

Commonsense Reasoning meets Theorem Proving

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Work supported by DFG FU 263/15-1 'Ratiolog'.

Benchmarks for Commonsense Reasoning

Winograd Schema Challenge [Levesque, 2011]:

The trophy would not fit in the brown suitcase because it was too big.

What was too big?

Alternative 1: the trophy

Alternative 2: the suitcase

Benchmarks for Commonsense Reasoning

Choice of Plausible Alternatives Challenge [Roemmele et al., 2011]:

1: My body cast a shadow over the grass. What was the CAUSE of this?

Alternative 1: The sun was rising.

Alternative 2: The grass was cut.

Benchmarks for Commonsense Reasoning

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13: The pond froze over for the winter. What happened as a RESULT?

Alternative 1: People skated on the pond.

Alternative 2: People brought boats to the pond.

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Cause Category

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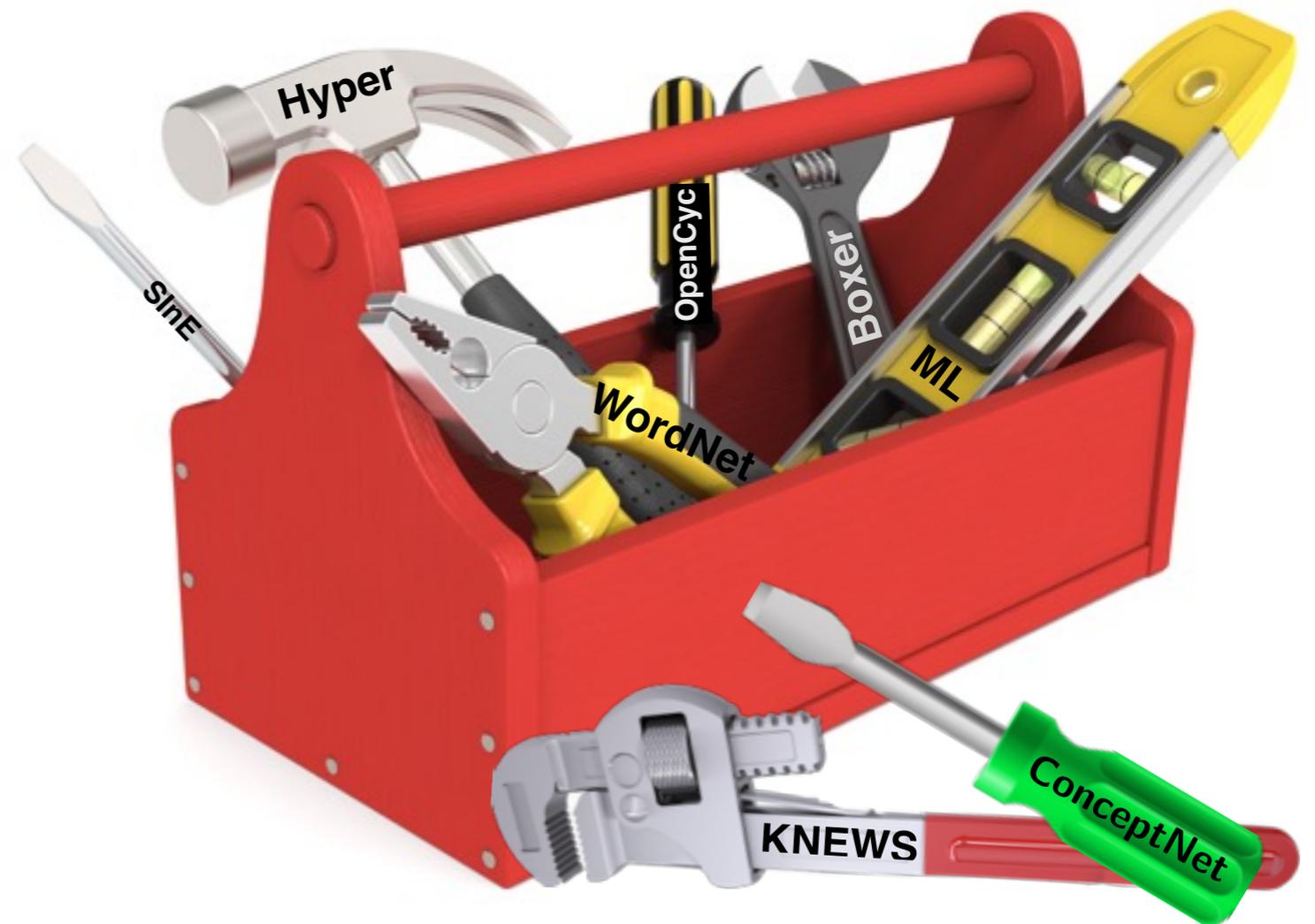
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Result Category

- NL to logic
- Connect problem description to background knowledge
- Compare reasoner results with alternatives



Gathering Background Knowledge

1: My body cast a shadow over the grass. What was the CAUSE of this?

Alternative 1: The sun was rising.

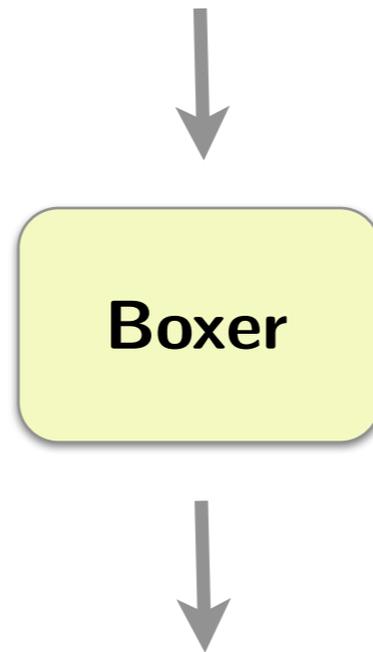
Alternative 2: The grass was cut.

