RDF and RDF Schema

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Acknowledgements: Axel Polleres, Mariano Fernández-López

Main References

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Capítulo 4: Ontology languages

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Prud'hommeaux E, Seaborne A (2008) *SPARQL Query Language for RDF*. W3C Recommendation.
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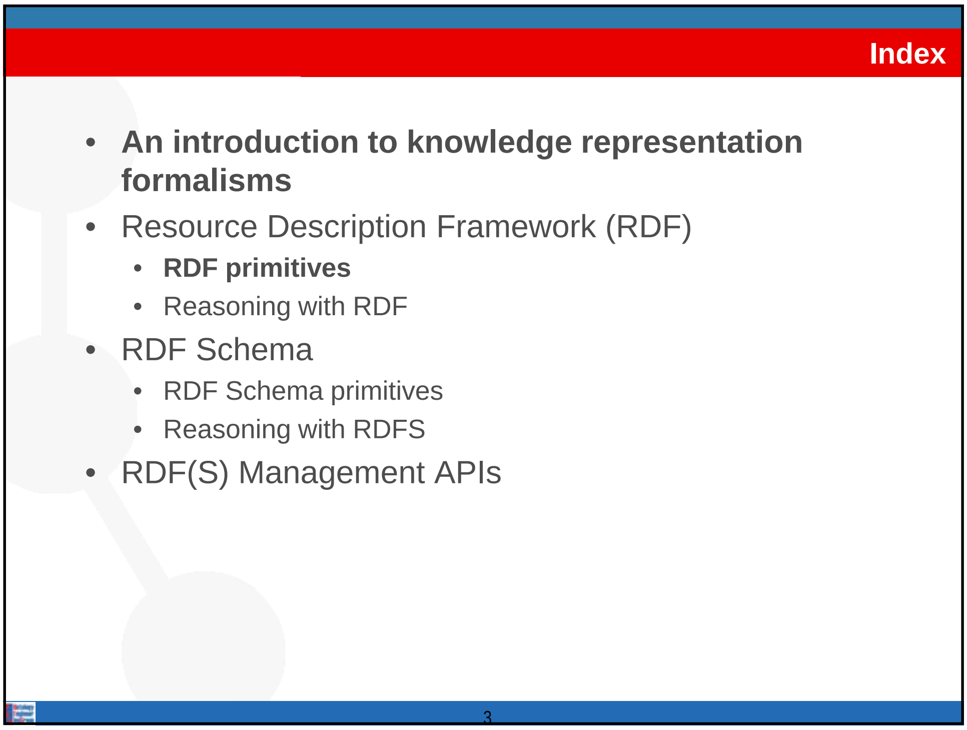
Jena web site: *http://jena.sourceforge.net/*
Jena API: *http://jena.sourceforge.net/tutorial/RDF_API/*
Jena tutorials: *http://www.ibm.com/developerworks/xml/library/j-jena/index.html*
http://www.xml.com/pub/a/2001/05/23/jena.html

SPARQL validator: *http://www.sparql.org/validator.html*
SPARQL implementations: *http://esw.w3.org/topic/SparqlImplementations*
SPARQL tutorials: *http://jena.sourceforge.net/ARQ/Tutorial/*
http://www.w3.org/2004/Talks/17Dec-sparql/intro/all.html
http://www.cs.man.ac.uk/~bparsia/2006/row-tutorial/



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- Resource Description Framework (RDF)
  - **RDF primitives**
  - Reasoning with RDF
- RDF Schema
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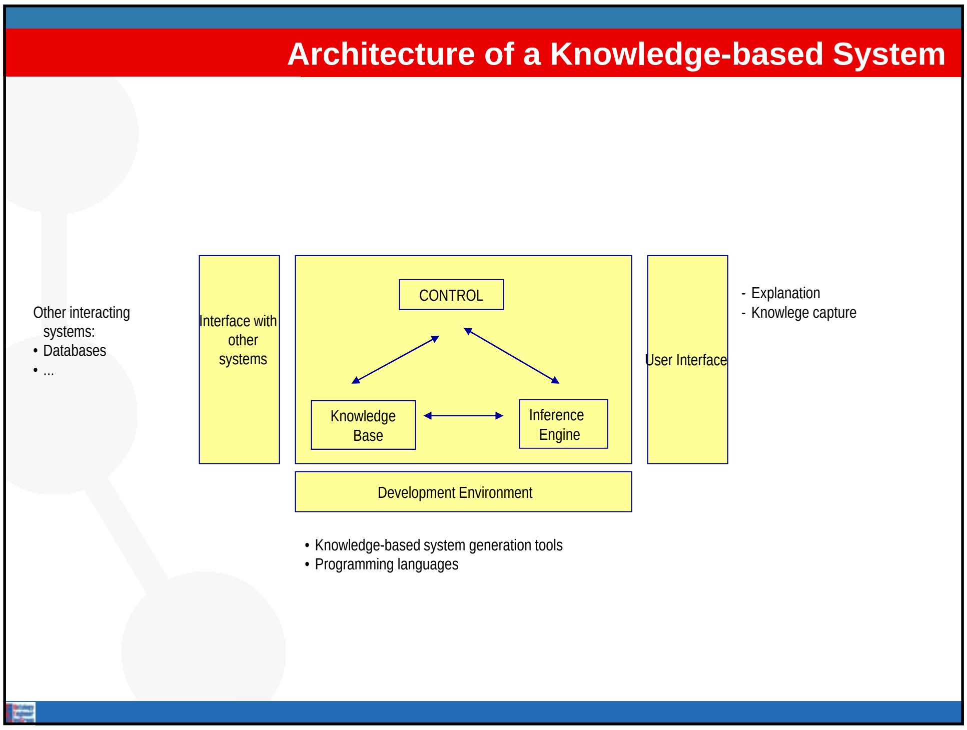
  - Reasoning with RDFS
- RDF(S) Management APIs

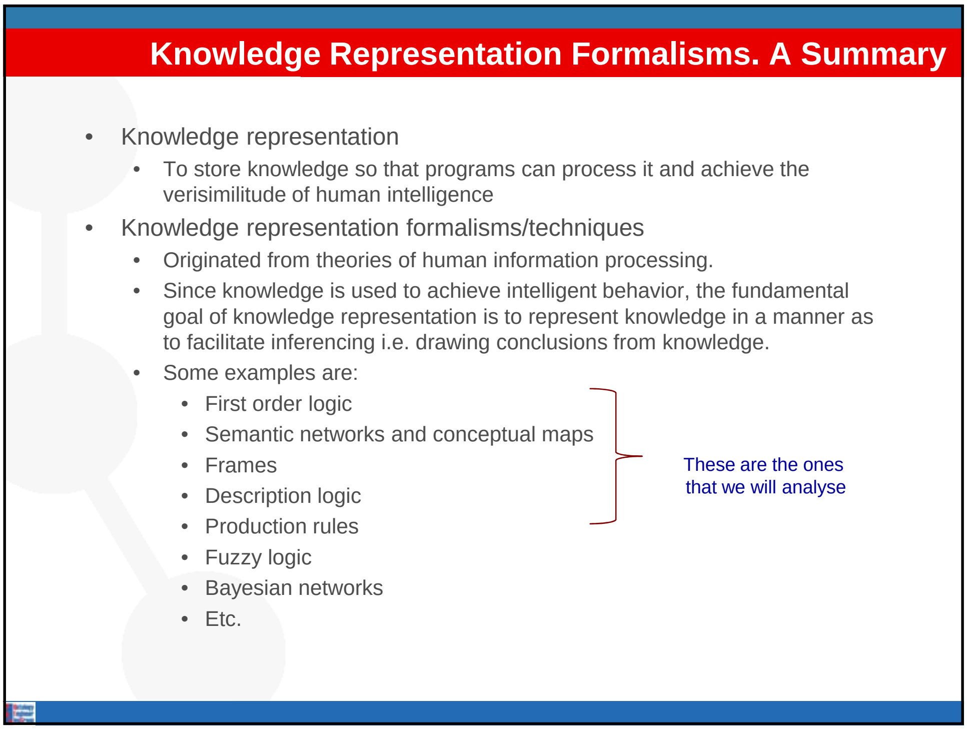


Architecture of a Knowledge-based System

Other interacting systems:
- Databases
- ...

- Explanation
- Knowlege capture

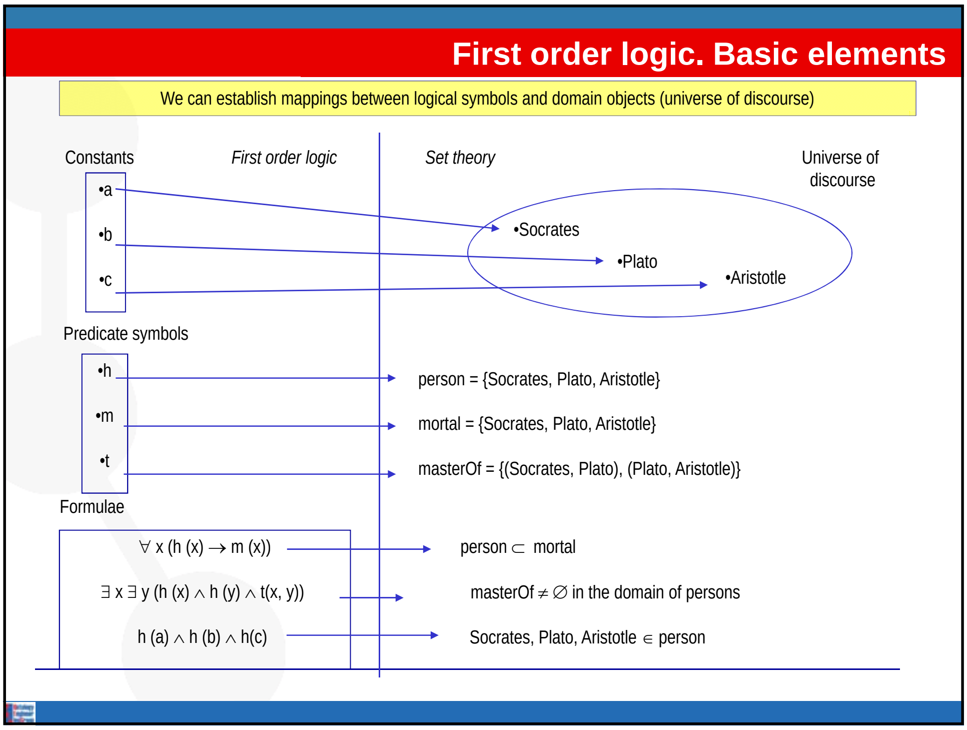
- Knowledge-based system generation tools
- Programming languages



Knowledge Representation Formalisms. A Summary

- Knowledge representation
  - To store knowledge so that programs can process it and achieve the verisimilitude of human intelligence
- Knowledge representation formalisms/techniques
  - Originated from theories of human information processing.
  - Since knowledge is used to achieve intelligent behavior, the fundamental goal of knowledge representation is to represent knowledge in a manner as to facilitate inferencing i.e. drawing conclusions from knowledge.
  - Some examples are:
    - First order logic
    - Semantic networks and conceptual maps
    - Frames
    - Description logic
    - Production rules
    - Fuzzy logic
    - Bayesian networks
    - Etc.

