Design: Ontology Engineering
Semantic Web (CSC688 P)

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1. Announcements
2. Requirements
3. Ontology creation
4. Quality
5. Modules

Concept
Symbol/Word
Evokes
Thing
Stands for
The meaning triangle
Reading
- Ch. 8 [HKR09]

Project proposal presentation
- You have **two minutes** to present the project proposal to the class. Please stick to two minutes.
- Approximately **two minutes** for the feedback.
- Explain the main ideas of your project, and describe how the semantic technologies are used in your scenario.
Class presentation: things to consider

- Some form of visual presentation is effective.
- Effectiveness of explanations.
- Time management is a must.
- Correctness of content.
- Proficiency in answering questions.
- Experiment results, comparison results, evaluations, and potential application demonstrations.
- It is up to you to select the content.
Introduction

- Ontology engineering: building complex ontologies by providing methodologies and auxiliary tools for their development, evaluation, and maintenance.

- Methodologies may be subjective.

- Defining a ontology life cycle: steps for software development and maintenance.
Requirement analysis

- Is a semantic representation the better choice or not (relational databases)?
  - Non-semantic solutions already exist.
  - Added value with expensive modeling efforts.
- Ontology based systems:
  - Knowledge represented in semantic format can be easily exchanged as well as integrated with knowledge from other sources.
  - Implicit knowledge via a deduction algorithm.
- Tool support: specific tools, licenses, maturity, vendor support and interoperability.
- Which logic should be used? Large data and less expressive RDF(S), moderate and more expressive OWL 2 DL, and/or OWL 2 DL profiles.
- Domain, granularity, the tasks that the ontology needs to cover, and the expected and desired inferences.
- Degree of axiomatization: individuals, classes, and roles.
How?

- There is no uniquely correct way to build an ontology satisfying all the requirements.
- There exists best practices and modeling patterns.

Where?

- Human, unstructured, semi-structured, and structured sources of knowledge.
- Trying to define “game”, “democracy” or “school”.
Sources

- Human:
  - Domain expert. Can the domain expert formulate his/her knowledge in a logical way?
  - Knowledge engineer as a form of mediator to cast the knowledge into a logical specification.
  - “I know it when I see it”.
  - Machine learning to learn rules based on positive/negative examples that the domain expert provides (decision trees, inductive logic programming, formal concept analysis etc.).

- Unstructured:
  - All kind of textual resources (books, magazines, web pages etc.).
  - Exchanging formal specification from arbitrary text is an NP-hard problem
  - Parsing texts for part-of-speech tagging, named entity recognition, chunking, word-sense disambiguation, pronoun resolution, so on
  - Transformation rule from parse trees to logic. e.g., Ubbo, Sam into individuals, School and intransitive verbs (sleep) into classes and transitive verbs (like) into roles.
Sources

- **Unstructured**
  - “Dish that contains fish” $\text{Dish} \sqcap \exists \text{contains}.\text{Fish}$
  - Normalization of words. e.g., nouns in nominative singular form and verbs in infinitive form.
  - Non-trivial to retain temporal information in standard ontology languages and no well-established best practices how to do this.
  - Common sense, or background knowledge. e.g., fishes are animals (WordNet).
  - Control natural languages.

- **Semi-structured:**
  - Web pages having hyperlinks and wiki articles.

- **Structured:**
  - Directly accessible information.
  - Database to $n$-ary relationships via reification.
  - Ontology population from database rows.
  - Schema such as “every person has at least one nationality” into TBox axioms.
  - Reuse other ontologies (ontology merging and ontology alignment).
  - Ontology mapping.
Ontology evaluation

- How the quality of the ontology is assessed.
  - Does it fulfill the intended purpose?
  - Does it infer the intended knowledge?
  - Do the logical inferences match with the reality?
  - Does the ontology and do the inferences help the user?

- Logical criteria:
  - Ontology is inconsistent or unsatisfiable, if it has no model. Then it is in almost every case a modeling error.
  - Existence of weaker version of class inconsistency ($C \sqsubseteq \bot$).
    
    $\text{Horse} \sqsubseteq \neg \text{Flies}$
    $\text{FlyingHorse} \equiv \text{Horse} \sqcap \text{Flies}$

  - Ontology is globally consistent, but $\text{FlyingHorse}$ is inconsistent.
  - The ontology becomes inconsistent as when an individual of $\text{FlyingHorse}$ is added.

- Create classes only if individuals can be added.
- Coherent: no inconsistent classes. A consistent ontology can be incoherent.
- Less constrains, but consider disjointness, property restrictions etc.
Ontology evaluation

Structural and formal criteria:
- Taxonomic cycles.

```
Architecture ⊆ Faculty
University ⊆ Building
Faculty ⊆ University
Building ⊆ Architecture
```

This ontology collapses with all equivalent concepts.
- Rrigidity: e.g., person cannot stop being person, where as a student can stop being a student while retaining his/her existence and attributes.
- Non-rigidity, identity, unity, and dependence.

