Thursday

Fine-grained justifications (ctd.)
Lemmata

Schedule for today

- Laconic/precise justs: evaluation
- Laconic/precise justs: discussion
- Quick tool demo
- Beyond Justifications

Wrap-up of yesterday

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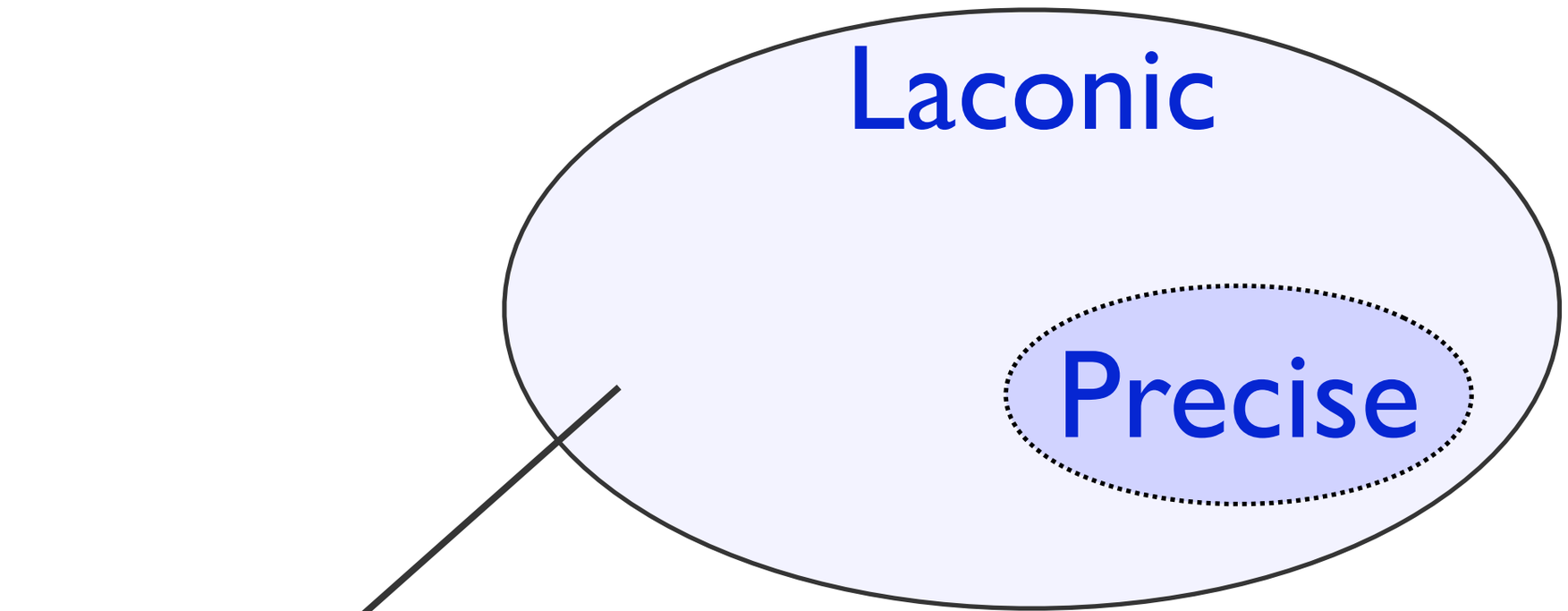
Wrap-up



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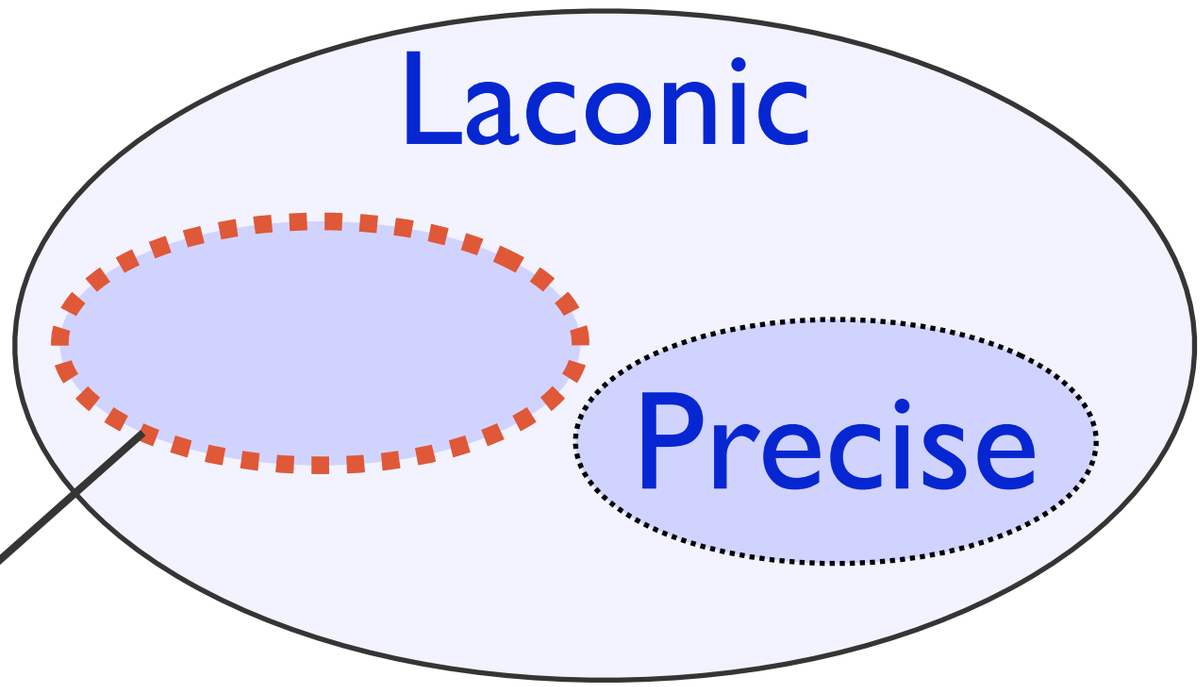
Wrap-up



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Algorithm

Ontology

Justifications

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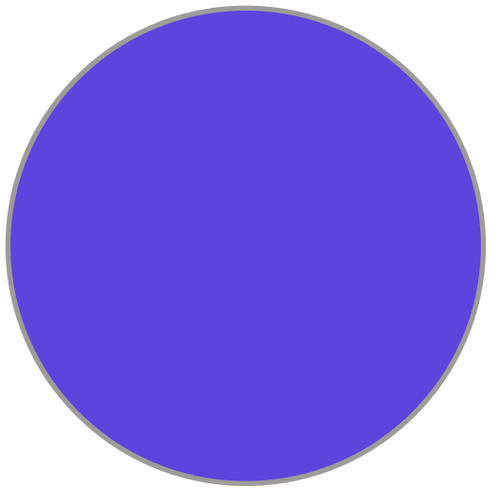

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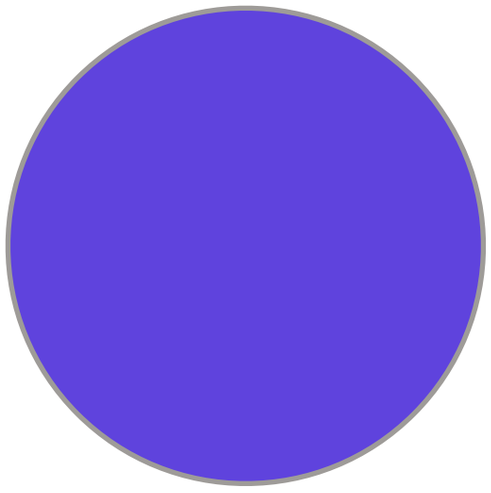

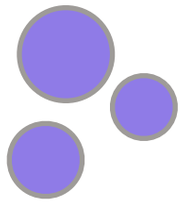

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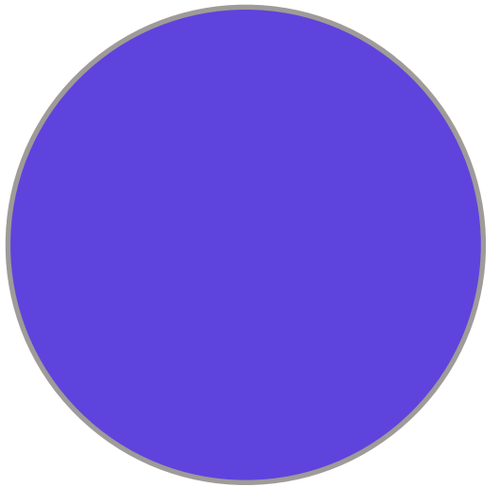

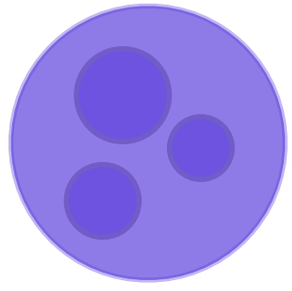

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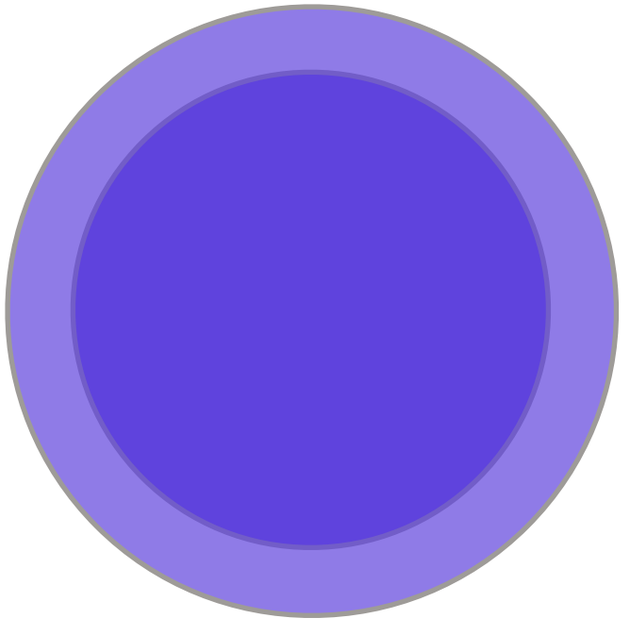

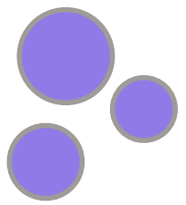

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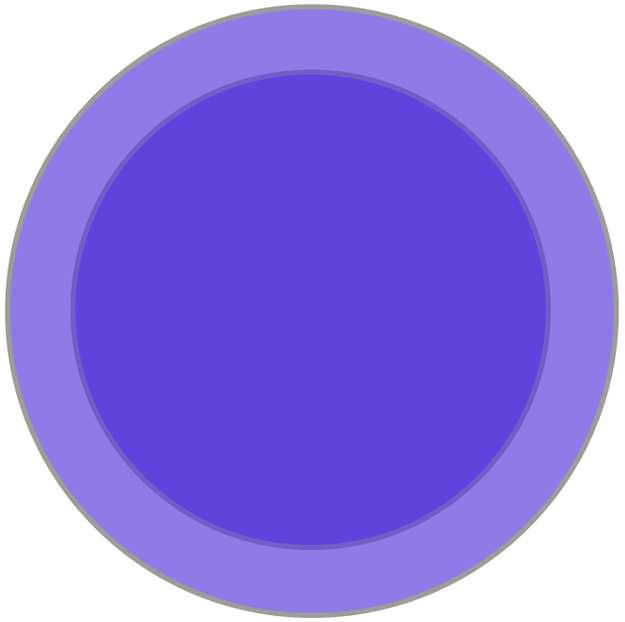