These are the ones that we will analyse



First order logic. Basic elements

We can establish mappings between logical symbols and domain objects (universe of discourse)

person = {Socrates, Plato, Aristotle}

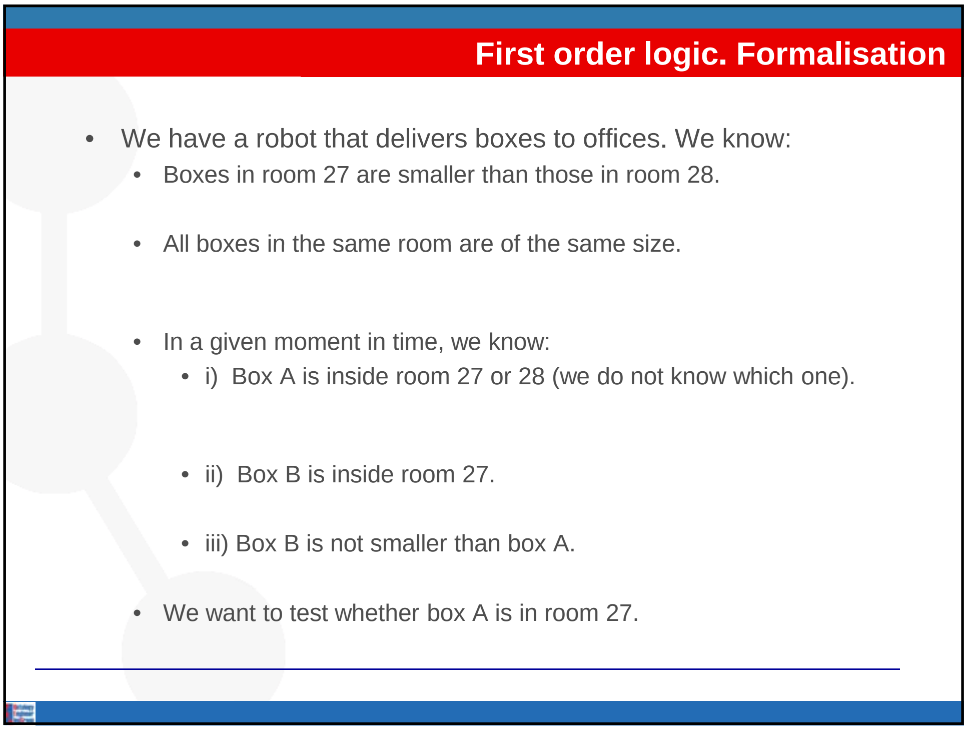
mortal = {Socrates, Plato, Aristotle}

masterOf = {(Socrates, Plato), (Plato, Aristotle)}

$\forall x\, (h(x) \rightarrow m(x))$ → person $\subset$ mortal

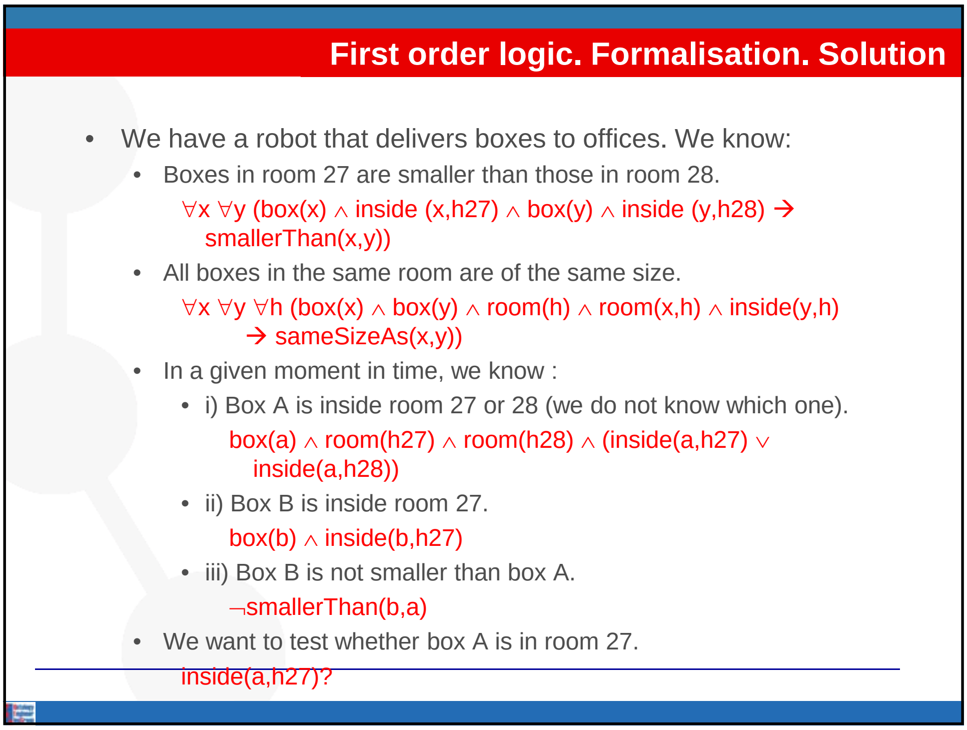
$\exists x\, \exists y\, (h(x) \wedge h(y) \wedge t(x, y))$ → masterOf $\neq \emptyset$ in the domain of persons

$h(a) \wedge h(b) \wedge h(c)$ → Socrates, Plato, Aristotle $\in$ person



First order logic. Formalisation

- We have a robot that delivers boxes to offices. We know:
  - Boxes in room 27 are smaller than those in room 28.
  - All boxes in the same room are of the same size.
  - In a given moment in time, we know:
    - i) Box A is inside room 27 or 28 (we do not know which one).
    - ii) Box B is inside room 27.
    - iii) Box B is not smaller than box A.
  - We want to test whether box A is in room 27.



First order logic. Formalisation. Solution

- We have a robot that delivers boxes to offices. We know:
  - Boxes in room 27 are smaller than those in room 28.

    $\forall x\ \forall y\ (\text{box}(x) \wedge \text{inside}\ (x,h27) \wedge \text{box}(y) \wedge \text{inside}\ (y,h28) \rightarrow \text{smallerThan}(x,y))$
  - All boxes in the same room are of the same size.

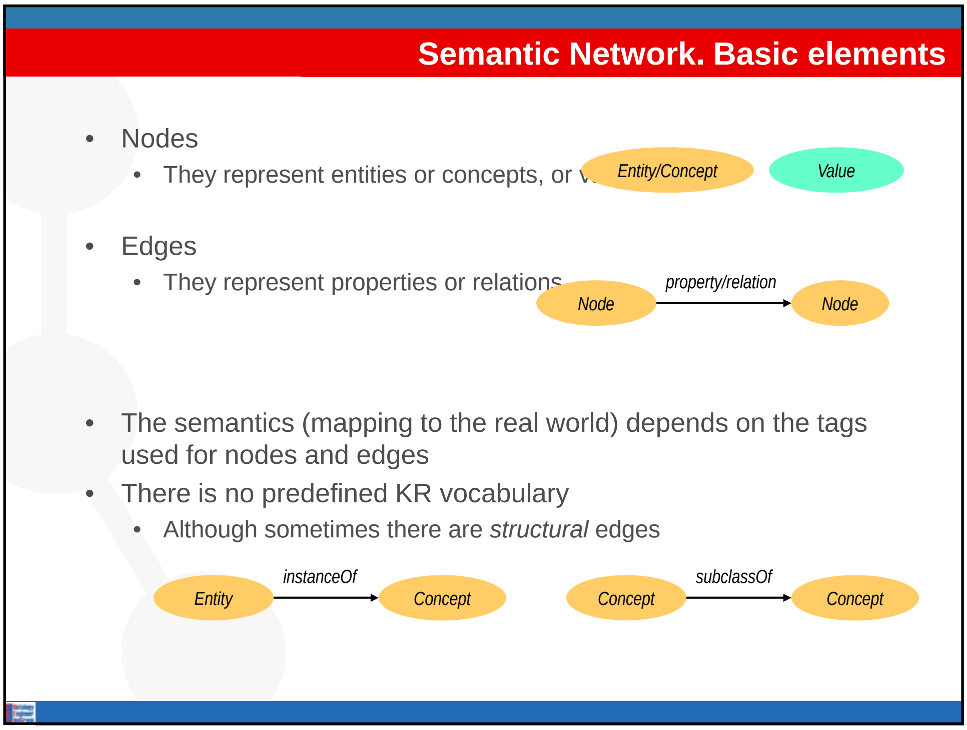
    $\forall x\ \forall y\ \forall h\ (\text{box}(x) \wedge \text{box}(y) \wedge \text{room}(h) \wedge \text{room}(x,h) \wedge \text{inside}(y,h) \rightarrow \text{sameSizeAs}(x,y))$
  - In a given moment in time, we know :
    - i) Box A is inside room 27 or 28 (we do not know which one).

      $\text{box}(a) \wedge \text{room}(h27) \wedge \text{room}(h28) \wedge (\text{inside}(a,h27) \vee \text{inside}(a,h28))$
    - ii) Box B is inside room 27.

      $\text{box}(b) \wedge \text{inside}(b,h27)$
    - iii) Box B is not smaller than box A.

      $\neg\text{smallerThan}(b,a)$
  - We want to test whether box A is in room 27.

    $\text{inside}(a,h27)$?



