Multi-agent and Semantic Web Systems: RDF Schema

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Outline

- Introduction to RDFS
  - Limitations of RDF
  - RDFS Statement
- Inference and Semantics
- More inference in RDFS
- Other constructs in RDFS
- Serialising RDF in XML
- Summary

Ground Assertions

- RDF allows us to make factual statements (assertions).
- These statements are always about individual objects.
- We can say things like *Kim is a man* (using `rdf:type`);
- but we can't say things like:
  - *Giraffes are mammals*
  - *If you are a friend of someone then you know that person*

Missing syntactic contraints

- By itself, RDF places no restrictions on how predicates combine with subjects and objects.

- Indeed, RDF has no way of telling which URIs can semantically act as predicates.

Anomalous Statements

```
infcourses:masws terms:knows edstaff:9888 .
meals:lunch06 terms:homepage dc:title .
mailto:kim@wanna.be edstaff:9888 'chicken' .
```

RDF vocabulary definition

- RDF has been extended with mechanisms to allow new vocabularies to be defined.

- Resulting language known as RDF Schema (RDFS; cf. http://www.w3.org/TR/rdf-schema/)

- Basic idea is to allow statements like the following:

Example RDFS Constraints

The subject of 'birthday' must be an Agent.
The object of 'homepage' must be a Document.
Every instance of Person is an instance of Agent.

RDFS as a schema language

- RDFS also known as a schema language;
- helps provide meaning to RDF data.
- meaning ⇒ inference; i.e. you get out more than is directly asserted.
- RDFS is expressed in RDF syntax (i.e., as a set of triples).
- *Cf.* XML Schema vs. XML DTDs

RDF / RDFS classes (most common)

RDF:

- `rdf:Resource` — the class resource, everything
- `rdf:Property` — the class of properties
- `rdf:Statement` — the class of RDF statements

RDFS:

- `rdfs:Literal` — the class of literal values, e.g. strings and integers
- `rdfs:Class` — the class of classes
- `rdfs:Datatype` — the class of RDF datatypes

RDF / RDFS classes (most common)

RDF:

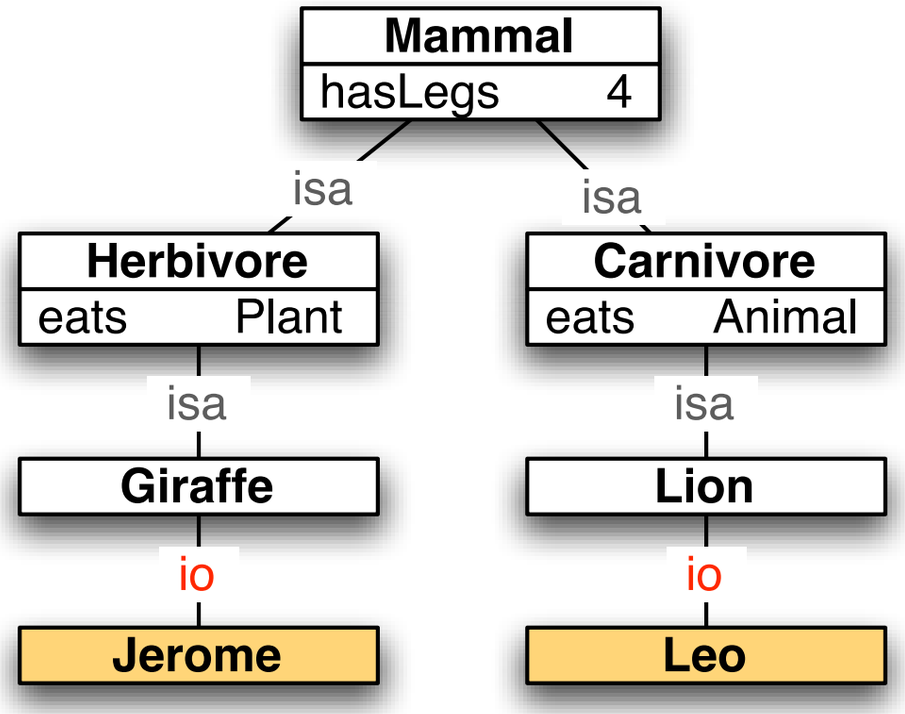
- `rdf:type` — an instance of rdf:Property used to state that a resource is an instance of a class
- `rdf:value` — idiomatic property used for structured values

RDFS:

- `rdfs:subClassOf` — the subject is a subclass of a class
- `rdfs:subPropertyOf` — the subject is a subproperty of a property
- `rdfs:domain` — a domain of the subject property
- `rdfs:range` — a range of the subject property
- `rdfs:label` — a human-readable name for the subject
- `rdfs:comment` — a description of the subject resource
- `rdfs:seeAlso` — further information about the subject resource

Frame-based KR

- ISA and IO links from frame-based knowledge representation:



Classes and instances

Declaring Classes

```
terms:Giraffe rdf:type rdfs:Class .
terms:Herbivore rdf:type rdfs:Class .
```

Giraffe and Herbivore are classes.

Instances

```
myzoo:jerome rdf:type terms:Giraffe .
myzoo:jerome a terms:Giraffe .
```

jerome is an instance of (IO) Giraffe.