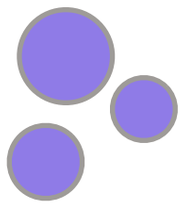

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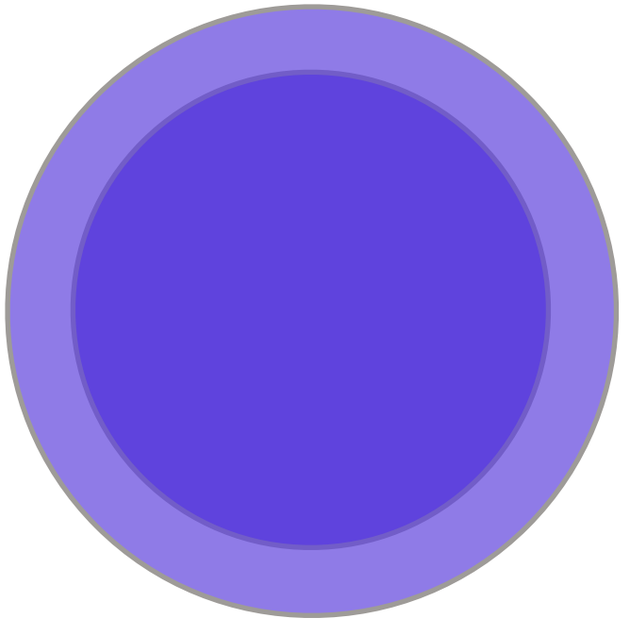

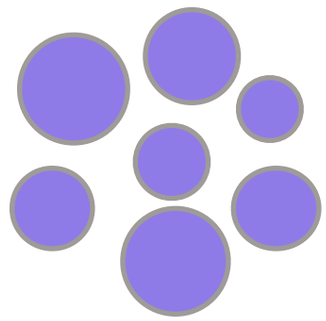

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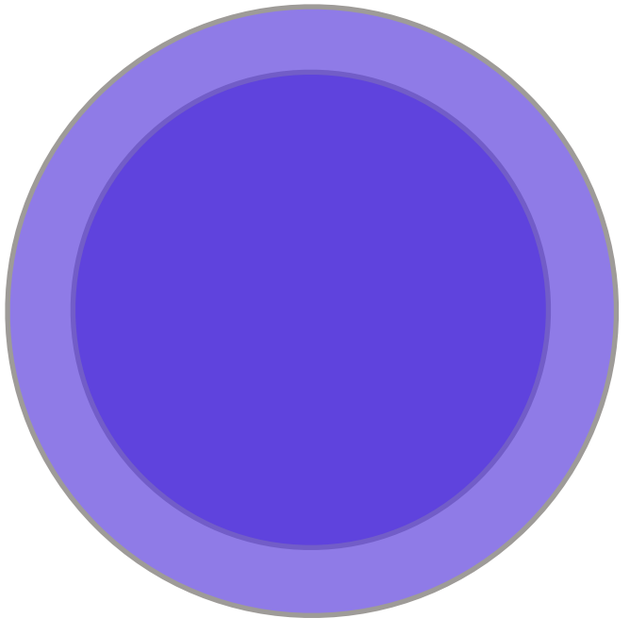

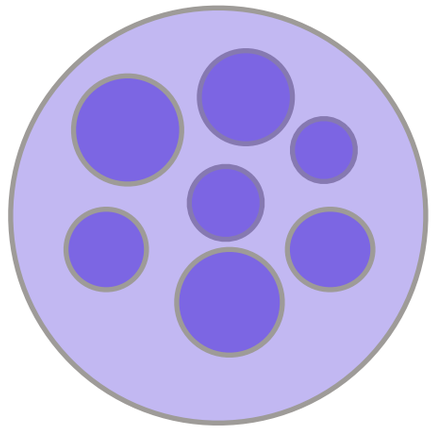

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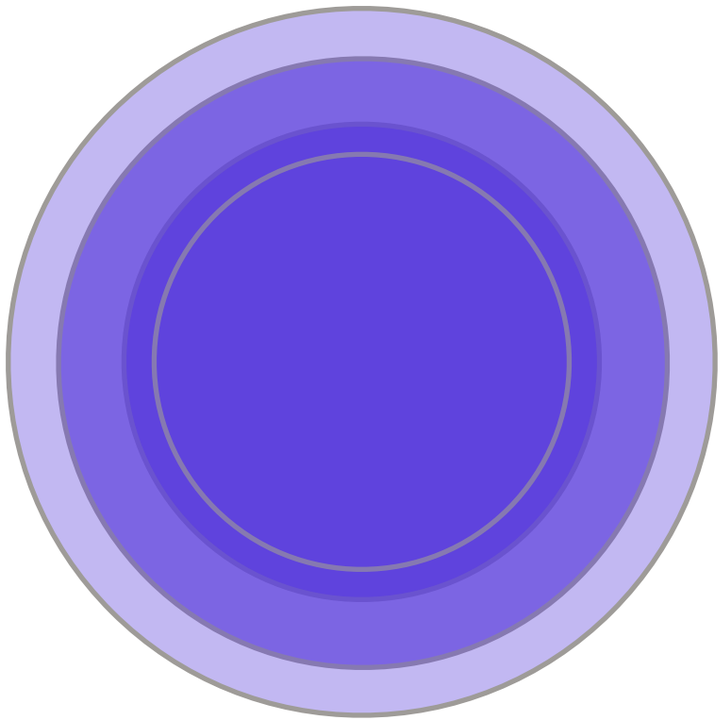
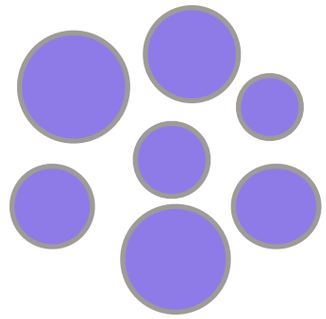


Justifications



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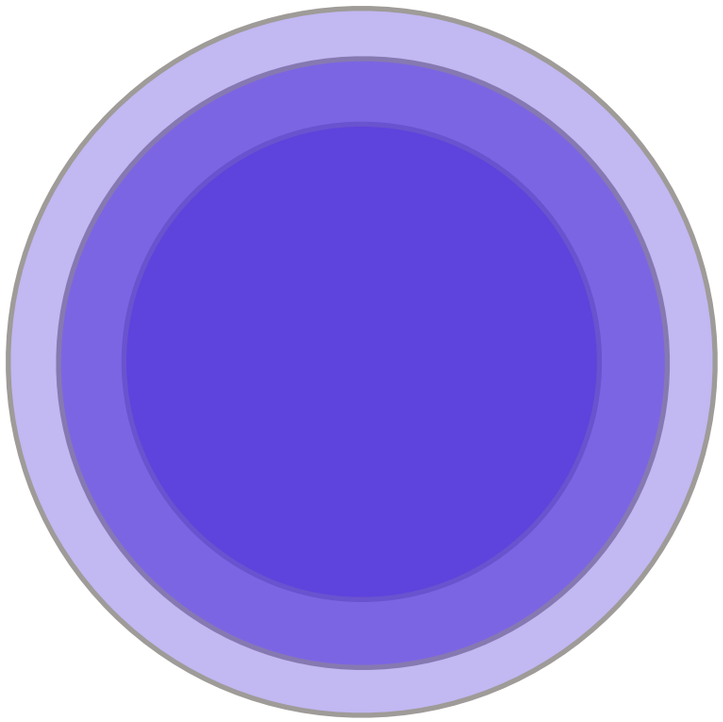

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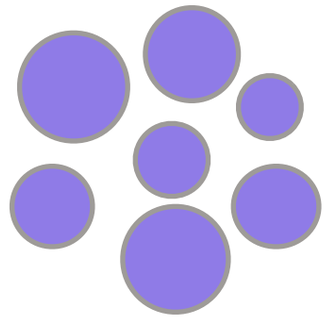

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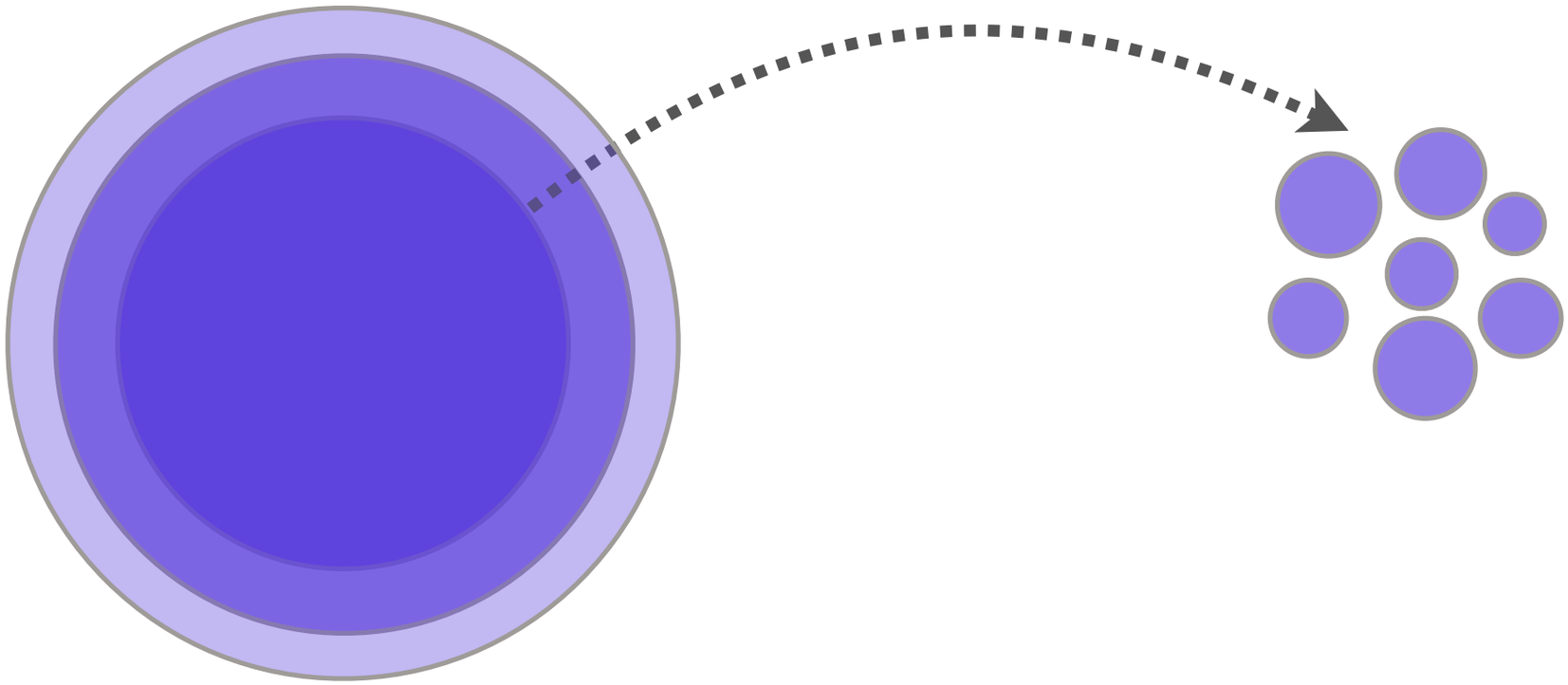