Gathering Background Knowledge

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$$\begin{aligned} &\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E((r1over(C, A) \wedge \\ &(r1Theme(C, D) \wedge (r1Actor(C, E) \wedge (v1cast(C) \wedge (n1shadow(D) \wedge \\ &(n1body(E) \wedge (r1of(E, D) \wedge n1person(D)))))))))) \wedge \\ &\exists F((r1Actor(F, B) \wedge v1rise(F)) \wedge \exists G(r1Theme(G, A) \wedge v1cut(G)))) \end{aligned}$$

Gathering Background Knowledge

FO-representation of COPA problem:

$\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E((r1over(C, A) \wedge$
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Background
Knowledge:
OpenCyc

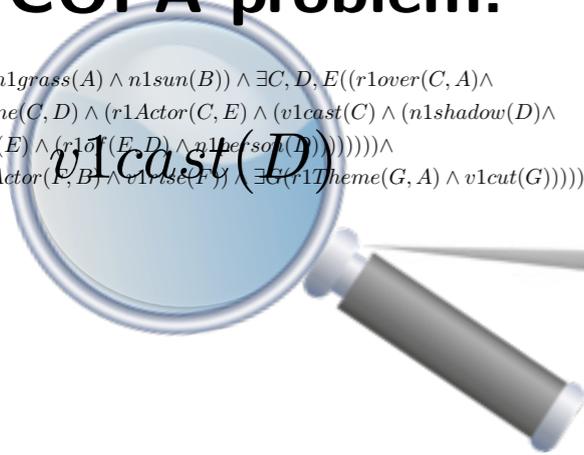


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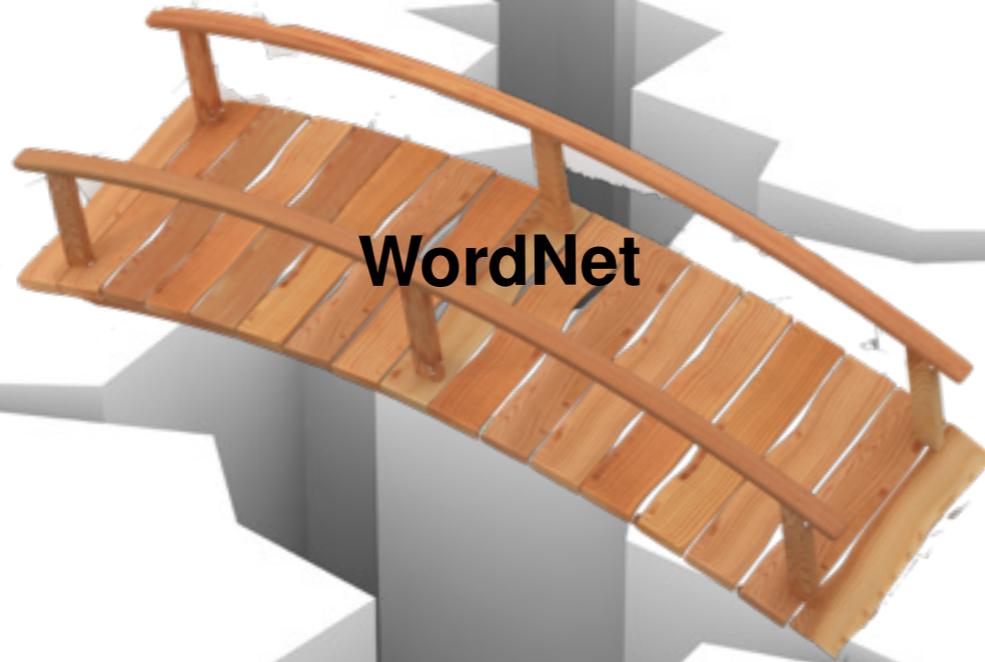
OpenCyc
project(X)



Gathering Background Knowledge

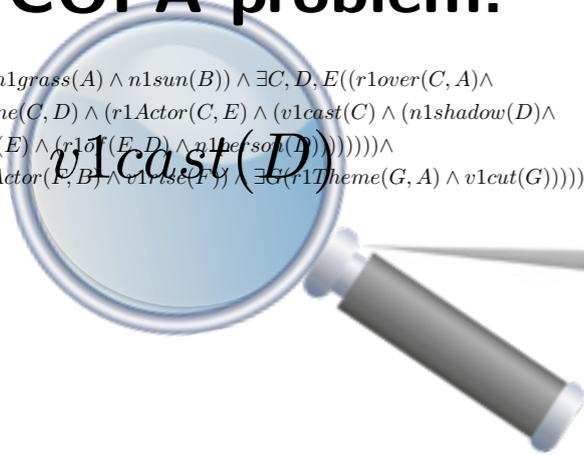
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Gathering Background Knowledge

