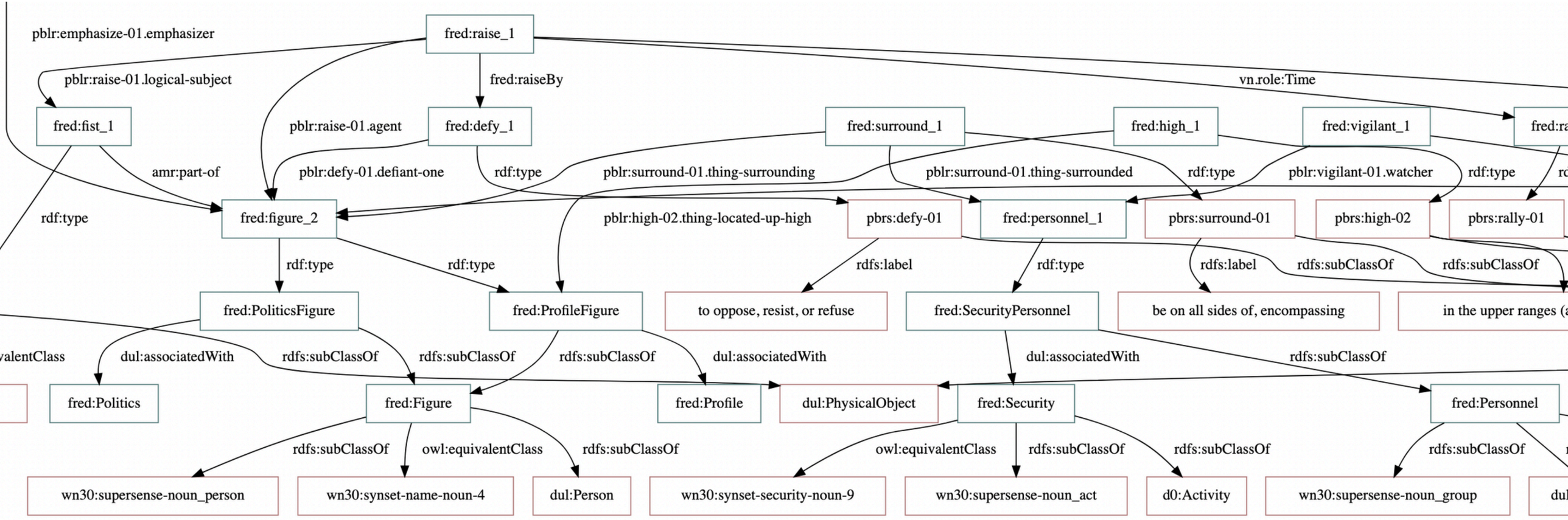
FRED graph



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Knowledge Extension Pipeline - 3

Knowledge Graph

LLM

"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

```
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 extrat
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
...
```