Semantic Network. Basic elements

- Nodes
  - They represent entities or concepts, or v

Entity/Concept

Value

- Edges
  - They represent properties or relations

Node

property/relation

Node

- The semantics (mapping to the real world) depends on the tags used for nodes and edges
- There is no predefined KR vocabulary
  - Although sometimes there are *structural* edges

Entity

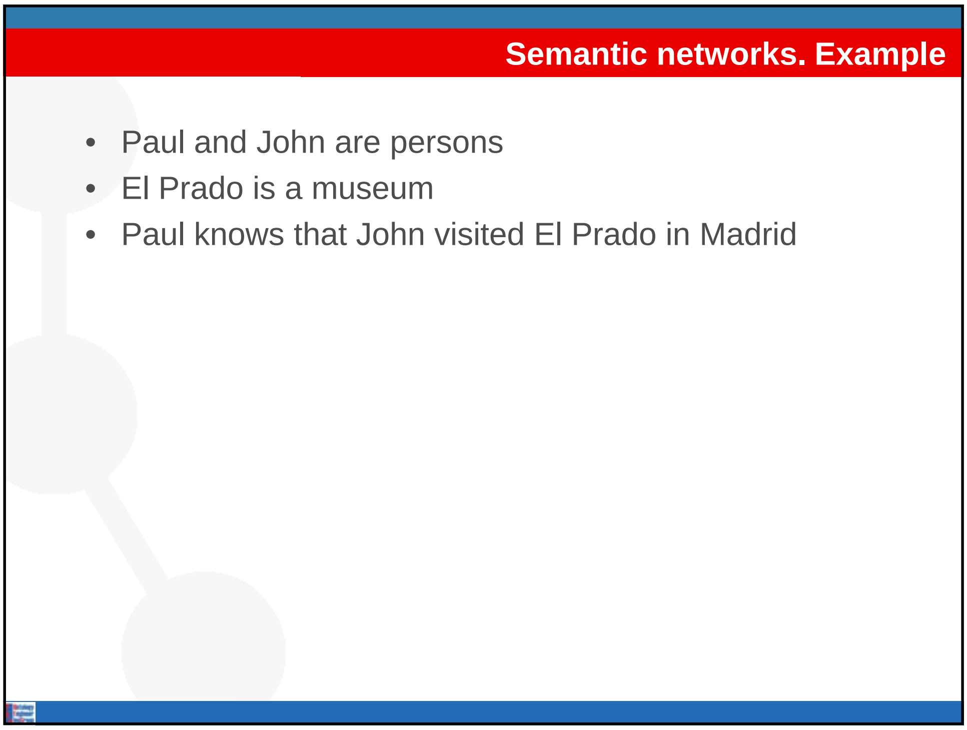
instanceOf

Concept

Concept

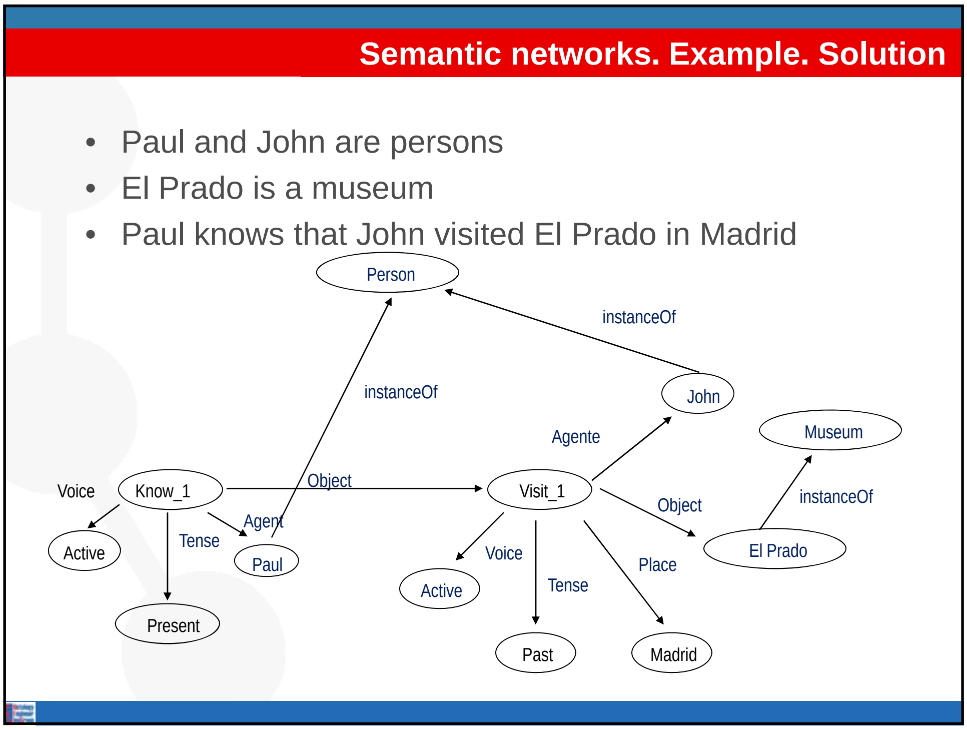
subclassOf

Concept



Semantic networks. Example

- Paul and John are persons
- El Prado is a museum
- Paul knows that John visited El Prado in Madrid



Semantic networks. Example. Solution

- Paul and John are persons
- El Prado is a museum
- Paul knows that John visited El Prado in Madrid

Person

instanceOf

instanceOf

John

Agente

Museum

Voice

Know_1

Object

Visit_1

Object

instanceOf

Agent

Tense

Active

Paul

Voice

El Prado

Place

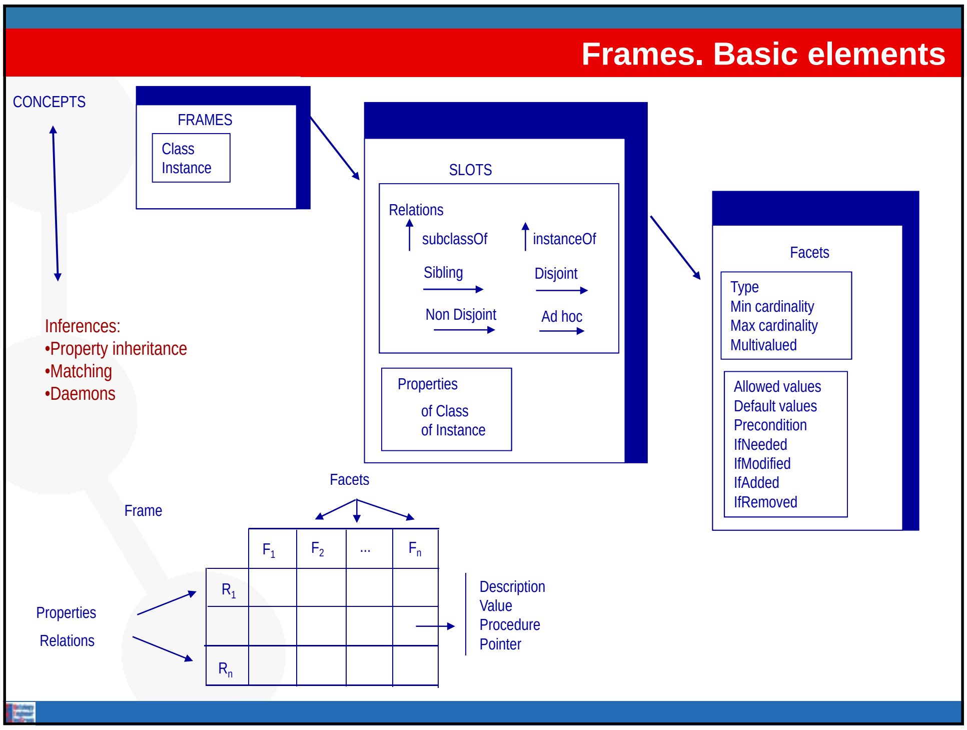
Active

Tense

Present

Past

Madrid



Frames. Basic elements

CONCEPTS

FRAMES

Class
Instance

SLOTS

Relations

subclassOf

instanceOf

Sibling

Disjoint

Non Disjoint

Ad hoc

Properties

of Class
of Instance

Facets

Type
Min cardinality
Max cardinality
Multivalued

Allowed values
Default values
Precondition
IfNeeded
IfModified
IfAdded
IfRemoved

Inferences:
•Property inheritance
•Matching
•Daemons

Facets

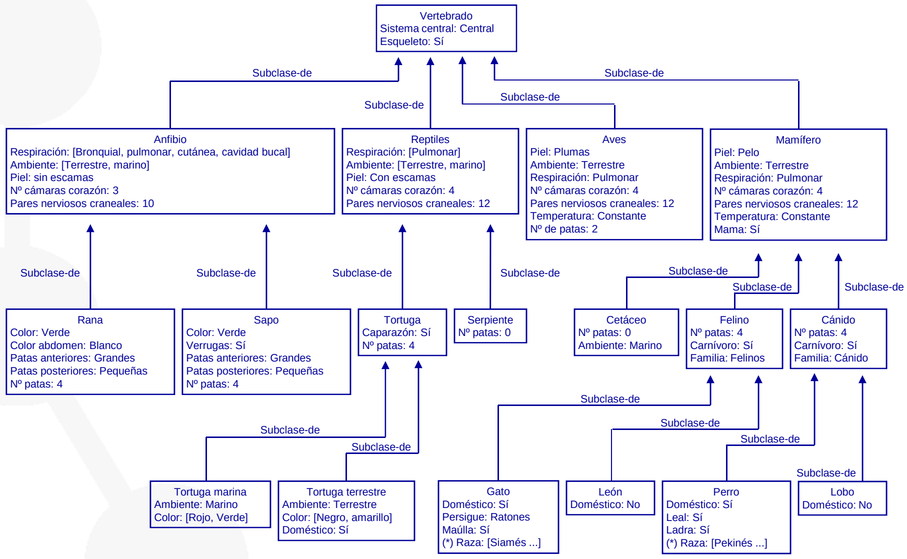
Frame

	F_1	F_2	...	F_n
R_1				
R_n				

Properties

Relations

Description
Value
Procedure
Pointer



Vertebrado
Sistema central: Central
Esqueleto: Sí

Anfibio
Respiración: [Bronquial, pulmonar, cutánea, cavidad bucal]
Ambiente: [Terrestre, marino]
Piel: sin escamas
Nº cámaras corazón: 3
Pares nerviosos craneales: 10

Reptiles
Respiración: [Pulmonar]
Ambiente: [Terrestre, marino]
Piel: Con escamas
Nº cámaras corazón: 4
Pares nerviosos craneales: 12

Aves
Piel: Plumas
Ambiente: Terrestre
Respiración: Pulmonar
Nº cámaras corazón: 4
Pares nerviosos craneales: 12
Temperatura: Constante
Nº de patas: 2

Mamífero
Piel: Pelo
Ambiente: Terrestre
Respiración: Pulmonar
Nº cámaras corazón: 4
Pares nerviosos craneales: 12
Temperatura: Constante
Mama: Sí

Rana
Color: Verde
Color abdomen: Blanco
Patas anteriores: Grandes
Patas posteriores: Pequeñas
Nº patas: 4

Sapo
Color: Verde
Verrugas: Sí
Patas anteriores: Grandes
Patas posteriores: Pequeñas
Nº patas: 4

Tortuga
Caparazón: Sí
Nº patas: 4

Serpiente
Nº patas: 0

Cetáceo
Nº patas: 0
Ambiente: Marino

Felino
Nº patas: 4
Carnívoro: Sí
Familia: Felinos

Cánido
Nº patas: 4
Carnívoro: Sí
Familia: Cánido

Tortuga marina
Ambiente: Marino
Color: [Rojo, Verde]

Tortuga terrestre
Ambiente: Terrestre
Color: [Negro, amarillo]
Doméstico: Sí

Gato
Doméstico: Sí
Persigue: Ratones
Maúlla: Sí
(*) Raza: [Siamés ...]

