TECHNISCHE UNIVERSITÄT DRESDEN

FOUNDATIONS OF SEMANTIC WEB TECHNOLOGIES

RDF Schema

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DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

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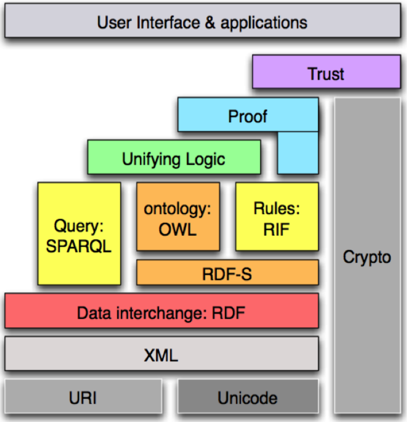
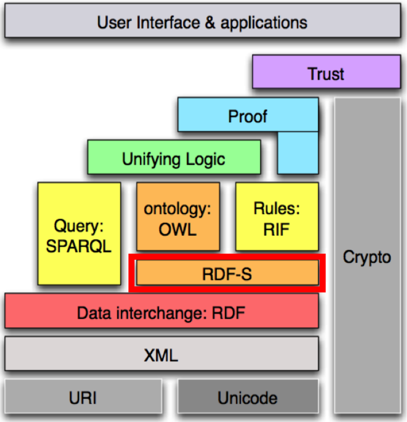
Content

RDF Schema


User Interface & applications
Trust
Proof
Unifying Logic
Query: SPARQL
ontology: OWL
Rules: RIF
RDF-S
Crypto
Data interchange: RDF
XML
URI
Unicode

RDF Schema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Agenda

- Motivation
- Classes and Class Hierarchies
- Properties and Property Hierarchies
- Property Restrictions
- Open Lists
- Reification
- Additional Information in RDFS
- Simple Ontologies

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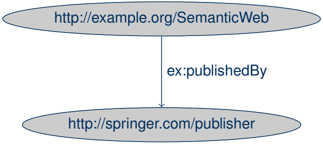
Schema Knowledge with RDFS

- RDF provides universal possibility to encode factual data on the Web



- = proposition about single resources (individuals) and their relationships
- desirable: propositions about generic sets of individuals (classes), e.g. publishers, organizations, persons etc.

Schema Knowledge with RDFS

- also desirable: specification of logical interdependencies between individuals, classes and relationships, in order to capture as much of the semantics of the described domain as possible, e.g.:
  "Publishers are Organizations."
  "Only persons write books."
- in database speak: schema knowledge

Schema Knowledge with RDFS

RDF Schema (RDFS):

- part of the W3C Recommendation of RDF
- allows for specifying schematic (also: terminological) Knowledge
- use of dedicated RDF vocabulary (thus: every RDFS document is an RDF document)
- name space (usually abbreviated with `rdfs`):
  `http://www.w3.org/2000/01/rdf-schema#`

Schema Knowledge with RDFS

RDF Schema (RDFS):

- yet: vocabulary not domain-specific (like, e.g., with FOAF), but generic
- allows for specifying (parts of) the semantics of arbitrary RDF vocabularies (could thus be called a “meta vocabulary”)
- advantage: every RDFS-compliant software faithfully supports every vocabulary that has been defined through RDFS
- this functionality makes RDFS an ontology language for lightweight ontologies
- “A little semantics goes a long way.”

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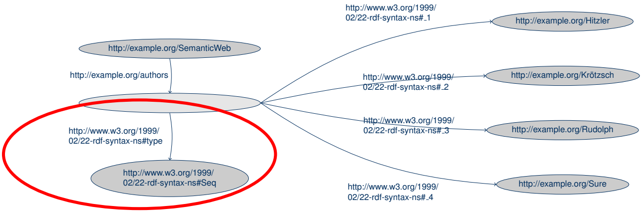
Classes and Instances

- We have already seen “typing” of resources in RDF when we discussed lists:



- the predicate `rdf:type` endows the subject with the type denoted by the object
- the object is seen as the identifier of a class, of which the resource denoted by the subject is a member (also called an instance of that class)