Empirical evaluation

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Experiments

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Experiments

Select ontologies:

Published Ontologies

Select entailments:

- Unsatisfiable classes
- Subsumptions between class names
- Equivalences between class names

Compute justifications:

- Regular Justifications
- Laconic Justifications

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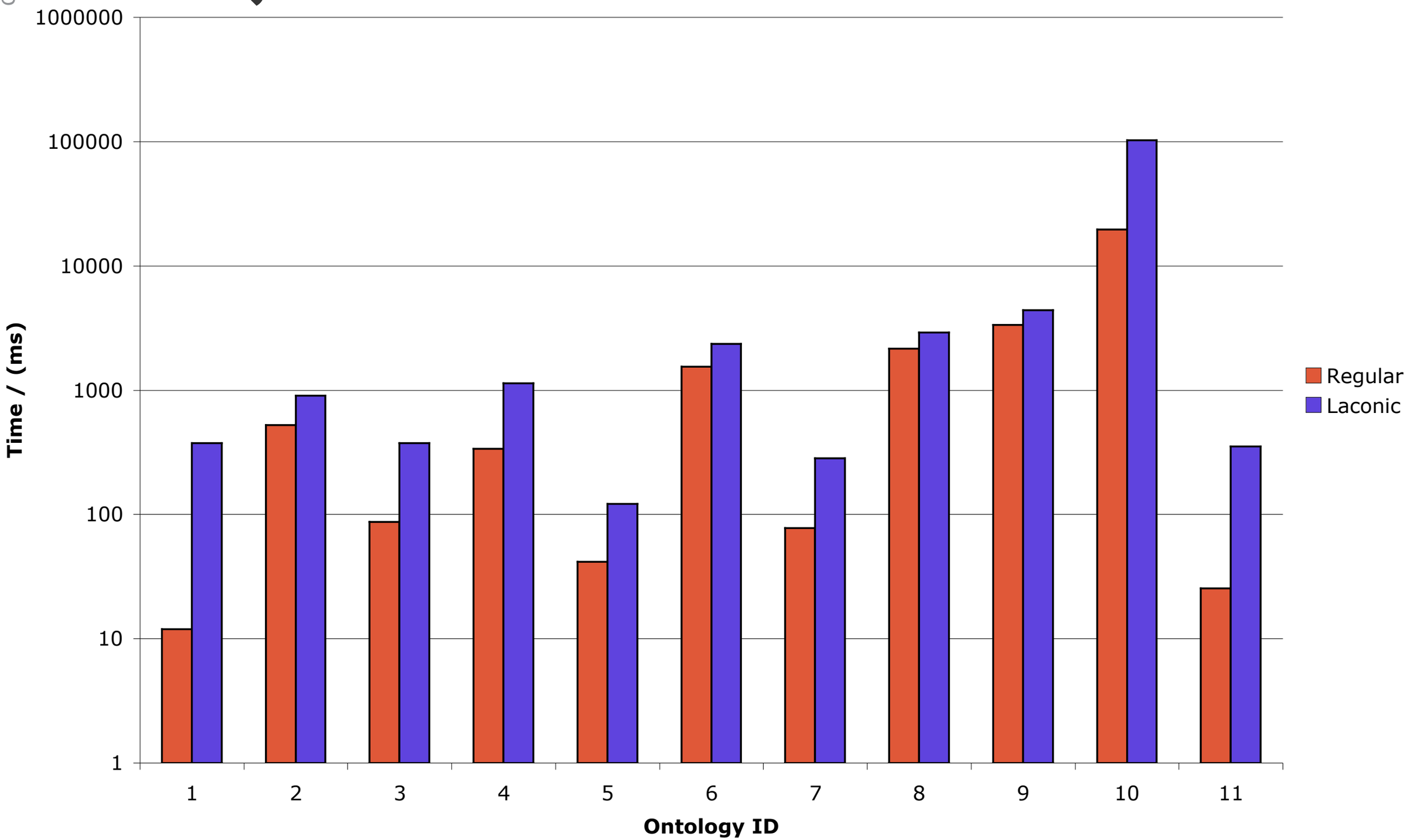
Mean times to compute all justifications of an entailment



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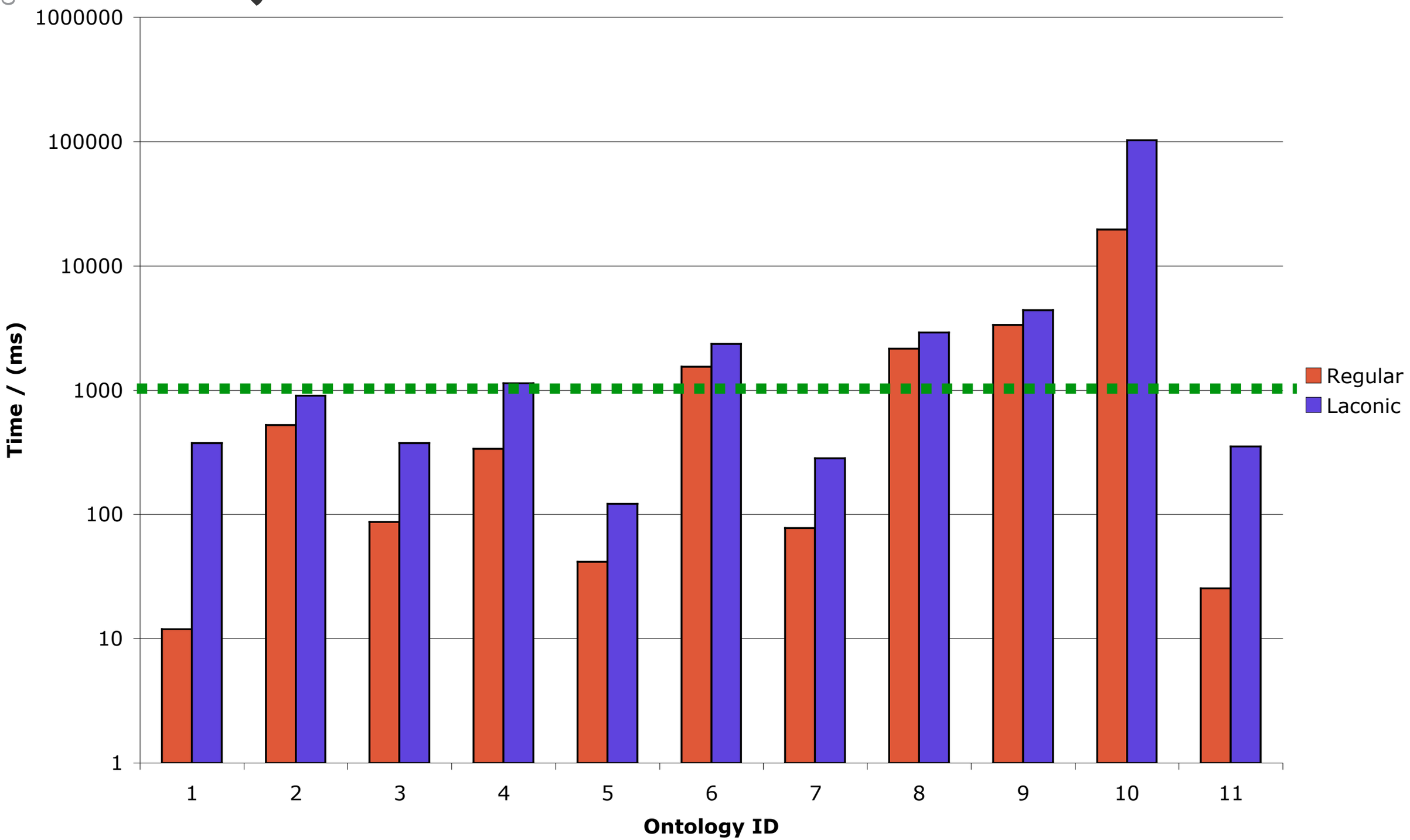
Mean times to compute all justifications of an entailment



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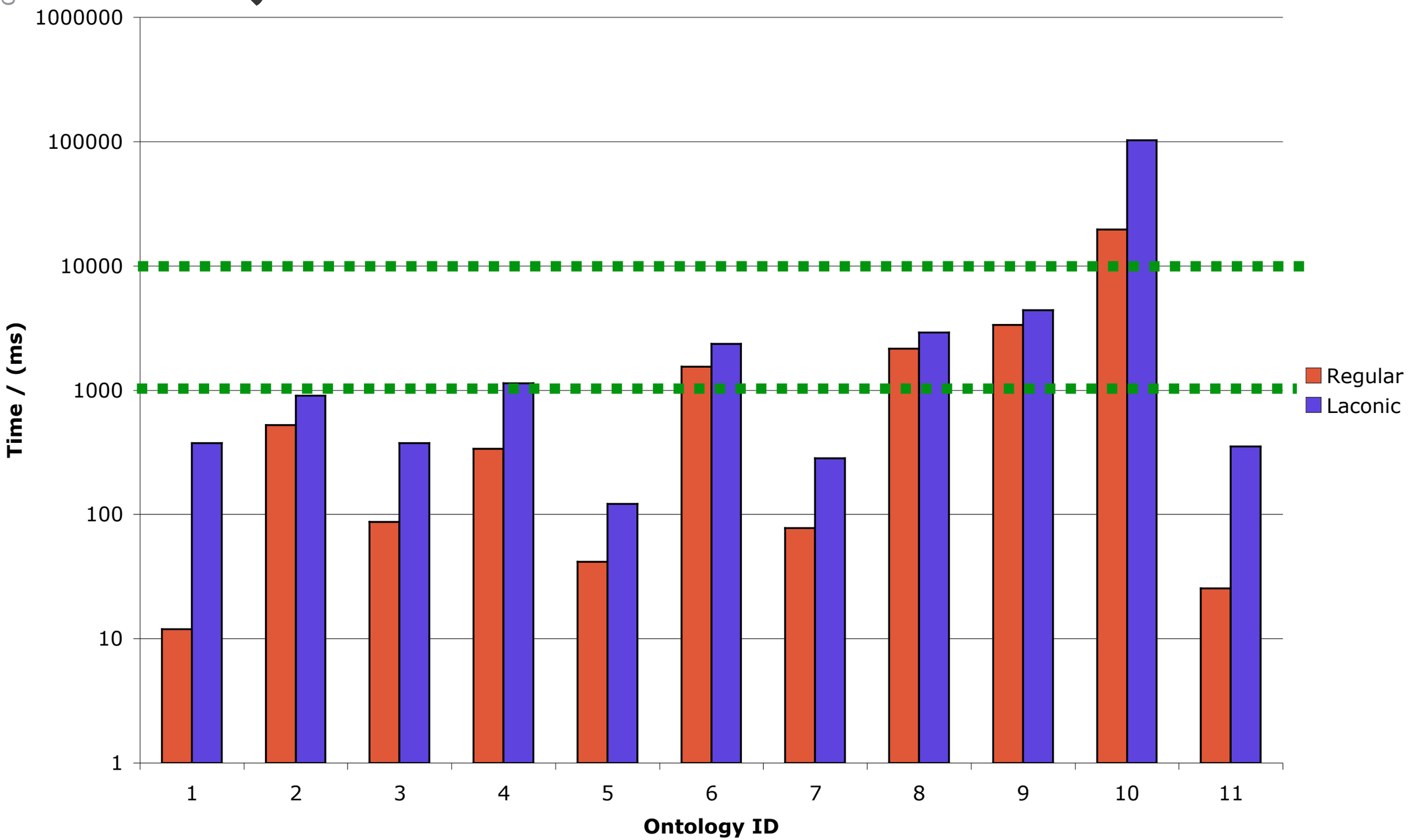
Mean times to compute all justifications of an entailment



