

# Commonsense Reasoning meets Theorem Proving

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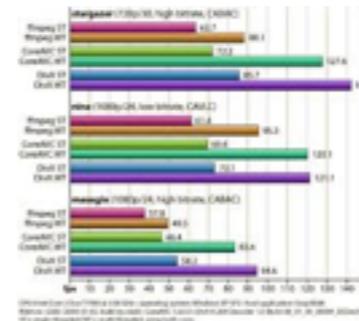
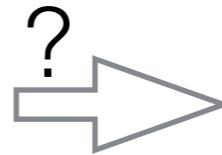




# Examples vrs. Benchmarks

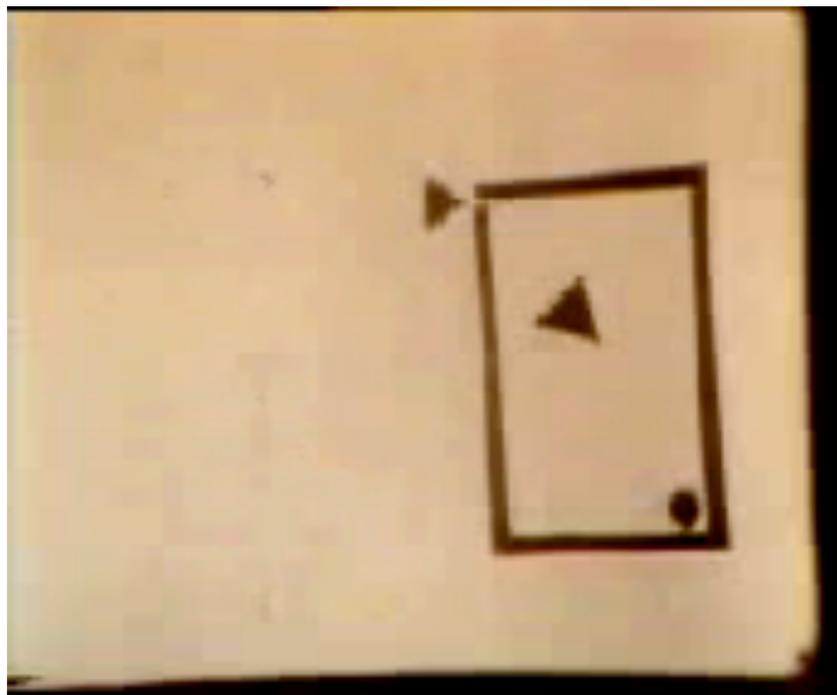


# Examples vrs. Benchmarks



# The Triangle-COPA Challenge

Maslan et al 2015

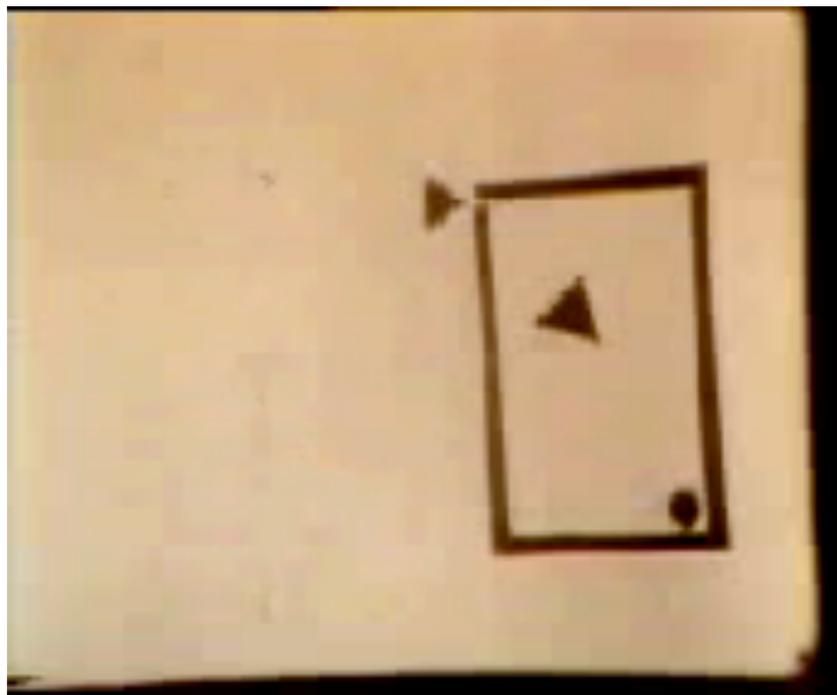


Heider & Simmel 1944

- begin of attribution theory
- example for commonsense reasoning
- role of emotions

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# The Triangle-COPA Challenge

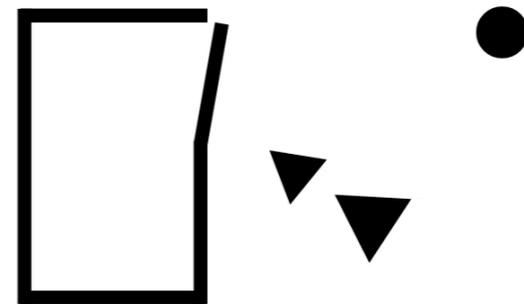
A small triangle and big triangle are next to each other. A circle runs by and pushes the small triangle. The big triangle chases the circle.

*approach(e1, c, lt).*

*push(e2, c, lt).*

*chase(e3, bt, c).*

*seq(e1, e2, e3).*



# The Triangle-COPA Challenge

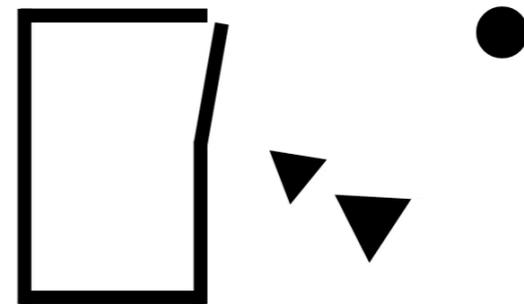
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*approach(e1, c, lt).*

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*seq(e1, e2, e3).*



**How does the little triangle feel?**

**a. The little triangle feels relieved:**

*relief(e4, lt, e3)*

**b. The little triangle is angry at the big triangle:**

*angryAt(e5, lt, bt)*

# Benchmarks

- **Winograd Schema Challenge:**

Levesque 2011

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

What was too big?

Answer 0: the trophy

Answer 1: the suitcase

- **Choice of Plausible Alternatives Challenge:**

Roemmele et al. 2011

Premise: The man broke his toe. What was the CAUSE of this?

Alternative 1: He got a hole in his sock.

Alternative 2: He dropped a hammer on his foot.

# Tasks

- NL to Logic
- Connect problem description to background knowledge
- Compare reasoner results

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- NL to Logic
- Connect problem description knowledge
- Compare reasoner results



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

**a) The sun was rising.**

**b) The grass was cut.**



Boxer


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

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Boxer



Johan Bos (2008): Wide-Coverage  
Semantic Analysis with Boxer.

In: J. Bos, R. Delmonte (eds):  
Semantics in Text Processing. STEP  
2008 Conference Proceedings, pp.  
277-286, Research in Computational  
Semantics, College Publications.