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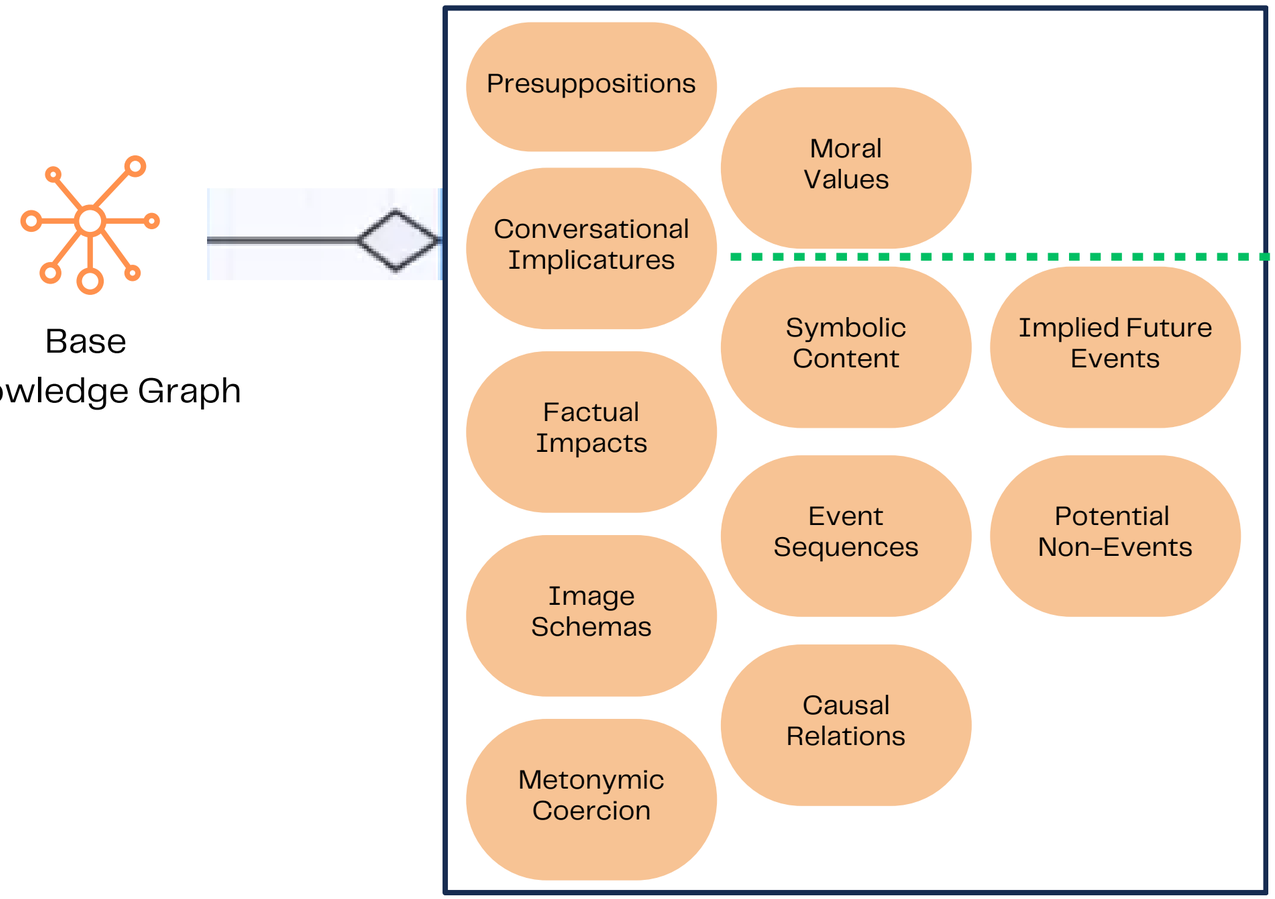
Knowledge Extension Pipeline - 4



"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
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```

conversational_implicatures.prompt

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BASE GRAPH

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

fred:surround_1 a pbrs: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.

SYMBOLIC COERCION

```
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.

FACTUAL IMPACT

