THE UNIVERSITY of EDINBURGH
informatics

Semantic Web Systems

RDF Schema

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In the previous lecture

- Turtle syntax

Triple in abbreviated form

```
@prefix  dc:  <http://purl.org/dc/elements/1.1/>  .
@prefix  :  <http://inf.ed.ac.uk/ont#>  .
 :aroast  dc:title  “Artisan Roast” .
```

More Turtle abbreviations

```
:aroast  dc:title  “Artisan Roast” ;
            db:locatedIn  :eastEnd ;
            :rating  “5”^^xsd:decimal ;
            :lovedBy  :stu ,  :rod .
```

In the previous lecture

- Blank nodes
  - Artisan Roast is run by a manager whose telephone number is 0131 229 0001.

Blank Node Version

```
:aroast  db:runBy  _:a .
_:a  pim:telno  "0131 229 0001" .
_:a  a  db:Manager .
```

Alternative Blank Node Notation

```
:aroast  db:runBy  [  pim:telno  "0131 229 0001" ;
                      a  db:Manager  ]  .
```

In the previous lecture

- DB Records as Triples

	Name	Artist	Place	
ID0039	"The Red Vineyard"	V. Van Gogh	Arles	

DB2RDF Triples

```
:Paintings_0039  :name  "The Red Vinyard" ;
                 :artist  db:Vincent_Van_Gogh ;
                 :place  db:Arles .
```

In this lecture

- Serialising RDF in XML
- RDF Schemas (RDFS)
  - Most common constructs
  - Inference
  - Other constructs

Serialising RDF in XML

Document tree

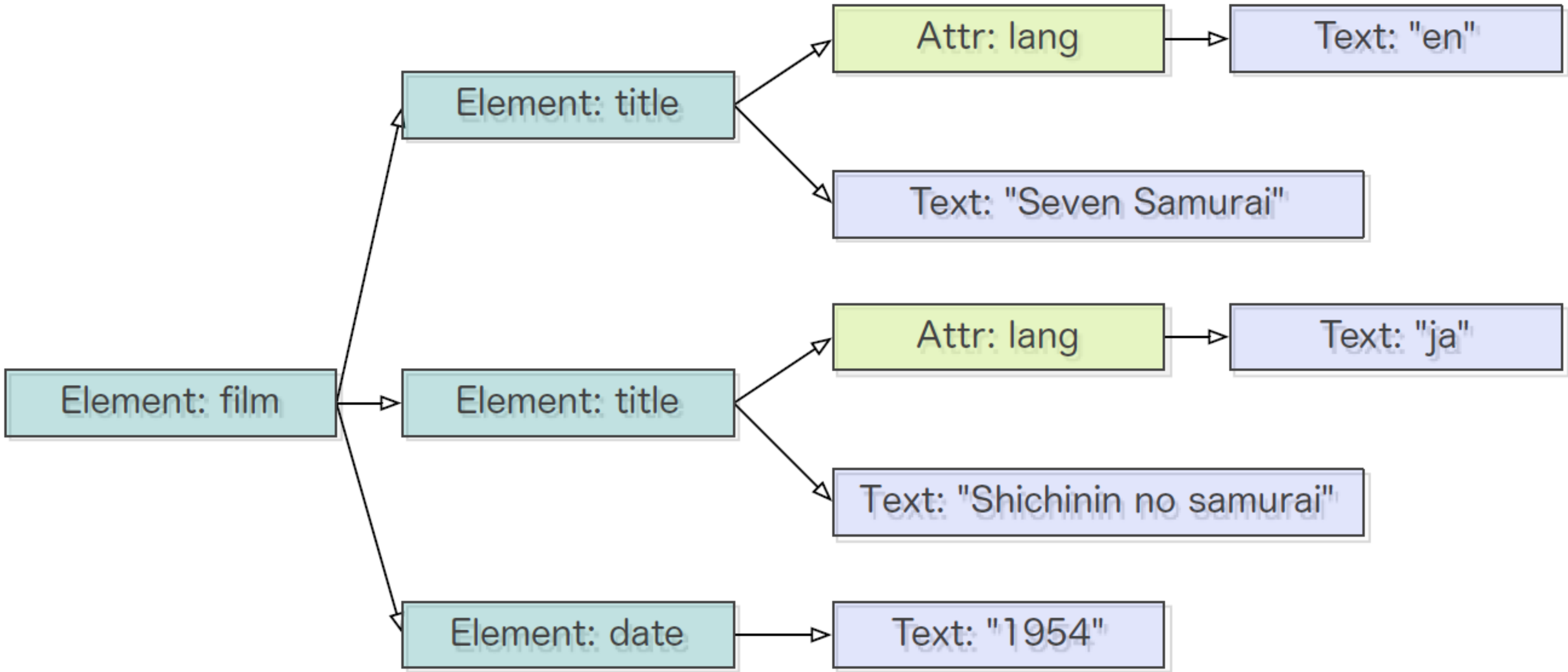
We can represent XML documents as trees.