Subclasses

```
terms:Giraffe rdfs:subClassOf terms:Herbivore .
```

Giraffe is a subclass of (ISA) Herbivore.

Properties

Properties

```
terms:eats rdf:type rdf:Property .
terms:eats a rdf:Property .
```

eats is a property.

Domain

```
terms:eats rdfs:domain terms:Animal .
```

The subjects of eats are instances of Animals.

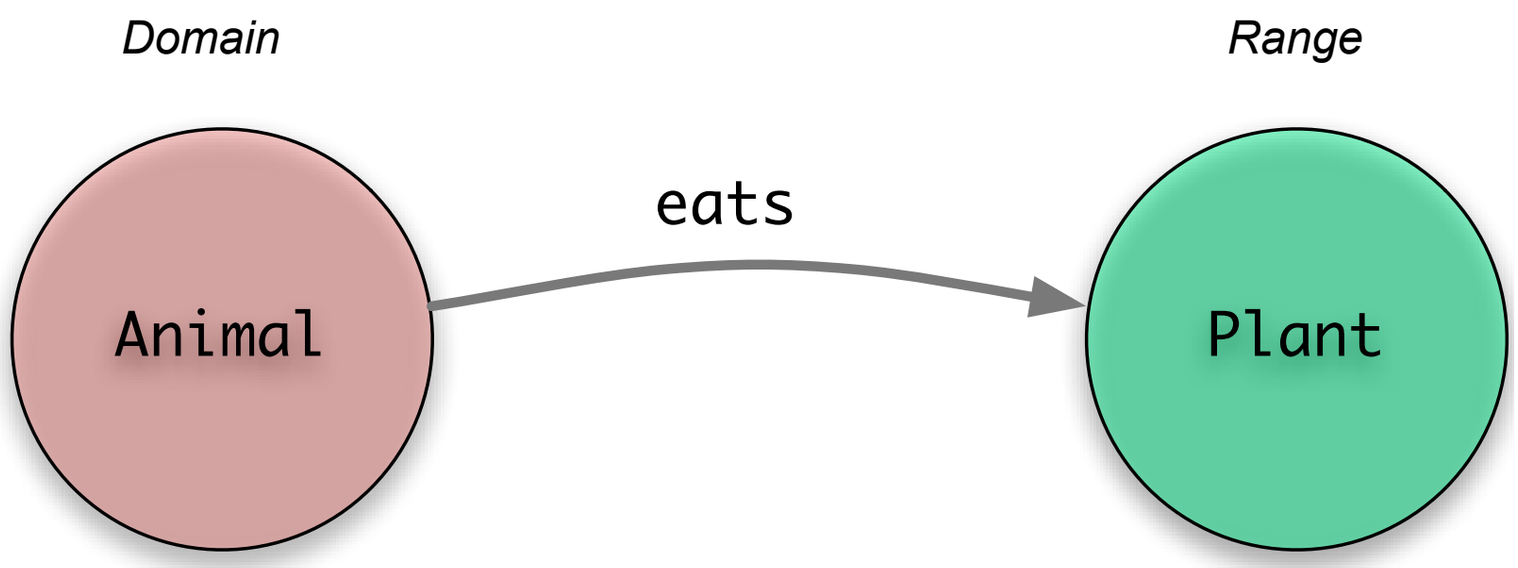
Range

```
terms:eats rdfs:range terms:Plant .
```

The values of eats are instances of Plant.

eats : Animal ↦ Plant

Domain and range



Type propagation in RDFS

- $\forall x.(P(x) \wedge P \subseteq Q) \rightarrow Q(x)$

Type propagation in RDFS

- $\forall x.(P(x) \wedge P \subseteq Q) \rightarrow Q(x)$
- Jerome is a Giraffe and Giraffes are Mammals. Therefore Jerome is a Mammal.

Type Propagation Rule

```
IF
?A rdfs:subClassOf ?B .
AND
?x rdf:type ?A .
THEN
?x rdf:type ?B .
```

Type propagation in RDFS

Schema statements

```
:Cafe rdf:type rdfs:Class .
:Restaurant rdf:type rdfs:Class .
:EatingPlace rdf:type rdfs:Class .

:Cafe rdfs:subClassOf :EatingPlace .
:Restaurant rdfs:subClassOf :EatingPlace .
```

Type propagation in RDFS

Asserted type statements

```
:ebagel rdf:type :Cafe .
:aroast rdf:type :Cafe .
:pyard rdf:type :Cafe .
:hacraft rdf:type :Cafe .
:vittoria rdf:type :Restaurant .
```

