

Semantic Requirements in the Ontology Lifecycle

Michael Grüninger

Semantic Technologies Lab
University of Toronto

September 10, 2021

Motivation

- What axioms do I need in my ontology?
- Do I have the right axioms?
- How do I know when I am finished?

Methodology

- Ontologies are designed artefacts.
- We specify their semantic requirements at the beginning of the ontology lifecycle, and then use these requirements as the basis for ontology evaluation throughout the lifecycle.

Requirements Specification

- Any consistent axiomatization of an ontology will have a nonempty set of models.
- Requirements specify which models are the ones that we intend to be the models of our ontology.

Requirements: Partial Characterization

- Competency questions are queries the ontology must be able to entail
- Competency questions can be used as a means for implicitly characterizing the set of intended models – any sentence that should be satisfied by all intended models should be provable from the axioms of the ontology.

Answering natural language questions about datasets

Alice lectures MATH456

MATH456 is a ScienceCourse

Bob teaches MIE123

MIE123 is an EngineeringCourse

- *Is Alice a professor in the Math Department?*
- *Is Bob enrolled in any courses?*

Datasets as Intended Semantics

- Examples

- ▶ Clean datasets without any errors should be considered to be consistent with the ontology, and hence they can be considered to be a specification of intended models for the ontology.

- Counterexamples

- ▶ Datasets with quality problems should be inconsistent with the ontology. They can be considered to be a specification of interpretations that falsify one or more axioms of the ontology.

Requirements: Explicit Characterization

- Intended models can also be specified using the models of existing mathematical theories:
 - ▶ orderings
 - ▶ graphs
 - ▶ magmas (generalizations of algebra)
 - ▶ incidence structures (generalization of geometry)

Semantic Errors

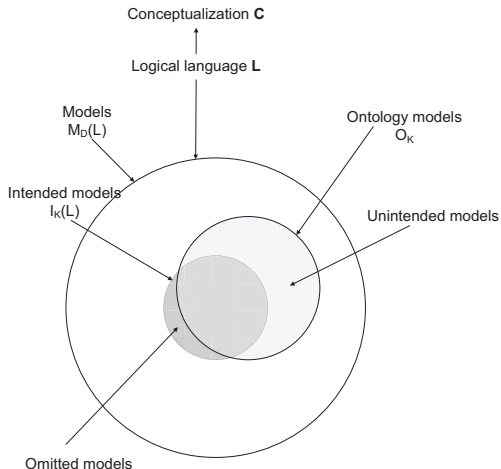


Figure: The possible relationships between the models of an ontology and the required structures (modified after [Guarino2009]).

Ontology Verification

- Verification is concerned with the relationship between the intended models of an ontology and the models of the axiomatization of the ontology.
- In particular, we want to characterize the models of an ontology up to isomorphism and determine whether or not these models are equivalent to the intended models of the ontology.
- We can use theorem proving to support verification:
 - ▶ Entailment of competency questions
 - ▶ Logical synonymy with mathematical theories whose models have been characterized.

Soundness

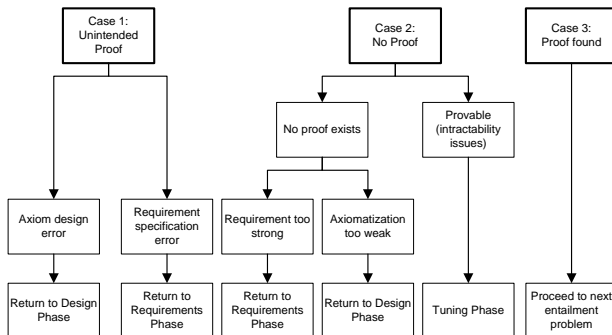
- A collection of inference rules is sound if and only if for each formula P derived by applying these inference rules on a given set of wffs S , we have that P is a logical consequence of S .
- In other words, a logic is sound if a contradiction cannot be deduced from S .
- if $P \vdash S$ then $P \models S$

Completeness

- A set of inference rules are complete if each logical consequence P of a given set of formulas S can be derived from the inference rules.
- In other words, a logic is complete if every true statement can be deduced from S .
- if $P \models S$ then $P \vdash S$

Verification

Guidance for each possible outcome of verification:



Ontology Validation

- If ontology verification is concerned with the relationship between the models of the axioms of the ontology and the intended models for the ontology, ontology validation addresses the problem of whether the intended models are actually the right ones for the user.

Finding the Right Models

- What procedures that can be used to support the validation of an ontology as a dialogue between the ontology curator and the ontology user/designer?
- At the heart of any such procedure is the identification of unintended and omitted models, followed by decisions about how to modify the ontology in light of the existence of any such models.
- If a model is unintended, the ontology needs to be strengthened.
- If a model is omitted, the ontology needs to be weakened.
 - ▶ Omitted correspond to “unintended proofs” – a sentence that is provable but should not be provable.

Ontology Lifecycle

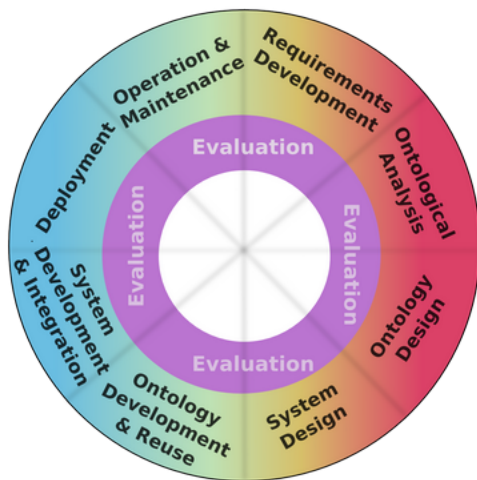


Figure: The Ontology Lifecycle (from Ontology Summit 2013).

Summary

- Ontology verification is concerned with the relationship between the intended models of an ontology and the models of the axiomatization of the ontology.
- An even more difficult challenge is ontology validation – are the intended models of the ontology indeed the correct models for the ontology?
- The only way to address validation is through a dialogue with the user who specifies the intended models
- There are many more analogues with software engineering that should be explored by the Applied Ontology community.