```
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

MORAL VALUES

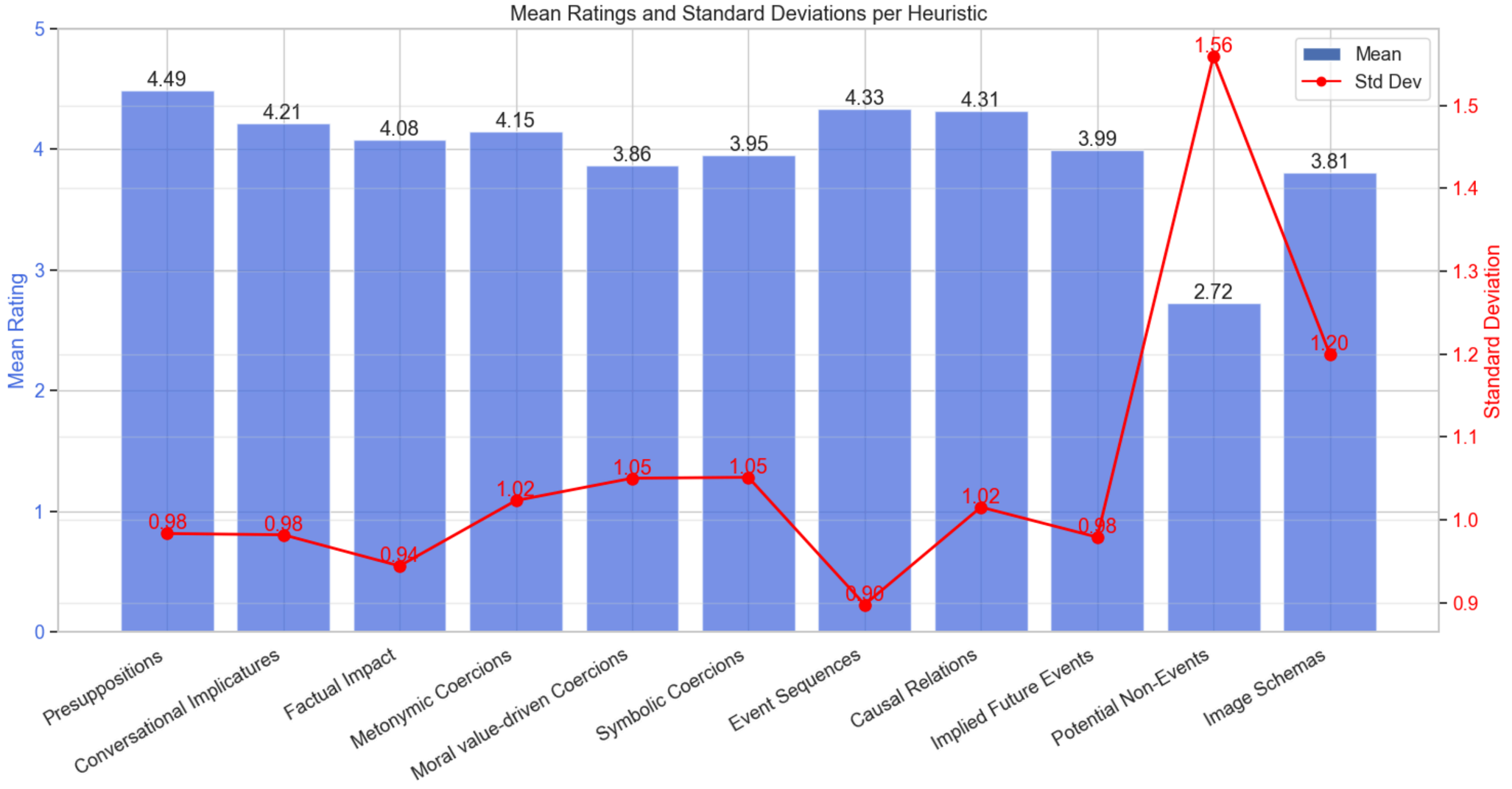
```
fred:assert_1 a pbrs:assert-02 ;
    mor:evokes mor:PowerDemonstration ;
    pblr:assert-02.agent fred:figure_2 ;
    pblr:assert-02.topic fred:power_1 .
```

The figure assertion is a demonstration of power.