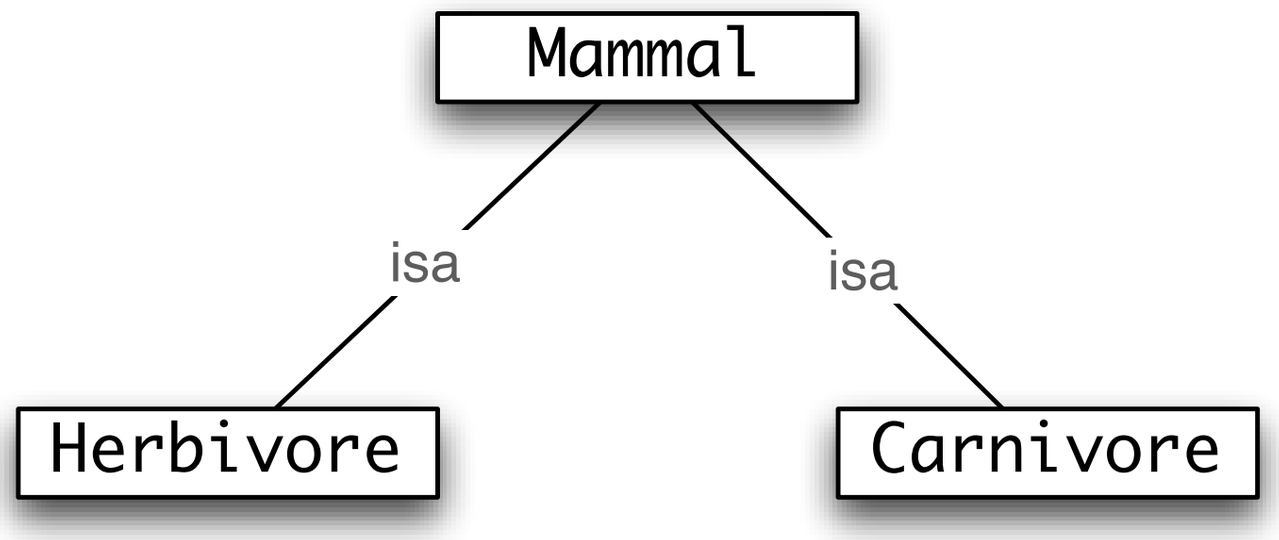
Inferred type statements

```
:ebagel rdf:type :EatingPlace .
:aroast rdf:type :EatingPlace .
:pyard rdf:type :EatingPlace .
:hacraft rdf:type :EatingPlace .
:vittoria rdf:type :EatingPlace .
```

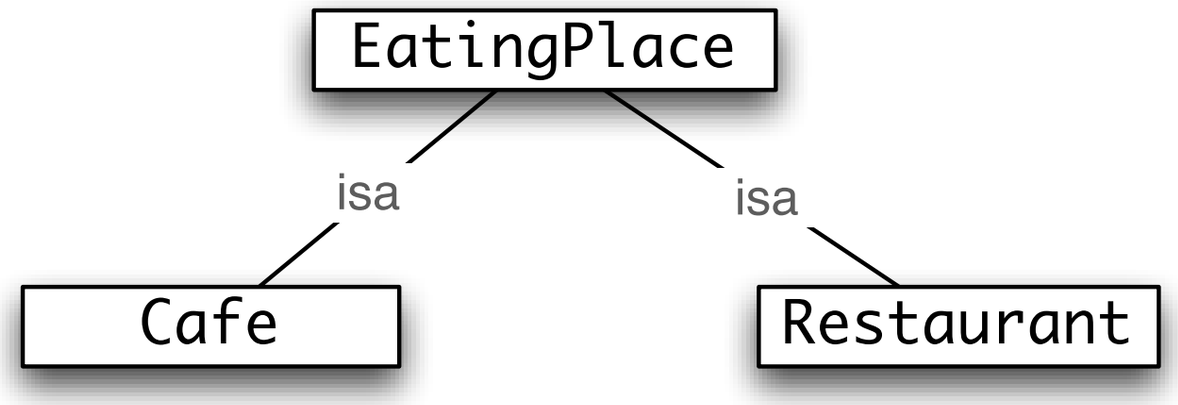
Inference support in Jena

- Jena provides support for RDFS Inference.
- But not via command line.
- See http://jena.sourceforge.net/inference/

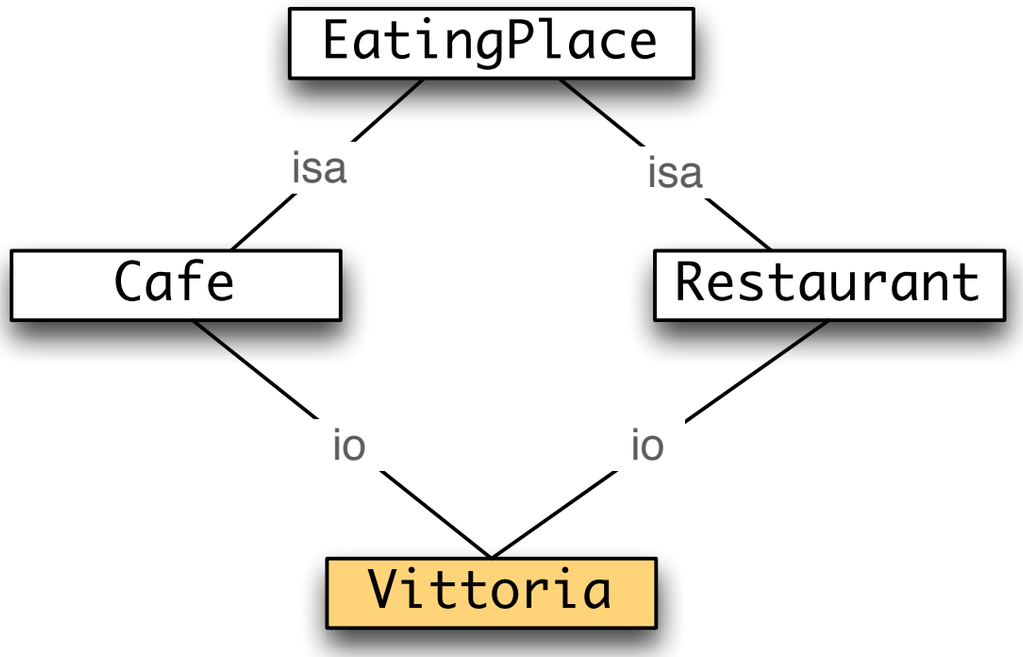
Disjointedness?