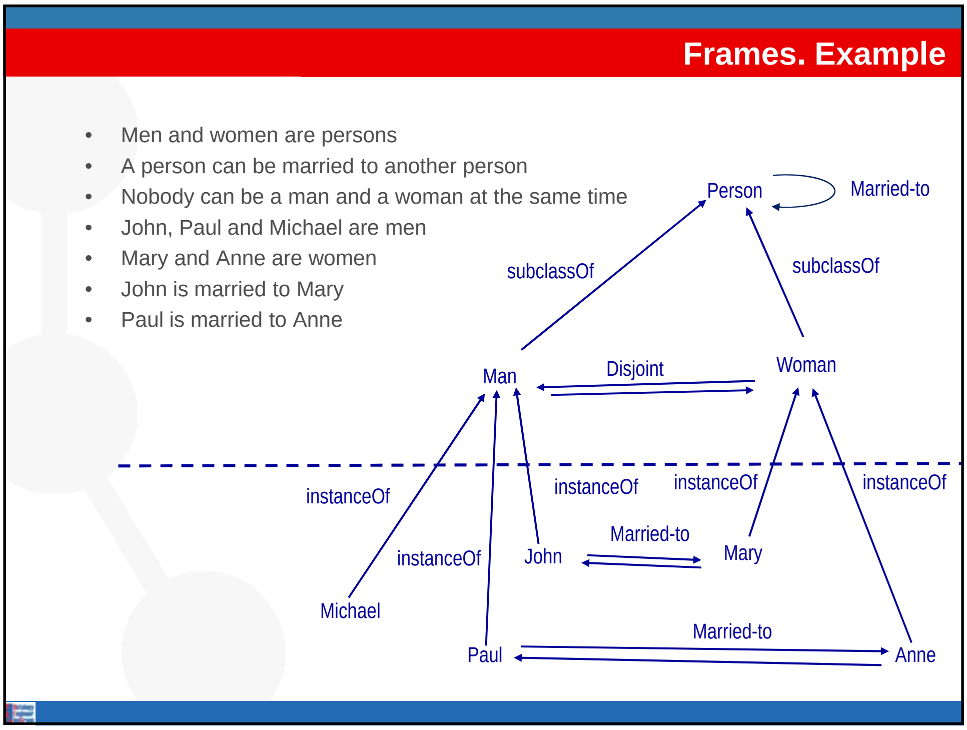
León
Doméstico: No

Perro
Doméstico: Sí
Leal: Sí
Ladra: Sí
(*) Raza: [Pekinés ...]

Lobo
Doméstico: No

Frames. Example

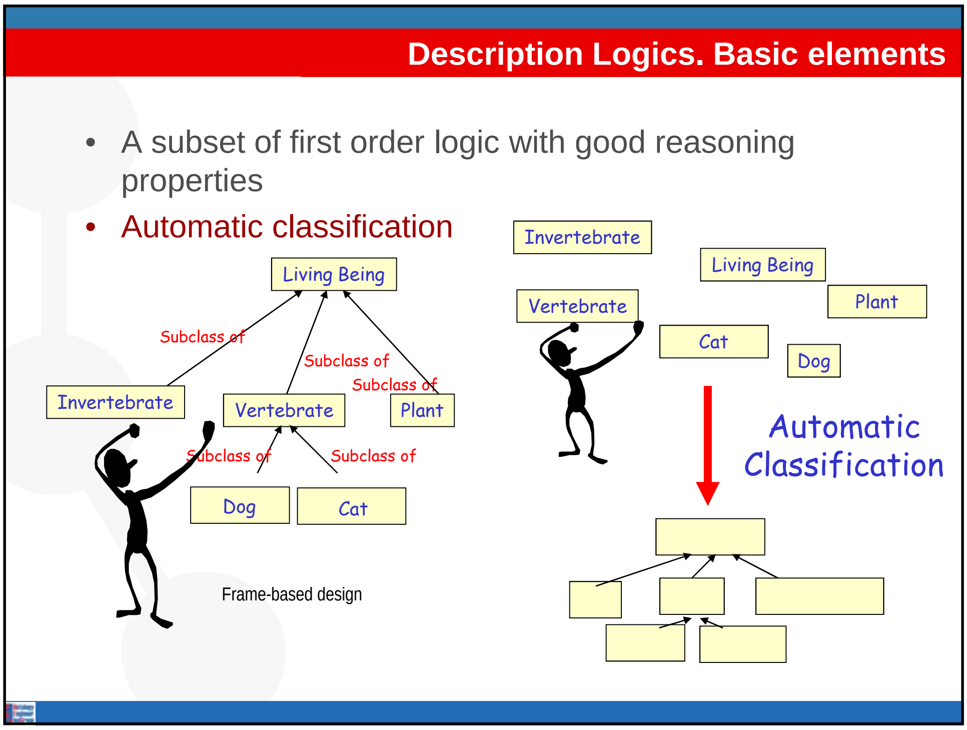
- Men and women are persons
- A person can be married to another person
- Nobody can be a man and a woman at the same time
- John, Paul and Michael are men
- Mary and Anne are women
- John is married to Mary
- Paul is married to Anne



Frames. Example

- Men and women are persons
- A person can be married to another person
- Nobody can be a man and a woman at the same time
- John, Paul and Michael are men
- Mary and Anne are women
- John is married to Mary
- Paul is married to Anne

Person
Married-to
subclassOf
subclassOf
Man
Disjoint
Woman
instanceOf
instanceOf
instanceOf
instanceOf
instanceOf
Married-to
John
Mary
Michael
Married-to
Paul
Anne



Description Logics. Basic elements

- A subset of first order logic with good reasoning properties
- Automatic classification

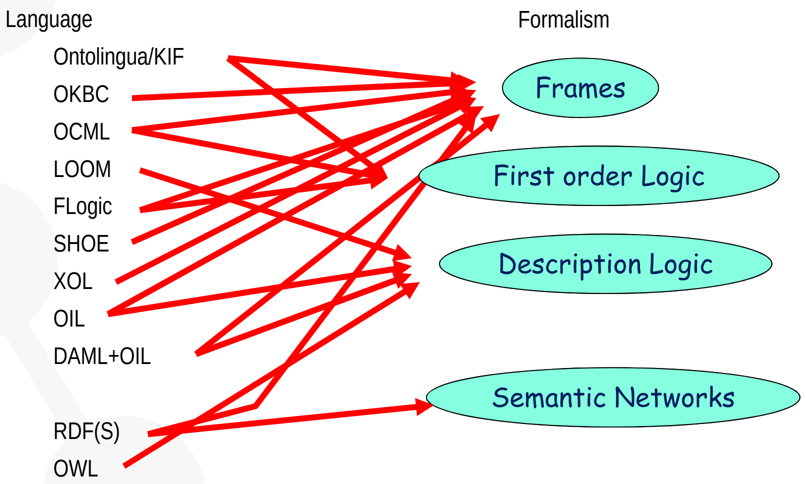
Living Being
Subclass of
Subclass of
Subclass of
Invertebrate
Vertebrate
Plant
Subclass of
Subclass of
Dog
Cat

Frame-based design

Invertebrate
Living Being
Plant
Vertebrate
Cat
Dog

Automatic Classification

KR Formalisms



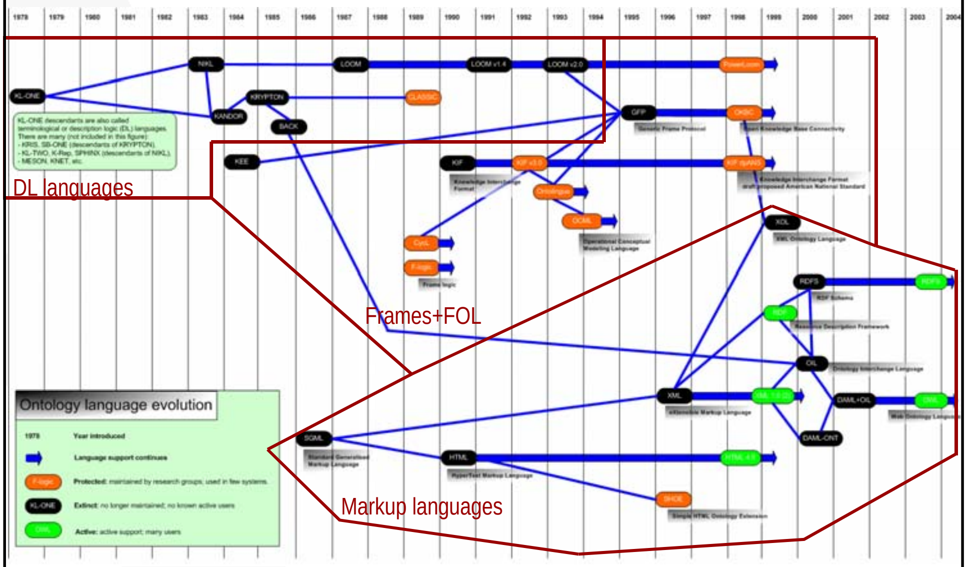
Language

- Ontolingua/KIF
- OKBC
- OCML
- LOOM
- FLogic
- SHOE
- XOL
- OIL
- DAML+OIL
- RDF(S)
- OWL

