Knowledge Representation for the Semantic Web

Winter Quarter 2012

Slides 7 – 02/07/2012

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Textbook (required)

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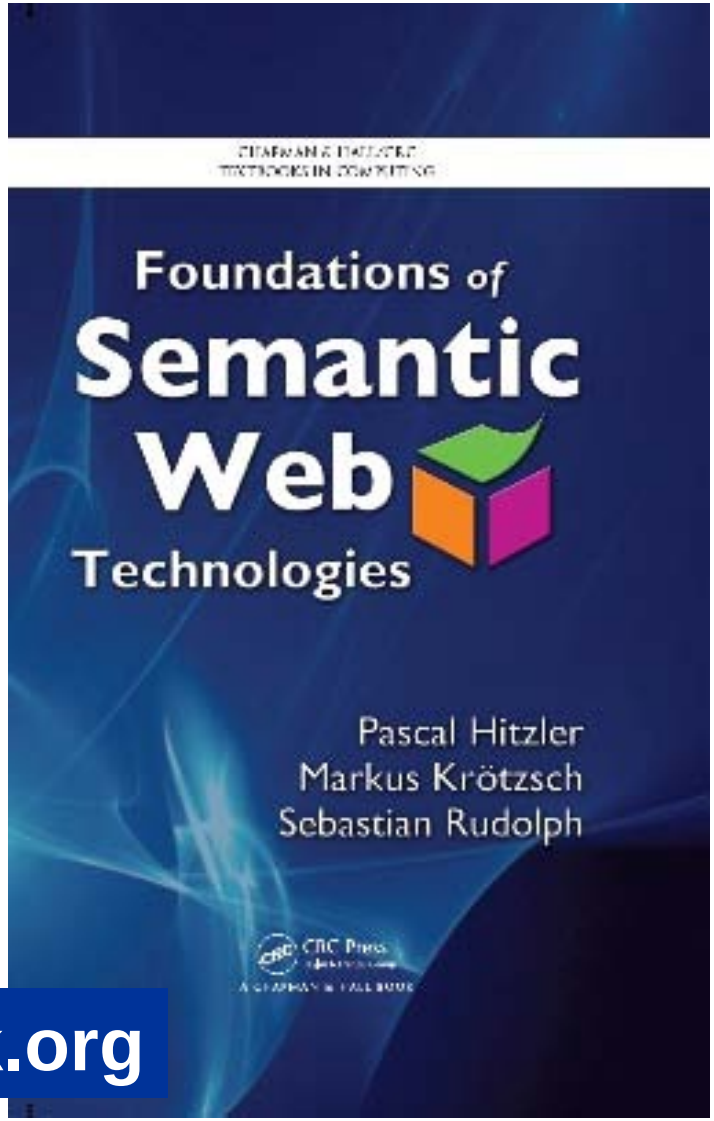
Foundations of Semantic Web Technologies