Accuracy criteria:
- Ontology accurately captures the domain.
- Judgment of humans are subjective.
## What must be avoided

- Don’t forget disjointness:

\[
\begin{align*}
\text{Man} \subseteq \text{Human} & \quad \text{Human} \subseteq \text{Man} \cap \text{Woman} & \quad \text{Woman} \subseteq \text{Human} \\
\text{Man}(\text{Jack}) & & \text{Woman}(\text{Jill})
\end{align*}
\]

This knowledge base does not entail that \(\neg \text{Woman}(\text{Jack})\). This is because no logical reasons prevent \text{Jack} being both \text{Man} and \text{Woman}. In order to fix this you need to include \text{Man} \cap \text{Woman} \subseteq \bot.

*Explicitly consider all siblings, i.e., classes having a common superclass, whether it is possible that an individual is an instance of both classes. If not, declare them as disjoint.*
What must be avoided

- Don’t forget role characteristics:

  Consider for every role occurring in an ontology whether it represents relations: transitive, symmetric, functional, inverse functional, reflexive, irreflexive, antisymmetry, role disjointness, and interdependencies involving role chains.

- Don’t choose too specific domains or ranges:

  If the domain and range are set, make sure that the class expressions are disjoint. If not there will be uncontrollable inferences.
What must be avoided

- Be careful with quantifiers:
  - When translating from natural language statements into logical axioms, existential quantification is more natural. E.g., birds have wings $\text{Bird} \sqsubseteq \exists \text{has.Wing}$. But the erroneous translation $\text{Bird} \sqsubseteq \forall \text{has.Wing}$ says that birds have only wings or no wings at all.
  - Use universal quantification with words such as “only”, “exclusively” or “nothing but”.
  - $\text{Happy} \equiv \forall \text{hasChild.Happy}$ and $\text{Happy} \equiv \forall \text{hasChild.Happy} \sqcap \exists \text{hasChild.Happy}$

*Make sure that the intended meaning is correctly casted into role quantification. Use existential quantification as default. Be aware that universal quantification alone does not enforce the existence of a respective role.*
What must be avoided

- Don’t mistake parts for subclasses:

\[
\begin{array}{ccc}
Finger \subseteq Hand & Hand \subseteq Arm & Arm \subseteq Body \\
Toe \subseteq Foot & Foot \subseteq Leg & Leg \subseteq Body \\
& Arm \sqcap Leg \subseteq \perp
\end{array}
\]

- This knowledge base infers that \( Hand \subseteq Body \). Is this natural?
- If we do this, we are mistaken meronymy for hyponymy, i.e., part-of relations for subclasses relations.
- Meronymy, i.e, the semantic relation that holds between a part and the whole, is modeled by a dedicated transitive role \( \text{partOf} \) and \( \text{partOf}^{-} \).

\[
\begin{array}{ccc}
Finger \subseteq \exists \text{partOf} . Hand & Hand \subseteq \exists \text{partOf} . Arm & Arm \subseteq \exists \text{partOf} . Body \\
Toe \subseteq \exists \text{partOf} . Foot & Foot \subseteq \exists \text{partOf} . Leg & Leg \subseteq \exists \text{partOf} . Body \\
& Arm \sqcap Leg \subseteq \perp
\end{array}
\]

A class \( A \) should be modeled as a subclass of \( B \) only if the statement “every \( A \) is a \( B \)” makes sense and is correct.
What must be avoided

- Watch the direction of roles:
  - For nouns, instead of `author`, use `authorOf` or `hasAuthor`. For verbs, instead of `wrote` or `written`, use `writtenBy`.

  *When introducing a new property or role names, add a comment that clarifies what its source and target are. Moreover, use names which allow only one unique intuitive reading.*

- Don’t confuse class subsumption and class equivalence:
  - `Orphan ≡ Person ⊓ ∀hasParent.Dead`

  *Only if a class description is both necessary and sufficient, an equivalent statement should be used.*

- Don’t translate too verbally:
  - “University staff members and students get a login”. `A ⊓ B ⊑ ∃gets.Login` vs. `A ⊔ B ⊑ ∃gets/Login`

  *If in doubt about the correct formalization, two strategies that might help are paraphrasing and testing.*
Import and reuse.

How much do we import: coverage vs. economy.

Coverage should preserve entailments, i.e., $O \cup E \models A \subseteq B$ then $O \cup E' \models A \subseteq B$.

OWL API is a highly recommended module extractor.