IMPLIED FUTURE EVENTS

```
fred:support_1 a owl:ObjectProperty,
        pbrs: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.



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

Event Segmentation

	0.12	0.15	0.51	0.54	0.57	0.75	0.81	0.96	0.99	1.02	1.05	1.11	1.17	1.86	1.95	2.34	2.73	2.91	3.33	3.42	3.54
Approach(hasParticipant: person_1,hasParticipant: person_2)	■	■	■	■	■	■	■	■	■	■	■										
Linkage(hasParticipant: person_1,hasParticipant: person_2)		■		■		■		■		■	■										
Contact(hasParticipant: person_1,hasParticipant: person_2)		■		■		■		■		■	■										
Departure(hasParticipant: cow_3,hasParticipant: person_1)		■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■		
Departure(hasParticipant: cow_3,hasParticipant: person_2)		■	■	■	■	■	■	■	■	■	■	■									
Stillness(hasParticipant: person_1,hasParticipant: sheep_3)											■	■	■	■							
Approach(hasParticipant: cow_3,hasParticipant: person_1)														■	■						■
Departure(hasParticipant: bird_3,hasParticipant: person_1)																	■		■	■	■
Approach(hasParticipant: bird_3,hasParticipant: person_1)																		■			
Stillness(hasParticipant: cow_3,hasParticipant: person_1)																				■	

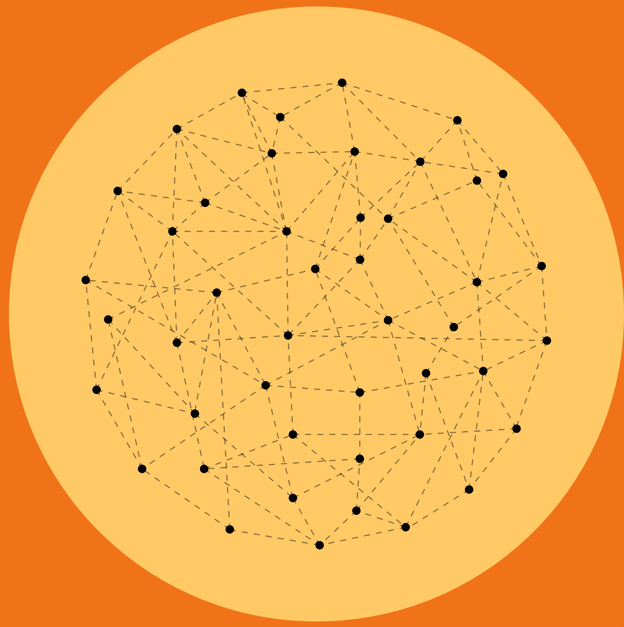
```
log:hasParticipant rdf:type owl:ObjectProperty .
log:hasId rdf:type owl:DatatypeProperty .