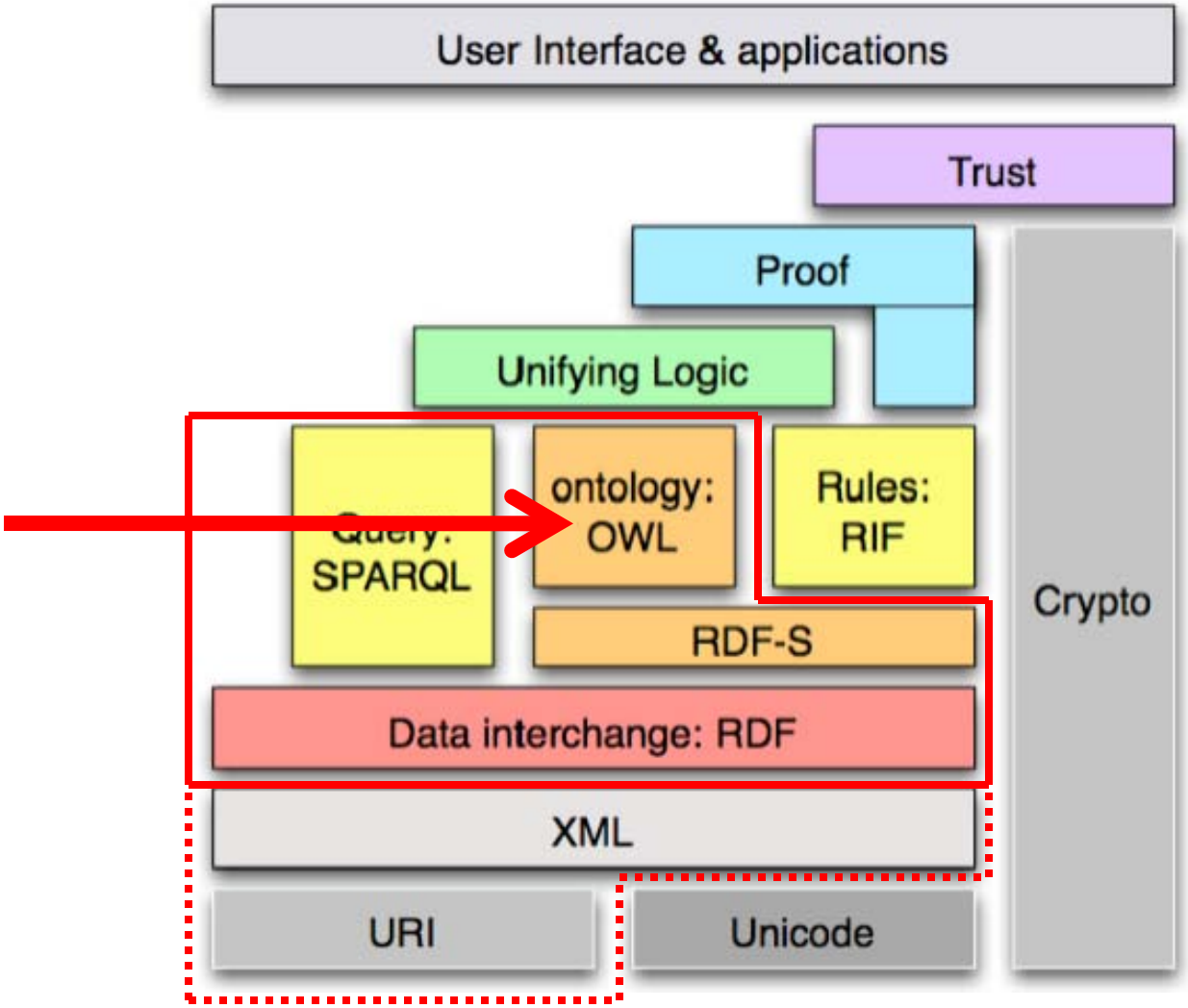
Chapman & Hall/CRC, 2010

Choice Magazine Outstanding Academic Title 2010 (one out of seven in Information & Computer Science)



http://www.semantic-web-book.org

Today: Model-theoretic Semantics



Today's Session: DL Semantics

1. **Partonomies**
2. **Class Project**
3. **Class Presentations**

Source

Content taken from

Morton E. Winston, Roger Chaffin, Douglas Herrmann, A Taxonomy of Part-Whole Relations, Cognitive Science 11, 417-444, 1987.

and the OWL modeling from

Prateek Jain, Pascal Hitzler, Kunal Verma, Peter Yeh, Amit Sheth, Moving beyond sameAs with PLATO: Partonomy detection for Linked Data. 2011, submitted to a conference.

part-of relationships

- the X is part of the Y
- X is partly Y
- X's are part of Y's
- X is a part of Y
- The parts of a Y include the Xs, the Zs, …

- The head is part of the body
- Bicycles are partly aluminum
- Pistons are part of engines
- Dating is a part of adolescence
- The parts of a flower include the stamen, the petals, etc. …

- "meronymic" relations ("meros" is greek for "part")

part-of: a possible view

One could think that part-of is a binary relation which is

- **a strict partial ordering, i.e.**
  - **transitive**
    If X part of Y, and Y part of Z. Then X part of Z.
  - **irreflexive**
    X is never part of X.
  - **antisymmetric**
    If X part of Y. Then Y is never part of X.

However, this view is problematic.

Transitivity

Simpson's finger is part of Simpson's hand.
Simpson's hand is part of Simpson's body.
Simpson's finger is part of Simpson's body.

This works, but the following doesn't:

Simpson's arm is part of Simpson.
Simpson is part of the Philosophy Department.
Hence(?) Simpson's arm is part of the Philosophy Department.

So when do we have transitivity?

Winston's approach

Distinguish 6 different types of meronymic relations:

1. **component – integral object** **(pedal – bike)**
2. **member – collection** **(ship – fleet)**
3. **portion – mass** **(slice – pie)**
4. **stuff – object** **(steel – car)**
5. **feature – activity** **(paying – shopping)**
6. **place – area** **(Everglades – Florida)**

Dimensions of meronymic relations

A type of part-of relationships

- **functional**
  Functional parts are restricted, by their function, in their spatial or temporal location.
  handle – cup
- **homeomerous**
  Homeomerous parts are the same kind of thing as their wholes.
  slice – pie
  but not tree – forest
- **separable**
  Separable parts can in principle be separated from the whole.
  handle – cup
  but not steel – bike

Dimensions

Relation	Examples	Relation Elements: Functional	Homeomerous	Separable
Component/ Integral Object	handle-cup punchline-joke	+	–	+
Member/ Collection	tree-forest card-deck	–	–	+
Portion/Mass	slice-pie grain-salt	–	+	+
Stuff/Object	gin-martini steel-bike	–	–	–
Feature/Activity	paying-shopping dating-adolescence	+	–	–
Place/Area	Everglades-Florida oasis-desert	–	+	–

From Winston et al., A Taxonomy of Part-whole Relations, Cognitive Science 11, 417-444, 1987.