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.

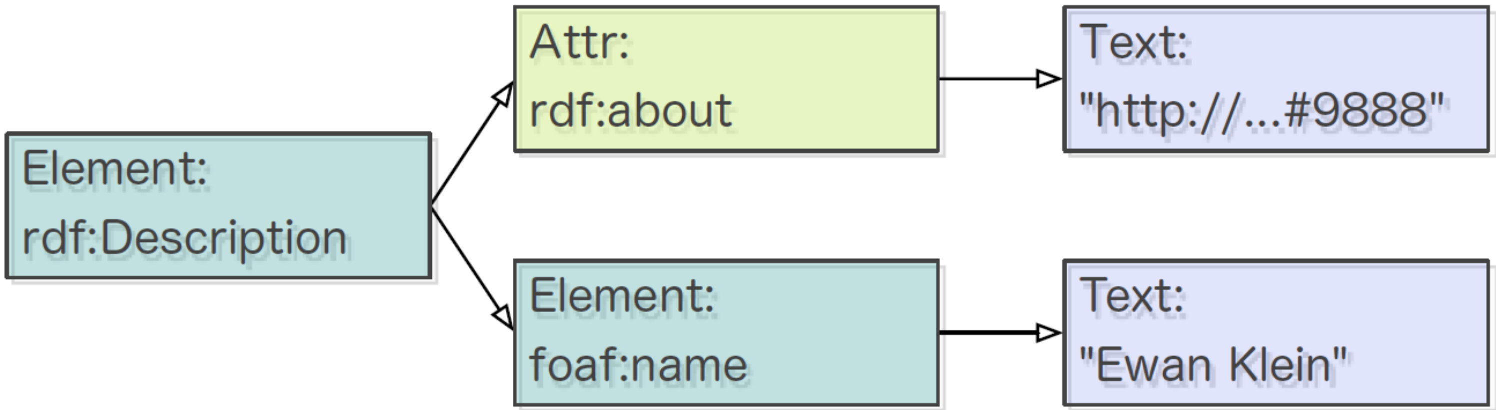


RDF triples as XML fields

RDF Triples are encoded as rdf:Description elements.

RDF Triples with literal Object

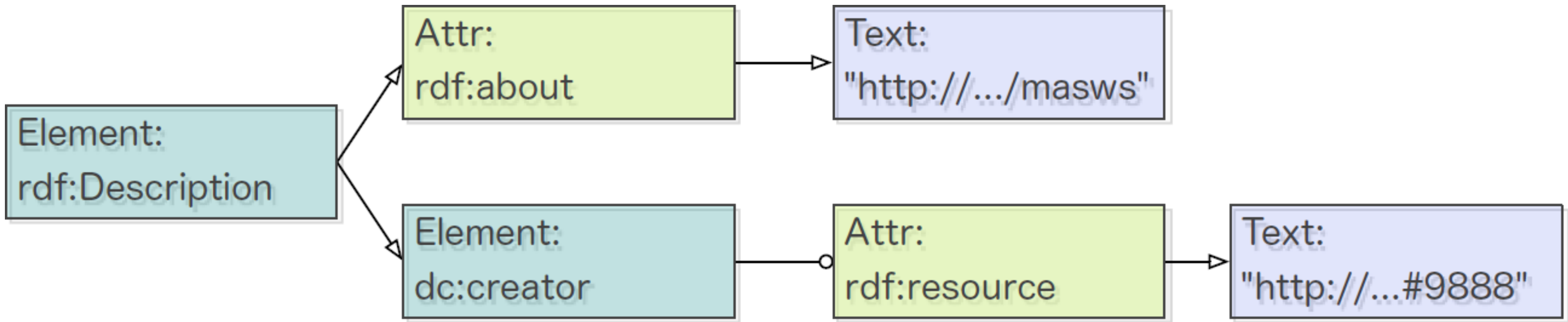
edstaff:9888 foaf:name ‘Ewan Klein’ .



