Roles of Logical Axiomatizations for Ontologies

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Content is partially based on:

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On the Roles of Logical Axiomatizations for Ontologies

Axioms and semantics

Classes:
Lion
Feline
Mammal
Animal

No axioms given.

(some) possible models on the right

Consequences:
Simba is a Lion (!)
Axioms and semantics

Classes:
- Lion
- Feline
- Mammal
- Animal

Lion ⊆ Feline
Mammal ⊆ Animal

(some) possible models on the right
Consequences:
Simba is a Feline
Axioms and semantics

Classes:
Lion
Feline
Mammal
Animal

Lion $\subseteq$ Feline
Mammal $\subseteq$ Animal
Feline $\subseteq$ Mammal

(some) possible models on the right

Consequences:
Simba is a Feline
Simba is an Animal
Axioms and Semantics

A, B sets of axioms (theories).

Assume

Then we have:

Sets of corresponding models:

\[ \text{models}(A) \subseteq \text{models}(B) \]

Sets of corresponding logical consequences:

\[ \text{cons}(A) \subseteq \text{cons}(B) \]

This is called **monotonicity** of a logic.

Monotonic logics include: first-order predicate logic, description logics (i.e., OWL)
A rich axiomatization helps to disambiguate the meaning of an ontology.

What graph structure is intended?

Place $\subseteq \leq 1 \text{hasBP}. \text{BoundaryPolygon}$ clarifies this!
Good axioms

Specificity matters: Problems with domain/range.

Recommendations often heard:
- Indicate domain and range for your properties.
- Reuse as many existing vocabularies as you can.

But there are problems with this:

Ontology 1:

\[
\text{Human} \xrightarrow{\text{foaf:name}} \text{xsd:string}
\]
\[
\text{domain(foaf:name)} = \text{Human}
\]

Ontology 2:

\[
\text{Organization} \xrightarrow{\text{foaf:name}} \text{xsd:string}
\]
\[
\text{domain(foaf:name)} = \text{Organization}
\]

Logical consequence after merge:

\[
\text{Human} \equiv \text{Organization}
\]
Recommendations

- Make rich axiomatizations
- Avoid re-use of external vocabularies (rather provide an additional file with mappings for those who want to use it)
- Avoid naïve domain and range axioms.

Alternative to naïve domain/range: scoped domain and range.

\[ A(x) \land p(x, y) \rightarrow B(y) \] scoped range

\[ B(y) \land p(y, x) \rightarrow A(x) \] scoped domain

both rules can be expressed in OWL.
ROWL Protégé plug-in

http://dase.cs.wright.edu/content/rowl
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In: Proceedings ESWC 2017, to appear
OWLAX Protégé plug-in

In: Proc. ISWC 2016 poster & demos
http://dase.cs.wright.edu/content/ontology-axiomatization-support
Monotonicity can often be used as a first test whether a particular notion can be captured in OWL.

E.g. “A region is more biodiverse than another region if it is inhabited by a higher number of different species.”

Assume we have an ABox listing all species in each region, can we then satisfactorily axiomatize the relation moreBiodiverseThan between regions?

It turns out that we cannot, for the following reason: Assume that from the axiomatization we would obtain region1 moreBiodiverseThan region2.

Now add additional Abox axioms for newly found species in region1, so that it exceeds those in region2.

At this point, we would want ‘region1 moreBiodiverseThan region2’ to no longer hold.

But by monotonicity, this is impossible in OWL.

[for a non-monotonic solution, see Proc. ACM GIS 2012]
Non-monotonic tasks

- Integrity constraints
e.g. an integrity constraint violated if a person is listed without corresponding SSN
  Cannot be done by monotonic reasoning: If a violation is inferred, then adding the SSN would have to remove the inferred violation.

- Shape constraints – closely related to integrity constraints;
  to inform the shape of the ABox graph
  (cf. W3C SHACL Working Draft)

There exist many good proposals how to extend OWL with non-monotonic features.
But none of these has been standardized or incorporated into main tools.
Instance-based inferences

- Given an RDF (knowledge) graph as ABox, and an ontology as type schema

  deductive reasoning can be used to draw additional conclusions about the graph.

- (very simple) Example:
  
  \[
  \begin{align*}
  \text{Lion}(\text{simba}) \\
  \text{Lion} \sqsubseteq \text{Feline} \\
  \text{Mammal} \sqsubseteq \text{Animal} \\
  \text{Feline} \sqsubseteq \text{Mammal}
  \end{align*}
  \]

  Inferences: Feline(simba); Mammal(simba); Animal(simba)

- Generally speaking, these types of inferences are very quick for the smaller OWL profiles EL, QL, RL.
Schema-based inferences

- Often used at ontology generation time, e.g. for debugging:
  - Is the ontology consistent?
  - Is it coherent? (Incoherence means that one or more classes can be inferred to be empty).

\[
\begin{align*}
\text{Person} &\sqsubseteq \neg \text{Movie} \\
\text{RRated} &\sqsubseteq \text{CatMovie} \\
\text{CatMovie} &\sqsubseteq \text{Movie} \\
\text{RRated} &\equiv (\exists \text{hasScript}. \text{ThrillerScript}) \sqsubseteq (\forall \text{hasViolenceLevel}. \text{High}) \\
\text{Domain} &\left(\text{hasViolenceLevel}, \text{Movie}\right)
\end{align*}
\]

**Fig. 1.** A justification for Person \(\sqsubseteq \bot\)

(Example courtesy of Matthew Horridge)
Roles of axiomatizations

- For humans (to disambiguate meaning & use of ontologies).
- As constraints (non-monotonic; not supported by current standards or tools).
- For instance-based deductions: Deductive enrichment of a knowledge graph.
- For schema-based deductions: Mainly for use at ontology creation time.

We are still not really leveraging the full power of axiomatizations and reasoning for ontology-based applications, knowledge graph construction and applications, etc.

(For monotonic reasoners: See the annual OWL Reasoner Evaluation (ORE) workshop, [https://www.w3.org/community/owled/workshop-2016/]())
Thanks!
Semantic Web journal

• EiCs: Pascal Hitzler
  Krzysztof Janowicz

• Funded 2010

• 2016 Impact factor of 1.786, top of all journals with “Web” in the title

• We very much welcome contributions at the “rim” of traditional Semantic Web research – e.g., work which is strongly inspired by a different field.

• Non-standard (open & transparent) review process.

• http://www.semantic-web-journal.net/
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- **Bioinformatics Research Group (BiRG)**, directed by Travis Doom and Mike Raymer.
- **Cybersecurity Lab**, directed by Junjie Zhang.
- **Data Science for Healthcare Lab**, directed by Tanvi Banerjee.
- **Data Semantics (DaSe) Lab**, directed by Michelle Cheatham and Pascal Hitzler.
- **Web and Complex Systems (WaCS) Lab**, directed by Derek Doran.
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