Knowledge Representation for the Semantic Web

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Slides 4 – 01/21/2010

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Slides are based on

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Foundations of Semantic Web Technologies

Chapman & Hall/CRC, 2010

Flyer with special offer is available.

http://www.semantic-web-book.org
Today: RDF syntax

+ conjunctive queries for OWL
Today’s Session: RDF Schema

1. Motivation
2. Classes and Class Hierarchies
3. Properties and Property Hierarchies
4. Property Restrictions
5. Open Lists Revisited
6. Reification
7. Supplementary Information in RDFS
8. Simple Ontologies in RDFS
9. Class project
10. Class presentations
Motivation

• RDF allows to express facts
  – Anne is the mother of Merula

• But we’d like to be able to express more generic knowledge
  – Mothers are female
  – If somebody has a daughter then that person is a parent

• This kind of knowledge is often called *schema* knowledge or *terminological* knowledge.
RDF Schema (RDFS)

- part of the W3C Recommendation RDF
- for schema/terminological knowledge
- uses RDF vocabulary with pre-defined semantics
- every RDFS document is an RDF document
- Namespace: http://www.w3.org/2000/01/rdf-schema# - usually abbreviated by rdfs:

- vocabulary is generic, not bound to a specific application area
  - allows to (partially) specify the semantics of other/user-defined vocabularies (it’s a kind of meta vocabulary)
  - hence, RDF software correctly interprets each vocabulary defined using RDF Schema
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Classes and Instances

- Classes stand for sets of things. In RDF: Sets of URIs.

- book:uri is a member of the class ex:Textbook
  

- A URI can belong to several classes
  

- Classes can be arranged in hierarchies: each textbook is a book
  
  ex:Textbook rdfs:subClassOf ex:Book .
Pre-defined classes

• every URI denoting a class is a member of rdfs:Class

  ex:Textbook  rdf:type  rdfs:Class .

• this also makes rdfs:Class a member of rdfs:Class (!)

  rdfs:Class  rdf:type  rdfs:Class .

• rdfs:Resource (class of all URIs)
• rdf:Property (class of all properties)
• rdf:XMLLiteral
• rdfs:Literal (each datatype is a subclass)
• rdf:Bag, rdf:Alt, rdf:Seq, rdfs:Container , rdf:List, rdf:nil,
  rdfs:ContainerMembershipProperty (see later)
• rdfs:Datatype (contains all datatypes – a class of classes)
• rdf:Statement (see later)
Implicit knowledge

- If an RDFS document contains
  
  $$u \quad \text{rdf:type} \quad \text{ex:Textbook}.$$

  and

  $$\text{ex:Textbook} \quad \text{rdfs:subClassOf} \quad \text{ex:Book}.$$

  then

  $$u \quad \text{rdf:type} \quad \text{ex:Book}.$$

is implicitly also the case: it’s a logical consequence. (We can also say it is deduced (deduction) or inferred (inference). We do not have to state this explicitly. Which statements are logical consequences is governed by the formal semantics (covered in the next session).
Implicit knowledge – another example

- From

\[
\text{ex:Textbook} \quad \text{rdfs:subClassOf} \quad \text{ex:Book}.
\]

\[
\text{ex:Book} \quad \text{rdfs:subClassOf} \quad \text{ex:PrintMedia}.
\]

the following is a logical consequence:

\[
\text{ex:Textbook} \quad \text{rdfs:subClassOf} \quad \text{ex:PrintMedia}.
\]

I.e. rdfs:subClassOf is **transitive**.
Using implicit knowledge

Ontology (Knowledge Base)  
e.g. RDF or OWL  

Reasoner (accesses implicit knowledge)  

Application  

Used like a database  

online
Using implicit knowledge

Ontology (Knowledge Base)
e.g. RDF or OWL

Reasoner (produces implicit knowledge)

Completed (materialized) knowledge base

Application

Used like a database
Class equivalence

\[
\text{ex:MorningStar} \quad \text{rdfs:subClassOf} \quad \text{ex:EveningStar}.
\]

\[
\text{ex:EveningStar} \quad \text{rdfs:subClassOf} \quad \text{ex:MorningStar}.
\]

\[
\text{ex:Book} \quad \text{rdfs:subClassOf} \quad \text{ex:Book}.
\]