Formalism

- Frames
- First order Logic
- Description Logic
- Semantic Networks

Ontology language evolution


1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
KL-ONE
NIKL
LOOM
LOOM v1.4
LOOM v2.0
PowerLoom
KRYPTON
CLASSIC
KANDOR
BACK
KL-ONE descendants are also called terminological or description logic (DL) languages. There are many (not included in this figure):
- KRIS, SB-ONE (descendants of KRYPTON),
- KL-TWO, K-Rep, SPHINX (descendants of NIKL),
- MESON, KNET, etc.
GFP
Generic Frame Protocol
OKBC
Open Knowledge Base Connectivity
KEE
KIF
KIF v3.0
KIF dpANS
Knowledge Interchange Format
Knowledge Interchange Format draft proposed American National Standard
Ontolingua
OCML
Operational Conceptual Modelling Language
CycL
F-logic
Frame logic
XOL
XML Ontology Language
RDFS
RDF Schema
RDF
Resource Description Framework
OIL
Ontology Interchange Language
XML
eXtensible Markup Language
XML 1.0
DAML+OIL
OWL
Web Ontology Language
DAML-ONT
SGML
Standard Generalised Markup Language
HTML
HyperText Markup Language
HTML 4.0
SHOE
Simple HTML Ontology Extension
Ontology language evolution
1978 Year introduced
Language support continues
F-logic Protected: maintained by research groups; used in few systems.
KL-ONE Extinct: no longer maintained; no known active users
OWL Active: active support; many users

DL languages

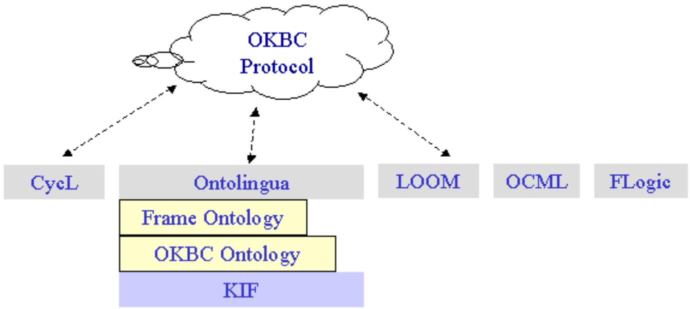
Frames+FOL

Markup languages

Ontology Languages (I)

Traditional ontology languages

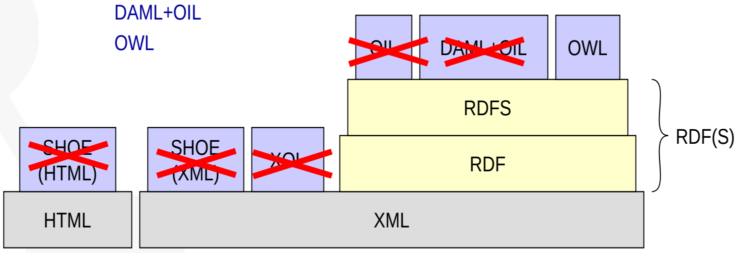
- Ontolingua/KIF
- OKBC
- OCML
- LOOM
- FLogic



Ontology Languages (II)

Ontology markup languages

- Standards & Recommendations of W3C
  - XML RDF(S)
- Ontology specification languages
  - SHOE XOL
  - OIL
  - DAML+OIL
  - OWL



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  - Reasoning with RDF
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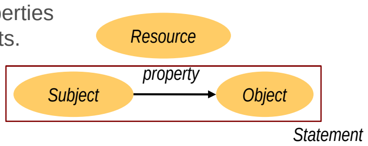
  - Reasoning with RDFS
- RDF(S) Management APIs

RDF: Resource Description Framework

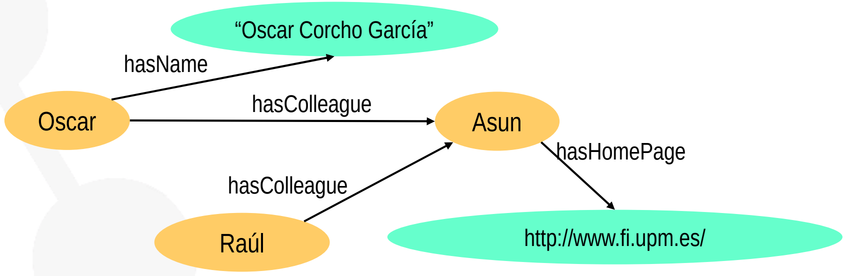
- W3C recommendation
- RDF is a basic KR language, based on semantic networks
  - Useful to represent metadata and describe any type of information in a machine- accessible way (aka data model)
  - Resources are described in terms of properties and property values using RDF statements.
  - Statements are represented as triples, consisting of a subject, predicate and object. [S, P, O]



Resource

Subject *property* *Object*

Statement



"Oscar Corcho García"

hasName

Oscar

hasColleague

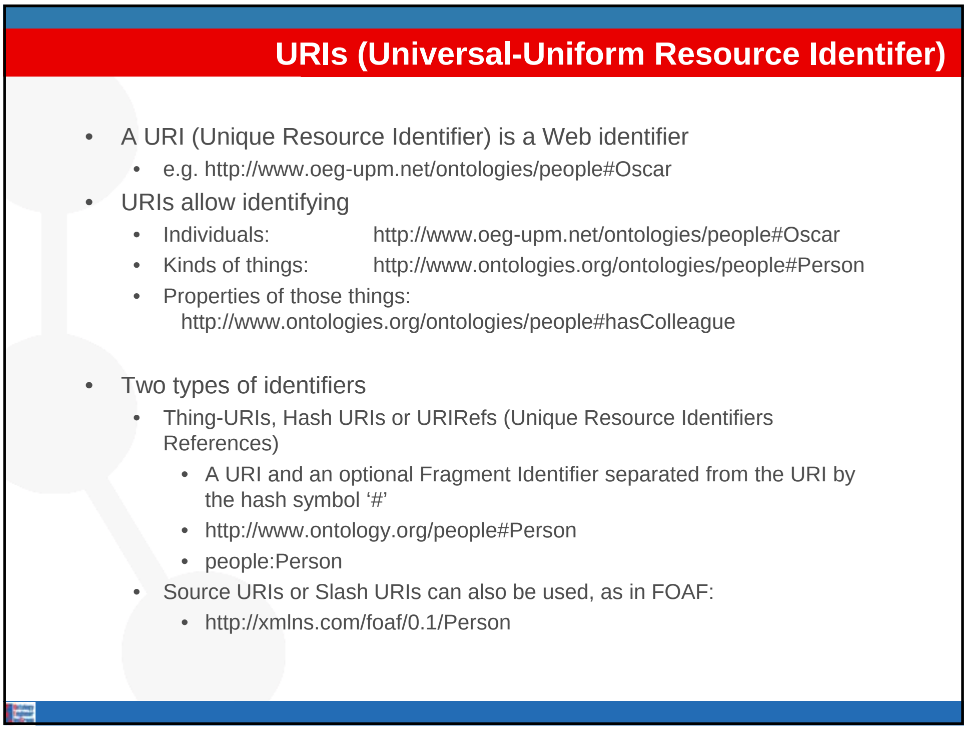
Asun

hasHomePage

hasColleague

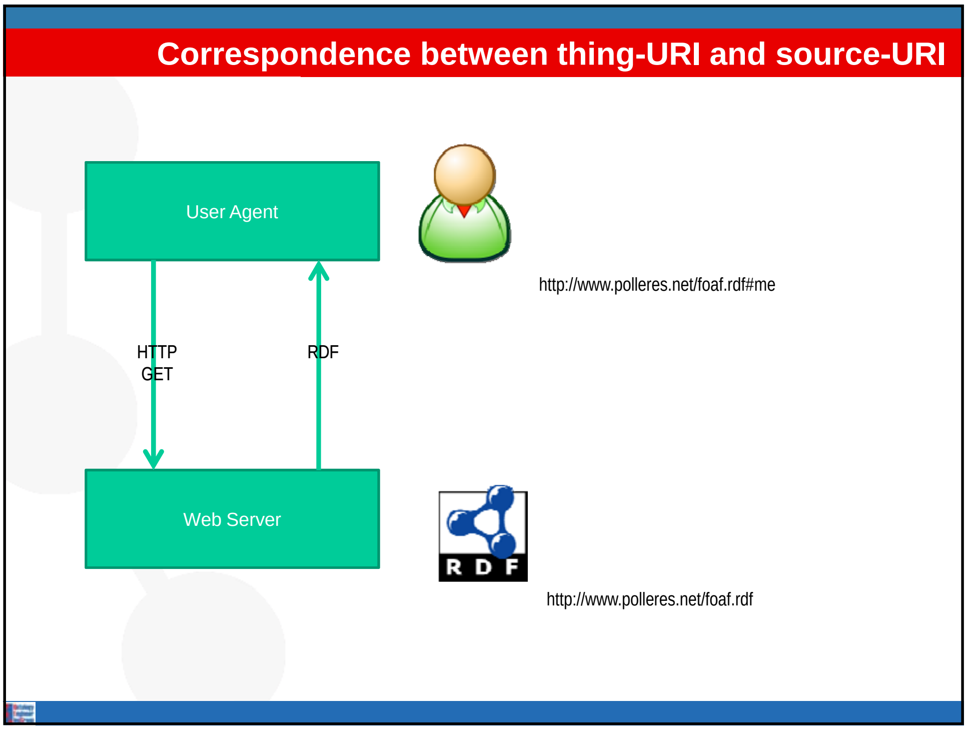
Raúl

http://www.fi.upm.es/



URIs (Universal-Uniform Resource Identifer)

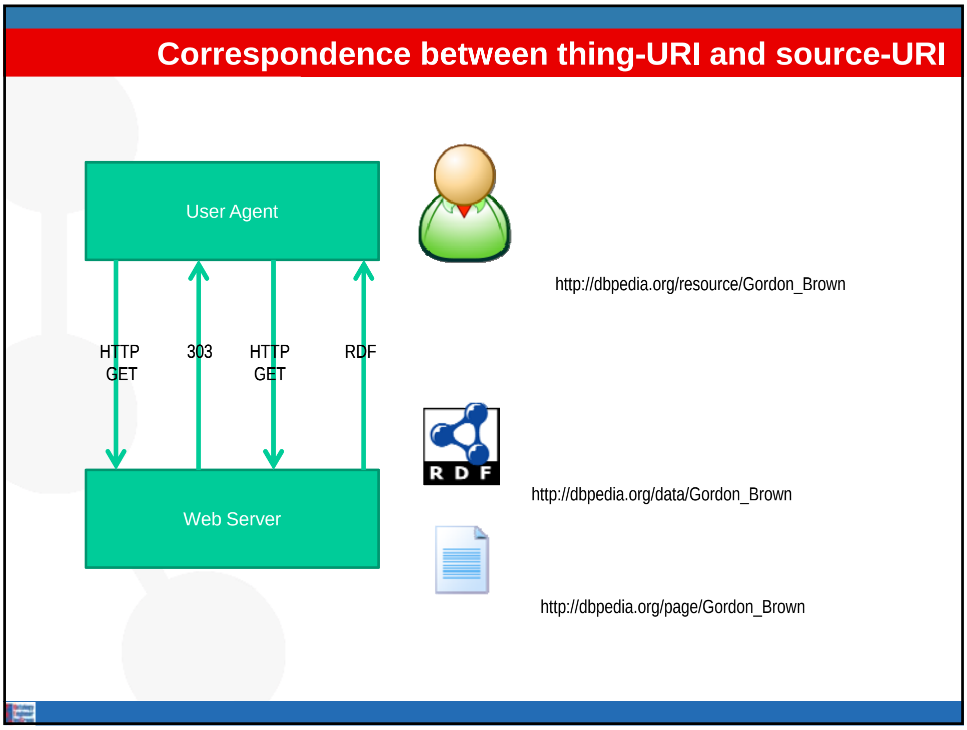
- A URI (Unique Resource Identifier) is a Web identifier
  - e.g. http://www.oeg-upm.net/ontologies/people#Oscar
- URIs allow identifying
  - Individuals: http://www.oeg-upm.net/ontologies/people#Oscar
  - Kinds of things: http://www.ontologies.org/ontologies/people#Person
  - Properties of those things: http://www.ontologies.org/ontologies/people#hasColleague
- Two types of identifiers
  - Thing-URIs, Hash URIs or URIRefs (Unique Resource Identifiers References)
    - A URI and an optional Fragment Identifier separated from the URI by the hash symbol '#'
    - http://www.ontology.org/people#Person
    - people:Person
  - Source URIs or Slash URIs can also be used, as in FOAF:
    - http://xmlns.com/foaf/0.1/Person