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 .
```

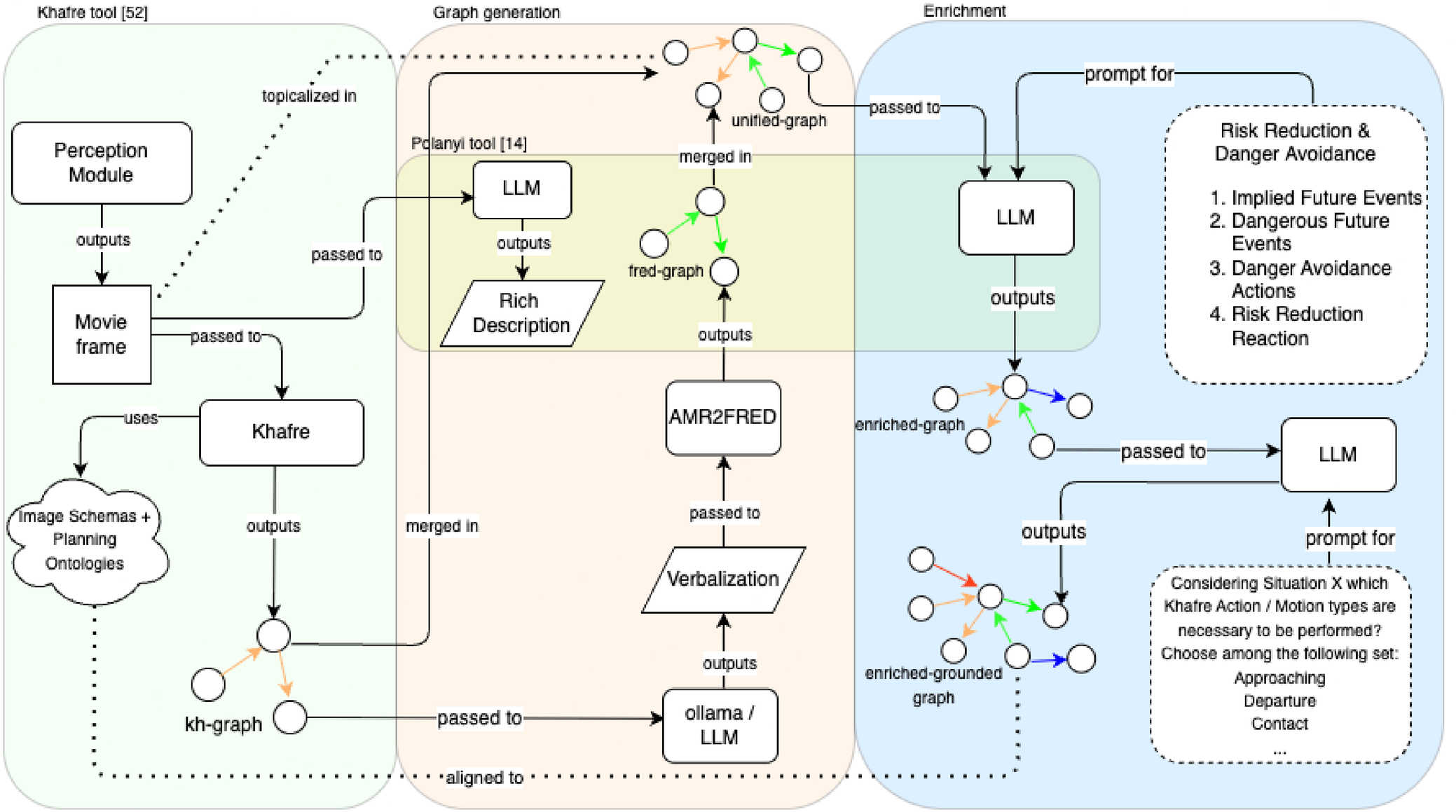
Neuro-symbolic knowledge enrichment - 2

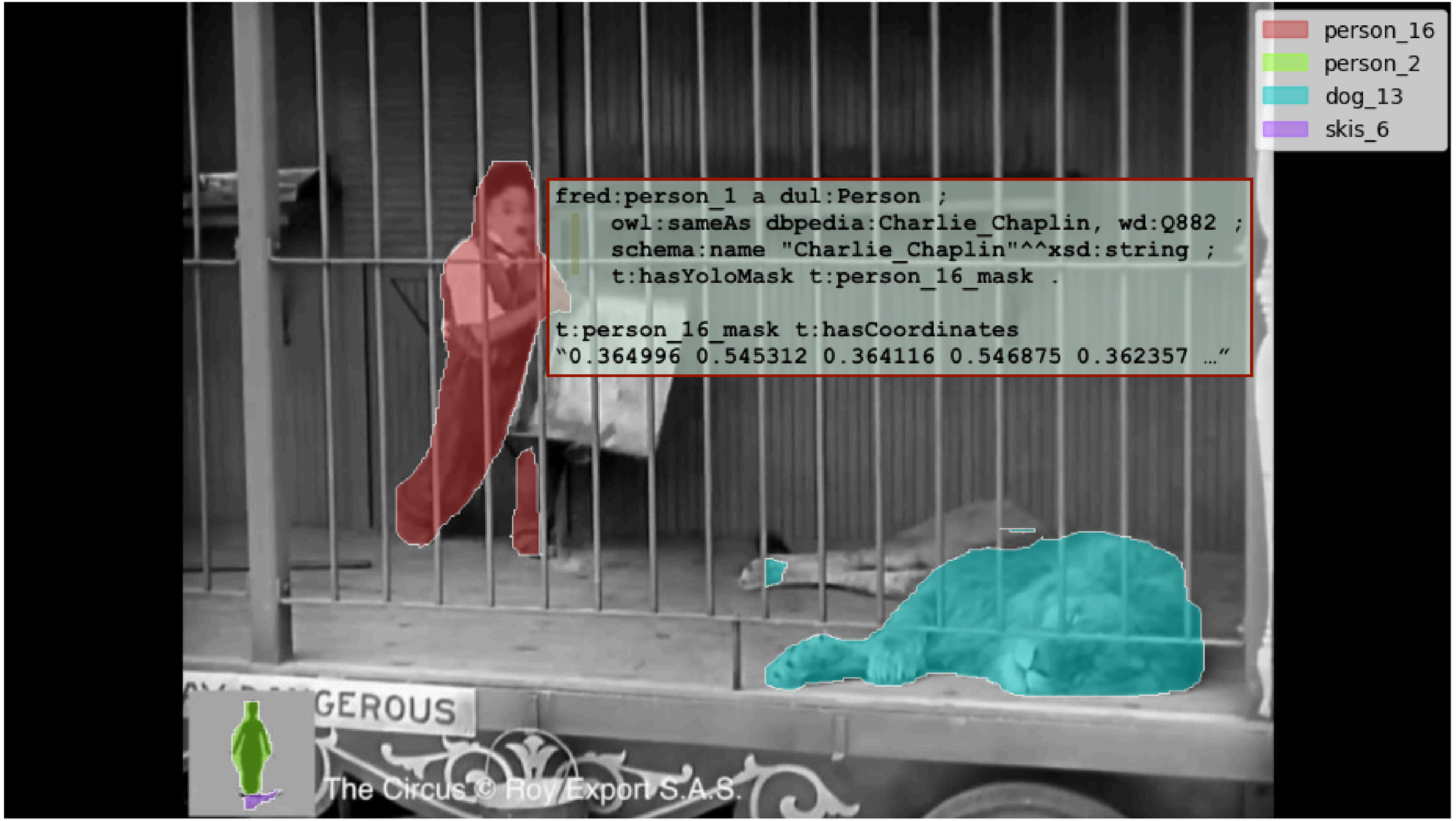


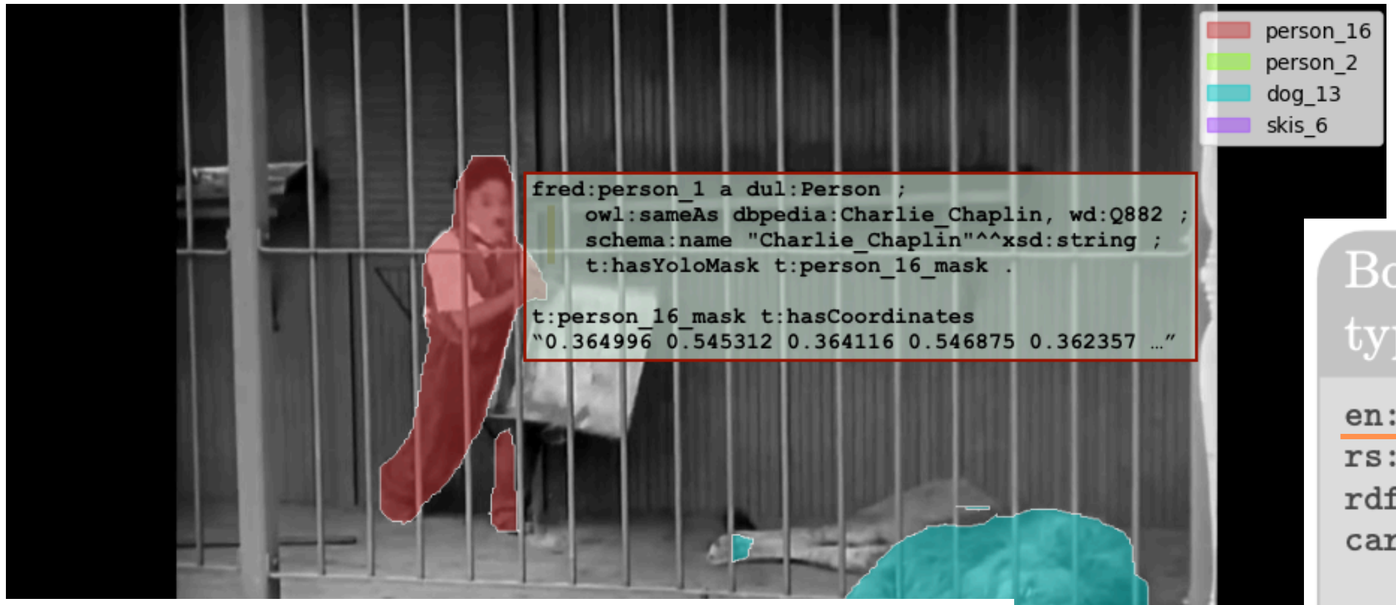
FRAMENET

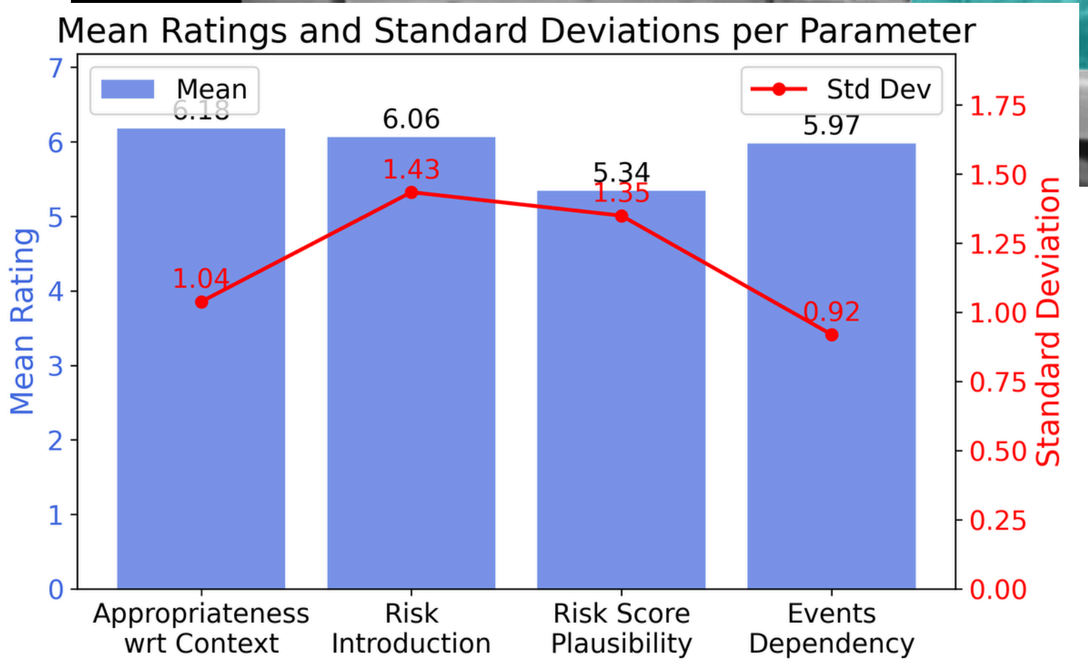
De Giorgis S., Righetti G., Pomarlan Hawkins M., Tsiogkas N., Hedblom M. Leemhuis M., Kutz O. - ongoing

NEURAL COMPONENT – OBJECT RECOGNITION


Khafre tool [52]
Graph generation
Enrichment
topicalized in
Perception Module
outputs
Movie frame
passed to
passed to
uses
Khafre
Image Schemas + Planning Ontologies
outputs
kh-graph