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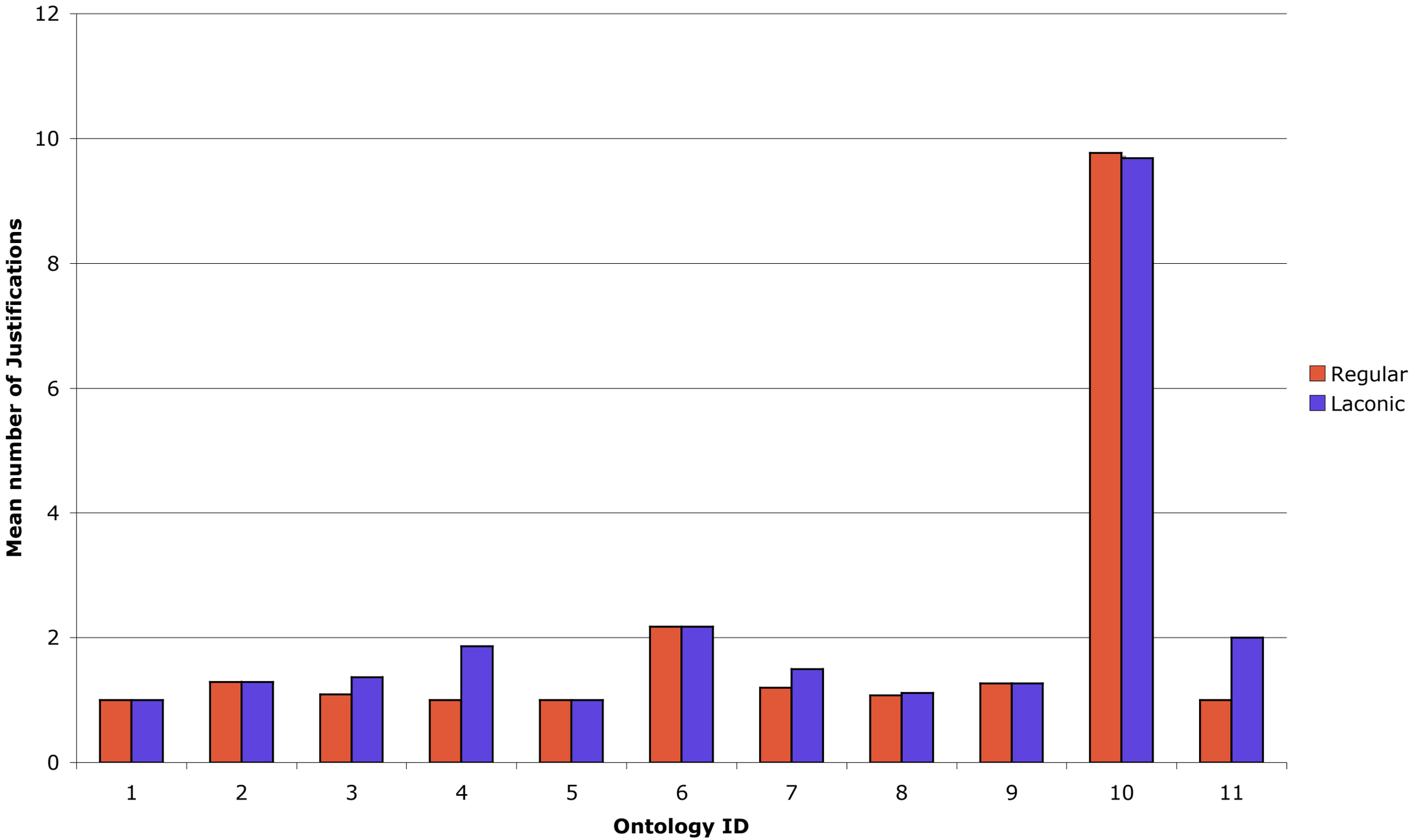
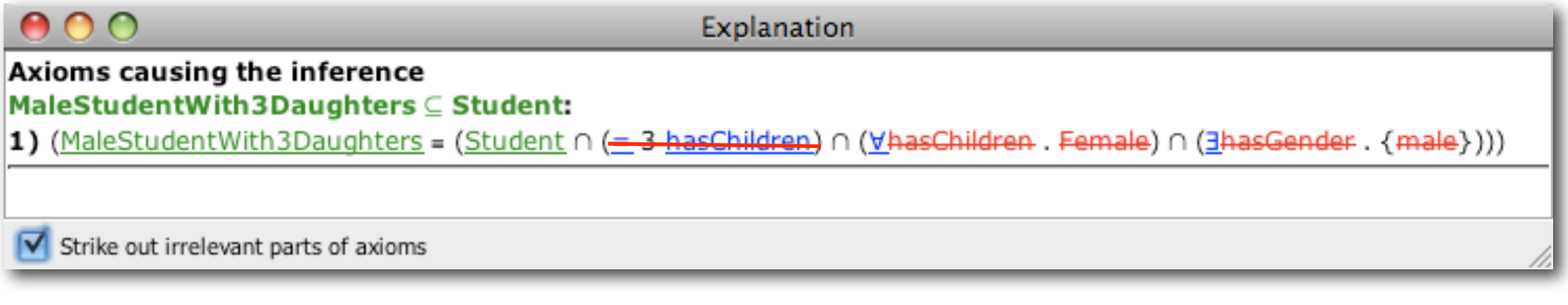
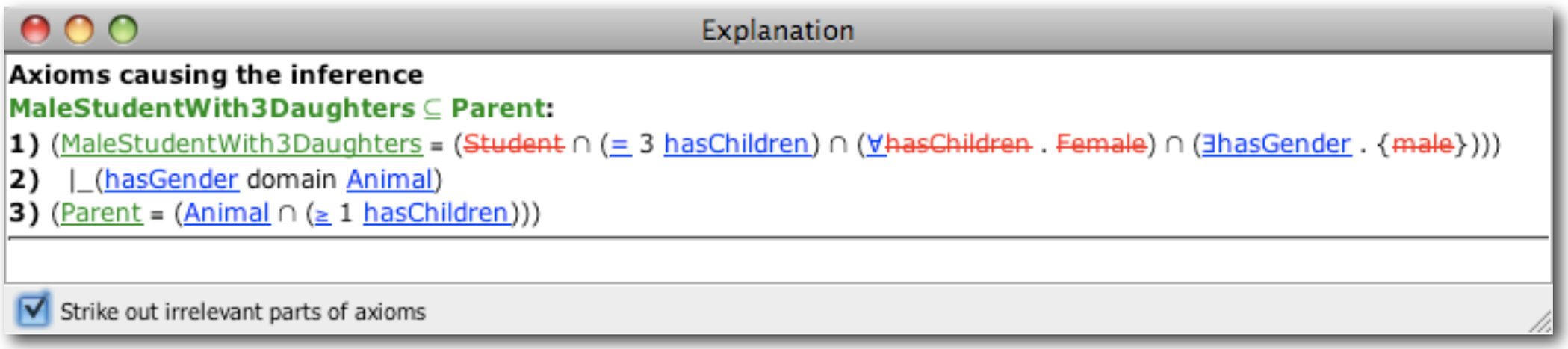
Mean Number of Regular Justifications vs. Mean Number of Laconic Justifications per Entailment



Results: superfluousness





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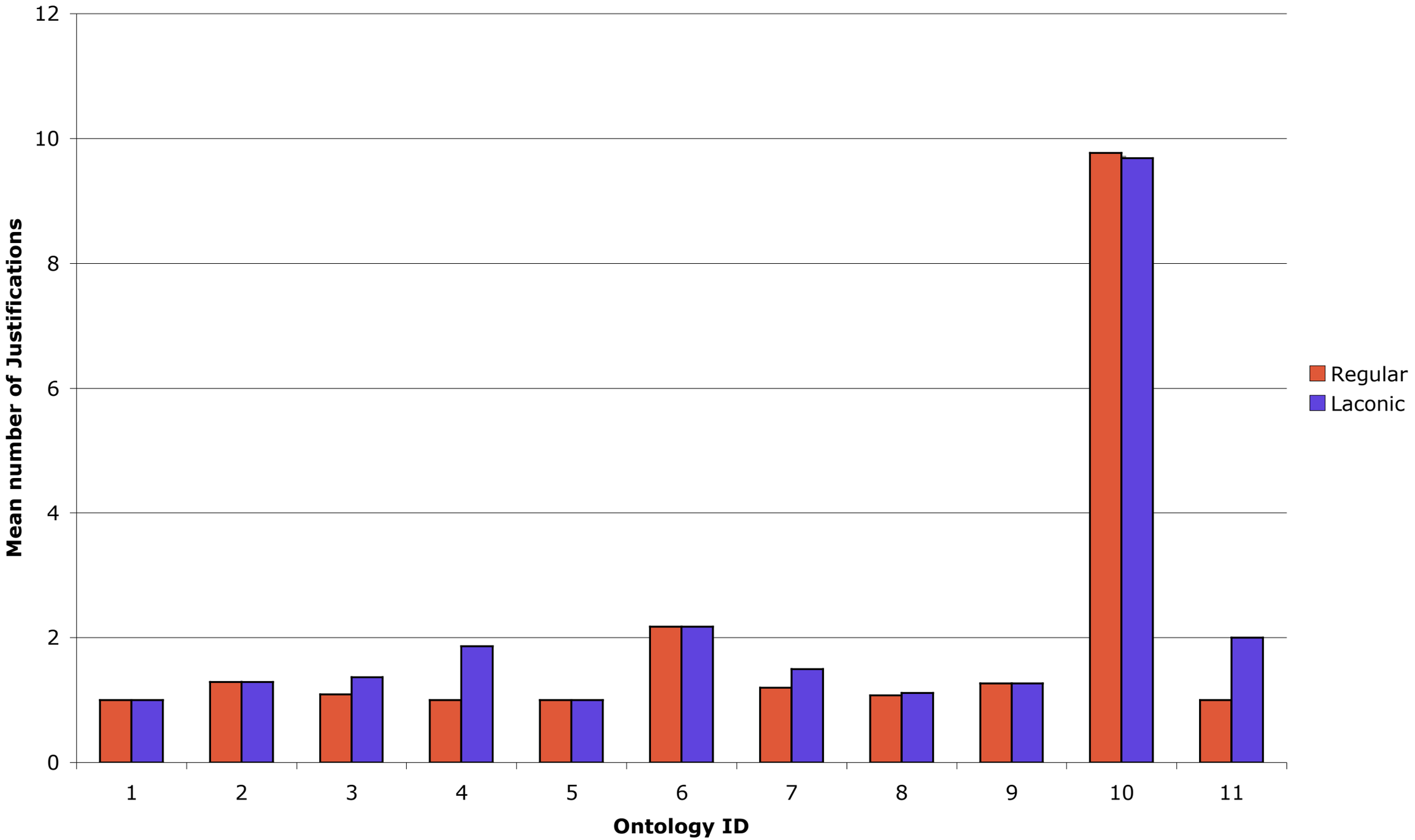