Bridging formulae

$$\forall X (v1cast(X) \leftrightarrow project(X))$$

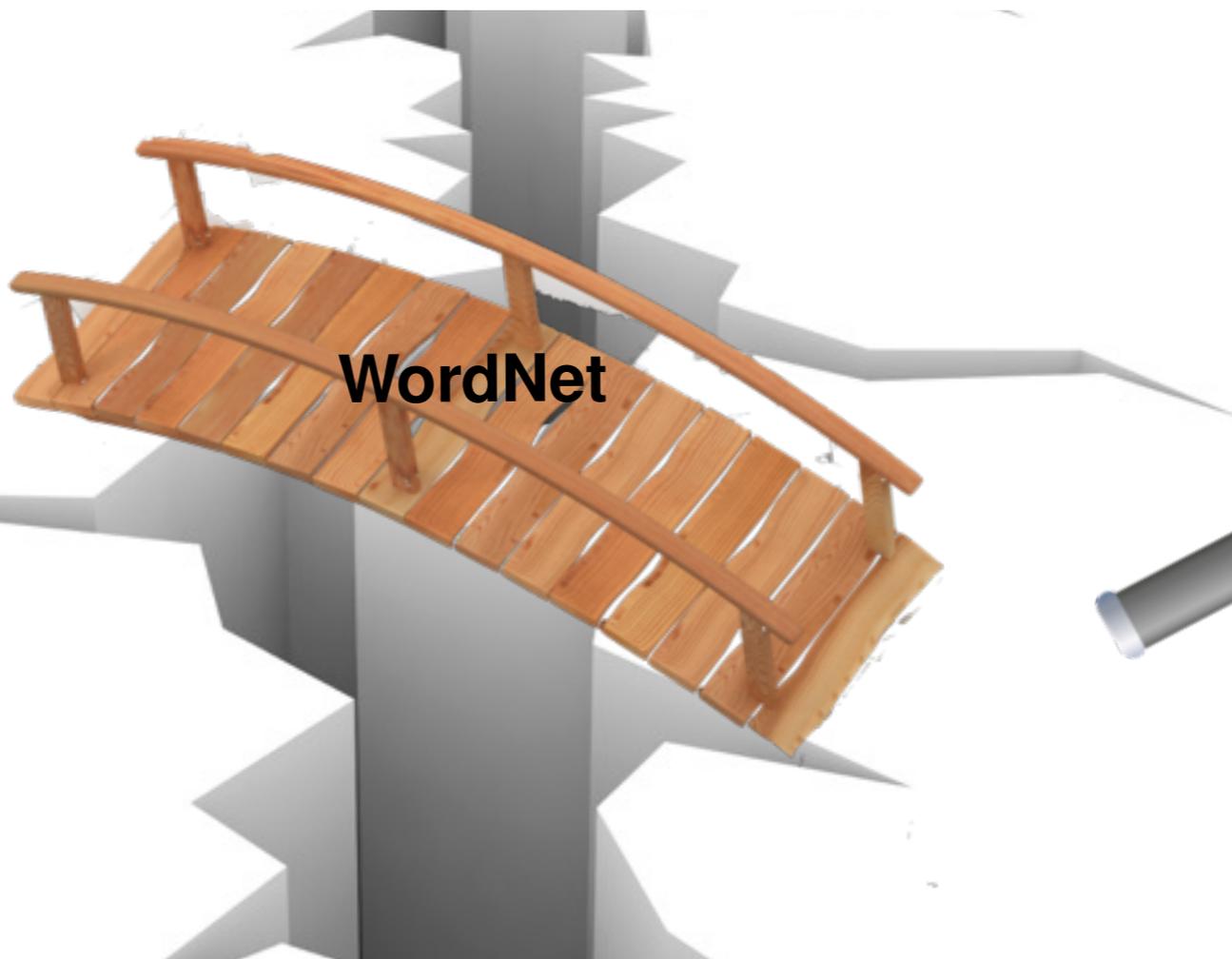
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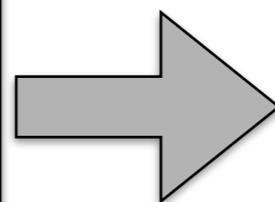
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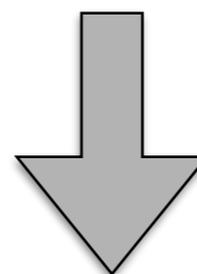
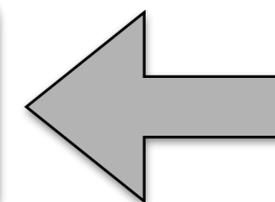
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SInE & k-NN



**Selected background
knowledge**

**Background
Knowledge:
OpenCyc**

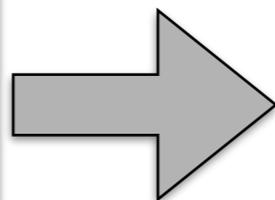
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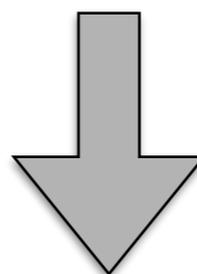
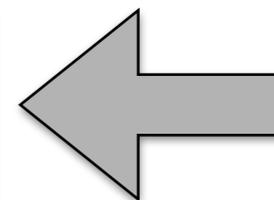
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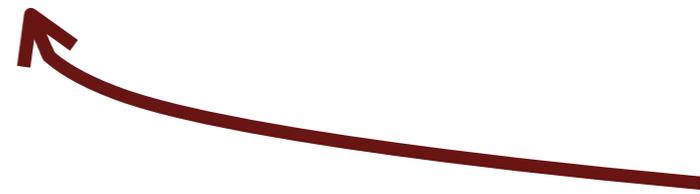
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SInE & k-NN



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Selected background knowledge

Gathering

The screenshot shows the ConceptNet 5 website interface. The browser address bar displays 'conceptnet5.media.mit.edu'. The page title is 'ConceptNet 5' with navigation links for 'About', 'Wiki', and 'Downloads'. A search bar contains the query 'shadow|' and the language is set to 'English'. Below the search bar, the results for 'shadow' are displayed in two columns. Each result is a relationship between 'shadow' and another concept, with a brief description.

shadow

- shadow — *AtLocation* → grind
You are likely to find a shadow in the ground
- shadow — *HasProperty* → dark
Shadows are dark
- shadow — *DerivedFrom* → shadow
- shadow — *IsA* → follow
- shadow — *DerivedFrom* → shadow
- shadow — *IsA* → darken
- shadow — *DerivedFrom* → tail
- shadow — *CreatedBy* → light
Shadows are created by light
- shadow — *AtLocation* → you
**Something you find beside you is a shadow*
- shadow — *DefinedAs* → absence of light
a shadow is the absence of light
- shadow — *IsA* → recourse
- shadow — *DerivedFrom* → dwarf
- shadow — *IsA* → shade
- shadow — *DerivedFrom* → shadow
- shadow — *IsA* → presence
- shadow — *RelatedTo* → block
shadow is related to block

FO-representation of COPA problem:

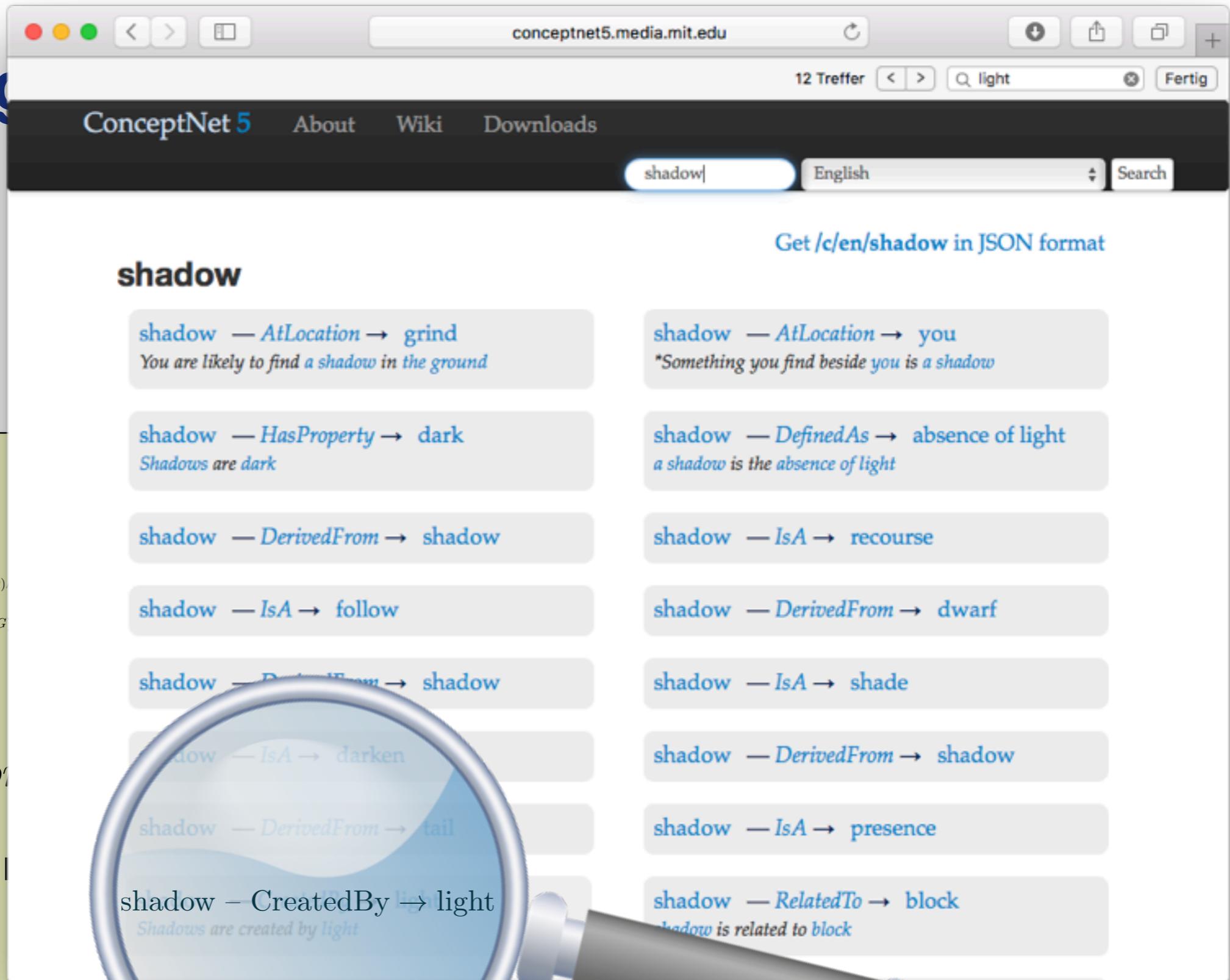
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Bridging formulae

$$\forall X(v1cast(X) \leftrightarrow p)$$

Selected background knowledge

Gathering



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conceptnet5.media.mit.edu

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ConceptNet 5 About Wiki Downloads

shadow| English Search

Get /c/en/shadow in JSON format

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Bridging formulae

$$\forall X(v1cast(X) \leftrightarrow p1(X))$$

Selected background knowledge

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Bridging formulae

$$\forall X(v1cast(X) \leftrightarrow p1(X))$$

Selected background knowledge

ConceptNet formulae:

$$\forall X(light(X) \rightarrow shadow(X))$$

Gathering Background Knowledge

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$\forall X(v1cast(X) \leftrightarrow project(X))$

Selected background knowledge

ConceptNet formulae:

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Gathe

The screenshot shows the ConceptNet 5 website interface. The browser address bar displays 'conceptnet5.media.mit.edu'. The navigation menu includes 'ConceptNet 5', 'About', 'Wiki', and 'Downloads'. A search bar contains the word 'sun', and the language is set to 'English'. A link 'Get /c/en/sun in JSON format' is visible. The main content area lists various semantic relations for 'sun', each with a label, a target, and an example sentence.

Relation	Target	Example
AtLocation	center of solar system	You are likely to find the sun in the center of the solar system
CapableOf	burn your skin	the sun can burn your skin
HasProperty	bright	sun is bright.
Causes	light	The effect of sun is light.
AtLocation	universe	*Something you find in the universe is suns
CapableOf	heat earth	The sun can heat the earth
CapableOf	shine on your day	The sun can shine on your day
CapableOf	dry laundry	the sun can dry laundry
CapableOf	shine brightly	sun can shine brightly
HasProperty	hot	sun is hot.
IsA	star	A sun is a star.
IsA	sun	a star is a sun
RelatedTo	star	sun is related to star

FO-representa of COPA prob

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Bridging form

$\forall X(v1cast(X, B) \wedge r1Actor(X, A))$

Selected back knowledge

ConceptNet

$\forall X(light(X) \rightarrow shadow(X))$

Gathe

conceptnet5.media.mit.edu

ConceptNet 5 About Wiki Downloads

sun English Search

Get /c/en/sun in JSON format

sun

- sun — *AtLocation* → center of solar system
You are likely to find the sun in the center of the solar system
- sun — *CapableOf* → shine brightly
sun can shine brightly
- sun — *HasProperty* → bright
sun is bright.
- sun — *Causes* → light
The effect of sun is light.
- sun — *AtLocation* → universe
Something you find in the universe is suns
- sun — *CapableOf* → heat earth
The sun can heat the earth
- sun — *CapableOf* → shine on your day
The sun can shine on your day
- sun — *CapableOf* → dry laundry
the sun can dry laundry
- sun — *IsA* → star
A sun is a star.
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Selected back
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ConceptNet

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FO-representation of COPA problem

$\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E((r1Theme(C, D) \wedge r1Actor(C, E) \wedge (v1cast(C, E) \wedge (n1body(E) \wedge r1of(E, D) \wedge n1person(D))))))$
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Bridging form

$\forall X(v1cast(X, F) \wedge r1Actor(X, G) \wedge v1cast(G, F))$

Selected background knowledge

ConceptNet

$\forall X(light(X) \rightarrow shadow(X))$

$\forall X(sun(X) \rightarrow light(X))$

Task for Problems of the Cause Category

1: My body cast a shadow over the grass. What was the CAUSE of this?

Alternative 1: The sun was rising.

Alternative 2: The grass was cut.

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Does together with the background knowledge imply ?