RDF triples as XML trees

RDF Triples with resource Object

infcourses:masws dc:creator edstaff:9888 .



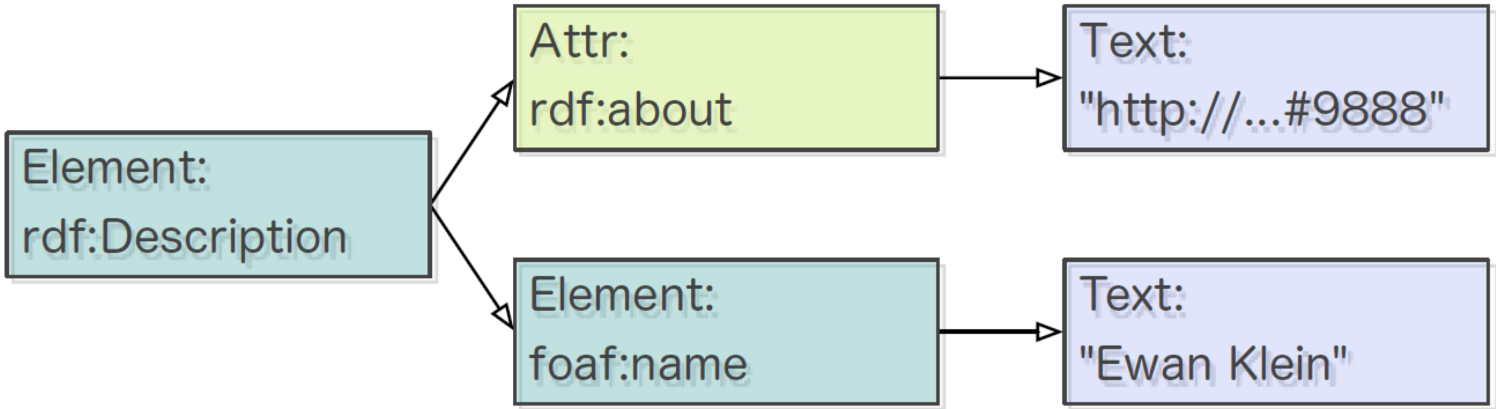
RDF triples as XML trees

- 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 Triples with literal Object

edstaff:9888 foaf:name ‘Ewan Klein’ .



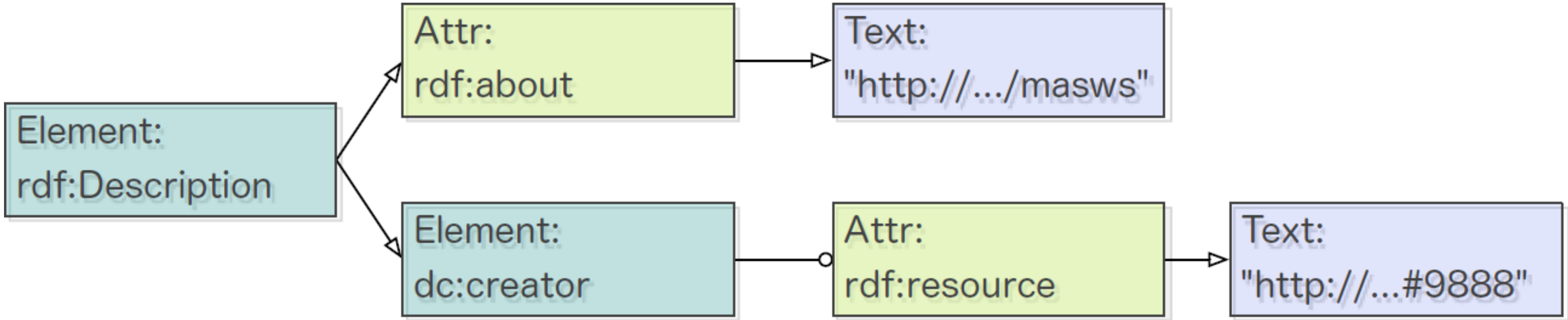
Linear version

```
<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 – no abbreviation