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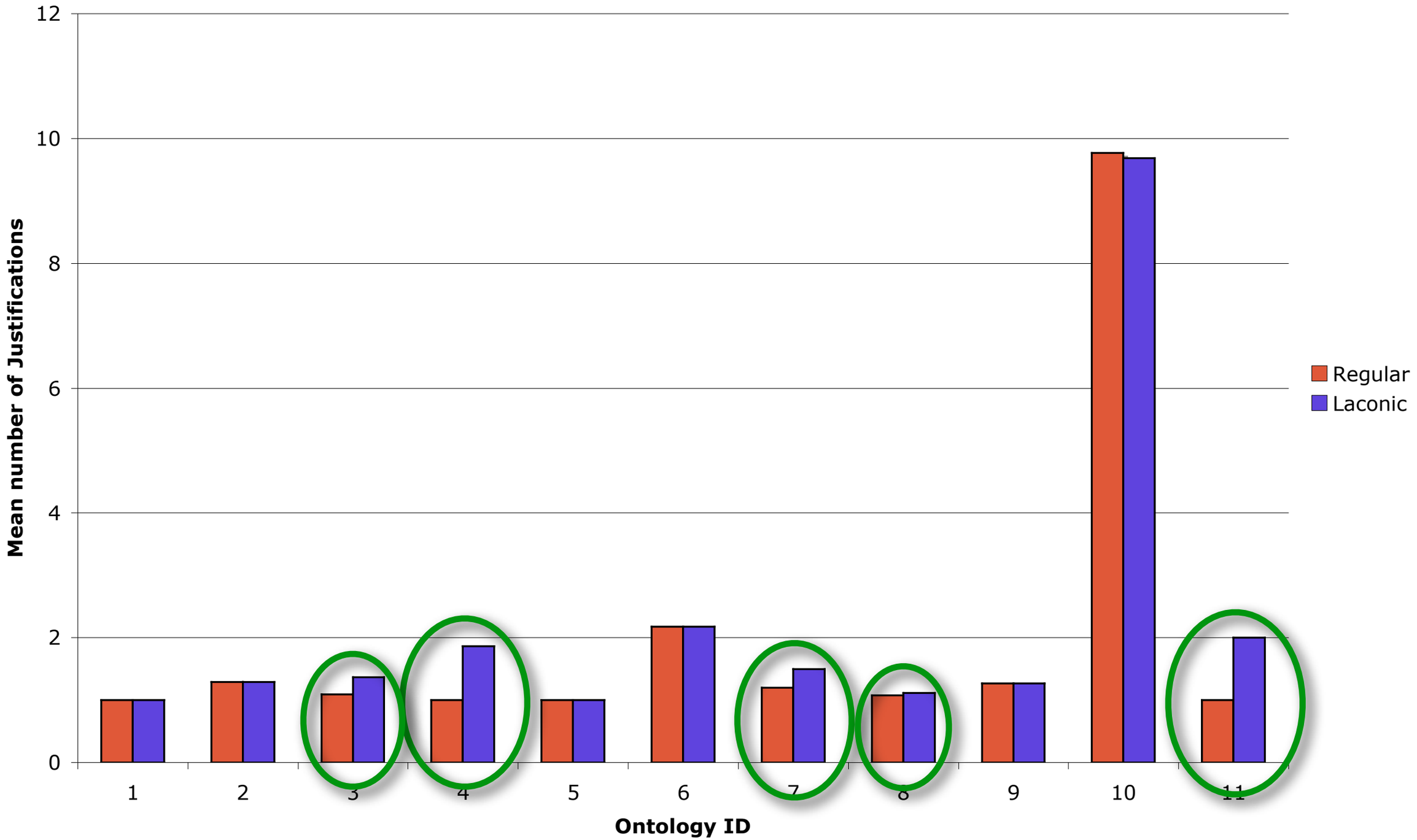

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Results: Masking

$\mathcal{O} \models \texttt{Quale} \sqsubseteq \texttt{Region}$

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Results: Masking

$$\mathcal{O} \models \texttt{Quale} \sqsubseteq \texttt{Region}$$

$$\texttt{Quale} \equiv \texttt{Region} \sqcap \exists \texttt{atomicPartOf}.\texttt{Region}$$

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Results: Masking

$$\mathcal{O} \models \texttt{Quale} \sqsubseteq \texttt{Region}$$

$$\texttt{Quale} \equiv \texttt{Region} \sqcap \exists \texttt{atomicPartOf}.\texttt{Region}$$

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Results: Masking

$$\mathcal{O} \models \texttt{Quale} \sqsubseteq \texttt{Region}$$

$$\texttt{Quale} \equiv \texttt{Region} \sqcap \exists \texttt{atomicPartOf}.\texttt{Region}$$

$$\texttt{Quale} \sqsubseteq \exists\, \texttt{atomicPartOf}.\texttt{Region}$$

$$\texttt{atomicPartOf} \sqsubseteq \texttt{partOf}$$

$$\texttt{partOf} \sqsubseteq \texttt{part}^{-}$$

$$\texttt{Region} \sqsubseteq \forall\, \texttt{part}.\texttt{Region}$$

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Results: Masking

$$\mathcal{O} \models \texttt{Quale} \sqsubseteq \texttt{Region}$$

$$\texttt{Quale} \equiv \texttt{Region} \sqcap \exists \texttt{atomicPartOf}.\texttt{Region}$$

$$\texttt{Quale} \sqsubseteq \exists\ \texttt{atomicPartOf}.\texttt{Region}$$

$$\texttt{atomicPartOf} \sqsubseteq \texttt{partOf}$$

$$\texttt{partOf} \sqsubseteq \texttt{part}^{-}$$

$$\texttt{Region} \sqsubseteq \forall\ \texttt{part}.\texttt{Region}$$

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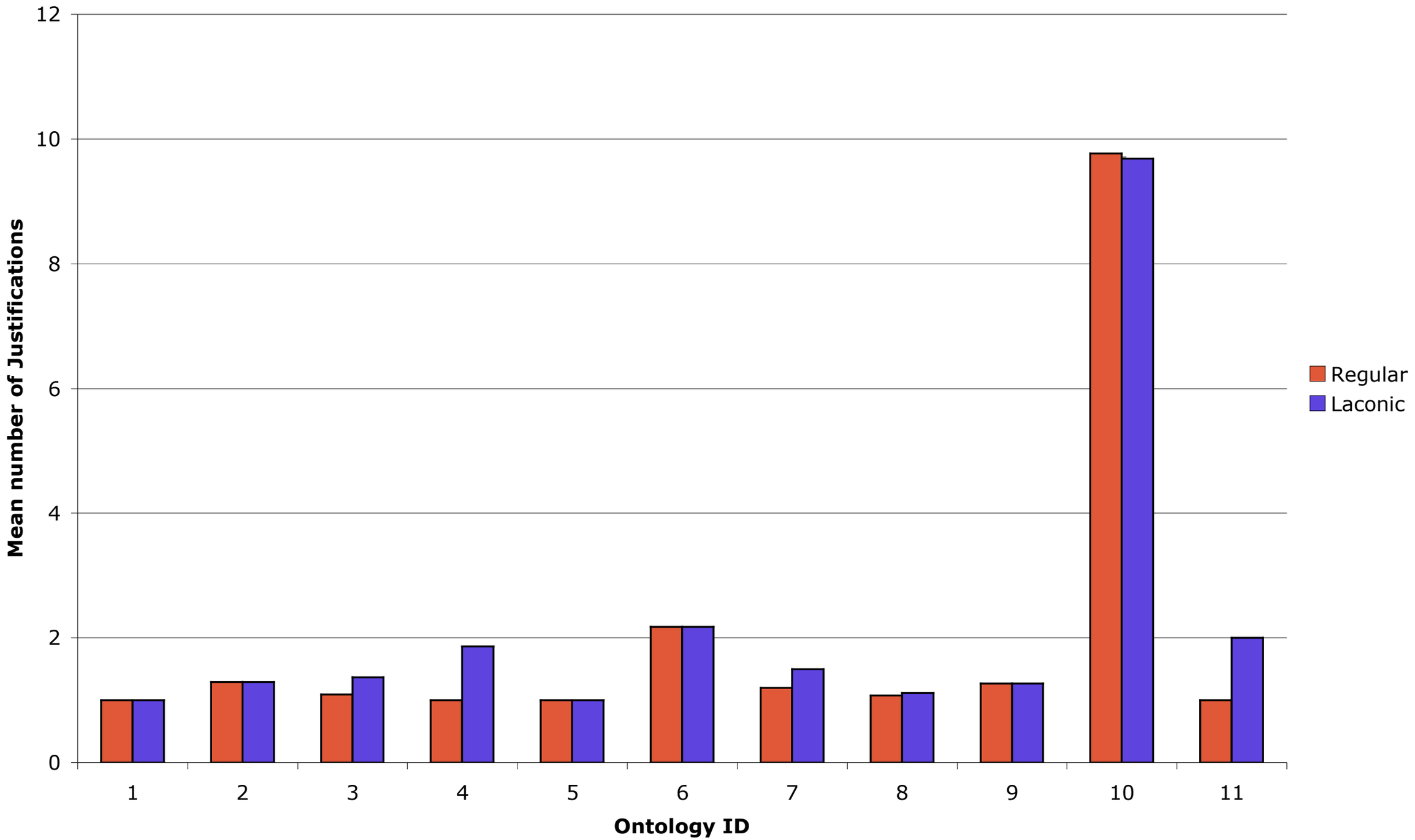
Mean Number of Regular Justifications vs. Mean Number of Laconic Justifications per Entailment