I.e. \text{rdfs:subClassOf} is \textit{reflexive}. 
<ex:HomoSapiens rdf:about="&ex;SebastianRudolph"/>

is short for

<rdf:Description rdf:about="&ex;SebastianRudolph">
  <rdf:type rdf:resource="&ex;HomoSapiens"/>
</rdf:Description>
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Property Hierarchies

From

\[ \text{ex:isHappilyMarriedTo} \quad \text{rdf:subPropertyOf} \quad \text{ex:isMarriedTo}. \]

and

\[ \text{ex:markus} \quad \text{ex:isHappilyMarriedTo} \quad \text{ex:anja}. \]

we can infer that

\[ \text{ex:markus} \quad \text{ex:isMarriedTo} \quad \text{ex:anja}. \]
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Property Restrictions

• Allow to state that a certain property can only be between things of a certain rdf:type.

• E.g. when a is married to b, then both a and b are Persons.

• Expressed by rdfs:domain and rdfs:range:

\[
\text{ex:isMarriedTo rdfs:domain ex:Person .} \\
\text{ex:isMarriedTo rdfs:range ex:Person .}
\]

• And similarly for datatypes:

\[
\text{ex:hasAge rdfs:range xsd:nonNegativeInteger .}
\]
### Pitfalls 1

<table>
<thead>
<tr>
<th>ex:author0f</th>
<th>rdfs:range</th>
<th>ex:Textbook .</th>
</tr>
</thead>
<tbody>
<tr>
<td>ex:author0f</td>
<td>rdfs:range</td>
<td>ex:Storybook .</td>
</tr>
</tbody>
</table>

states that everything in the rdfs:range of ex:authorOf is **both** a ex:Textbook and a ex:Storybook!
A logical consequence of this is

```
ex:isMarriedTo  rdfs:domain  ex:Person .
ex:isMarriedTo  rdfs:range   ex:Person .
ex:instituteAIFB rdfs:type     ex:Institution .
ex:pascal       ex:isMarriedTo ex:instituteAIFB .
ex:instituteAIFB rdf:type     ex:Person .
```
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Open Lists revisited

- New class: rdfs:ContainerMembershipProperty containing the properties used with containers, e.g.

```xml
  rdf:_1 rdf:type rdfs:ContainerMembershipProperty .
  rdf:_2 rdf:type rdfs:ContainerMembershipProperty .
```
Open Lists revisited

• New property rdfs:member
  Is superproperty of all properties contained in
  rdfs:ContainerMembershipProperty.

• The RDFS semantics specifies:

  From
  \[ p \text{ rdf:type rdfs:ContainerMembershipProperty} \]
  and
  \[ a \text{ p b} \]
  the following is inferred:
  \[ a \text{ rdfs:member b} \]
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Talking about triples

• How do you state in RDF: “The detective supposes that the butler killed the gardener.”

• unsatisfactory:

```
ex:detective ex:supposes "The butler killed the gardener." .
```

• We would really like to talk about the triple

```
ex:butler ex:killed ex:gardener .
```
Talking about triples

• How to do it properly in RDFS:

```
ex:detective   ex:supposes   ex:theory .
ex:theory      rdf:predicate  ex:hasKilled .
```

• Note however, that the following is **not** a logical consequence of this:

```
ex:butler       ex:hasKilled  ex:gardener .
```

• One would usually use a blank node instead of ex:theory.
A reification puzzle

You know that story? It’s in the old testament :)

ex:יהוה

ex:wantsTo Prevent

ex:יהוה

ex:hasKilled

ex:יהוה

ex:discovers

rdfs:Statement

You know that story? It’s in the old testament :)
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Supplementary information

- comments etc. which are not part of the actual ontology, but are for the human reader/user/developer

- in RDF, we also use triples to encode these

- i.e. we have a set of pre-defined properties which do this job

- `rdfs:label`: e.g. to give a human-readable name for a URI
- `rdfs:comment`: used for lengthy commentary/explanatory text
- `rdfs:seeAlso`, `rdfs:definedBy`: properties pointing to URIs where further information or definitions can be found
Supplementary Information example

```xml

<
rdfs:Class rdf:about="&ex;& Primates">
  <rdfs:label xml:lang="en">primates</rdfs:label>
  <rdfs:comment>
    Order of mammals. Primates are characterized by an advanced brain. They mostly populate the tropical earth regions. The term 'Primates' was coined by Carl von Linné.
  </rdfs:comment>
  <rdfs:seeAlso rdf:resource="&wikipedia;Primates" />
  <rdfs:subClassOf rdf:resource="&ex;& Mammalia" />
</rdfs:Class>
```
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An example ontology