```
<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

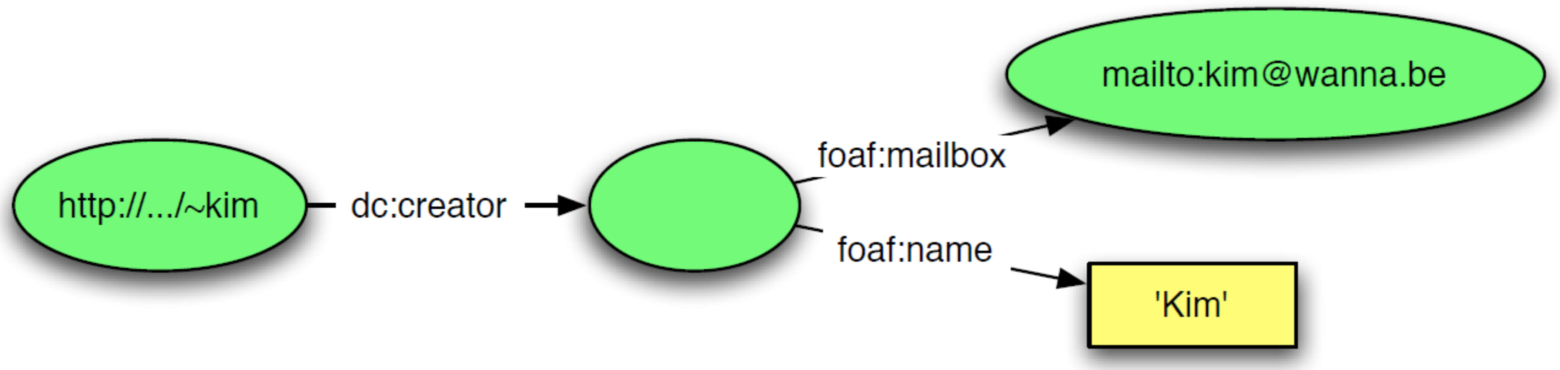
RDF Triples with shared Subject

edstaff:9888 foaf:name ‘Ewan Klein’ .
edstaff:9888 foaf:homepage http://.../~ewan .