passed to
ollama / LLM
outputs
Verbalization
passed to
AMR2FRED
outputs
fred-graph
merged in
unified-graph
merged in
Polanyi tool [14]
LLM
outputs
Rich Description
passed to
prompt for
Risk Reduction & Danger Avoidance
1. Implied Future Events
2. Dangerous Future Events
3. Danger Avoidance Actions
4. Risk Reduction Reaction
LLM
outputs
enriched-graph
passed to
LLM
outputs
enriched-grounded graph
prompt for
Considering Situation X which Khafre Action / Motion types are necessary to be performed? Choose among the following set:
Approaching
Departure
Contact
...
aligned to


person_16
person_2
dog_13
skis_6
fred:person_1 a dul:Person ;
owl:sameAs dbpedia:Charlie_Chaplin, wd:Q882 ;
schema:name "Charlie_Chaplin"^^xsd:string ;
t:hasYoloMask t:person_16_mask .
t:person_16_mask t:hasCoordinates
"0.364996 0.545312 0.364116 0.546875 0.362357 …"
GEROUS
The Circus © Roy Export S.A.S.





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:Departer .

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:Departer,
kh:Faller .

kh:person_16 dul:hasRole kh:Mover, kh:Departer .
kh:dog_13 dul:hasRole kh:ReferencePoint .
```

Q&A?

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s.degiorgis@vu.nl