Disjointedness?



Disjointedness?



Asserted type statements

```
:vittoria rdf:type :Cafe .
:vittoria rdf:type :Restaurant .
```

Disjointedness?

- RDFS cannot express the statement that two sets are disjoint.
- We need OWL for this.
- We also cannot infer from previous example that `:Cafe` and `:Restaurant` have a non-null intersection.

Relationship Propagation in RDFS

- $\forall R, S, x, y.(R(x, y) \wedge R \subseteq S) \rightarrow S(x, y)$

Relationship Propagation in RDFS

- $\forall R, S, x, y.(R(x, y) \wedge R \subseteq S) \rightarrow S(x, y)$
- Ann is a sister of Bea, and 'sister' is a subproperty of 'sibling'. Therefore, Ann is sibling of Bea.
- *NB* subproperty can be expressed set theoretically if we regard a relation as a set of pairs: $\forall \langle x,y \rangle . \langle x,y \rangle \in R \rightarrow \langle x,y \rangle \in S$

Relationship Propagation Rule

```
IF
?R rdfs:subPropertyOf ?S .
AND
?x ?R ?y .
THEN
?x ?S ?y .
```

Relationship Propagation in RDFS

Schema statement

```
dbp:likes rdfs:subPropertyOf foaf:knows .
```

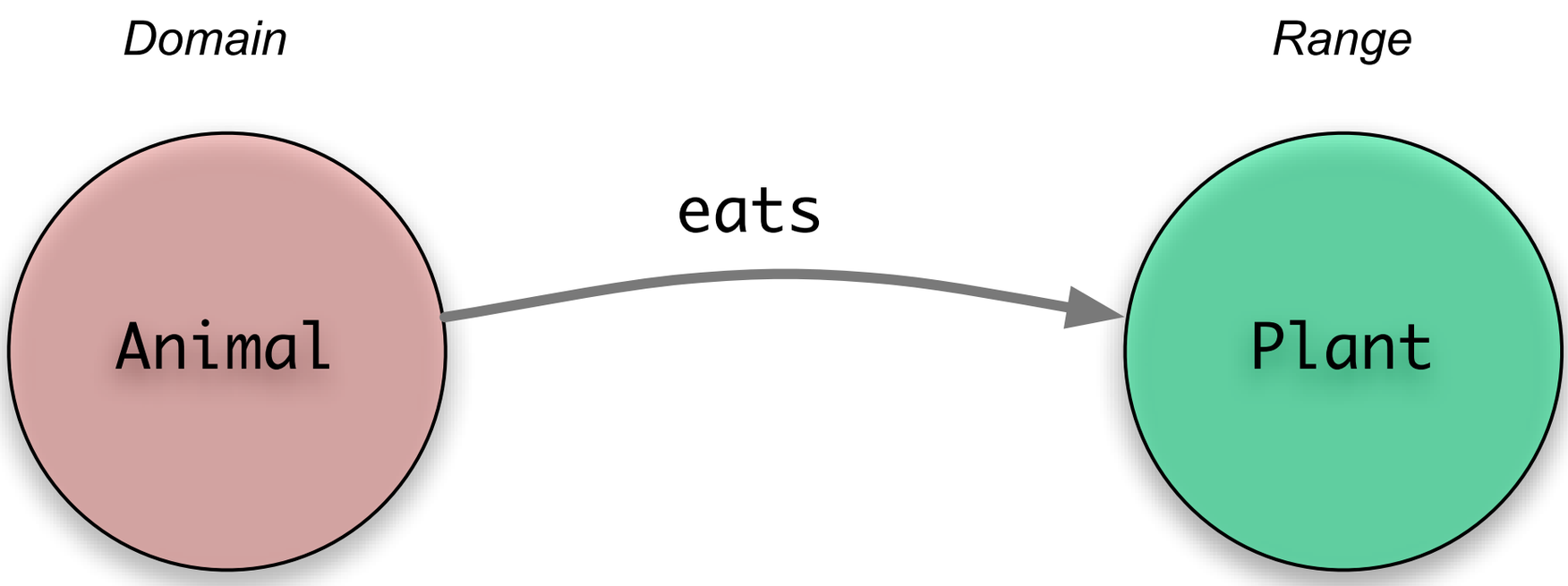
Asserted triple

```
:bea dbp:likes :stu .
```

Inferred triple

```
:bea foaf:knows :stu .
```

Domain and range



Domain and range typing in RDFS

Domain Typing Rule

```
IF
?R rdfs:domain ?A .
AND
?x ?R ?y .
THEN
?x rdf:type ?A .
```

Range Typing Rule

```
IF
?R rdfs:range ?B .
AND
?x ?R ?y .
THEN
?y rdf:type ?B .
```