Linear version - abbreviated

```
<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. We'll stick to Turtle syntax.

RDF recap

RDF in a nutshell

- RDF allows us to make factual statements (about individuals) in the form of triples: *subject-predicate-object*
- Suppose you want to talk about the 2005 record "In the Heart of the Moon" by Ali Farka Touré. You want to say that:
  - "In the Heart of the Moon" was created by Ali Farka Touré.
  - "In the Heart of the Moon" was released in 2005.
- But ambiguity is present:
  - Which Ali Farka Touré?
    - We use URIs to identify our resources.
  - What do you mean that it was "created by" Ali Farka Touré?
    - We use terms from vocabularies that define their meanings. We use URIs to identify those terms.

RDF in a nutshell

RDF Triples (N-triples)

<http://dbpedia.org/resource/In_The_Heart_of_the_Moon> <http://purl.org/dc/elements/1.1/creator> <http://dbpedia.org/resource/Ali_Farka_Touré> .

<http://dbpedia.org/resource/In_The_Heart_of_the_Moon> <http://purl.org/dc/elements/1.1/date> "2005" .

RDF Triples (Turtle)

@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix dbpedia: <http://dbpedia.org/resource/> .

dbpedia:In_The_Heart_of_the_Moon dc:creator dbpedia:Ali_Farka_Touré .
dbpedia:In_The_Heart_of_the_Moon dc:date “2005” .

RDFS

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 constraints

- 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:sws 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):
  - 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 an Agent.

RDFS as a schema language

- RDFS also known as a schema language
- It 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)

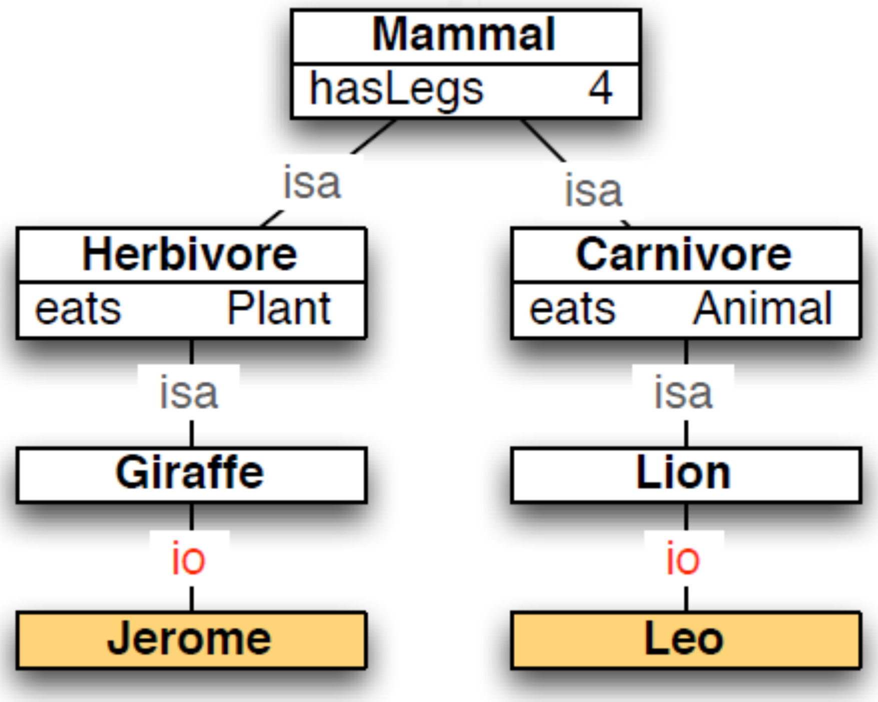
- RDF:
  - rdf:Resource – the class resource, everything
