Ontologies, modeling languages, and hints on applications

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Ontologies
Ontologies: how they look like

**Taxonomy** [basic structure]:

- **Classes:**
  - Categories of things sharing common traits
  - Person *vs.* John; Dog *vs.* fido (my dog); Pottery *vs.* pottery_on_my_desk

- **Relation:** **IS-A** [subsumption]
  - C1 **IS-A** C2 means that all instances of C1 are instances of C2, too
  - E.g.: Person **IS-A** Mammal; John *instance-of* Person, therefore John *instance-of* Mammal

Recall that IS-A: reflexive, anti-symmetric, and transitive (partial order)
Example

Do **NOT** confuse:

- **IS-A** *(rdfs:subClassOf)*: holds between **classes** *(e.g., Animal and Mammal)*

- **Instance-of**: holds between **individuals** and **classes** *(John and Person)*
Ontologies: how they look like (con’t)

Taxonomy + horizontal relations

- **Classes**
- **Relations**, e.g.,
  - Man-Made Artefact **IS-A** Non-Living Being
  - Man-Made Artefact **created-by** Person
  - Pottery **IS-A** Man-Made Artefact
  - Pottery **has-part** Body
  - Pottery **has-part** Handle
  - etc.

**Purpose**: enhance the expressivity of the taxonomy by making more explicit the intended semantics of the terms.
Example
taxonomy (including horizontal relations)
Ontologies: how they look like (con’t)

Taxonomy + horizontal relations + restrictions (axioms)

- **Restrictions** (only some examples):
  - **Disjointness:** Non-Living Being disjoint-with Living Being, means that
    - Instances of Non-Living Being cannot be instances of Living Being, too.
  - **Cardinality:**
    - Each instance of Pottery is related via has-part to at least one instance of Body
    - Each instance of Pottery may not be related via has-part to any instance of Handle. If such a relation holds, a Pottery has-part at most two instances of Handle
Example
taxonomy (including horizontal relations and restrictions)
Good practice for ontology design

Pick up your classes and build first the IS-A taxonomy

Then add the horizontal relations between the classes and the restrictions (axioms) needed to grasp the intended semantics of your vocabulary

Pay attention to properly distinguish IS-A from other relations, e.g., part-of

XML tree:

```
<vase>
  <body> body_1 </body>
  <handle> handle_1 </handle>
  <handle> handle_2 </handle>
</vase>
```

IS-A Taxonomy:

- Handle (proper-)part-of Vase
- Body (proper-)part-of Vase

NOT

- Body IS-A Vase
- Handle IS-A Vase
Modeling languages for ontological analysis and ontology design
Common languages for ontology development

- Unified Modeling Language (UML) Class Diagram
- First-order logic (FOL)
- Description logics (DL)
- Semantic Web Languages [W3C standards]
  - Resource Description Framework (RDF)
  - RDF Schema (RDFS)
  - Web Ontology Language (OWL)

How to choose? Likely it depends on your requirements (e.g., foundational ontology vs. task ontology)
Minimal Mereology (MM) in FOL

% Axioms of Minimal mereology (MM) (temporally indexed)

all x all t (part0f(x,x,t)).
all x all y all t (part0f(x,y,t) & part0f(y,x,t) -> x=y).
all x all y all z all t (part0f(x,y,t) & part0f(y,z,t) -> part0f(x,z,t)).
% axioms of Ground Mereology (M)

all x all y all t (overlaps(x,y,t) <-> exists z (part0f(z,x,t) & part(z,y,t))).
% overlap
all x all y all t (properPart0f(x,y,t) <-> part0f(x,y,t) & -part0f(y,x,t)).
% proper parthood
all x all y all t (properPart0f(x,y,t) -> exists z (part0f(z,y,t) & -overlaps(z,x,t))).
% weak supplementation principle (WS):
% every proper part must be supplemented by another, disjoint part
% M + WS = MM


THERE ARE MANY, MUCH MORE EXPRESSIVE MERELOGIES!
Mereology (??) in OWL

\[ \text{partOf} \text{ rdf:type owl:ObjectProperty,} \\
\text{owl:TransitiveProperty,} \\
\text{owl:ReflexiveProperty.} \]

\[ \text{overlaps} \text{ rdf:type owl:ObjectProperty,} \\
\text{owl:SymmetricProperty,} \\
\text{owl:ReflexiveProperty.} \]

\[ \text{properPartOf} \text{ rdf:type owl:ObjectProperty,} \\
\text{owl:TransitiveProperty.} \]

Result:
- **Sacrifice expressivity** (e.g., no ternary relations, no anti-symmetry for partOf, no definition for overlaps, no weak supplementation, etc.)