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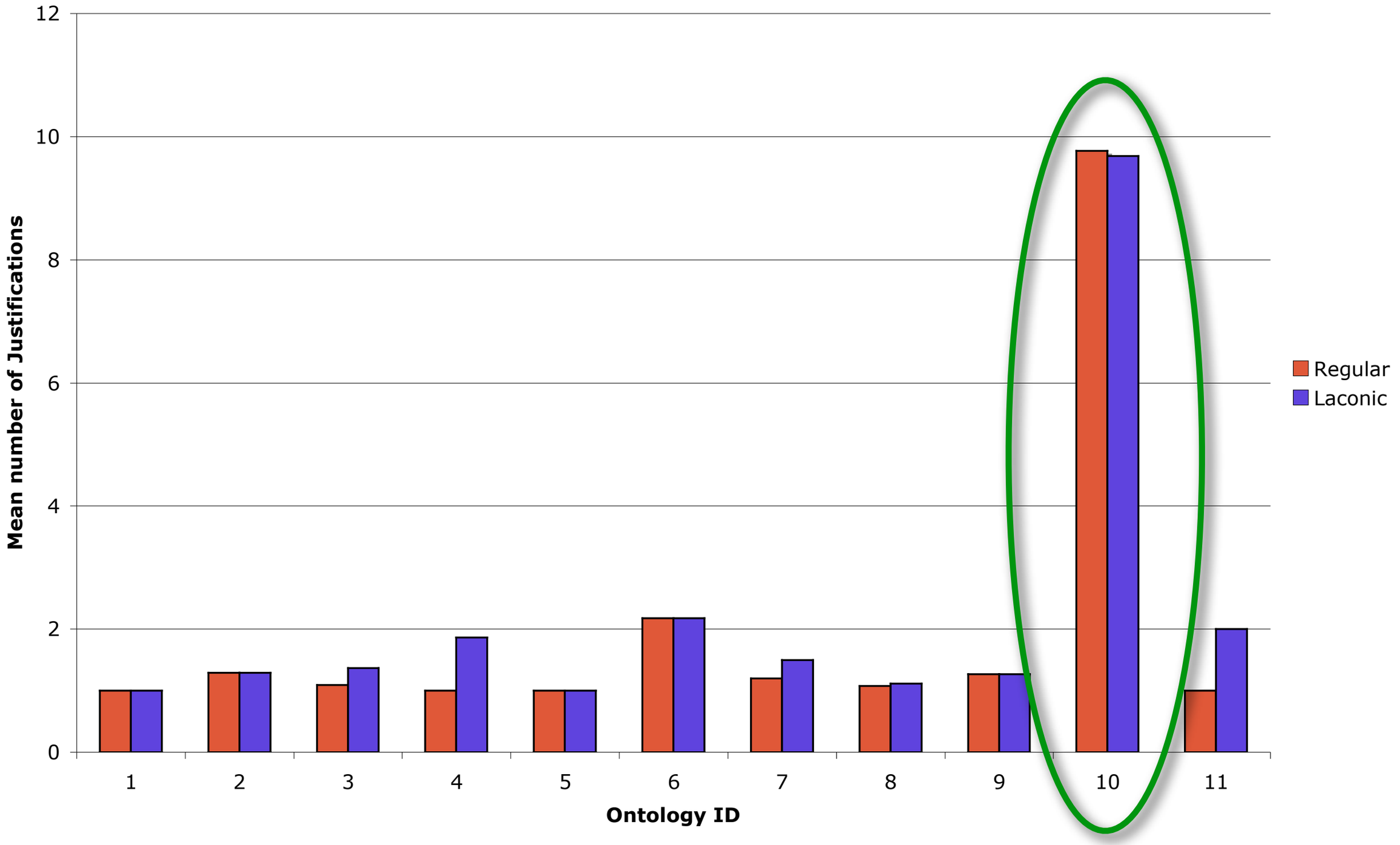

Results: shared cores

Show regular justifications ● All explanations
Show laconic justifications ○ Limit explanation to 2

Explanation 1 (Entailment 1) ☐ Display laconic explanation

	Group18Element subClassOf PeriodElement
1)	Group18Element equivalentTo Argon or Helium or Krypton or Neon or Radon or Xenon
2)	Period4Element equivalentTo Astatine or Bromine or Calcium or Chromium or Cobalt or Copper or Gallium or Iron or Krypton or
3)	Period4Element subClassOf PeriodElement
4)	Period6Element equivalentTo Astatine or Barium or Bismuth or Caesium or Gold or Hafnium or Iridium or Lanthanide or Lead or
5)	Period6Element subClassOf PeriodElement
6)	Period1Element equivalentTo Helium or Hydrogen
7)	Period1Element subClassOf PeriodElement
8)	Period3Element equivalentTo Aluminium or Argon or Chlorine or Magnesium or Phosphorus or Silicon or Sodium or Sulfur
9)	Period3Element subClassOf PeriodElement
10)	Period2Element equivalentTo Beryllium or Boron or Carbon or Fluorine or Lithium or Neon or Nitrogen or Oxygen
11)	Period2Element subClassOf PeriodElement
12)	Period5Element equivalentTo Antimony or Cadmium or Indium or Iodine or Molybdenum or Niobium or Palladium or Rhodium or R
13)	Period5Element subClassOf PeriodElement

Explanation 2 (Entailment 1) ☐ Display laconic explanation

	Group18Element subClassOf PeriodElement
1)	Group18Element equivalentTo Argon or Helium or Krypton or Neon or Radon or Xenon
2)	Period4Element equivalentTo Astatine or Bromine or Calcium or Chromium or Cobalt or Copper or Gallium or Iron or Krypton or
3)	Period6Element equivalentTo Astatine or Barium or Bismuth or Caesium or Gold or Hafnium or Iridium or Lanthanide or Lead or
4)	Period1Element equivalentTo Helium or Hydrogen
5)	Period5Element equivalentTo Antimony or Cadmium or Indium or Iodine or Molybdenum or Niobium or Palladium or Rhodium or R
6)	Period3Element equivalentTo Aluminium or Argon or Chlorine or Magnesium or Phosphorus or Silicon or Sodium or Sulfur
7)	Period2Element equivalentTo Beryllium or Boron or Carbon or Fluorine or Lithium or Neon or Nitrogen or Oxygen
8)	PeriodElement equivalentTo Period1Element or Period2Element or Period3Element or Period4Element or Period5Element or Period6El

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Results: shared cores

Show regular justifications All explanations
Show laconic justifications Limit explanation to 2

Explanation 1 (Entailment 1) Display laconic explanation

	Group18Element subClassOf PeriodElement
1)	Group18Element subClassOf Argon or Helium or Krypton or Neon or Radon or Xenon
2)	Helium subClassOf Period1Element
3)	Period1Element subClassOf PeriodElement
4)	Neon subClassOf Period2Element
5)	Period2Element subClassOf PeriodElement
6)	Argon subClassOf Period3Element
7)	Period3Element subClassOf PeriodElement
8)	Krypton subClassOf Period4Element
9)	Period4Element subClassOf PeriodElement
10)	Xenon subClassOf Period5Element
11)	Period5Element subClassOf PeriodElement
12)	Radon subClassOf Period6Element
13)	Period6Element subClassOf PeriodElement

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- ...

Discussion

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Laconic vs. Precise

	Laconic justifications	*Precise justifications*
contain ...	no superfluous parts	smallest possible axioms
are used ...	for presentation services	for minimal removal
	to strike out irrelevant parts	

Problems—Presentation

Get Axiom Explanations

Axiom: AmericanHot **subClassOf** SpicyPizza

Explanations (5):

1) SpicyTopping **equivalentClass** ((hasSpiciness **some** Hot) **and** PizzaTopping)
hasTopping **inverseOf** isToppingOf
SpicyPizza **equivalentClass** ((hasTopping **some** SpicyTopping) **and** Pizza)
NamedPizza **subClassOf** Pizza
isToppingOf **domain** PizzaTopping
AmericanHot **subClassOf** NamedPizza
JalapenoPepperTopping **subClassOf** (hasSpiciness **some** Hot)
AmericanHot **subClassOf** (hasTopping **some** JalapenoPepperTopping)

Explanation: Explanations for: AmericanHot subClassOf CheeseyPizza

Explanation 1

- MozzarellaTopping subClassOf CheeseTopping
- CheeseyPizza equivalentTo Pizza and hasTopping some CheeseTopping
- Pizza domainOf hasTopping
- AmericanHot subClassOf hasTopping some MozzarellaTopping

Problems—Presentation

Get Axiom Explanations

Axiom: AmericanHot **subClassOf** SpicyPizza

Explanations (5):

1) SpicyTopping **equivalentClass** ((hasSpiciness **some** Hot) **and** PizzaTopping)
hasTopping **inverseOf** isToppingOf

Axioms causing the inference
alpha-helix = owl:Nothing:
1) (alpha-helix ⊆ protein-secondary-structure)
2) |_(protein-secondary-structure ⊆ protein-structure)
3) |_(protein-structure = (biological-structure ∩ (∀structure-of . macromolecular-compound) ∩ (∃structure-of . macromolecular-compound)))
4) |_(macromolecular-compound = ((∃has-length . residue-number) ∩ (∀polymer-of . small-organic-molecular-compound) ∩ (= 1 has-molecular-weight) ∩ (molecule ∩ compound) ∩ (= 1 has-length) ∩ (∃polymer-of . small-organic-molecular-compound) ∩ (∃has-molecular-weight . xsd:integer)))
5) |_(small-organic-molecular-compound ⊆ (organic-molecular-compound ∩ small-molecular-compound))
6) |_(organic-molecular-compound ⊆ (∃contains . carbon))
7) |_(carbon = ((= 1 atomic-number) ∩ (∃atomic-number . xsd:integer) ∩ chemical))
8) (nonmetal ⊆ ¬ metal)
9) |_(metal = ((= 1 atomic-number) ∩ (∃atomic-number . xsd:integer) ∩ chemical))
10) (nonmetal = ((= 1 atomic-number) ∩ (∃atomic-number . xsd:integer) ∩ chemical))

MozzarellaTopping **subClassOf** CheeseTopping
CheeseyPizza **equivalentTo** Pizza **and** hasTopping **some** CheeseTopping
Pizza **domainOf** hasTopping
AmericanHot **subClassOf** hasTopping **some** MozzarellaTopping

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Problems—Presentation

- Explanations pinpoint the axioms responsible for a given entailment — but are still difficult for users to understand.
- Typically, explanations presented as lists of axioms
- Even experts struggle to understand these explanations
  ~> What chance do normal people stand?
- Goal: make developing ontologies easier
  ~> Need to focus on usability issues

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Problems—Presentation

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Problems—Presentation

What visual enhancements are required to make explanations easier to understand?

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Problems—Presentation

What visual enhancements are required to make explanations easier to understand?

Are visual enhancements enough or are axiom rewrites necessary?

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Problems—Presentation

- Visual enhancements
  - Simple: colour, highlighting, indentation, ordering
  - More complex: e.g. syntax used for explanations—CNL?
- Not clear that these visual enhancements are enough
- General feeling: users ...
  - ... don't want their axioms touched
  - ... want to see original axioms in their explanations
- This should shift slightly towards automatic lemma generation / proof steps — tomorrow!

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Syntax sensitivity

- Ignore syntactical structure ~> users get confused
- Which language used?
  - DL ~> provides easy-to-recognise patterns
  - Manchester syntax ~> “human-readable”

Entailments versus non-entailments

- Sometimes we'd like to know why our ontology does not have a certain entailment.
- Model-based explanation, hopefully on Friday

Tool demo:
Explanation Workbench

Explanation workbench

Entailments

Entailment	No. Justi...
AIStudent	1
AssistantProfessor	1
CS_Department	1
HCIStudent	1
Lecturer	1
AI_Dept	1
CS_Course	1
CS_StudentTakingCourses	1
LecturerTaking4Courses	3

Regular justifications
Laconic justifications
Show all explanations
Explanation limit: 2

1 – AIStudent subClassOf Nothing Display laconic explanation

	AIStudent subClassOf Nothing		
1)	AIStudent subClassOf hasAdvisor some ProfessorInHCIorAI	1	
2)	advisorOf inverseOf hasAdvisor	2	
3)	ProfessorInHCIorAI subClassOf advisorOf only HCIStudent	1	
4)	AIStudent disjointWith HCIStudent	2	