  - rdf:Property – the class of properties
  - rdf:Statement – the class of RDF statements
- RDFS:
  - rdfs:Literal – the class of literal values, e.g. strings and integers
  - rdfs:Class – the class of classes
  - rdfs:Datatype – the class of 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.

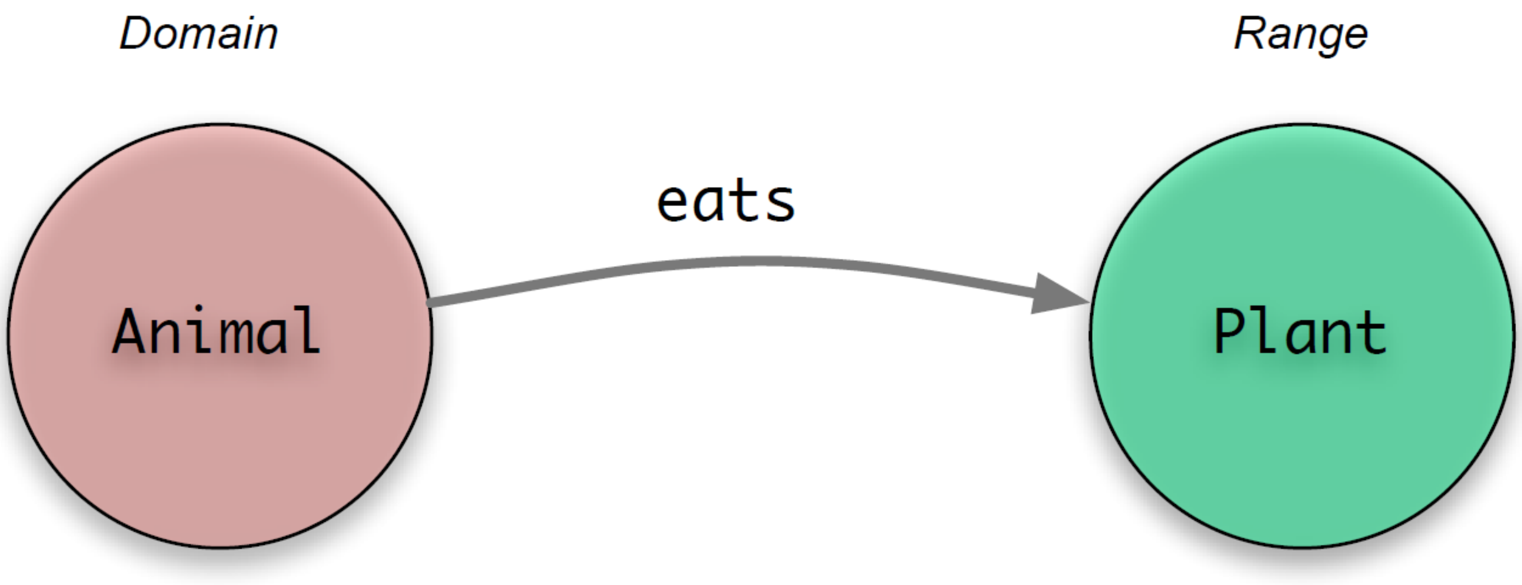
Range

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

The values of eats are instances of Plant.

$eats : \text{Animal} \mapsto \text{Plant}$

Domain and range



Type propagation in RDFS

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

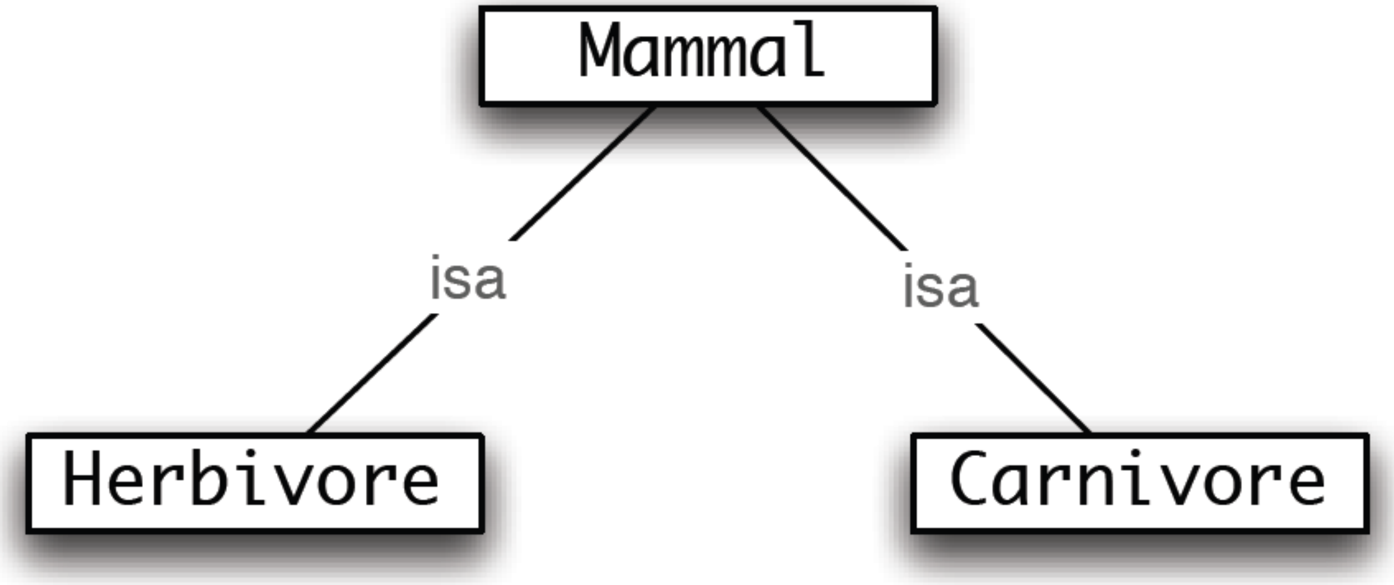
Inferred type statements

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

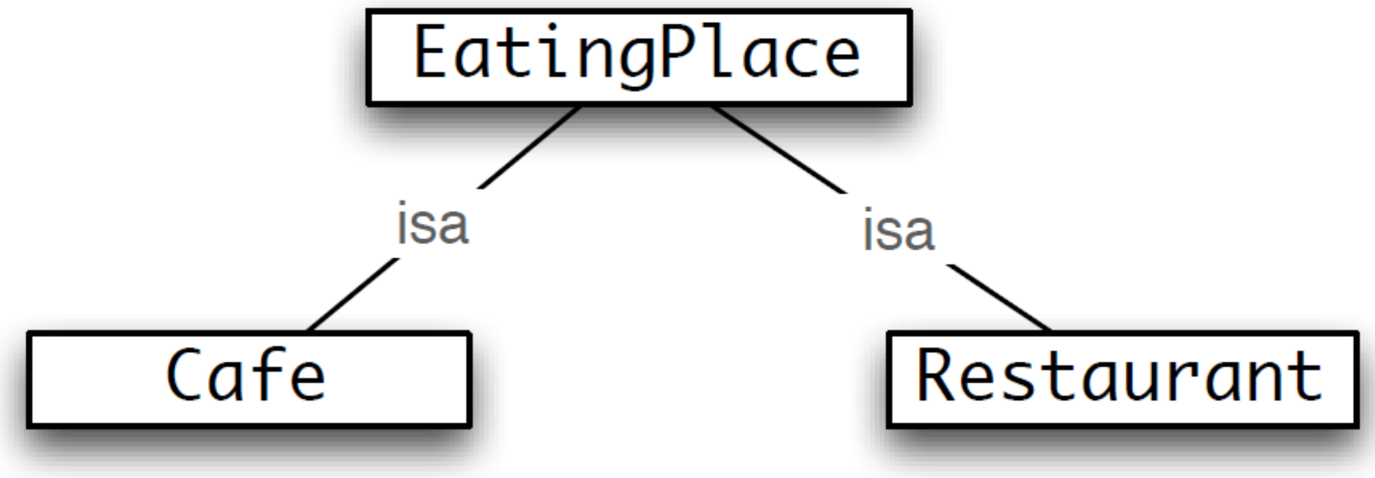
Inference support in Jena

- Jena provides support for RDFS Inference.
- But not via command line.
- See http://jena.apache.org/