- **Gain computational treatment!**

Good practice for ontology design

For ontological analysis, use a language which allows you

- To formulate -- in a transparent way -- the intended meaning of your vocabulary
- **E.g., first-order logic:**
  - Well-known in Computer Science, (some) Human Sciences, Engineering, Cognitive Sciences, etc.
  - Sound and complete but undecidable

For application purposes:

- Formulate your ontology in the language which is the most suited for your application purposes (nowadays, **Semantic Web languages** are widely used)
Ontologies in use:
Semantic interoperability and data integration
Ontologies, what for...

- **Data Management**
  - Classification, interpretation, sharing, integration, retrieval
  - Interoperability at the semantic level
  - Etc.

- **Knowledge representation (AI)**
  - Knowledge reuse
  - Automated reasoning
  - Knowledge discovery
  - Computer-aided decision making
  - Planning
  - Etc.

Some references:
- Journals:
  - Applied Ontology
  - Semantic Web
  - etc.
- Conference Proceedings, see:
  - FOIS
  - JOWO
  - Some proceedings
  - ISWC
  - ESWC
  - etc.
Semantic interoperability

The capability of two or more information systems to exchange data while making explicit, preserving, and sharing the intended meaning of the data.

“Communication is an exchange of information about entities and relations between a sender and a receiver. Information is formulated in some language. A language consists of symbols arranged in a well defined manner. The symbols of a language are not meaningful per se. The meaning of a symbol needs to be made explicit by specifying its intended interpretation, i.e., by specifying to which entity (entities) or relation it refers to”.

(Bittner, T., Donnelly, M., & Winter, S. (2005). Ontology and semantic interoperability. Large-scale 3D data integration: Challenges and Opportunities, 139-160.)
Formal ontology in information systems: Proceedings of the first international conference (FOIS'98), June 6-8, Trento, Italy

Research on ontology is becoming increasingly widespread in the computer science community. While this term has been rather confined to the philosophical sphere in the past, it is now gaining a specific role in areas such as Artificial Intelligence, Computational...
Ontology as *interlingua* across multiple data sources


*(see: Bittner, T., Donnelly, M., & Winter, S. (2005). Ontology and semantic interoperability. Large-scale 3D data integration: Challenges and Opportunities, 139-160.)*

*(see: Guarino, Oberle, Staab (2010), What is an ontology? In Handbook on Ontologies Springer Science & Business Media)*
Data integration

Combine multiple datasets in a meaningful way

(From: Choffé & Leresche, F. (2016). DOREMUS: connecting sources, enriching catalogues and user experience. In 24th IFLA World Library and Information Congress)
DOREMUS

Project supported by French National Agency for Research (ANR) with

- National Library of France (BnF)
- Philharmonie de Paris
- Radio France … + other partners for technical development

“[…] to provide cultural institutions, publishers and distributors […] with ontologies and shared multilingual controlled vocabularies, methods to publish, share, connect, enrich catalogues of musical works and events in the web of data […]”

The DOREMUS ontology

Available at: (http://data.doremus.org/ontology)

- Extends CIDOC-CRM, FRBRoo, and PRESSoo to model explicitly knowledge about music
- Datasets from BnF, Radio France, and Philharmonie
  - From MARC or XML
  - To RDF
  - Each dataset is modelled according to the same ontology, i.e., DOREMUS
- All datasets are integrated within a unique RDF knowledge base (called the DOREMUS knowledge graph)

Figure from: Choffé, P., & Leresche, F. (2016)
DOREMUS SPARQL Endpoint

To access the DOREMUS knowledge graph:

- [http://data.doremus.org/](http://data.doremus.org/) [general info, tools, etc.]
- [http://data.doremus.org/sparql](http://data.doremus.org/sparql) [SPARQL Endpoint based on Virtuoso]

“The DOREMUS dataset includes more than 16 million triples, which describe over 3 million distinct entities”.

Some general info

Ontology repositories
- Bio-Portal (https://bioportal.bioontology.org/)
- Agro-Portal (http://agroportal.lirmm.fr/)
- Industrial Ontology Foundry (IOF) (https://www.industrialontologies.org/)
- OntoHub (https://ontohub.org/)

International Association for Ontology and its Applications (IAOA)
- https://iaoa.org/
- Formal Ontology in Information Systems (FOIS)

- FOIS 2020, 14-17 September 2020, Free University of Bolzano-Bozen (Italy),
  https://fois2020.inf.unibz.it/
- Interdisciplinary Summer School on Applied Ontology (ISAO)
Applied Ontology: an emerging interdisciplinary area

- Applied Ontology builds on philosophy, cognitive science, linguistics and logic with the purpose of understanding, clarifying, making explicit and communicating people's assumptions about the nature and structure of the world.

- This orientation towards helping people understanding each other distinguishes applied ontology from philosophical ontology, and motivates its unavoidable interdisciplinary nature.
Some references

Conceptual modeling:

Applied Ontology:
Some references

Semantic Web:

Description logics:
Thank you!

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