Knowledge Representation for the Semantic Web

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Pascal Hitzler
Kno.e.sis Center
Wright State University, Dayton, OH
http://www.knoesis.org/pascal/
Textbook (required)

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

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: RDF syntax – RDF Schema
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 allows us to do some schema knowledge modeling. OWL (discussed later) gives even more expressivity.
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

\[
\text{u} \quad \text{rdf\hspace{1pt}:type} \quad \text{ex\hspace{1pt}:Textbook} .
\]

and

\[
\text{ex\hspace{1pt}:Textbook} \quad \text{rdfs\hspace{1pt}:subClassOf} \quad \text{ex\hspace{1pt}:Book} .
\]

then

\[
\text{u} \quad \text{rdf\hspace{1pt}:type} \quad \text{ex\hspace{1pt}:Book} .
\]

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

```
ex:Textbook  rdfs:subClassOf  ex:Book .
ex:Book      rdfs:subClassOf  ex:PrintMedia .
```

the following is a logical consequence:

```
ex:Textbook  rdfs:subClassOf  ex:PrintMedia .
```

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

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

Reasoner (accesses implicit knowledge)

Used like a database

Application

online
Using implicit knowledge

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

Reasoner (produces implicit knowledge)

Completed (materialized) knowledge base

Used like a database

Application
Class equivalence

I.e. rdfs:subClassOf is 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

```
ex:isHappilyMarriedTo rdf:subPropertyOf ex:isMarriedTo.
```

and

```
ex:markus ex:isHappilyMarriedTo ex:anja .
```

we can infer that

```
ex:markus ex:isMarriedTo 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:

  ```prolog
  ex:isMarriedTo  rdfs:domain   ex:Person .
  ex:isMarriedTo  rdfs:range    ex:Person .
  ```

- And similarly for datatypes:

  ```prolog
  ex:hasAge       rdfs:range    xsd:nonNegativeInteger .
  ```
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

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

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

\[
\text{ex:instituteAIFB} \quad \text{rdf:type} \quad \text{ex:Institution} .
\]

\[
\text{ex:pascal} \quad \text{ex:isMarriedTo} \quad \text{ex:instituteAIFB} .
\]

\[
\text{ex:instituteAIFB} \quad \text{rdf:type} \quad \text{ex:Person} .
\]
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Open Lists revisited

- **New class**: rdfs:Container as superclass of rdf:Seq, rdf:Bag, rdf:Alt.
- **New class**: rdfs:ContainerMembershipProperty containing the properties used with containers, e.g.

  
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

  \[ a \ p \ b \ . \]

  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:

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


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

```r
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:יהי
ex:wantsToPrevent
ex:hasKilled

ex:יהו

ex:discovers
rdfs:Statement
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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>
```
Note the multiple views: RDF

```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>
```
Note the multiple views: RDF Schema

```xml
<rdfs:subClassOf rdf:resource="#MotorVehicle"/>
</rdf:Description>
```
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Type separation

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

  Father rdf:type SocialRole .
  Pascal rdf: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 Tuesday
  – 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 – first topics

• SPARQL 1.1 entailment regimes: 
  http://www.w3.org/2009/sparql/docs/entailment/xmlspec.xml

• Aidan Hogan, Andreas Harth, Axel Polleres: SAOR: Authoritative Reasoning for the Web. ASWC 2008: 76-90

• Jacopo Urbani, Spyros Kotoulas, Jason Maassen, Frank van Harmelen, Henri E. Bal: OWL Reasoning with WebPIE: Calculating the Closure of 100 Billion Triples. ESWC (1) 2010: 213-227

• Yuan Ren, Jeff Z. Pan, Yuting Zhao: Soundness Preserving Approximation for TBox Reasoning. AAAI 2010

• Franz Baader, Sebastian Brandt, Carsten Lutz: Pushing the EL Envelope. IJCAI 2005: 364-369
Thursday 13\textsuperscript{th} of January: RDFS Part I
Tuesday 18\textsuperscript{th} of January: Exercise Session
Thursday 20\textsuperscript{th} of January: RDF and RDFS Semantics

Estimated breakdown of sessions:
   Intro + XML: 2
   RDF: 3
   OWL and Logic: 6
   SPARQL and Querying: 2
   Class Presentations: 3
   Exercise sessions: 3