Component – Integral Object

- A handle is part of a cup.
- Wheels are parts of cars.
- The refrigerator is part of the kitchen.
- Chapters are parts of books.
- A punchline is part of a joke.
- Belgium is part of NATO.
- Phonology is part of linguistics.
- The viola part in a symphony.

Member – Collection

- A tree is part of a forest.
- A juror is part of a jury.
- This ship is part of a fleet.

Do not confuse with class – member relationships, such as

- The Nile is a river.
- Fido is a dog.

which are not part-of relationships.

class membership: determined on the basis of similarity to other members.

member – collection: determined on the basis of spatial proximity or by social connection.

Portion – Mass

- **This slice is part of a pie.**
- **A yard is part of a mile.**
- **This hunk is part of my clay.**

Homeomerous: Every portion of a pie is “pie”.
(while, e.g., a window is quite unlike the house of which it is part.)

Portion – Mass

Can be distinguished from component – integral object by substituting the phrase "some of":

- **She asked me for part of my orange. (… for some of my orange)**

However *not*: The engine is some of the car.

This test won't distinguish from member – collection:

- **Some of the fraternity brothers are sophomores. (this is the "count" sense of "some", not the "mass" sense)**

However, for member – collection we can phrase it as:

- **One of the brothers is a sophomore.**

Stuff – Object

- A martini is partly alcohol.
- The bike is partly steel.
- Water is partly hydrogen.

By asking for: “What is it made of?”

(For component – integral object we would ask:
“What are its parts?”)

Stuff cannot be separated from the object.

Feature – activity

- Paying is part of shopping.
- Bidding is part of playing Bridge.
- Ovulation is part of the menstrual cycle.
- Dating is part of adolescence.

Features or phases of activities and processes.

Unlike the other types, in this case we cannot say “X has Y”, such as for others in

- Sororities have members.
- Bicycles have pedals
- Plays have acts.

E.g. we cannot say “Shopping has paying”.

Place – Area

- The Everglades are part of Florida.
- An oasis is a part of a desert.
- The baseline is part of a tennis court.

Other apparently similar relations which are not meronymic

- **Topological Inclusion**
  - **The wine is in the cooler.**
  - **The meeting is in the morning.**
  - **Careful: “The Everglades are part of Florida” is meronymic. But “West Berlin is part of East Germany” is wrong. [Note paper was written 1987.]**
- **Class Inclusion**
  - **Cars are a type of vehicle.**
  - **Theft is a crime.**
  - **Careful: “Frying is a type of cooking” is meronymic, as is “Honesty is a type of virtue”.**

Other apparently similar relations which are not meronymic

- Attribution
  - Towers are tall.
  - Coal burns.
  - The joke was funny.
- Attachment
  - Earrings are attached to ears.
  - Fingers are attached to hands.
    (note: they are also parts of hands)
- Ownership
  - A millionaire has money.
  - The author has the copyright.
  - Jenny has a bicycle.

Transitivity again

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Simpson's hand is part of Simpson's body.

Simpson's finger is part of Simpson's body.

This works, but the following doesn't:

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Hence(?) Simpson's arm is part of the Philosophy Department.

Winston argues: If we combine two sentences with the same type of meronymic relation, then we have transitivity.
Indeed, in all mixed cases, counterexamples to transitivity can be found (given in the paper).

Other properties – and some OWL modeling

Winston et al. list several properties of meronymic relations.

First some notation for the 6 types of part-of relations:

- po-component
- po-member
- po-portion
- po-stuff
- po-feature
- po-place

PO is the set containing these six binary relations.

- part-of: The “general” part-whole relation.
- spatially-located-in: topological located-in relationship

Axioms (extracted from Winston et al.)

1. For all $R \in PO$, R is transitive, asymmetric, and irreflexive (i.e., a strict partial order).
2. For all $R \in PO$, $R \sqsubseteq$ part-of.
   Does not imply transitivity of part-of.
3. spatially-located-in is transitive and reflexive.

Axioms (extracted from Winston et al.)