Relationship propagation in RDFS

Schema statements

```
foaf:knows rdfs:domain foaf:Person .
foaf:knows rdfs:range foaf:Person .
```

Asserted triple

```
:bea foaf:knows :stu .
```

Inferred triples

```
:bea rdf:type foaf:Person .
:stu rdf:type foaf:Person .
```

Relationship propagation in RDFS

Schema statements

```
:hasCuisine rdfs:domain :Restaurant .
:hasCuisine rdfs:range :Cuisine .
```

Asserted triple

```
:vittoria :hasCuisine :italian .
```

Inferred triples

```
:vittoria rdf:type :Restaurant .
:italian rdf:type :Cuisine .
```

Relationship propagation in RDFS

Schema statements

```
:hasCuisine rdfs:domain :Restaurant .
:hasCuisine rdfs:domain :Cafe .
```

Asserted triples

```
:witchery :hasCuisine :scottish .
```

Inferred triples

```
:witchery rdf:type :Restaurant .
:witchery rdf:type :Cafe .
```

- Multiple statements of form x rdf:type A are interpreted conjunctively
- Unwanted consequence: :witchery is both a :Restaurant and a :Cafe.

Relationship propagation in RDFS

A simple mistake:

Schema statements

```
:hasCuisine rdfs:domain :Cuisine .
:hasCuisine rdfs:range :Restaurant .
```

Asserted triples

```
:vittoria :hasCuisine :italian .
:vittoria rdf:type :Restaurant .
```

RDFS doesn't complain!

Inferred triples

```
:vittoria rdf:type :Cuisine .
:italian rdf:type :Restaurant .
```

RDFS v Type checking

- In typed languages, domain and range are used to control syntactic well-formedness.

- If $\tau(R) = (A \rightarrow B) \rightarrow Sent$ and $\tau(x) = A$, $\tau(y) = B$ then $\tau(R(x, y)) = Sent$.

- No such constraints in RDF(S) — domain and range used for inference rather than syntactic correctness.

Combined inference in RDFS

Schema statements

```
:hasCuisine rdfs:domain :Restaurant .
:Restaurant rdfs:subClassOf :EatingPlace .
```

Asserted triple

```
:vittoria :hasCuisine :italian .
```

Inferred triple

```
:vittoria rdf:type :EatingPlace .
```

NB Contrast with inheritance in OOP languages, where e.g., *Restaurant* could extend behaviour of *EatingPlace*.

Set intersection

Schema statements

```
:WineBar rdfs:subClassOf :EatingPlace .
:WineBar rdfs:subClassOf :LicencedPremises .
```

This is equivalent to statement of the form $C \subseteq A \cap B$

Asserted triple

```
:maxies rdf:type :WineBar .
```

Inferred triple

```
:maxies rdf:type :EatingPlace .
:maxies rdf:type :LicensedPremises .
```

rdfs: label

- URIs often not readable or not informative.
- rdfs:label provides a printable name for any resource;
- can be used by presentation engines where available.

Uninformative URI

```
https://projects.inf.ed.ac.uk/msc/project?number=P090
```

URI with Label

```
<https://projects.inf.ed.ac.uk/msc/project?number=P090>
rdfs:label
”Detecting web spam using machine learning” .
```

Use existing triples

```
<https://projects.inf.ed.ac.uk/msc/project?number=P090>
:title
”Detecting web spam using machine learning” .
:title rdfs:subPropertyOf rdfs:label .
```

rdfs: seeAlso

- Generally recommended that Semantic Web URIs should be de-referenceable.

- But URI might just resolve to, e.g., a bunch of RDF statements.

- Can use `rdfs:seeAlso` to point to additional (human-readable) documentation about a resource.

- Also crucial for providing links in FOAF files.

rdfs:seeAlso for FOAF

```
:bea foaf:knows
  [rdf:type foaf:Person;
   foaf:mbox <mailto:stu@gmail.com>;
   rdfs:seeAlso <http://example.com/~stu/foaf.rdf> ] .
```