Correspondence between thing-URI and source-URI

http://www.polleres.net/foaf.rdf#me

http://www.polleres.net/foaf.rdf



Correspondence between thing-URI and source-URI

User Agent

HTTP GET

303

HTTP GET

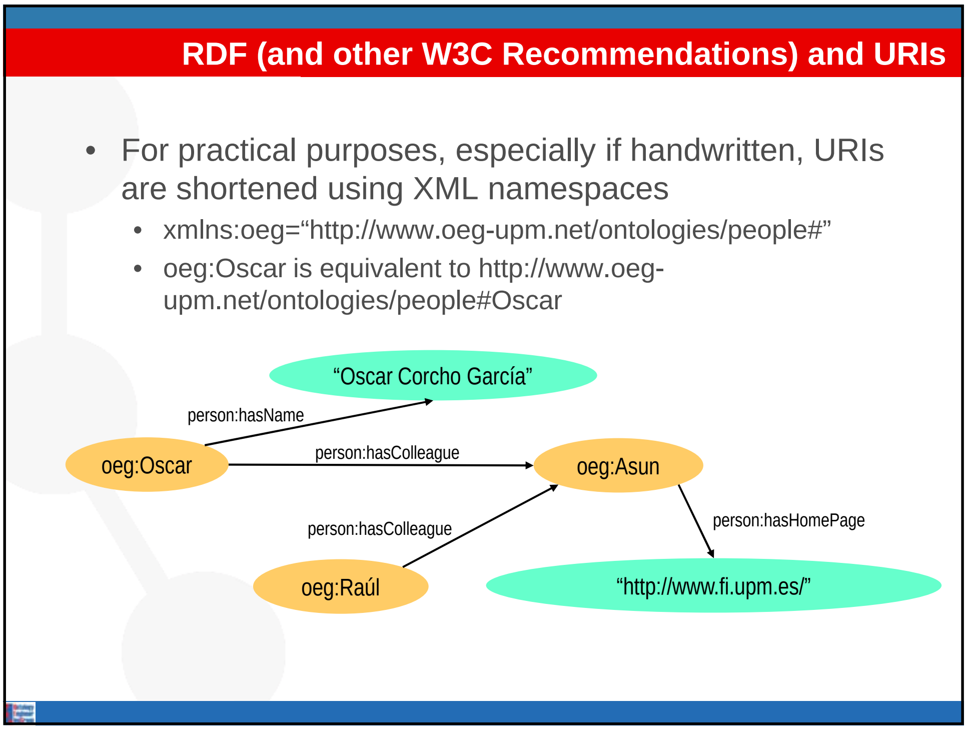
RDF

Web Server

http://dbpedia.org/resource/Gordon_Brown

http://dbpedia.org/data/Gordon_Brown

http://dbpedia.org/page/Gordon_Brown



RDF (and other W3C Recommendations) and URIs

- For practical purposes, especially if handwritten, URIs are shortened using XML namespaces
  - xmlns:oeg="http://www.oeg-upm.net/ontologies/people#"
  - oeg:Oscar is equivalent to http://www.oeg-upm.net/ontologies/people#Oscar

"Oscar Corcho García"

person:hasName

oeg:Oscar

person:hasColleague

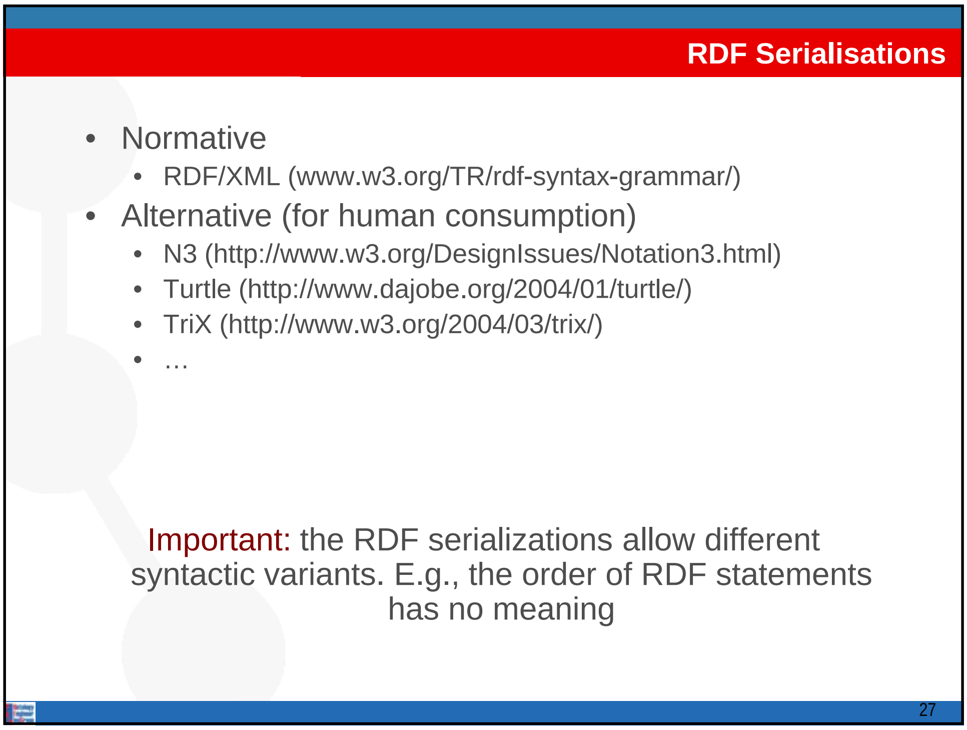
oeg:Asun

person:hasColleague

person:hasHomePage

oeg:Raúl

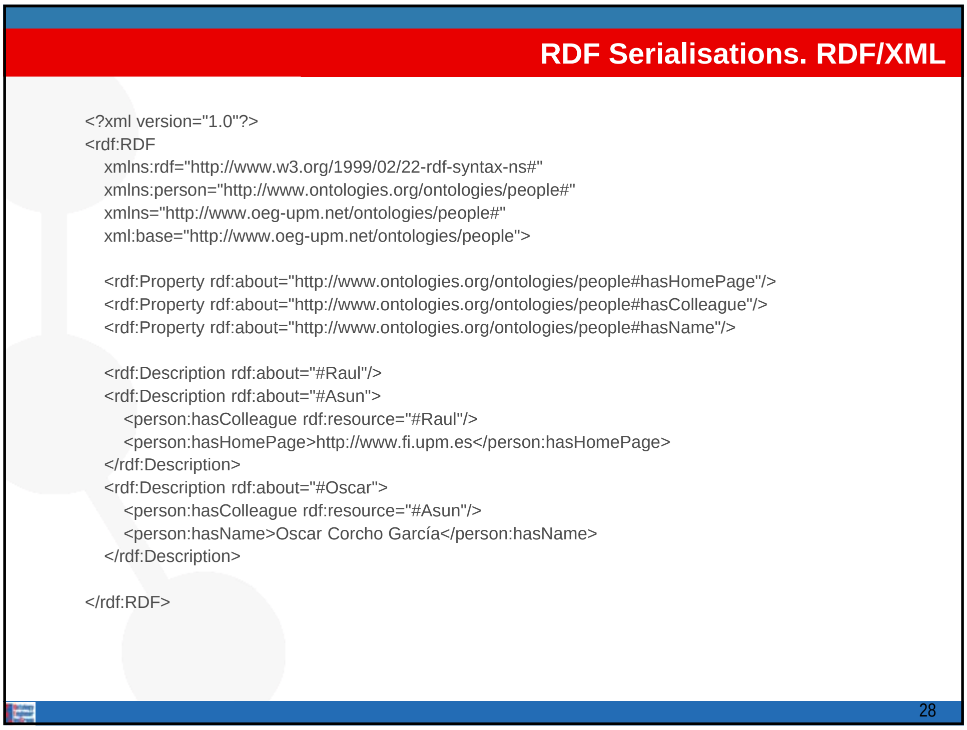
"http://www.fi.upm.es/"