1 – HCIStudent subClassOf Nothing Display laconic explanation

	HCIStudent subClassOf Nothing		
1)	HCIStudent subClassOf hasAdvisor some ProfessorInHCIorAI	1	
2)	advisorOf inverseOf hasAdvisor	2	
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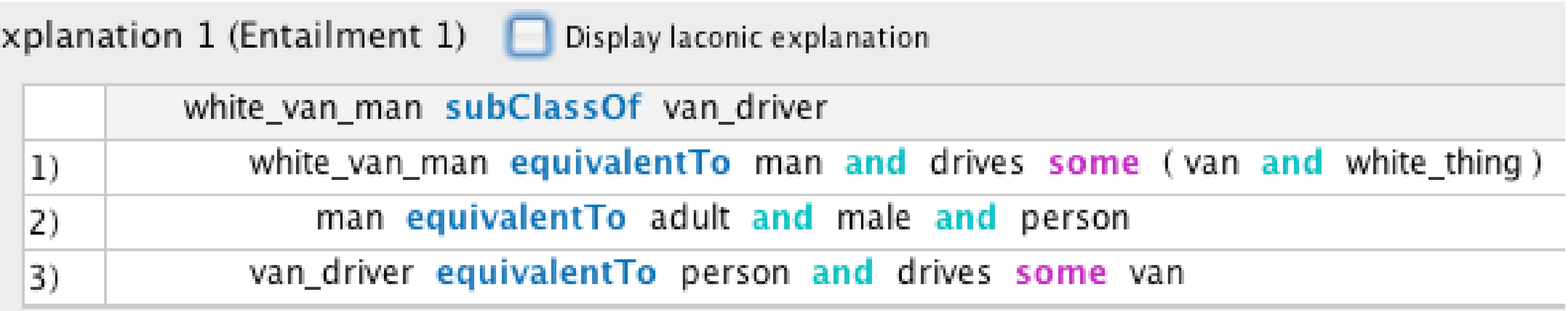
Laconic Justifications



Laconic Justifications

xplanation 1 (Entailment 1) ☐ Display laconic explanation

	white_van_man subClassOf van_driver
1)	white_van_man equivalentTo man and drives some (van and white_thing)
2)	man equivalentTo adult and male and person
3)	van_driver equivalentTo person and drives some van

Explanation 1 (Entailment 1) ☑ Display laconic explanation

	white_van_man subClassOf van_driver
1)	white_van_man subClassOf man and drives some van
2)	man subClassOf person
3)	person and drives some van subClassOf van_driver

Explanation workbench

Entailments

Entailment	No. Justi...
AIStudent	1
AssistantProfessor	1
CS_Department	1
HCIStudent	1
Lecturer	1
AI_Dept	1
CS_Course	1
CS_StudentTakingCourses	1
LecturerTaking4Courses	3

Regular justifications
Laconic justifications
Show all explanations
Explanation limit: 2

1 – AssistantProfessor subClassOf Nothing
Display laconic explanation

	AssistantProfessor subClassOf Nothing		
1)	AssistantProfessor equivalentTo TeachingFaculty and hasTenure value false	1	
2)	AssistantProfessor disjointWith Lecturer	1	
3)	Lecturer equivalentTo TeachingFaculty and hasTenure value false	1	

Explanation workbench

Entailments

Entailment	No. Justi...
AIStudent	1
AssistantProfessor	4
CS_Department	1
HCIStudent	1
Lecturer	4
AI_Dept	1
CS_Course	1
CS_StudentTakingCourses	1
LecturerTaking4Courses	6

Regular justifications
Laconic justifications
Show all explanations
Explanation limit: 2

1 – AssistantProfessor subClassOf Nothing Display laconic explanation

	AssistantProfessor subClassOf Nothing		
1)	AssistantProfessor subClassOf hasTenure value false	1	
2)	hasTenure domain TeachingFaculty	2	
3)	TeachingFaculty and hasTenure value false subClassOf Lecturer	4	
4)	AssistantProfessor disjointWith Lecturer	4	

2 – AssistantProfessor subClassOf Nothing Display laconic explanation

	AssistantProfessor subClassOf Nothing		
1)	AssistantProfessor subClassOf hasTenure some Literal	1	
2)	hasTenure domain TeachingFaculty	2	
3)	hasTenure range boolean	2	
4)	TeachingFaculty and hasTenure value true subClassOf Professor	2	
5)	AssistantProfessor disjointWith Professor	2	
6)	TeachingFaculty and hasTenure value false subClassOf Lecturer	4	
7)	AssistantProfessor disjointWith Lecturer	4	

3 – AssistantProfessor subClassOf Nothing Display laconic explanation

	AssistantProfessor subClassOf Nothing		
1)	AssistantProfessor subClassOf TeachingFaculty and hasTenure value false	1	
2)	TeachingFaculty and hasTenure value false subClassOf Lecturer	4	
3)	AssistantProfessor disjointWith Lecturer	4	

4 – AssistantProfessor subClassOf Nothing Display laconic explanation

	AssistantProfessor subClassOf Nothing		
1)	AssistantProfessor subClassOf TeachingFaculty and hasTenure some Literal	1	
2)	hasTenure range boolean	2	
3)	TeachingFaculty and hasTenure value true subClassOf Professor	2	
4)	AssistantProfessor disjointWith Professor	2	
5)	TeachingFaculty and hasTenure value false subClassOf Lecturer	4	
6)	AssistantProfessor disjointWith Lecturer	4	

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Show regular justifications All explanations
Show laconic justifications Limit explanation to
2

Explanation 1 (Entailment 1) Display laconic explanation

	Group18Element subClassOf PeriodElement
1)	Group18Element equivalentTo Argon or Helium or Krypton or Neon or Radon or Xenon
2)	Period4Element equivalentTo Astatine or Bromine or Calcium or Chromium or Cobalt or Copper or Gallium or Iron or Krypton or
3)	Period4Element subClassOf PeriodElement
4)	Period6Element equivalentTo Astatine or Barium or Bismuth or Caesium or Gold or Hafnium or Iridium or Lanthanide or Lead or
5)	Period6Element subClassOf PeriodElement
6)	Period1Element equivalentTo Helium or Hydrogen
7)	Period1Element subClassOf PeriodElement
8)	Period3Element equivalentTo Aluminium or Argon or Chlorine or Magnesium or Phosphorus or Silicon or Sodium or Sulfur
9)	Period3Element subClassOf PeriodElement
10)	Period2Element equivalentTo Beryllium or Boron or Carbon or Fluorine or Lithium or Neon or Nitrogen or Oxygen
11)	Period2Element subClassOf PeriodElement
12)	Period5Element equivalentTo Antimony or Cadmium or Indium or Iodine or Molybdenum or Niobium or Palladium or Rhodium or R
13)	Period5Element subClassOf PeriodElement

Explanation 2 (Entailment 1) Display laconic explanation

	Group18Element subClassOf PeriodElement
1)	Group18Element equivalentTo Argon or Helium or Krypton or Neon or Radon or Xenon
2)	Period4Element equivalentTo Astatine or Bromine or Calcium or Chromium or Cobalt or Copper or Gallium or Iron or Krypton or
3)	Period6Element equivalentTo Astatine or Barium or Bismuth or Caesium or Gold or Hafnium or Iridium or Lanthanide or Lead or
4)	Period1Element equivalentTo Helium or Hydrogen
5)	Period5Element equivalentTo Antimony or Cadmium or Indium or Iodine or Molybdenum or Niobium or Palladium or Rhodium or R
6)	Period3Element equivalentTo Aluminium or Argon or Chlorine or Magnesium or Phosphorus or Silicon or Sodium or Sulfur
7)	Period2Element equivalentTo Beryllium or Boron or Carbon or Fluorine or Lithium or Neon or Nitrogen or Oxygen
8)	PeriodElement equivalentTo Period1Element or Period2Element or Period3Element or Period4Element or Period5Element or Period6El

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Show regular justifications ○ All explanations ●
Show laconic justifications ● Limit explanation to ○
2

Explanation 1 (Entailment 1) ☐ Display laconic explanation

	Group18Element **subClassOf** PeriodElement
1)	Group18Element **subClassOf** Argon **or** Helium **or** Krypton **or** Neon **or** Radon **or** Xenon
2)	Helium **subClassOf** Period1Element
3)	Period1Element **subClassOf** PeriodElement
4)	Neon **subClassOf** Period2Element
5)	Period2Element **subClassOf** PeriodElement
6)	Argon **subClassOf** Period3Element
7)	Period3Element **subClassOf** PeriodElement
8)	Krypton **subClassOf** Period4Element
9)	Period4Element **subClassOf** PeriodElement
10)	Xenon **subClassOf** Period5Element
11)	Period5Element **subClassOf** PeriodElement
12)	Radon **subClassOf** Period6Element
13)	Period6Element **subClassOf** PeriodElement

Beyond Justifications

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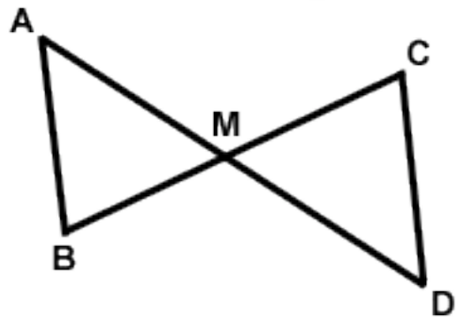
Understanding

- Given a proposition:



  Triangles ABM and DCM are congruent.

- Is it sufficient to know the premises?

  Segment AD bisects segment BC.
  Segment BC bisects segment AD.

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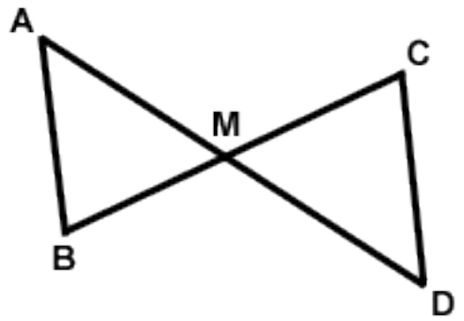
Understanding

- Given a proposition:



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  Segment BC bisects segment AD.

We want more!

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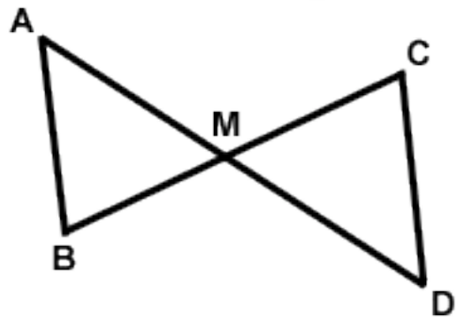
Understanding

- Given a proposition:



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We want more!

Perhaps… some *proof*

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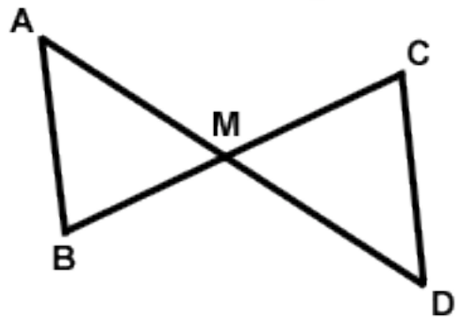
Understanding

- Given a proposition:



Triangles ABM and DCM are congruent.

- Is it sufficient to know the premises?

Segment AD bisects segment BC.
Segment BC bisects segment AD.