Document tree

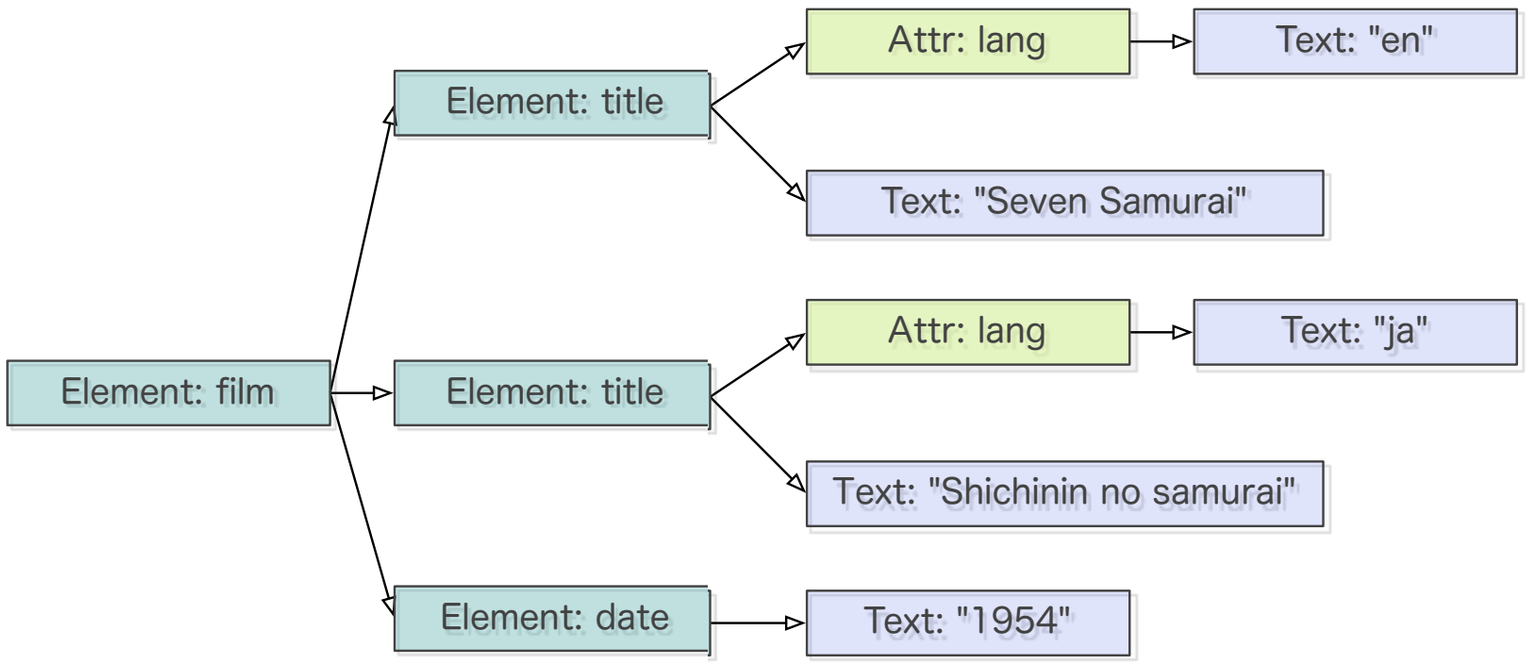
We can represent XML documents as trees.

Example XML Document

```
<film>
 <title lang="en">Seven Samurai</title>
 <title lang="ja">Shichinin no samurai</title>
  <date>1954</date>
</film>
```

Document trees

- Elements are represented as nodes.
- So are Attributes and Text items.

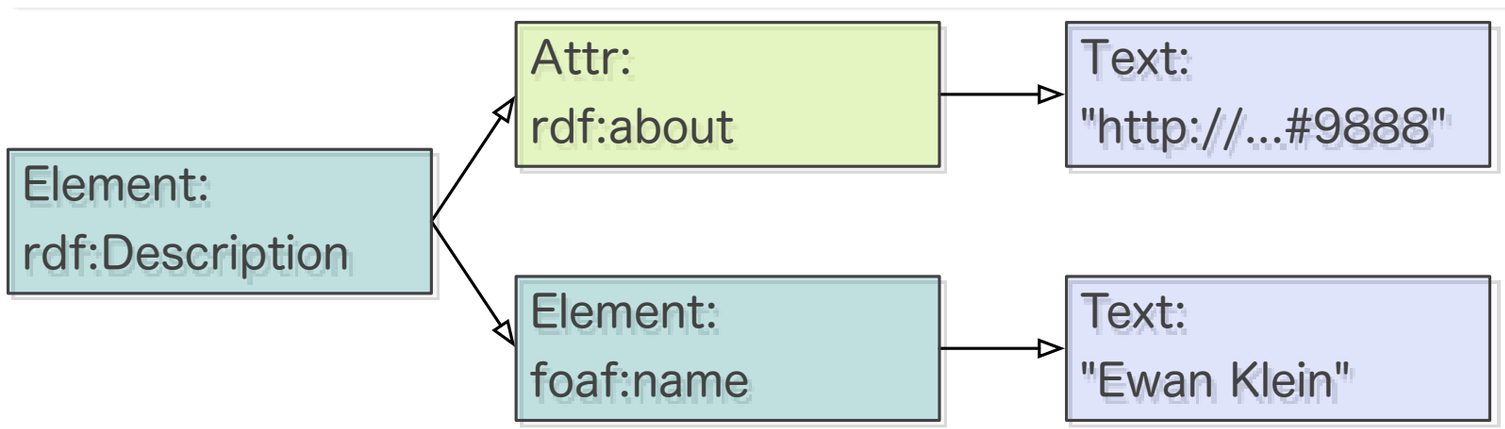


RDF triples as XML fields

RDF Triples are encoded as `rdf:Description` elements.