RDF Serialisations

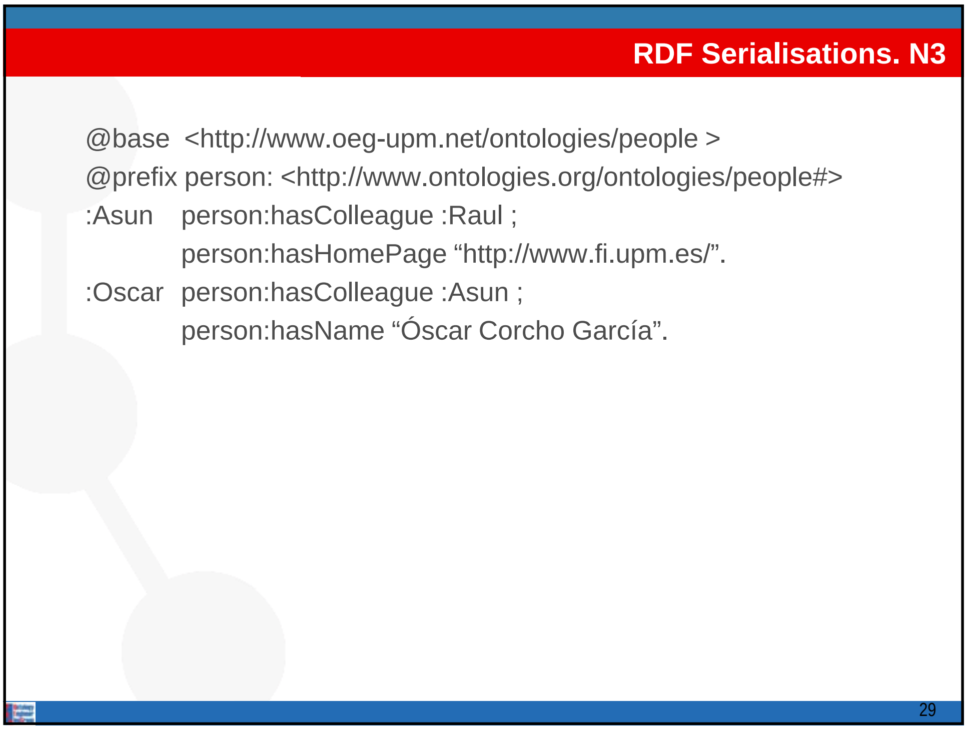
- Normative
  - RDF/XML (www.w3.org/TR/rdf-syntax-grammar/)
- Alternative (for human consumption)
  - N3 (http://www.w3.org/DesignIssues/Notation3.html)
  - Turtle (http://www.dajobe.org/2004/01/turtle/)
  - TriX (http://www.w3.org/2004/03/trix/)
  - …

Important: the RDF serializations allow different syntactic variants. E.g., the order of RDF statements has no meaning



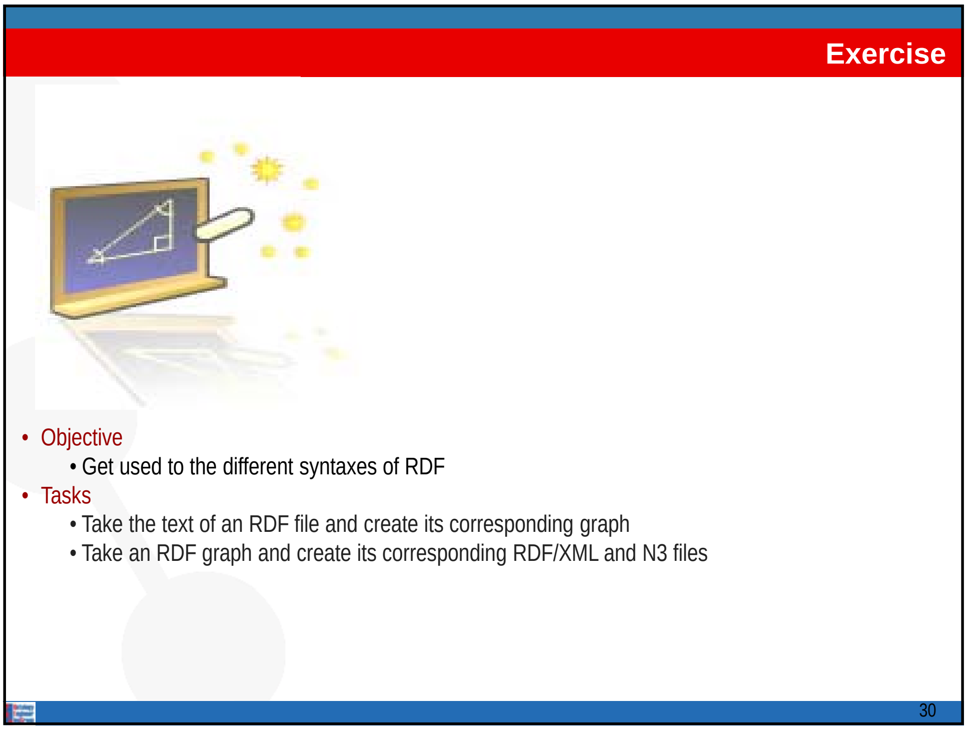
RDF Serialisations. RDF/XML

```
<?xml version="1.0"?>
<rdf:RDF
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:person="http://www.ontologies.org/ontologies/people#"
   xmlns="http://www.oeg-upm.net/ontologies/people#"
   xml:base="http://www.oeg-upm.net/ontologies/people">

   <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasHomePage"/>
   <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasColleague"/>
   <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasName"/>

   <rdf:Description rdf:about="#Raul"/>
   <rdf:Description rdf:about="#Asun">
      <person:hasColleague rdf:resource="#Raul"/>
      <person:hasHomePage>http://www.fi.upm.es</person:hasHomePage>
   </rdf:Description>
   <rdf:Description rdf:about="#Oscar">
      <person:hasColleague rdf:resource="#Asun"/>
      <person:hasName>Oscar Corcho García</person:hasName>
   </rdf:Description>

</rdf:RDF>
```



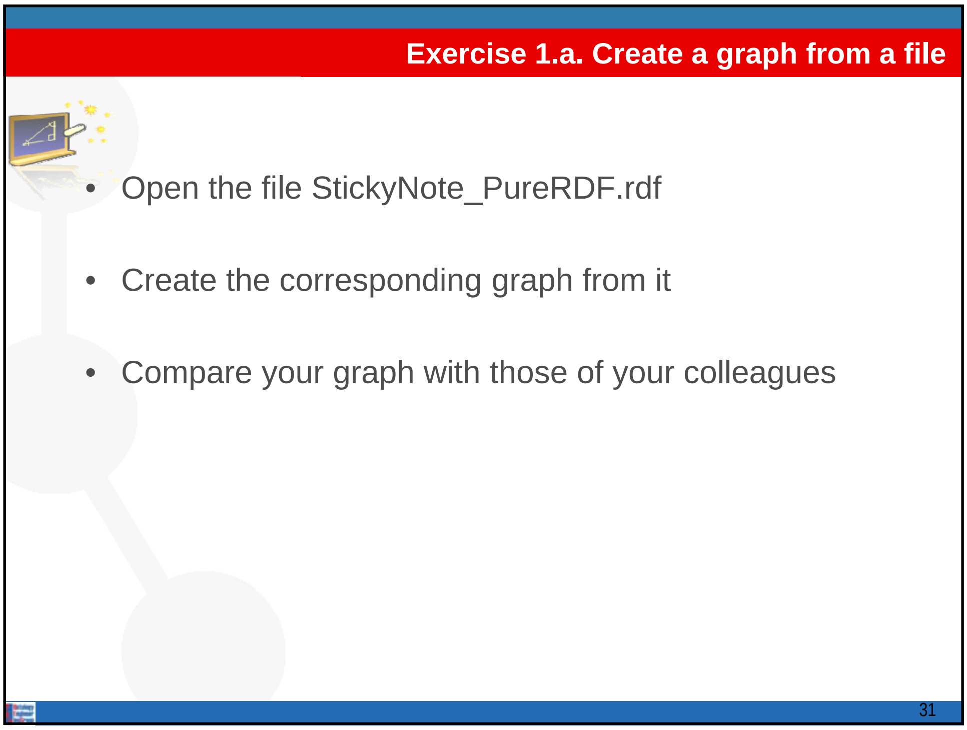
RDF Serialisations. N3

```
@base  <http://www.oeg-upm.net/ontologies/people >
@prefix person: <http://www.ontologies.org/ontologies/people#>
:Asun    person:hasColleague :Raul ;
         person:hasHomePage “http://www.fi.upm.es/”.
:Oscar   person:hasColleague :Asun ;
         person:hasName “Óscar Corcho García”.
```



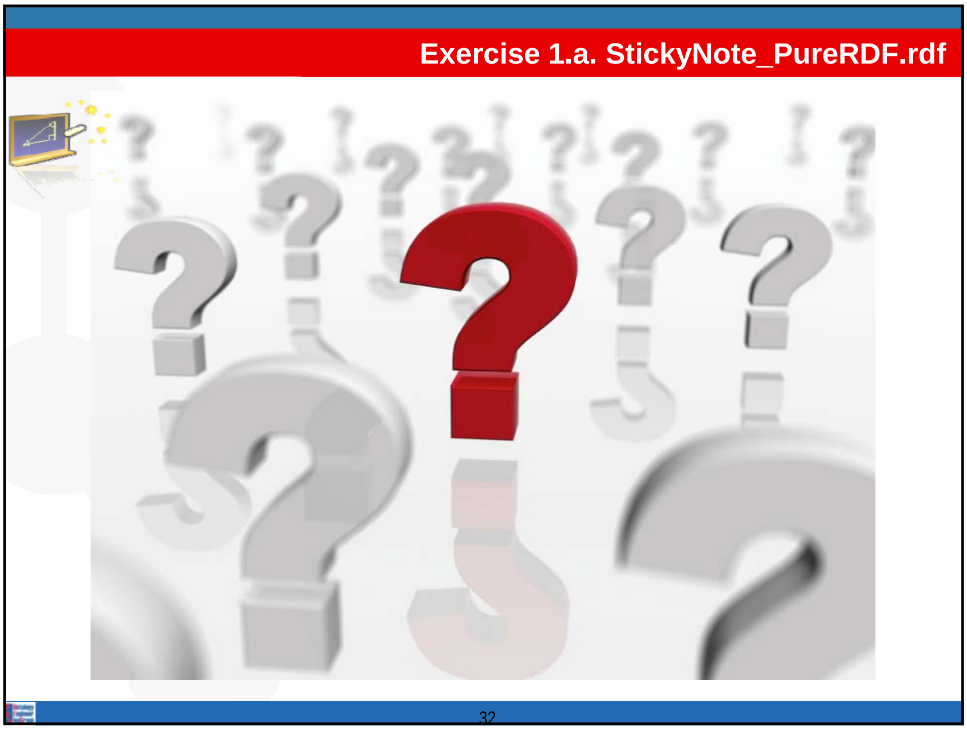
Exercise

- Objective
  - Get used to the different syntaxes of RDF
- Tasks
  - Take the text of an RDF file and create its corresponding graph
  - Take an RDF graph and create its corresponding RDF/XML and N3 files