Classes and Instances

`ex:SemanticWeb rdf:type ex:Textbook .`

- characterizes “Semantic Web - Grundlagen” as instance of the (newly defined) class “Textbook”
- class membership is not exclusive, e.g. together with the above triple we may have:
  `ex:SemanticWeb rdf:type ex:Entertaining .`
- in general: a priori individual and class names cannot be distinguished syntactically
- also in reality, this distinction is sometimes difficult: e.g. for
  `http://www.un.org/#URI`

The Class of all Classes

- however, sometimes one wants to state that a URI denotes a class
- can be done by “typing” that URI as `rdfs:Class`

```
es:Textbook rdf:type rdfs:Class .
```

- `rdfs:Class` is the “class of all classes” and therefore also contains itself, thus the following triple is always valid:

```
rdfs:Class rdf:type rdfs:Class .
```

Subclasses – Motivation

- given the triple
  `ex:SemanticWeb rdf:type ex:Textbook .`
- we do not get a result when searching for instances of the class ex:Book
- option: add the triple
  `ex:SemanticWeb rdf:type ex:Book .`
- this just solves the problem only for the specific resource
  `ex:SemanticWeb`
- automatically adding it for all instances would blow up the RDF document

Subclasses

- better: one statement telling that every textbook is also a book, i.e., every instance of `ex:Textbook` is automatically also an instance of `ex:Book`
- realized via the `rdfs:subClassOf` property:

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

"The class of all textbooks is a subclass of the class of all books."

Subclasses

- the `rdfs:subClassOf` property is reflexive, i.e., every class is its own subclass, thus:

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

- on the contrary, we can enforce that two URIs refer to the same class by declaring them as mutual subclasses, like:

```
ex:Haven rdfs:subClassOf ex:Port .
ex:Port rdfs:subClassOf ex:Haven .
```

Class Hierarchies

- common: not just singular subclass relationships but whole class hierarchies (aka: taxonomies) e.g.:

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

- “built in” in RDFS semantics: transitivity of the `rdfs:subClassOf` property, i.e., it follows

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

Class Hierarchies

- class hierarchies particularly often used for modeling, e.g. in biology (e.g. Classification of living beings)
- Example: zoological categorization of the modern human

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:ex="http://www.semantic-web-grundlagen.de/Beispiele#">
  <rdfs:Class rdf:about="&ex;Animalia"/>
  <rdfs:Class rdf:about="&ex;Chordata">
    <rdfs:subClassOf rdfs:resource="&ex;Animalia"/>
  </rdfs:Class>
  <rdfs:Class rdf:about="&ex;Mammalia">
    <rdfs:subClassOf rdfs:resource="&ex;Chordata"/>
  </rdfs:Class>
  <rdfs:Class rdf:about="&ex;Primates">
    <rdfs:subClassOf rdfs:resource="&ex;Mammalia"/>
  </rdfs:Class>
  <rdfs:Class rdf:about="&ex;Hominidae">
    <rdfs:subClassOf rdfs:resource="&ex;Primates"/>
  </rdfs:Class>
  ...
```

Classes

- intuitive conection to set theory:

`rdf:type`	corresponds to	$\in$
`rdfs:subClassOf`	corresponds to	$\subseteq$

- this also justifies the reflexivity and transitivity of `rdfs:subClassOf`

Classes in RDF/XML Syntax

- abbreviated notation for specifying class instances:

```
<ex:HomoSapiens rdf:about="&ex;SebastianRudolph"/>
```

  instead of

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

- Likewise:

```
<rdfs:Class rdf:about="&ex;HomoSapiens"/>
```

Predefined Class URIs

- `rdfs:Resource`
  class of all resources (i.e., all elements of the domain)
- `rdf:Property`
  class of all relationships
  (= those resources, that are referenced via predicate URIs)
- `rdf:List`, `rdf:Seq`, `rdf:Bag`, `rdf:Alt`, `rdfs:Container`
  diverse kinds of lists
- `rdfs:ContainerMembershipProperty`
  class of all relationships that represent a containedness relationship

Predefined Class URIs

- `rdf:XMLLiteral`
  class of all values of the predefined datatype XMLLiteral
- `rdfs:Literal`
  class of all literal values (every datatype is a subclass of this class)
- `rdfs:Datatype`
  class of all datatypes (therefore it is a class of classes, similar to `rdfs:Class`)
- `rdf:Statement`
  class of all reified propositions (discussed later)

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Properties

- also called: relations, relationships
- beware: unlike in OOP, properties in RDF(S) are not assigned to classes
- property URIs normally in predicate position of a triple
- properties characterize, in which way two resources are related to each other
- mathematically often represented as set of pairs:
  marriedWith = $\{(\text{Adam}, \text{Eve}), (\text{Brad}, \text{Angelina}), \ldots\}$
- URI can be marked as property name by typing it accordingly:
  `ex:publishedBy rdf:type rdf:Property .`

Subproperties

- like sub-/superclasses also sub-/superproperties possible and useful
- specification in RDFS via `rdfs:subPropertyOf` e.g.:

```
ex:happilyMarriedWith rdf:subPropertyOf
rdf:marriedWith .
```

- Then, given the triple

```
ex:markus ex:happilyMarriedWith ex:anja .
```

  we can infer

```
ex:markus ex:marriedWith ex:anja .
```

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Property Restrictions

- common: usage of property only makes sense for certain kinds of resources, e.g. `ex:publishedBy` only connects publications with publishers
- thus, for all URIs `a`, `b`, the triple
  `a ex:publishedBy b .`
  intuitively entails:
  ```
  a rdf:type ex:Publication .
  b rdf:type ex:Publisher .
  ```
- We can express this directly in RDFS:
  ```
  ex:publishedBy rdfs:domain ex:Publication .
  ex:publishedBy rdfs:range ex:Publisher .
  ```
- Can also be used to “prescribe” datatypes for literals:
  ```
  ex:hasAge rdfs:range xsd:nonNegativeInteger .
  ```

Property restrictions

- property restrictions are the only way of specifying semantic interdependencies between properties and classes
- beware: property restrictions are interpreted globally and conjunctively: z.B.

```
ex:authorOf rdfs:range ex:Cookbook .
ex:authorOf rdfs:range ex:Storybook .
```

  means: every entity having an author is both a cookbook and a storybook
- thus: always pick the most general possible class for domain/range specifications

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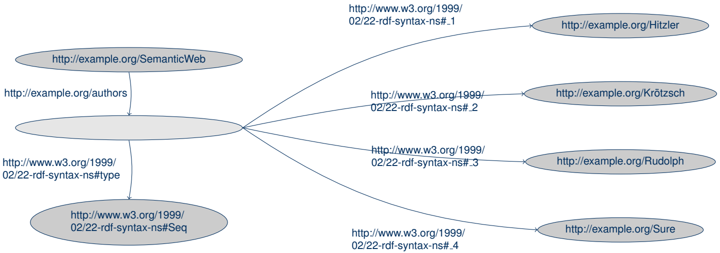
Working with open lists

Zur Erinnerung: offene Listen in RDF:



Working with Open Lists

- new class: `rdfs:Container` as superclass of `rdf:Seq`, `rdf:Bag`, `rdf:Alt`
- new class: `rdfs:ContainerMembershipProperty`
  instances of this class are no proper individuals, but themselves properties
- intended semantics: every property encoding that the subject contains the object is an instance of `rdfs:ContainerMembershipProperty`
- in particular, we have

  ```
  rdf:_1 rdf:type rdfs:ContainerMembershipProperty .
  rdf:_2 rdf:type rdfs:ContainerMembershipProperty .
  ```
  etc.

Working with Open Lists

- new property: `rdfs:member`
  superproperty of all properties that are instances of `rdfs:ContainerMembershipProperty`, could be called the "universal containedness relation"
- Hard-wired in the semantics of RDFS: whenever for a property `p` the triple

  ```
  p rdf:type rdfs:ContainerMembershipProperty .
  ```

  holds, then the triple

  ```
  a p b .
  ```

  gives rise to the triple

  ```
  a rdfs:member b .
  ```

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Reification

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- first modeling attempt:

```
ex:detektive ex:suspects "The butler killed the
gardener." .
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  – Suboptimal: the literal object cannot be easily referenced in other triples.