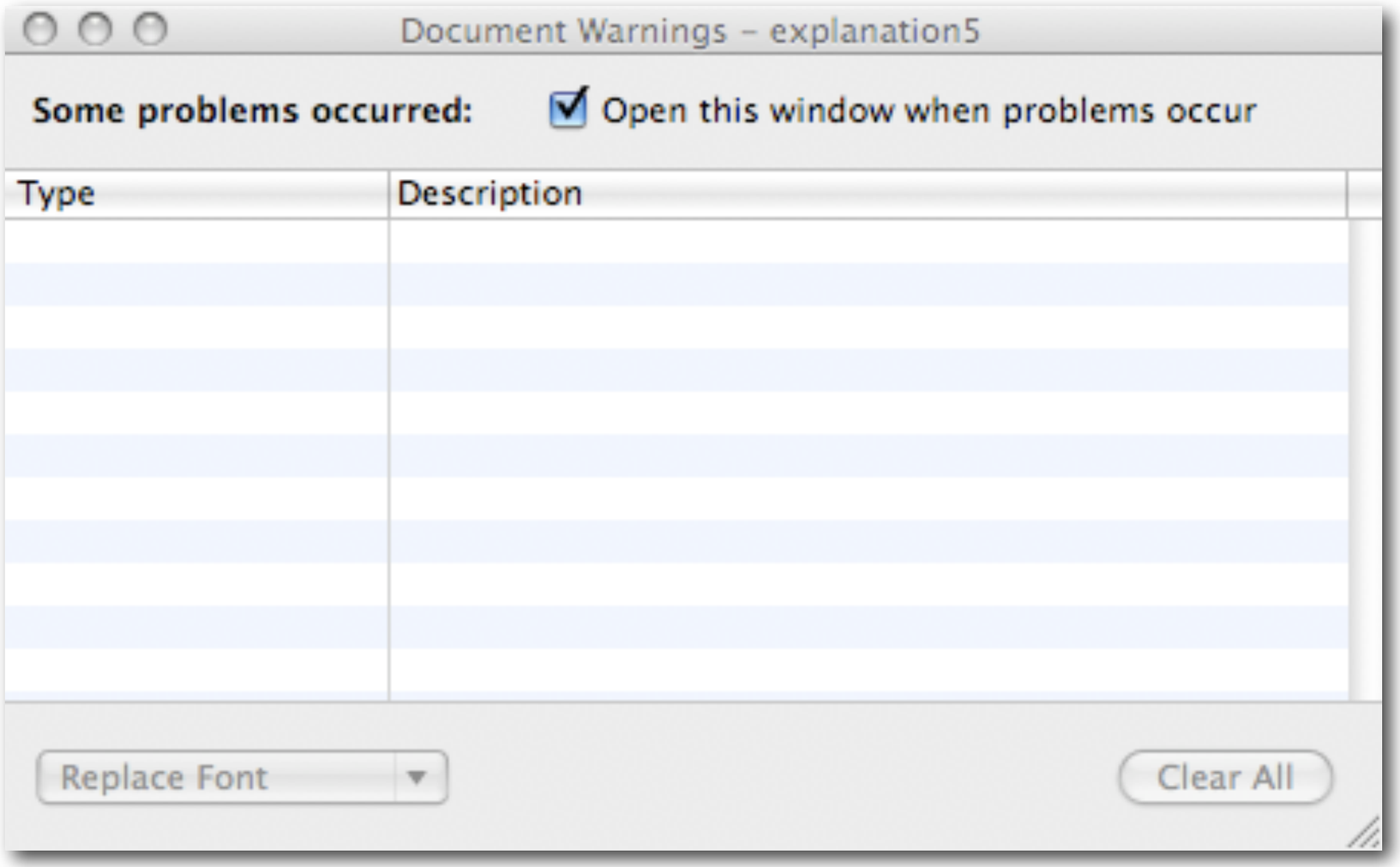
We want more!

Statements	Reasons
1. Segment AD bisects segment BC.	1. Given.
2. Segments AM and MD are congruent.	2. When a segment is bisected, the two resulting segments are congruent.
3. Segment BC bisects segment AD.	3. Given.
4. Segments BM and CM are congruent.	4. When a segment is bisected, the two resulting segments are congruent.
5. Angles AMB and DMC are congruent.	5. Vertical angles are congruent.
6. Triangles ABM and DCM are congruent.	6. SAS postulate (2, 4, 5).

Perhaps… some *proof*

As an aside ...

This is *not* what we want:



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Proofs?

- Proof theory in (automated) reasoning
  - Basis for algorithms
  - How we find entailments
- Proof theory for explanation
  - Proofs explicate the relationship between the premises (justification) and the conclusion
  - Each step is "obvious" and "immediate"
    - Relative to the proof theory!?
    - Relative to the task or circumstances?

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Immediacy & Obviousness?

- Immediacy
  - The direct application of a rule
    - Pure pattern match
- Obviousness: two senses
  - Obvious thus unnecessary
  - Obvious thus understandable

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Interactive case
Proofs are the point

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Immediacy & Obviousness?

- Immediacy
  - The direct application of a rule
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Interactive case
Proofs are the point

Ontology case?

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Immediacy & Obviousness?

- Immediacy
  - The direct application of a rule
    - Pure pattern match
- Obviousness: two senses
  - Obvious thus unnecessary
  - Obvious thus understandable

Steps vs. Flow (or "gist")

Interactive case
Proofs are the point

Ontology case?

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Proofs for Understanding?

- Hypothesis
  - Understanding PT $\Rightarrow$ understanding every step
  - Understanding every step IS understanding the proof
    - Understanding the proof $\Rightarrow$ understanding how the premises support the conclusion
      - $\Rightarrow$ understanding the entailment
- Thus, proofs are necessary for explanation
  - The articulation of the steps explain

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A Nice Story

- Proofs explain (and explain in the best way)
- Proofs are free (reasoners generate them)
- Dump the proofs from the reasoners!
  - (Teach people the proof theory)
  - (Offer some tools to help browse them)

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A Nice Story

- Proofs explain (and explain in the best way)
- Proofs are free (reasoners generate them)
- Dump the proofs from the reasoners!
  - (Teach people the proof theory)
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What's wrong with this story?

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$$\top \sqcap \neg((\exists \texttt{child}.\neg\texttt{Doctor}) \sqcup (\exists \texttt{child}.\texttt{Lawyer})) \sqsubseteq \forall \texttt{child}.(\texttt{Rich} \sqcup \texttt{Doctor})$$

This step can be explained as: *In order to check that the combination of an $\exists R.A$ concept and an $\forall R.B$ is subsumed by an $\exists R.C$ concept, we can check whether the conjunction of A and B is subsumed by C.* This step is clearly more complex than the proceeding ones, and some users may require a more detailed explanation, possibly utilising the fact that from the conjunction of $\exists R.A$ and $\forall R.B$ we can derive $\exists R.(A \sqcap B)$; such detail is, however, beyond the scope of this document.

Then, by applying the $(l\neg\vee)$ rule, we obtain the following judgement:

$$\top \sqcap \neg(\exists \texttt{child}.\neg\texttt{Doctor}) \sqcap \neg(\exists \texttt{child}.\texttt{Lawyer}) \sqsubseteq \forall \texttt{child}.(\texttt{Rich} \sqcup \texttt{Doctor})$$

This step can be explained as: *Applying de Morgan's laws, we propagate negation inward.*. An explanation of de Morgan's laws would of course be available if required.

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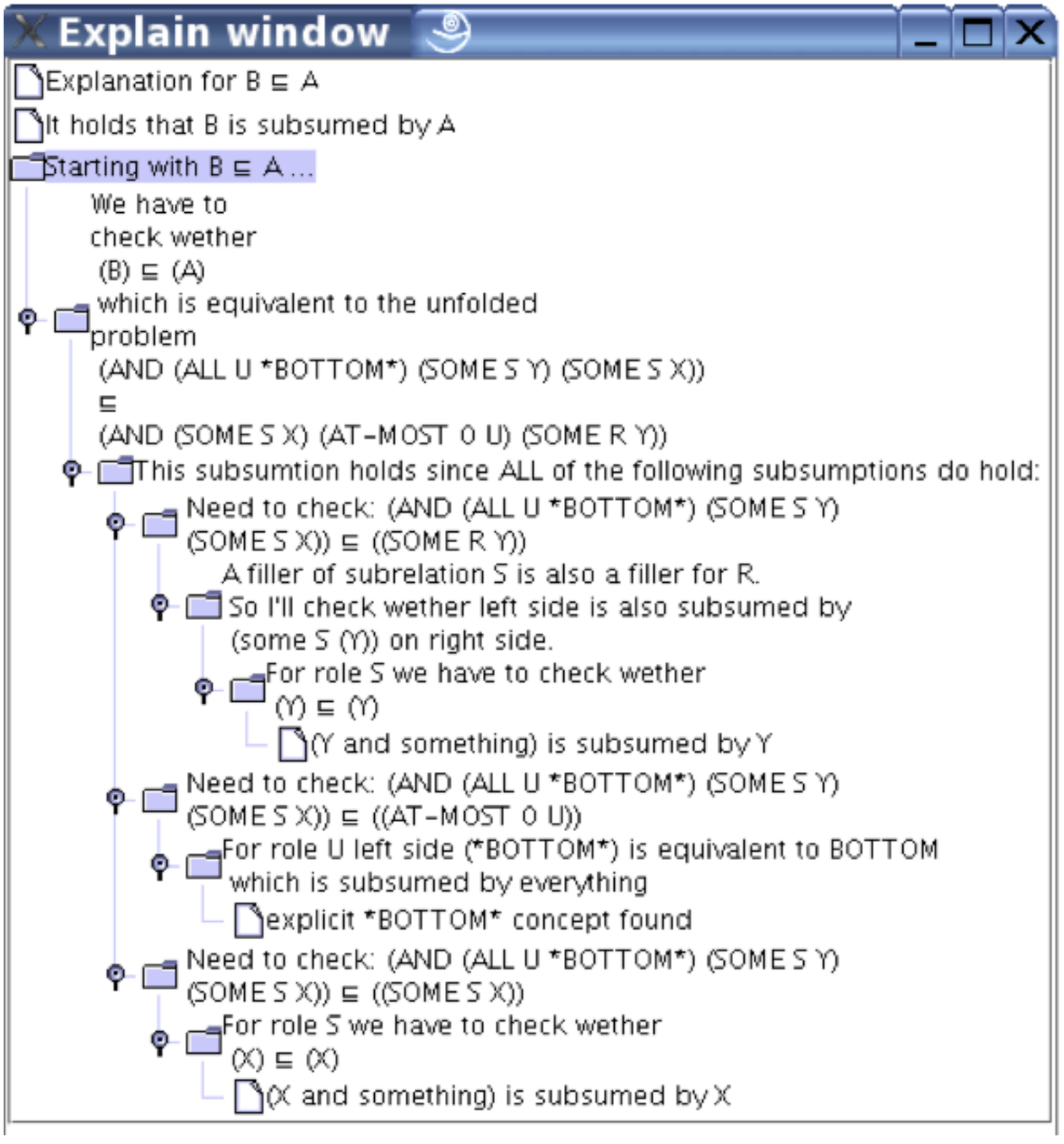

A Tableau-Based Explainer for DL Subsumption , Liebig and Halfmann

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http://browser.inference-web.org/iwbrowser/NodeSetBrowser?url=http://inference-web.org/proofs/tonys/tonys.owl%23tonys

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Proofs are hard

- Full proofs have mind numbing detail
  - Major concern of interactive proof checkers
- You need to know the proof theory
  - Which proof theory? Resolution anyone?
  - Proofs may be difficult to compute
- Way more proofs than justifications
  - Variation in proof can be immaterial
- Proofs are not repair oriented
- Are proofs always (or ever) needed?
- Excellent tools needed!

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What do we want?

- Explanation should yield/provoke understanding
  - But what sort of understanding?
- Consider some tasks
  1. Debugging an unsatisfiable class
  2. Explaining an entailment to someone
  3. Verifying a possible entailment
     - (Debugging the reasoner)
- Consider other goals
  - E.g., formalism mastery, understanding reasoners

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What else?

- Don't make things worse
  - Ever (if possible); definitely not often
- Integrate with existing
  - Tools
  - Practice
- Good cost/benefit
- Beware confounding factors and wishful thinking