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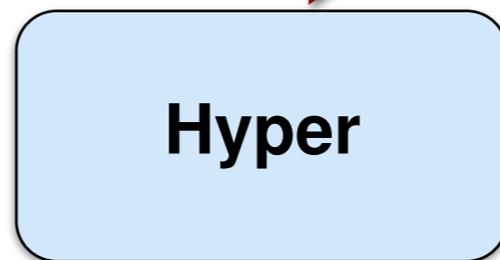
Alternative 2: The grass was cut.

Does together with the background knowledge imply ?

Follows A from B ?

Hyper

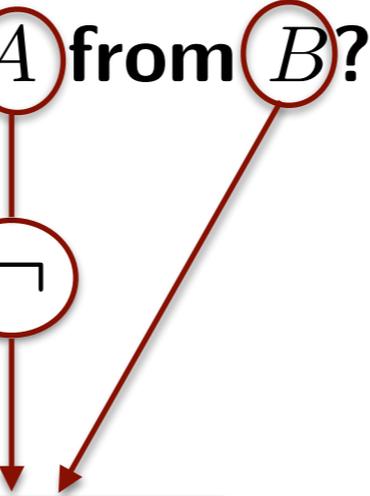
Follows A from B ?



Follows A from B ?

\neg

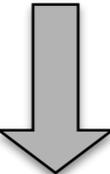
Hyper



Follows A from B ?

\neg

Hyper



Proof!

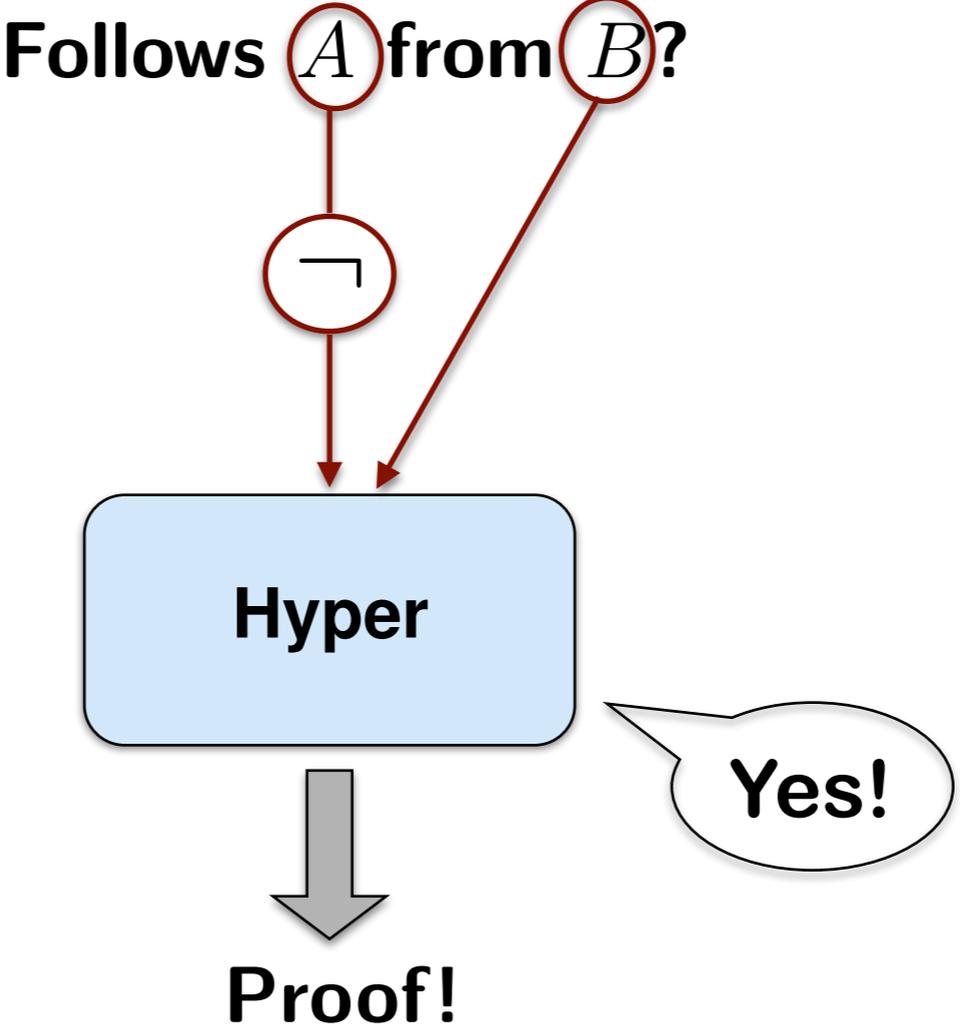
Follows A from B ?

\neg

Hyper

Yes!

Proof!



Tackling Problems in the Cause Category



Naive Approach

Tackling Problems in the Cause Category



Naive Approach

Tackling Problems in the Cause Category

Naive Approach

1: My body cast a shadow over the grass. What was the CAUSE of this?

Alternative 1: The sun was rising.

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FO-representation of alternative 1

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Bridging formulae

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Selected background knowledge