ex:vegetableThaiCurry ex:thaiDishBasedOn ex:coconutMilk .
ex:sebastian rdf:type ex:AllergicToNuts .
ex:sebastian ex:eats ex:vegetableThaiCurry .
ex:AllergicToNuts rdfs:subClassOf ex:Pitiable .
ex:thaiDishBasedOn rdfs:domain ex:Thai .
ex:thaiDishBasedOn rdfs:range ex:Nutty .
ex:thaiDishBasedOn rdfs:subPropertyOf ex:hasIngredient .
ex:hasIngredient rdf:type rdfs:ContainerMembershipProperty.
The same as graph

terminological knowledge (RDFS)

assertional knowledge (RDF)
Note the multiple views: XML

```xml
<rdf:Description rdf:ID="Truck">
  <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
  <rdfs:subClassOf rdf:resource="#MotorVehicle"/>
</rdf:Description>
```
<rdf:Description rdf:ID="Truck">
  <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
  <rdfs:subClassOf rdf:resource="#MotorVehicle"/>
</rdf:Description>
Note the multiple views: RDF Schema

```xml
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```
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Type separation

- When is something an instance? When is something a class?

  Father rdfs:type SocialRole .
  Pascal rdfs:type Father .

- What about triples like the following?

  Parasite hasHostOrganism LivingThing .
  LeapYear isFollowedby NonLeapYear .

- These all are valid RDF triples, and it’s also valid RDFS.

- But what does it mean?
Type separation

- It’s usually good to clearly separate **types** (as long as it’s feasible) and only break this if really needed. Types: instances, properties, classes
- Reason: The semantics is clearer.

- `<instance> rdf:type <class>`
- `<instance> someProperty <instance>`
- `<class> rdfs:subClassOf <class>`
- `<property> rdfs:subPropertyOf <property>`

- In OWL 1 DL, type separation was strictly enforced.
- In OWL 2 DL, it’s more relaxed, but the semantics is different.

- We’ll talk more about this in the OWL sessions.
Class project: next step

- keep bugfixing
- extend, where necessary, your ontology so that it makes a correct use of each of the following (each at least once):
  - rdf:datatype
  - rdfs:subPropertyOf
- for each property in your ontology, add triples which give their rdfs:domain and rdfs:range.
- write up your ontology in RDF Turtle syntax and group axioms in such a way that it’s easy to keep an overview of the contents.

- send to me by next Wednesday
  - the Turtle file as .txt file (validator: http://www.rdfabout.com/demo/validator/)
  - brief notes with lessons learned from this round of modeling (including the bugfixing)
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Class presentations – scheduled

- RDFa – embedding RDF in HTML (W3C standard)
  Pavan, Thursday 28\(^{th}\) of January

- Scalable Distributed Reasoning using MapReduce (Urbani, Kotoulas, Oren, van Harmelen, ISWC2009)
  Wenbo, Thursday 28\(^{th}\) of January

- Semantic MediaWiki, Vinh, to be scheduled
- Linked Open Data, Ashutosh, to be scheduled
- FOAF, Hemant, to be scheduled
Applications:
- The SNOMED ontology (major biomedical ontology)
- Yahoo! Search Monkey (enhancing web search)

Standards:
- SKOS – data model for sharing and linking knowledge organization systems via the Web (W3C standard)

Research papers:
- Parallel Materialization of the Finite RDFS Closure for Hundreds of Millions of Triples  (Weaver, Hendler, ISWC2009)
Class presentations – open topics

Tools:
• Protege – Ontology editing tool
• Jena – Java framework for Semantic Web by HP
• RDF triple stores (Virtuoso, Redland, Sesame, AllegroGraph)
Class Planning

Tuesday 26\textsuperscript{th} of January: RDF and RDFS Semantics
+ you get an exercise sheet
Thursday 28\textsuperscript{st} of January: 2 class presentations
Tuesday 2\textsuperscript{nd} of February: Exercise session

Estimated breakdown of sessions:
Intro + XML: 2
RDF: 3
OWL and Logic: 5
SPARQL and Querying: 2
Class Presentations: 3
Exercise sessions: 3