Reification

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- first modeling attempt:

```
ex:detektive ex:suspects "The butler killed the
gardener." .
```

  - Suboptimal: the literal object cannot be easily referenced in other triples.

- second modeling attempt:

```
ex:detektiv ex:suspects ex:theButlerKilledTheGardener
.
```

  - Suboptimal: we lose the inner structure of the talked about proposition

Reification

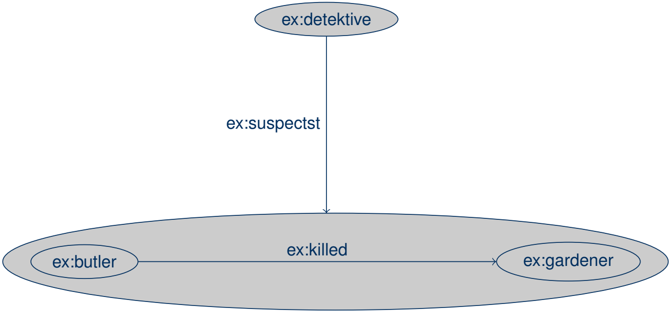
- problematic in RDF(S): model propositions about proposition (in natural language, such propositions can be identified by a leading “that”), e.g.: “The detective suspects that the butler killed the gardener.”
- Out of context, proposition can be easily modeled in RDF:

```
ex:butler ex:killed ex:gardener .
```

- desirable: this whole triple should occur as an object of another triple, however, this is not valid RDF

Reification

solution (similar to multi-valued relationships): introduce auxiliary nodes representing the nested proposition:



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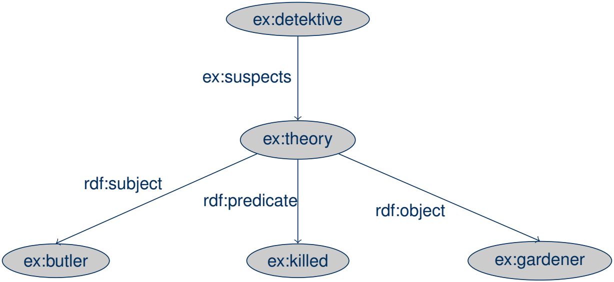
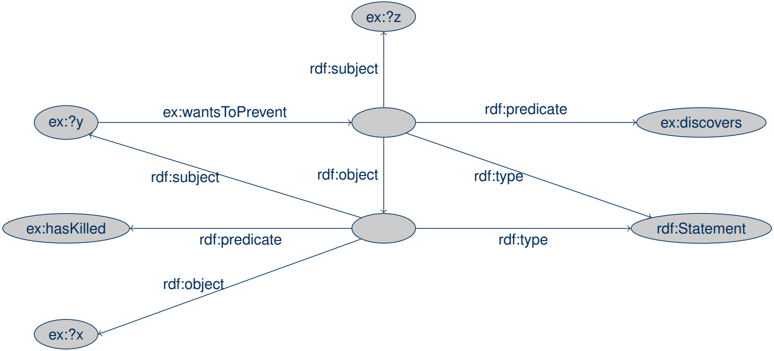


Reification

- caution: reified triple does not need to hold (would not be always sensible either, cf. propositions like: “The detective has doubts that the butler killed the gardener.”)
- if this is wanted, the original (un-reified) triple has to be added to the RDF document
- the class `rdf:Statement` is used to mark nodes which represent reified propositions
- in case this proposition is not referred to from the “outside”, the auxiliary node may be a bnode

Reification

A small reification riddle: another criminal story...