RDF Triple with literal Object

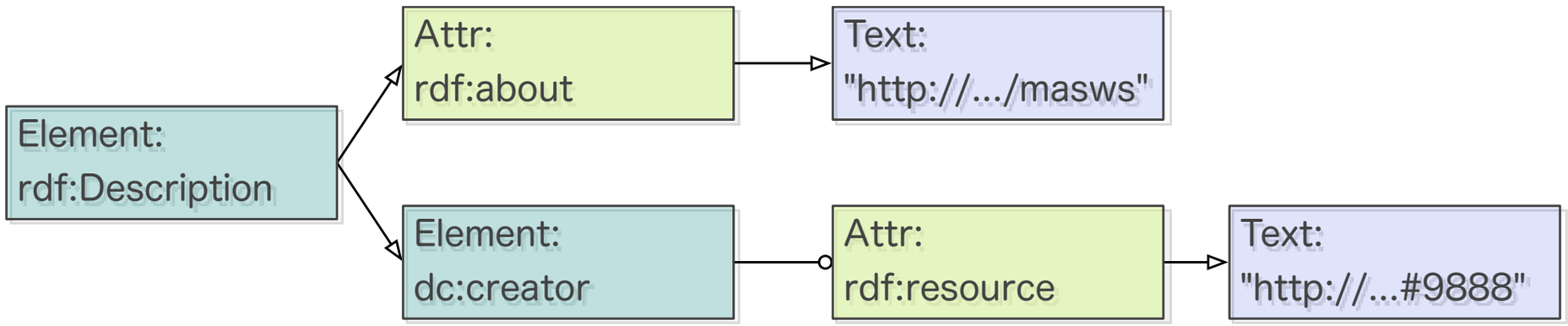
```
edstaff:9888 foaf:name 'Ewan Klein'
```



RDF triples as XML trees

RDF Triples with resource Object

```
infcourses:masws dc:creator edstaff:9888
```



RDF triples as XML trees

- RDF Triples are serialised as `rdf:Description` elements.

- The Subject is the value of the `rdf:about` attribute on `rdf:Description`.

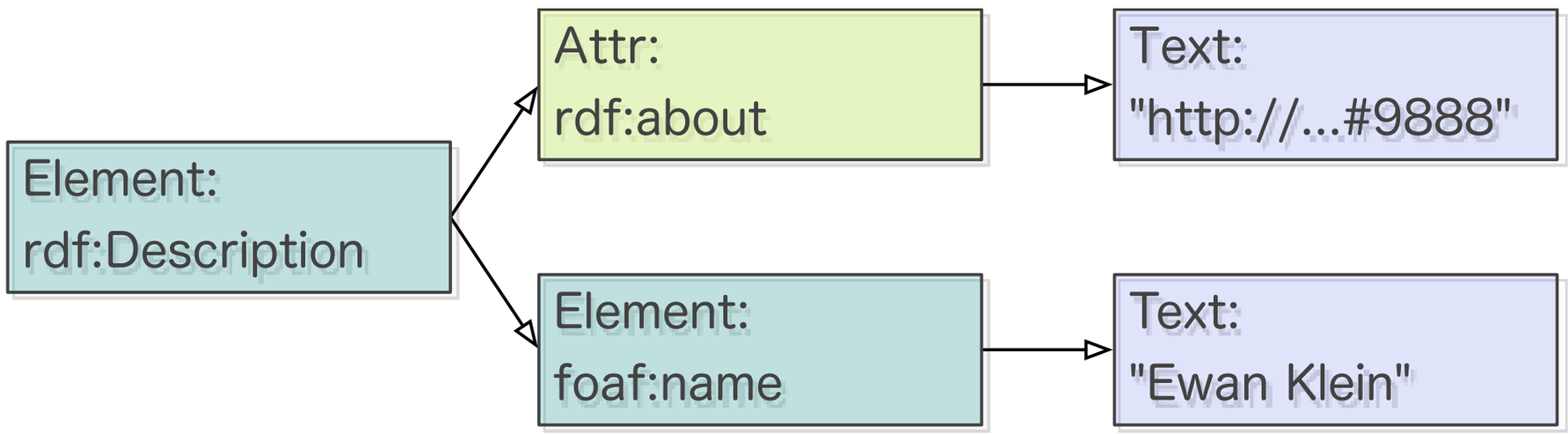
- The Predicate becomes a child element of `rdf:Description`.

- Objects:
  - Literal Objects are text content of the 'Predicate' element.
  - Resource Objects are values of the `rdf:resource` attribute of the 'Predicate' element.
  - URIs have to be written out in full (no Qnames) when they are attribute values.

RDF triples as XML trees

RDF Triple with literal Object

```
edstaff:9888 foaf:name 'Ewan Klein'
```



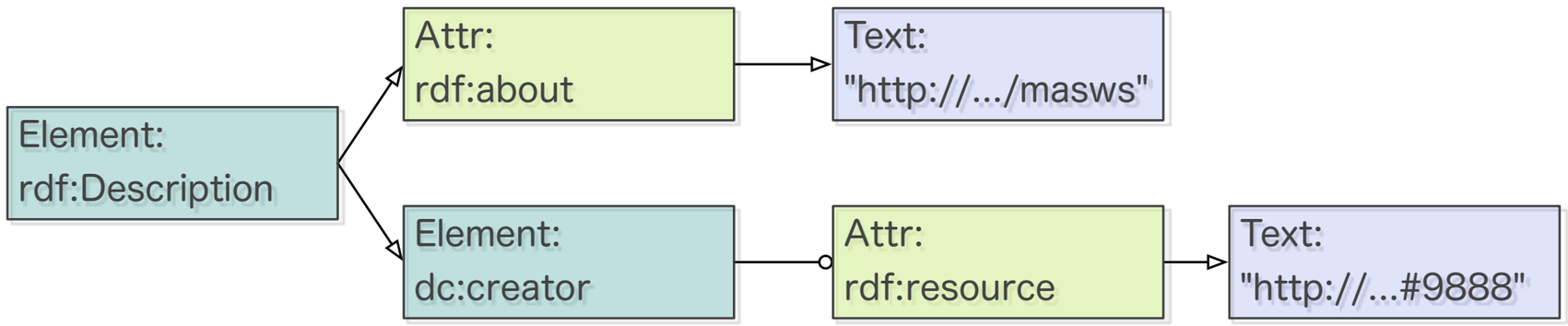
Linear version

```
<rdf:Description rdf:about="http://...#9888"> <foaf:name>Ewan
 Klein</foaf:name> </rdf:Description'>
```