> These results suggest that a hierarchical ordering exists among these types of inclusion relationship, such that mixed inclusion relation syllogisms are valid if and only if the conclusion expresses the lowest relation appearing in the premises, where the ordering of relations is:
>
> CLASS INCLUSION > MEROLOGICAL INCLUSION > SPATIAL INCLUSION

4. **For all $R \in PO$, we have**
   - **$R \circ$ spatially-located-in $\sqsubseteq$ spatially-located-in**
   - **spatially-located-in $\circ R \sqsubseteq$ spatially-located-in**
5. **For all $R \in PO \cup \{\text{spatially-located-in}\}$ and all classes C, we have $(\forall x)(\forall y)(R(x,y) \wedge C(y) \rightarrow (\exists z)(R(x,z) \wedge C(z)))$.**
6. **For all $R \in PO \cup \{\text{spatially-located-in}\}$ and all classes C, we have $(\forall x)(\forall y)(C(y) \wedge (C(y) \rightarrow R(x,y)) \rightarrow R(x,y))$.**

Note: 5+6 are tautologies, so need not be modeled in OWL.

Axioms (extracted from Winston et al.)

1. For all $R \in PO$, R is transitive, asymmetric, and irreflexive (i.e., a strict partial order).
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4. For all $R \in PO$, we have
   - $R \circ$ spatially-located-in $\sqsubseteq$ spatially-located-in
   - spatially-located-in $\circ R \sqsubseteq$ spatially-located-in
5. For all $R \in PO \cup \{\text{spatially-located-in}\}$ and all classes C, we have $(\forall x)(\forall y)(R(x,y) \wedge C(y) \rightarrow (\exists z)(R(x,z) \wedge C(z)))$.
6. For all $R \in PO \cup \{\text{spatially-located-in}\}$ and all classes C, we have $(\forall x)(\forall y)(C(y) \wedge (C(y) \rightarrow R(x,y)) \rightarrow R(x,y))$.

Note: 5+6 are tautologies, so need not be modeled in OWL.

Meronymic relations in OWL

1. For all $R \in PO$, R is transitive, asymmetric, and irreflexive (i.e., a strict partial order).
2. For all $R \in PO$, $R \sqsubseteq$ part-of.
   Does not imply transitivity of part-of.
3. spatially-located-in is transitive and reflexive.
4. For all $R \in PO$, we have
   - $R \circ$ spatially-located-in $\sqsubseteq$ spatially-located-in
   - spatially-located-in $\circ R \sqsubseteq$ spatially-located-in

This results in a total of $3 \cdot 6 + 2 \cdot 6 + 2 + 6 \cdot 2 = 44$ axioms, all expressible in OWL 2.

However, there is a catch!

A Catch

1. For all $R \in PO$, R is transitive, asymmetric, and irreflexive (i.e., a strict partial order).

Problem: A relation in OWL 2 DL cannot be transitive and reflexive at the same time:
A transitive property is complex, and thus not simple. However only simple properties are allowed to be irreflexive.

So: this ends up in OWL 2 Full.

Straightforward fix:
Drop irreflexivity. This will probably work in most cases.

Better fixes are based on rules or nominal schemas (covered later in class).

Another two catches

All properties occuring in the above given part-of ontology are complex (i.e., non-simple).

OWL 2 has global restrictions on the use of such properties.

This hampers modeling, and may yield to OWL 2 Full ontologies after all desired relationships have been modeled.

Another problem: Regularity conditions may become violated if merging the part-of ontology with a domain ontology.

Fixes: as above (drop some axioms)

Better: rules or nominal schemas (covered later in class).

Today's Session: DL Semantics

1. Model-theoretic Semantics of SROIQ(D)
2. Class Project
3. Class Presentations

Class Project

- **Add some meronymic relations to your ontology and identify an inference which could be drawn from your ontology if the part-of ontology presented today would also be included in your ontology (irreflexivity removed).**

Send to me by 14th of February 9pm.

Today's Session: DL Semantics

1. **Model-theoretic Semantics of SROIQ(D)**
2. **Class Project**
3. **Class Presentations**

Class Presentations

- **<nothing new>**

Class planning (tentative)

Tuesday 10th of January: RDF Schema
Thursday 12th of January: RDF and RDFS Semantics
Tuesday 17th of January: RDF and RDFS Semantics
Thursday 19th of January: exercise session 1
Tuesday 24th of January: OWL part 1 – Description Logics
Thursday 2nd of February: OWL pt 2 – model-theoretic Semantics
Tuesday 7th of February: Partonomies
Thursday 9th of February: SPARQL
Tuesday 14th of February: OWL part 3 – web syntax
Thursday 16th of February: exercise session 2