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Additional Information

- like with programming languages, one sometimes wants to add comments (without changing the semantics)
- purpose: increase understandability for human users
- it is to be preferred to model this knowledge in a graph-based way (e.g., due to compatibility reasons)
- thus: defined set of properties that serve this purpose

Additional Information

`rdfs:label`

- property that assigns a name (Literal) to an arbitrary resource
- often, URIs themselves are difficult to read, or “bulky” at best
- names provided via `rdfs:label` are often used by tools that graphically represent the data

example (also feat. language information):

```
<rdfs:Class rdf:about="&ex;Hominidae">
  <rdfs:label xml:lang="en">great apes</rdfs:label>
</rdfs:Class>
```

Additional Information

`rdfs:comment`

- property assigning an extensive comment (literal) to an arbitrary resource
- may e.g. contain the natural language description of a newly introduced class – this facilitates later usage

`rdfs:seeAlso, rdfs:definedBy`

- properties giving resources (URIs!) where one can find further information or a definition of the subject resource

Additional Information

Example of usage

```
:
xmlns:wikipedia="http://en.wikipedia.org/wiki" : <rdfs:Class
rdf:about="\&ex;Primates">
  <rdfs:label xml:lang="de">Primaten</rdfs:label>
  <rdfs:comment>
    An order of mammals. Primates are characterized by a highly
    developed brain. Most primates live in tropical or subtropical
    regions.
  </rdfs:comment>
  <rdfs:seeAlso rdfs:resource="/&wikipedia;Primate"/>
  <rdfs:subClassOf rdfs:resource="\&ex;Mammalia"/>
</rdfs:Class>
```

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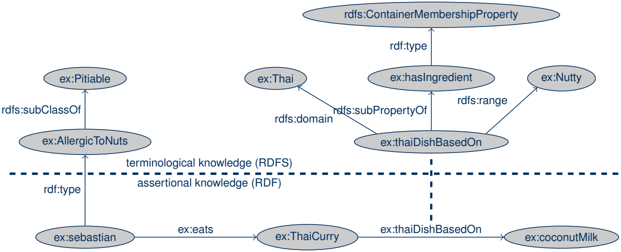
Simple Ontologies

- By means of the modeling features of RDFS, important aspects of many domains can already be captured semantically.
- Based on the RDFS semantics, a certain amount of implicit knowledge can be derived.
- Consequently, RDFS can be seen as a (though not overly expressive) ontology language.

Simple Ontologies - Example

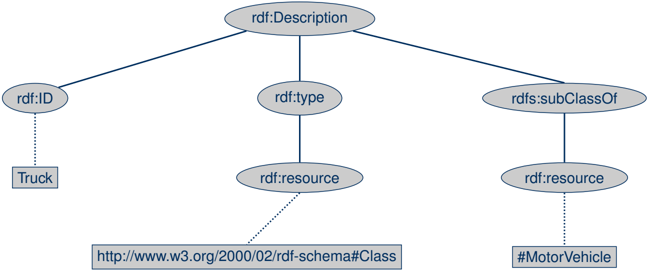
```
ex:vegetableThaiCurry  ex:thaiDishBasedOn    ex:coconutMilk .
ex:sebastian           rdf:type              ex:AllergicToNuts .
ex:sebastian           ex:eats               ex:vegetableThaiCurry .
ex:AllergicToNuts      rdfs:subClassOf       ex:Pitiable .
ex:thaiDishBasedOn     rdfs:domain       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



1 Document - 3 Interpretations

```
<rdf:Description rdf:ID="Truck">
  <rdf:type rdf:resource=
    "http://http://www.w3.org/2000/02/rdf-schema#Class"/>
  <rdfs:subClassOf rdf:resource="#MotorVehicle"/>
</rdf:Description>
```

Interpretation as XML:



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

Interpretation as RDF:

- another data model
- `rdf:Description`, `rdf:ID` and `rdf:resource` have a fixed meaning

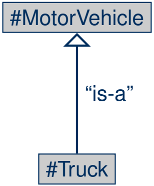
subject	predicate	object
`#Truck`	`rdf:type`	`rdfs:Class`
`#Truck`	`rdfs:subClassOf`	`#Motorvehicle`

1 Document - 3 Interpretations

```
<rdf:Description rdf:ID="Truck">
  <rdf:type rdf:resource=
    "http://http://www.w3.org/2000/02/rdf-schema#Class"/>
  <rdfs:subClassOf rdf:resource="#MotorVehicle"/>
</rdf:Description>
```

Interpretation as RDF Schema:

- yet another data model
- `rdf:type` and `rdf:subClassOf` have a specific interpretation



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