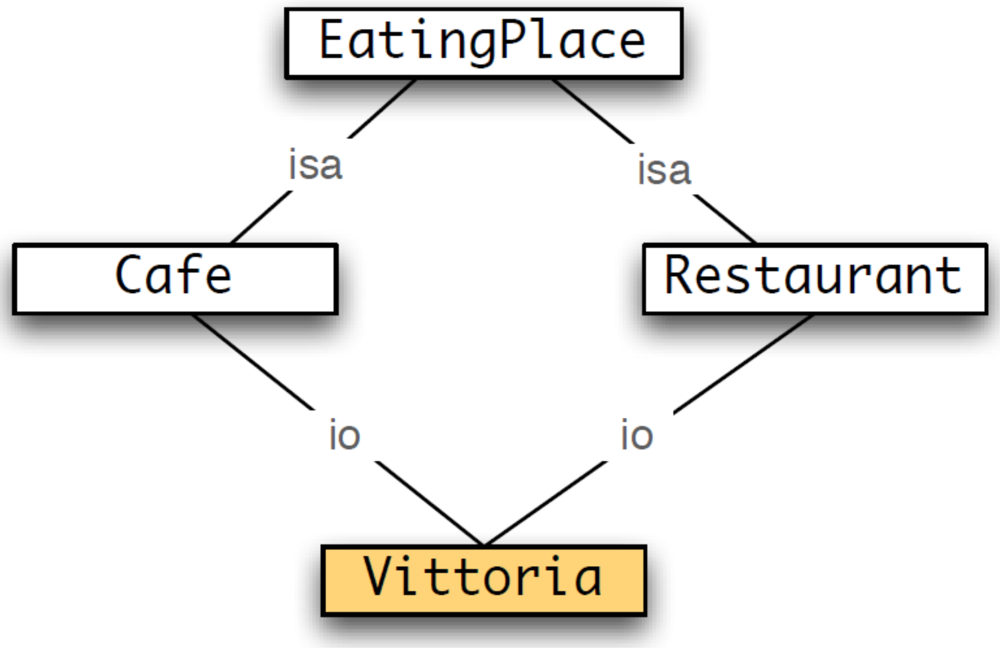
Disjointedness?



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

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

$$\forall \langle x,y \rangle. (\langle x,y \rangle \in R \land R \subseteq S) \rightarrow \langle x,y \rangle \in S$$

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 .

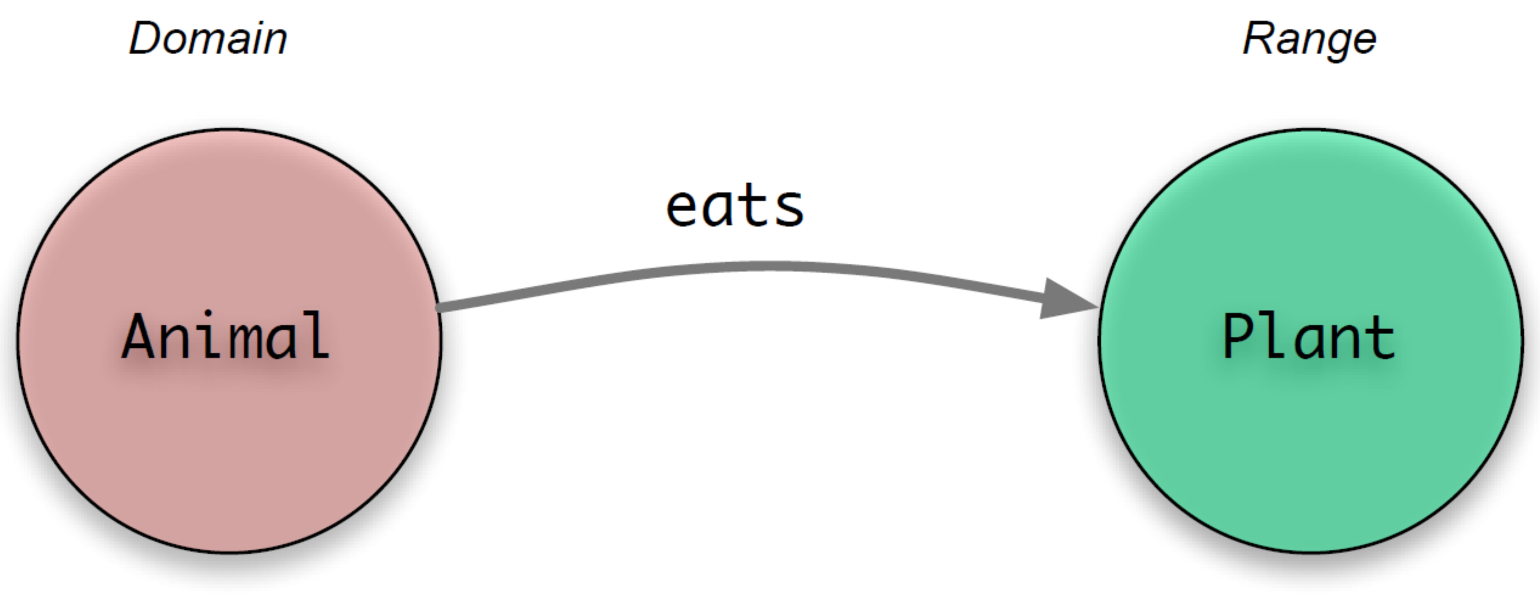
Asserted triple

: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 triple

: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 vs 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 triples

:maxies rdf:type :EatingPlace .
:maxies rdf:type :LicencedPremises .

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>  ] .
```

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 Ch6)

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

- SWWO Ch 6, 7

Task

- 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.