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# Background Knowledge

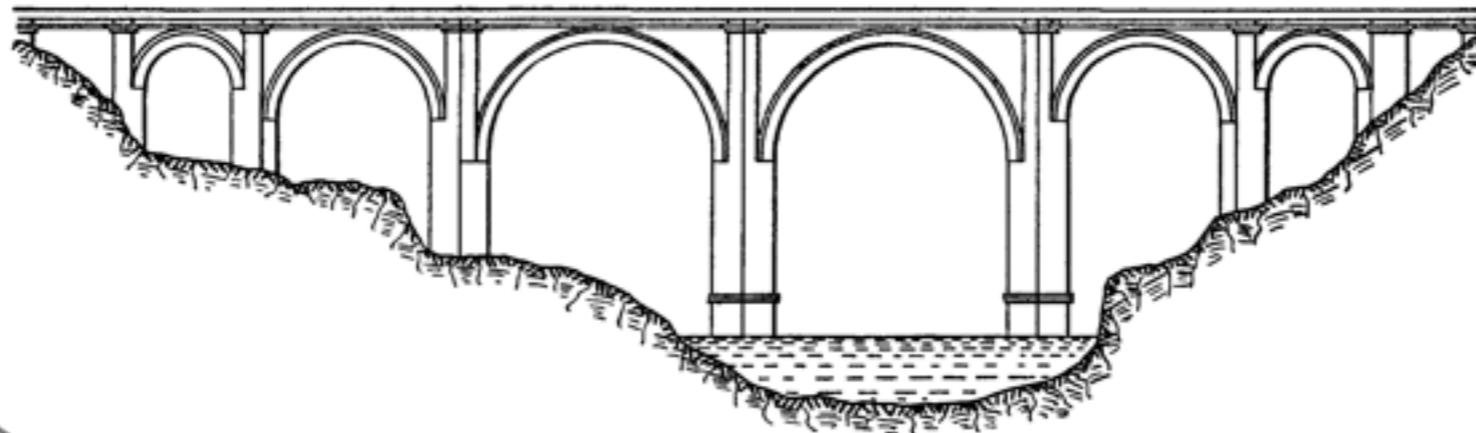
FO-representation  
of COPA problem:

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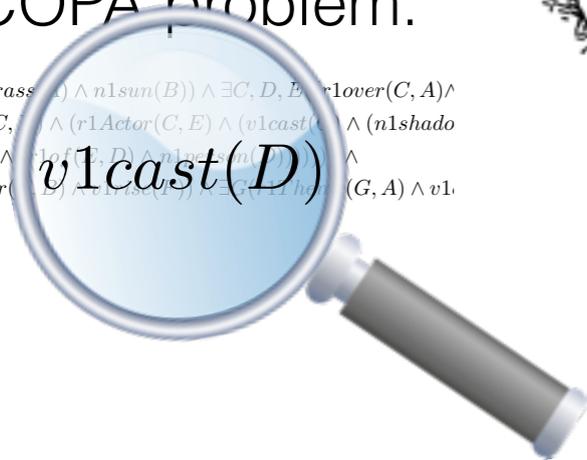
OpenCyc

# WordNet



FO-representation  
of COPA problem:

$\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E, G(r1lover(C, A) \wedge$   
 $(r1Theme(C, B) \wedge (r1Actor(C, E) \wedge v1cast(C, D) \wedge (n1shado$   
 $(n1body(E) \wedge r1of(E, D) \wedge n1grass(B) \wedge$   
 $\exists F((r1Actor(F, B) \wedge v1isc(F, G) \wedge \exists G(r1th$   
 $(G, A) \wedge v1$



Background  
Knowledge:

OpenCyc  
 $project(X)$



## WordNet Search - 3.1

- [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for:

Display Options:

Key: "S:" = Show Synset (semantic) relations, "W:" = Show Word (lexical) relations  
Display options for sense: (gloss) "an example sentence"

### Noun

- **S: (n) cast**, [cast of characters](#), [dramatis personae](#) (the actors in a play)
- **S: (n) mold**, [mould](#), **cast** (container into which liquid is poured to create a given shape when it hardens)
- **S: (n) cast**, [mold](#), [mould](#), [stamp](#) (the distinctive form in which a thing is made) "*pottery of this cast was found throughout the region*"
- **S: (n) form**, [shape](#), **cast** (the visual appearance of something or someone) "*the delicate cast of his features*"
- **S: (n) cast**, [plaster cast](#), [plaster bandage](#) (bandage consisting of a firm covering (often made of plaster of Paris) that immobilizes broken bones while they heal)
- **S: (n) cast**, [casting](#) (object formed by a mold)
- **S: (n) cast**, [roll](#) (the act of throwing dice)
- **S: (n) casting**, **cast** (the act of throwing a fishing line out over the water by means of a rod and reel)
- **S: (n) hurl**, **cast** (a violent throw)