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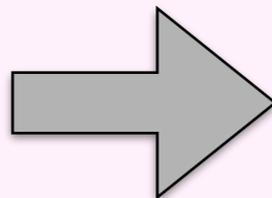
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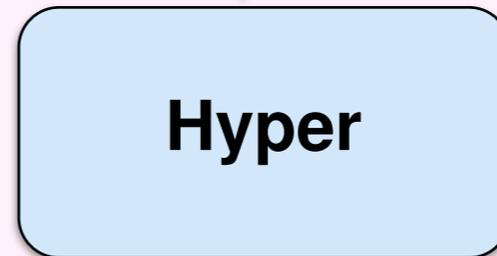
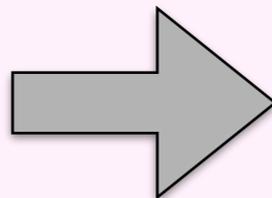
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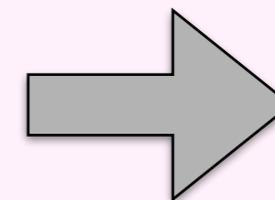
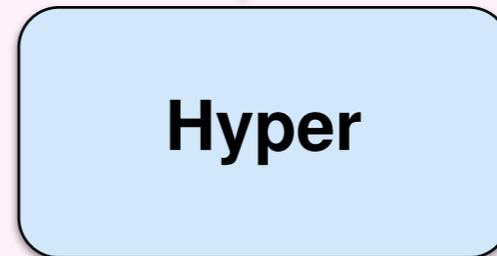
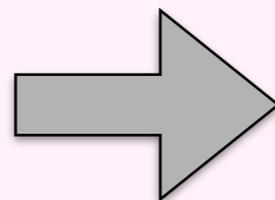
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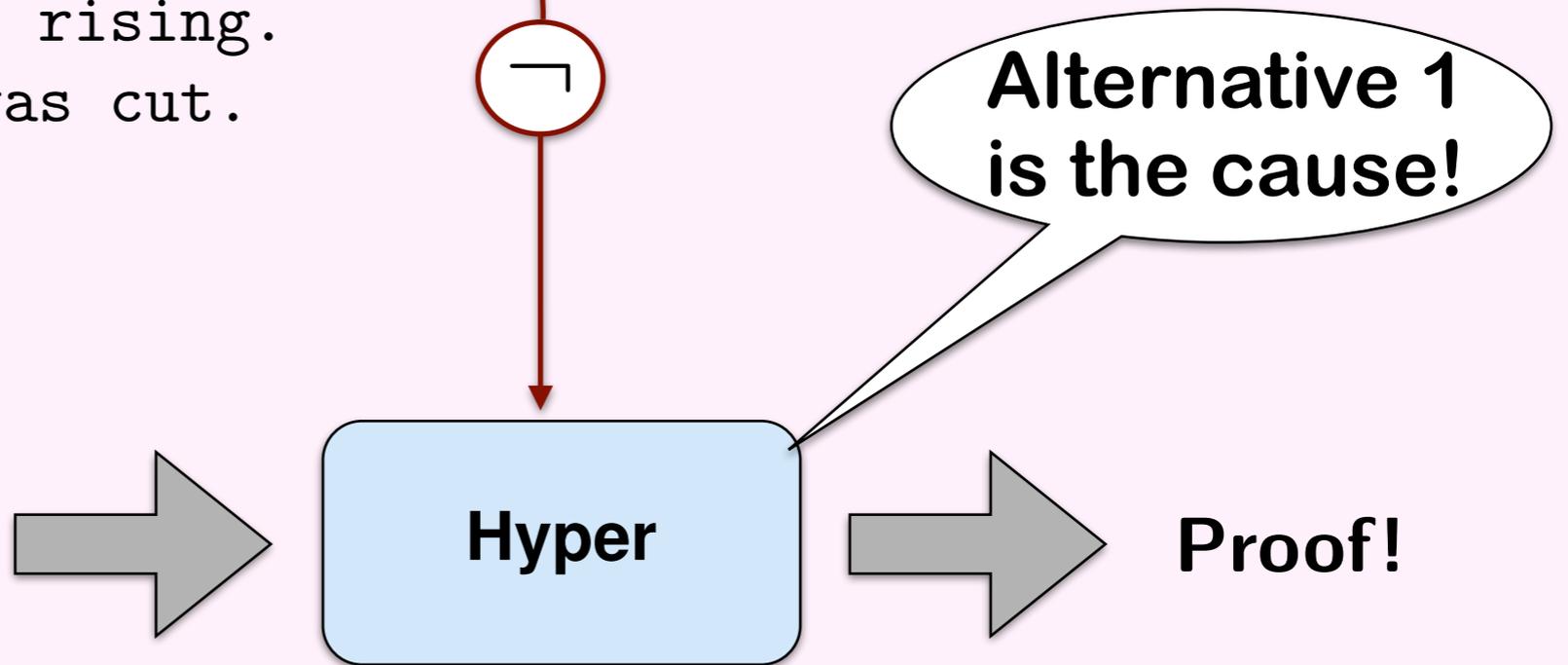
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But Hyper does not find a proof!

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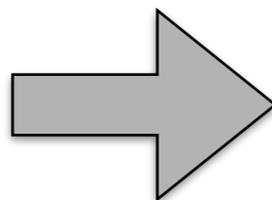
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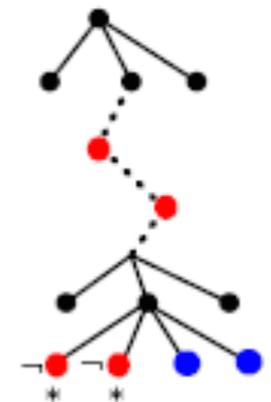
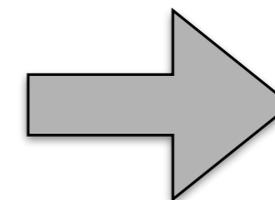
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Hyper



Hyper
tableau

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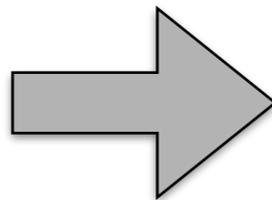
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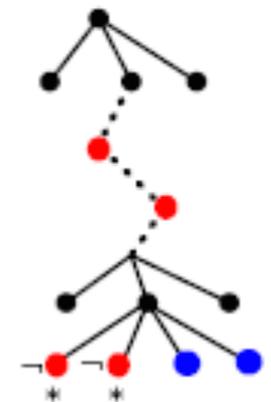
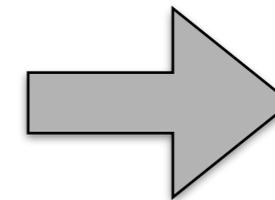
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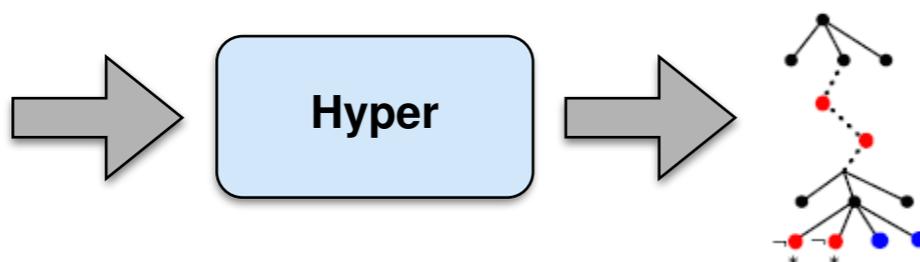
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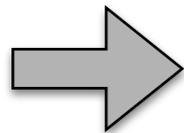
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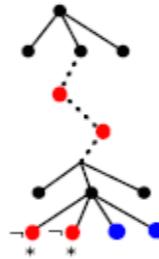
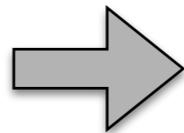
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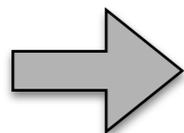


FO-representation of alternative 2
The grass was cut.