RDF triples as XML trees

RDF Triples with resource Object

```
infcourses:masws dc:creator edstaff:9888
```



Linear version

```
<rdf:Description rdf:about=”http://.../masws”>
   <dc:creator rdf:resource=”http://...#9888”/>
</rdf:Description’>
```

Abbreviating multiple properties

RDF Triples with shared Subject

```
edstaff:9888 foaf:name 'Ewan Klein'
edstaff:9888 foaf:homepage http://.../~ewan/
```

Linear version

```
<rdf:Description rdf:about="http://...#9888">
   <foaf:name>Ewan Klein</foaf:name>
</rdf:Description'>
<rdf:Description rdf:about="http://...#9888">
   <foaf:homepage rdf:resource="http://.../~ewan/>
</rdf:Description'>
```

Abbreviating multiple properties

RDF Triples with shared Subject

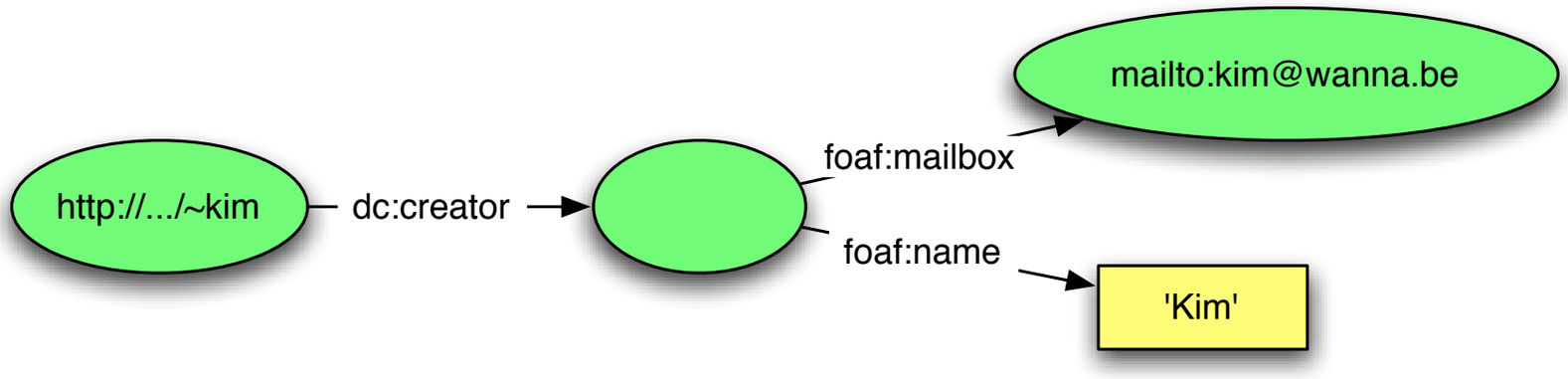
```
edstaff:9888 foaf:name 'Ewan Klein'
edstaff:9888 foaf:homepage http://.../~ewan/
```

Linear version

```
<rdf:Description rdf:about="http://...#9888">

   <foaf:name>Ewan Klein</foaf:name>
   <foaf:homepage rdf:resource="http://.../~ewan/>
</rdf:Description'>
```

Blank nodes



XML version of blank node

```
<rdf:Description rdf:about="http://.../~kim">
 <dc:creator rdf:nodeID="abc"/>
</rdf:Description>
<rdf:Description rdf:nodeID="abc">
   <foaf:mailbox rdf:resource="mailto:kim@wanna.be>
   <foaf:name>Kim</foaf:name>
</rdf:Description'>
```

Summary: RDF and XML

- XML is just a way of serialising RDF

- But think of RDF models in terms of graphs (*cf.* thinking of XML in terms of trees).

- Hard to avoid RDF/XML

- But knowledge of RDF/XML will not be tested in the exam; I'll stick to Turtle syntax.

Summary: RDFS entailment

- All schema information is expressed as RDF triples.

- Meaning of RDFS constructs is stated in terms of inferences that can be drawn.

- Inference in RDFS based on notion of set inclusion.

- `rdfs:subClassOf` and `rdfs:subPropertyOf` can be used for data integration (*cf.* SWWO Ch. 6)

Summary: RDFS

- RDF Schema (RDFS) provides mechanisms for describing (simple) ontologies.

- RDFS build on top of RDF, using rdf:type.

- Provides
  - `Class, subClassOf`
  - `Property, subPropertyOf`
  - `domain, range`

- Deliberately not 'object-oriented':
  - Properties are defined independently, not relative to classes.

- Classes are primitives, not defined in terms of necessary and sufficient properties.

Reading and Task

- SWWO, Chs 5, 6
- Consider your RDF from last task. Use RDFS to add domains and ranges. Add a few more assertions and use them to infer new facts.