### Verb

- **S: (v) project**, **cast**, [contrive](#), [throw](#) (put or send forth) "*She threw the flashlight beam into the corner*"; "*The setting sun threw long shadows*"; "*cast a spell*"; "*cast a warm light*"
- **S: (v) cast** (deposit) "*cast a vote*"; "*cast a ballot*"
- **S: (v) cast** (select to play, sing, or dance a part in a play, movie, musical, opera, or ballet) "*He cast a young woman in the role of Desdemona*"

Princeton University "About WordNet."  
WordNet. Princeton University. 2010.

<<http://wordnet.princeton.edu>>

## Bridging Formulae

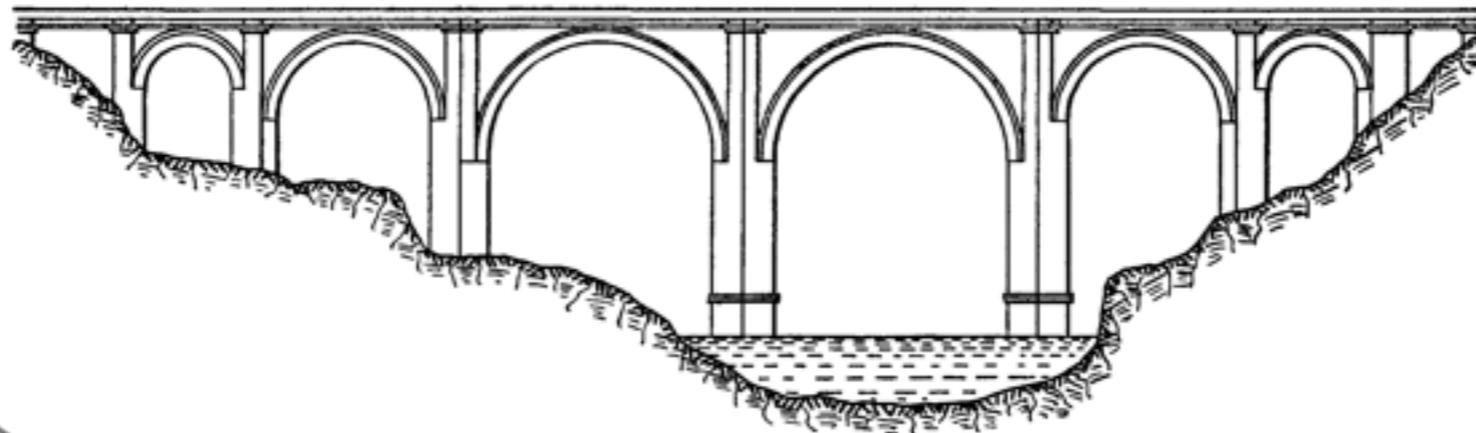
$$\forall X (v1cast(X) \leftrightarrow project(X))$$

## WordNet

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*v1cast(D)*



Background  
Knowledge:

OpenCyc

*project(X)*

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Bridging Formulae

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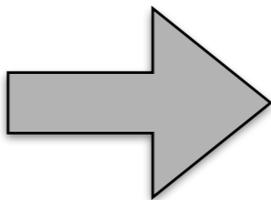
OpenCyc

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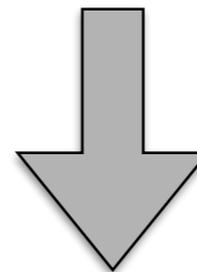
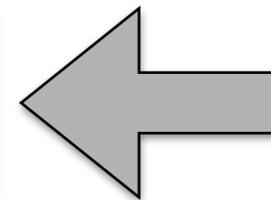
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Bridging Formulae

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



SInE & k-NN



selected background  
knowledge



Background  
Knowledge:

OpenCyc

## FO-representation of COPA problem:

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## Bridging Formulae

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

selected background knowledge

FO-representation of „*My body cast a shadow over the grass.*“

Bridging Formulae

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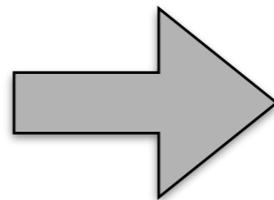
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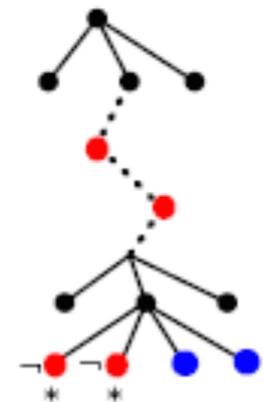
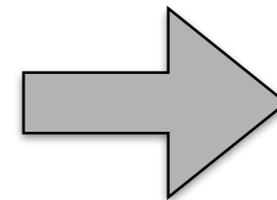
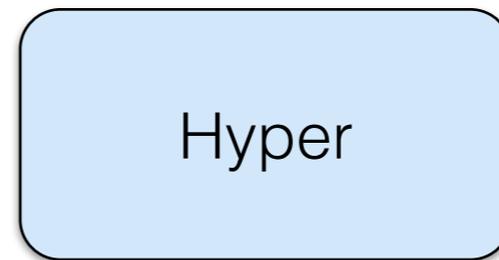
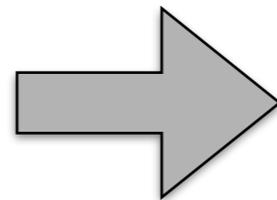
Hyper

FO-representation of „*My body cast a shadow over the grass.*“

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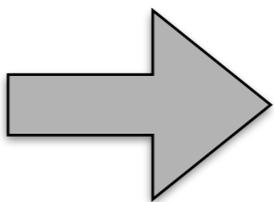
Hyper  
Tableau

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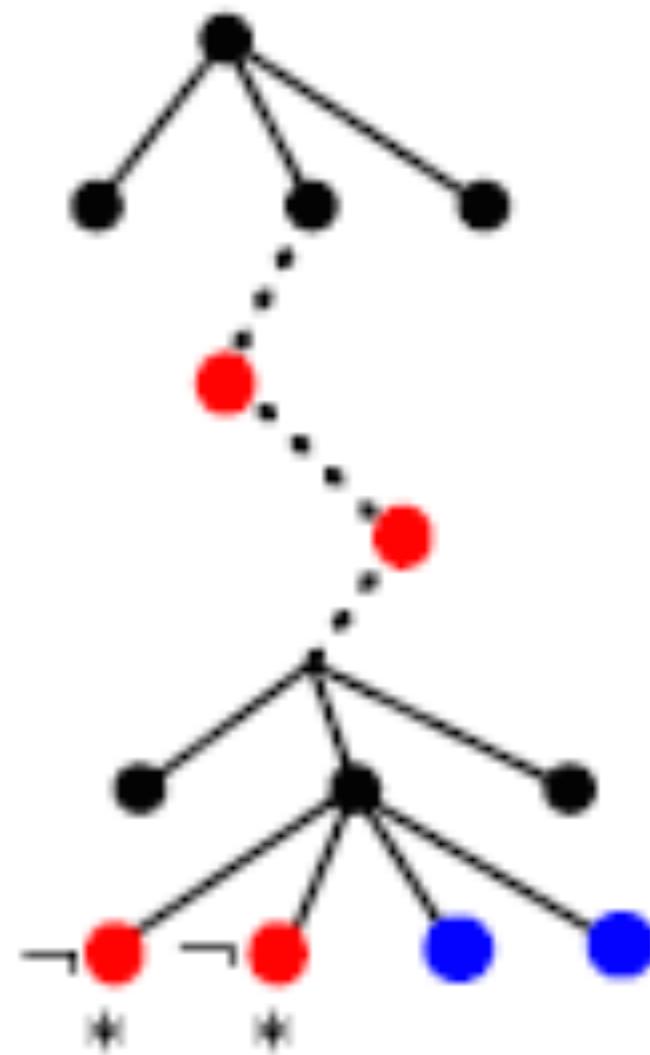
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$\forall X (v1cast(X) \leftrightarrow project(X))$

selected background knowledge



Hyper



## Lessons learnt so far

Experiments with 75 COPA problems:

- 75 proof tasks for Hyper
- 24 proofs
- 35 models
- remainder: time out

## Lessons learnt so far

Necessary to deal with inconsistencies:

- introduced by selected knowledge from OpenCyc:

$$\forall X \text{ speed}(f\_qpquantityfn\text{speed}(X))$$

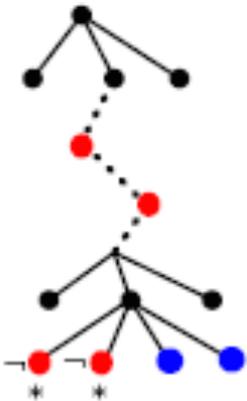
$$\forall X \neg \text{speed}(X)$$

- introduced by the interaction of adding hypernyms  
+ OpenCyc

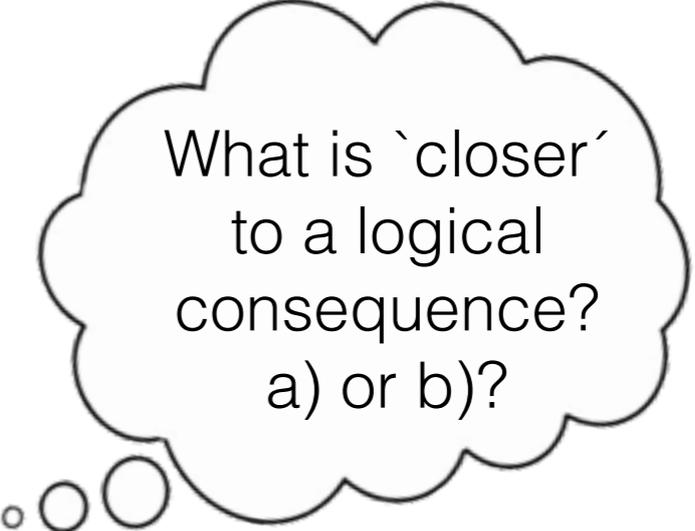
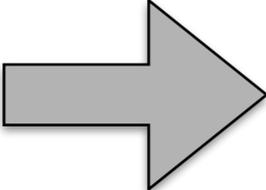
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Hyper  
Tableau



# What is 'closer' to a logical consequence?

$p_0$

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

$p_0$  or  $p_2$ ?  $p_0!$

$p_0 \rightarrow p_4$

$p_3 \wedge p_5 \rightarrow p_6$

$p_5$  or  $p_6$ ?  $p_5!$

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

$p_2 \rightarrow \perp$

$p_1$  or  $p_6$ ?  $p_6!$

Turn this into a classification problem!

# What is 'closer' to a logical consequence?

$p_0$

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

$p_0 > p_2$

$p_0 \rightarrow p_4$

$p_3 \wedge p_5 \rightarrow p_6$

$p_5 > p_6$

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

$p_2 \rightarrow \perp$

$p_1 < p_6$

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

# Experimental Results

Training set:

- created from 1,000 randomly created sets of clauses
- ~ 10 clauses
- ~ 12 variables
- one instance per pair of variables (~123,200)

Test set:

- created from 100 randomly created sets of clauses
- ~ 12,200 instances

Learning Method: Decision Trees

# Experimental Results

	<	>	=
< (actual)	5,595	78	33
> (actual)	90	5,589	27
= (actual)	9	5	772

98.02 % correctly classified

# to conclude

- Implemented workflow
- Experiments with connecting background knowledge
  - Controlling Wordnet-Bridging
  - Avoiding inconsistencies
  - Alternatives ConceptNet and UMBEL
- Very basic experiments with ranking of answers