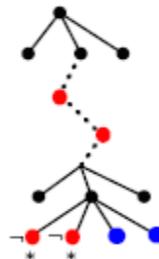
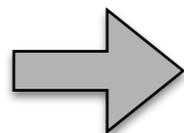
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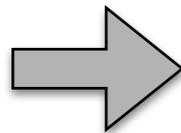
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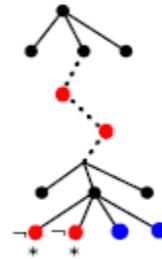
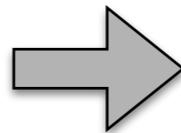
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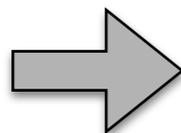
ML

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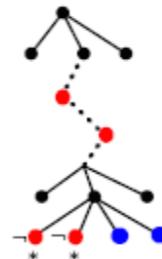
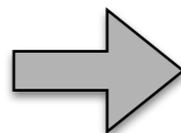
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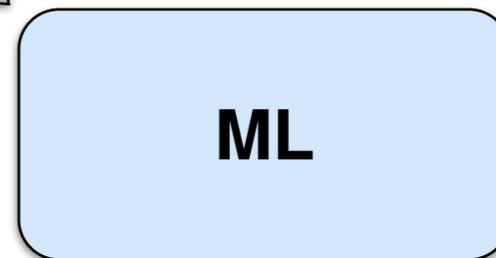
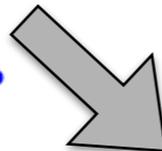
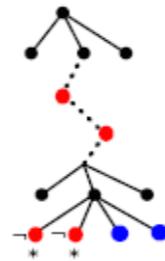
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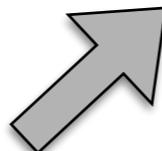
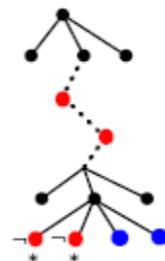


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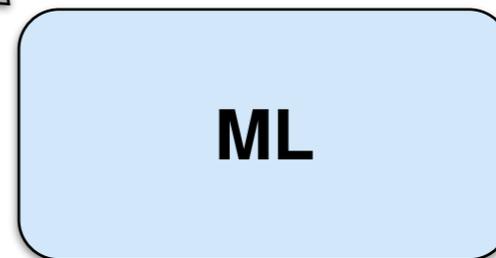
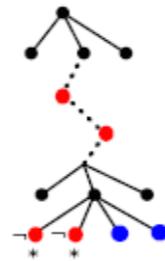
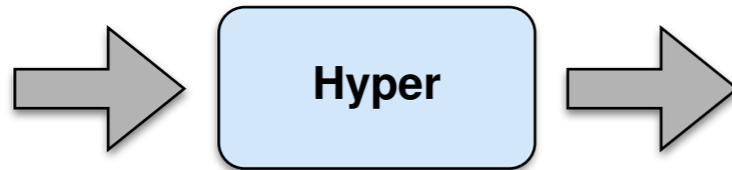
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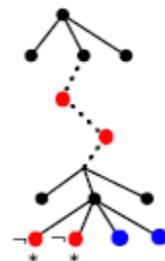


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FO-representation of COPA problem

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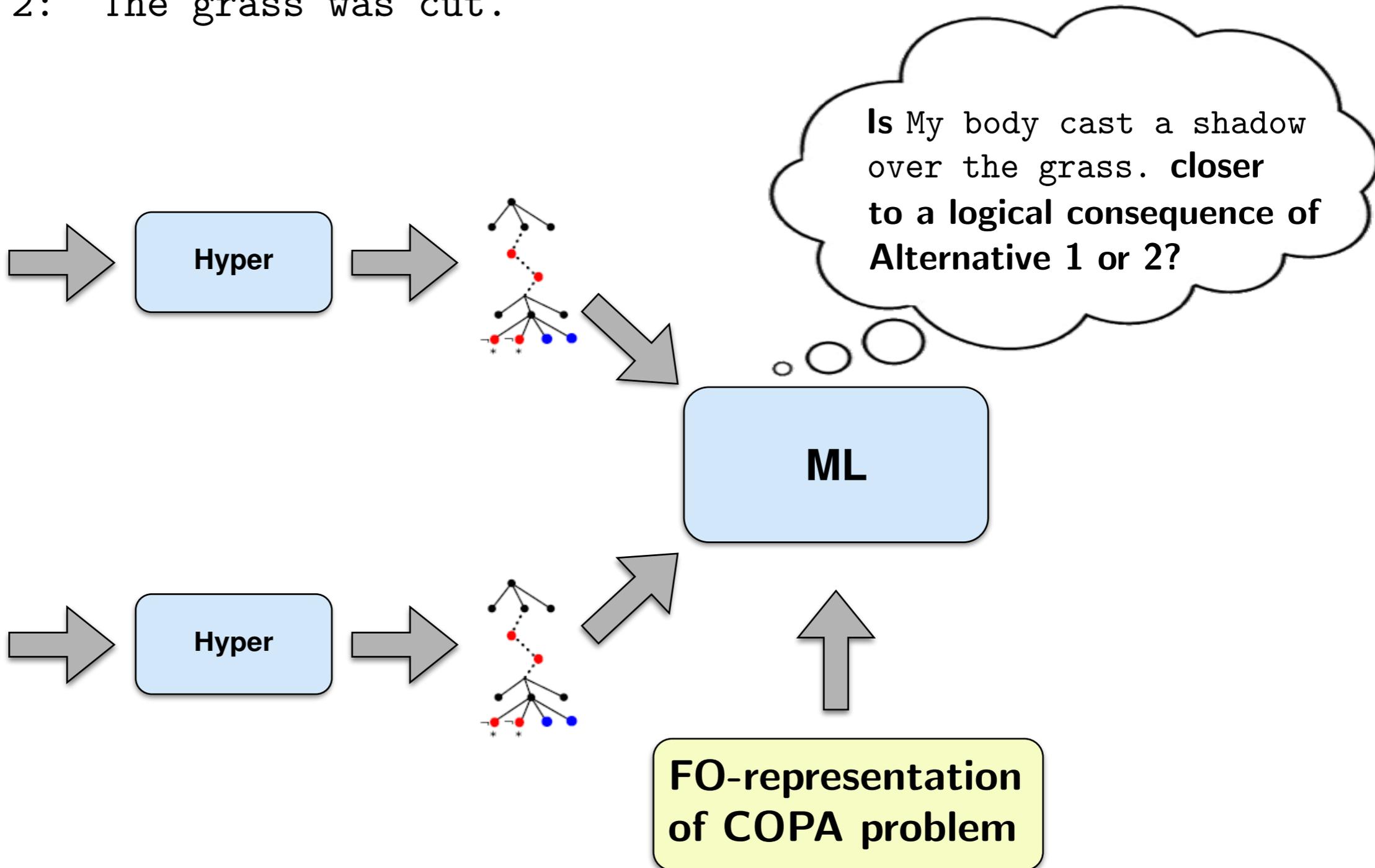
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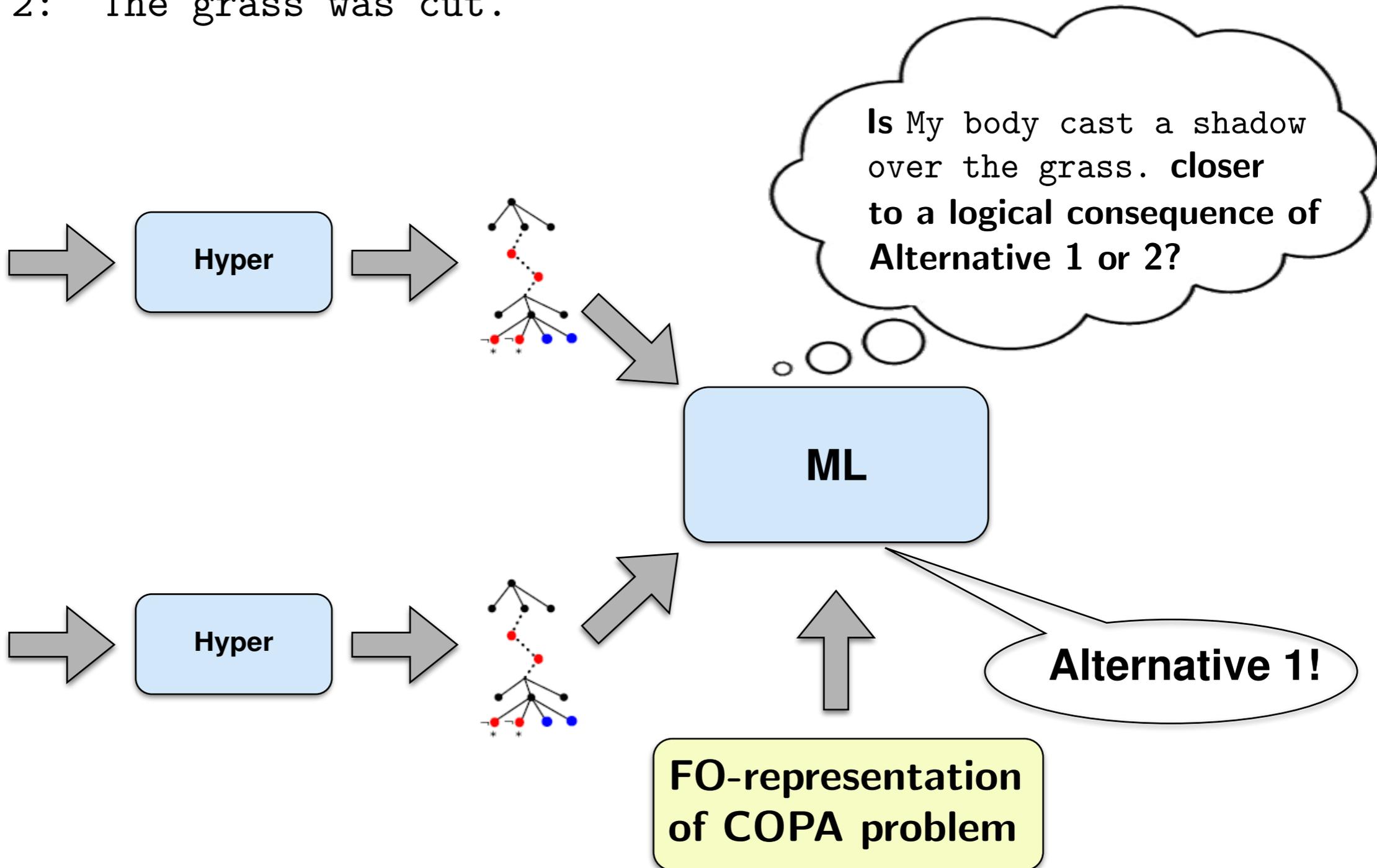
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What is 'closer' to a logical consequence?

p_0

$p_4 \rightarrow p_2 \vee p_3 \vee p_7$

$p_0 \rightarrow p_4$

$p_3 \wedge p_5 \rightarrow p_6$

$p_3 \wedge p_5 \wedge p_8 \rightarrow p_1$

$p_2 \rightarrow \perp$

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p_0 or p_2 ?

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Turn this into a classification problem!

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p_5 or p_6 ?

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$p_1 < p_6$

Turn this into a classification problem!

Classification Problem

- Instance: corresponds to a pair of variables p, q
- Class: $<$, $>$ or $=$
- Attributes: properties of p and q
 - clause set features:
 - proportion of clauses with p in the head
 - rudimentary dependencies
 - tableau features:
 - proportion of open branches containing p
- attribute mimicking abduction

(Very) Preliminary Experimental Results

Result Category:

- **without ConceptNet: 58,7 % correct answers**

Much air upward...

(Very) Preliminary Experimental Results

Result Category:

- without ConceptNet: 58,7 % correct answers

Much air upward...

Other results:

Simple corpus statistics: 62,6% (1 million personal stories)

Simple corpus statistics: 65,4% (10 million personal stories)

CausalNet: 70,2 %

Future Work

- **use more background knowledge**
 - **better integration of ConceptNet**
 - **CausalNet**
- **similarity measures on models and alternatives**
- **experiment with different ML approaches**

All Pictures:
colourbox.de