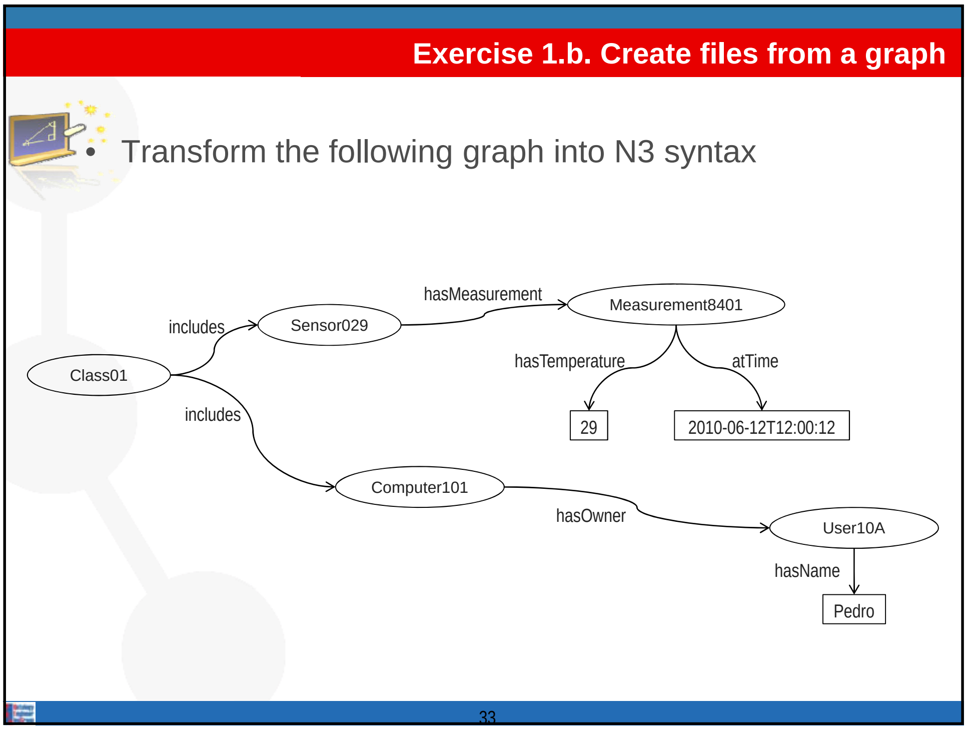


Exercise 1.a. Create a graph from a file

- Open the file StickyNote_PureRDF.rdf
- Create the corresponding graph from it
- Compare your graph with those of your colleagues

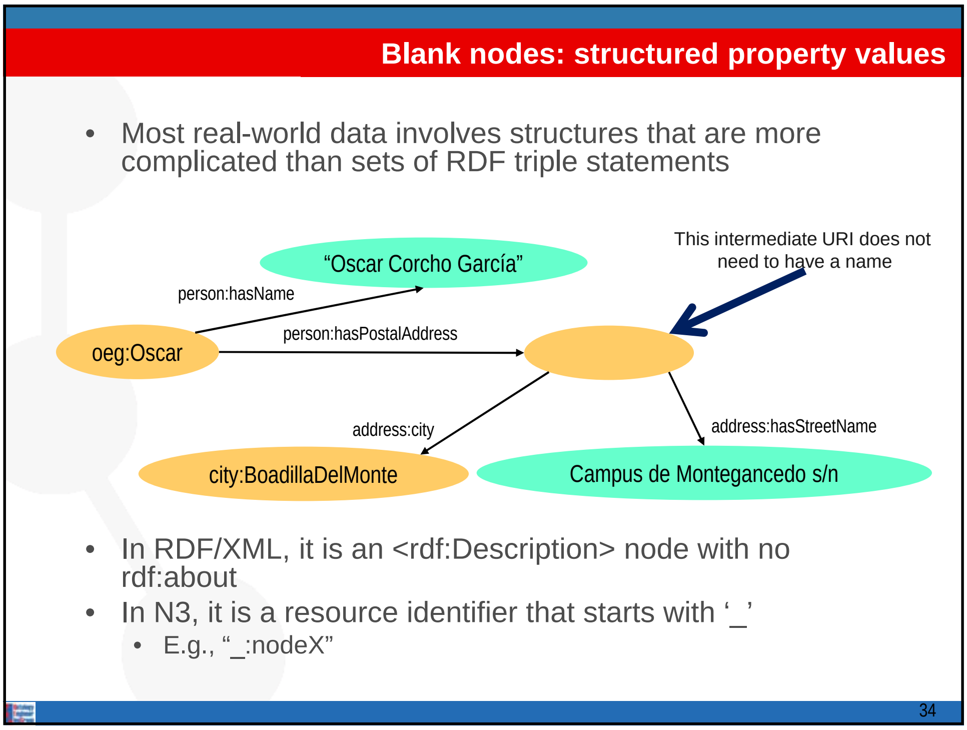


Exercise 1.a. StickyNote_PureRDF.rdf



Exercise 1.b. Create files from a graph

- Transform the following graph into N3 syntax

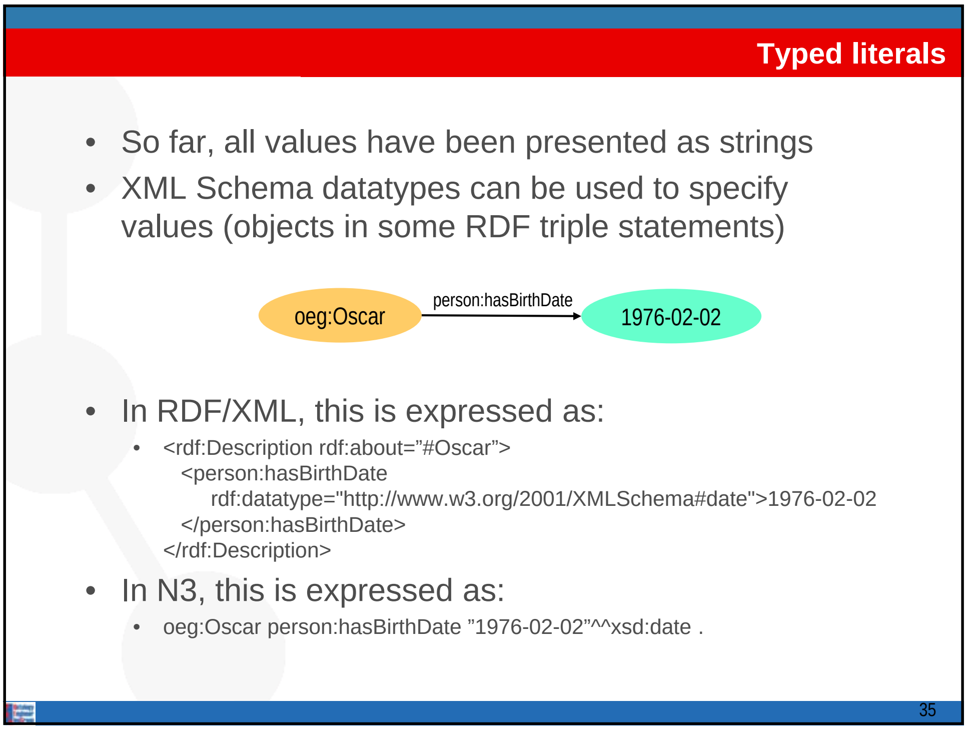


Blank nodes: structured property values

- Most real-world data involves structures that are more complicated than sets of RDF triple statements

This intermediate URI does not need to have a name

- In RDF/XML, it is an <rdf:Description> node with no rdf:about
- In N3, it is a resource identifier that starts with '_'
  - E.g., "_:nodeX"



Typed literals

- So far, all values have been presented as strings
- XML Schema datatypes can be used to specify values (objects in some RDF triple statements)

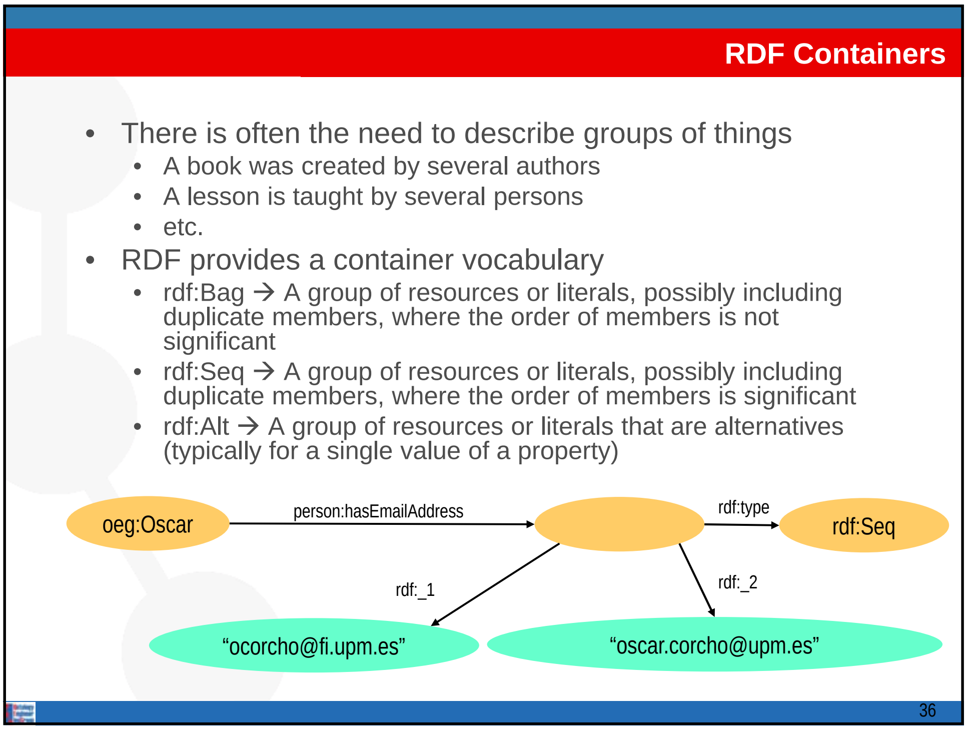
oeg:Oscar

person:hasBirthDate

1976-02-02

- In RDF/XML, this is expressed as:

  -
    ```
    <rdf:Description rdf:about=”#Oscar”>
      <person:hasBirthDate
          rdf:datatype="http://www.w3.org/2001/XMLSchema#date">1976-02-02
      </person:hasBirthDate>
    </rdf:Description>
    ```
- In N3, this is expressed as:
  - oeg:Oscar person:hasBirthDate ”1976-02-02”^^xsd:date .



RDF Containers

- There is often the need to describe groups of things
  - A book was created by several authors
  - A lesson is taught by several persons
  - etc.
- RDF provides a container vocabulary
  - rdf:Bag → A group of resources or literals, possibly including duplicate members, where the order of members is not significant
  - rdf:Seq → A group of resources or literals, possibly including duplicate members, where the order of members is significant
  - rdf:Alt → A group of resources or literals that are alternatives (typically for a single value of a property)

oeg:Oscar

person:hasEmailAddress

rdf:type

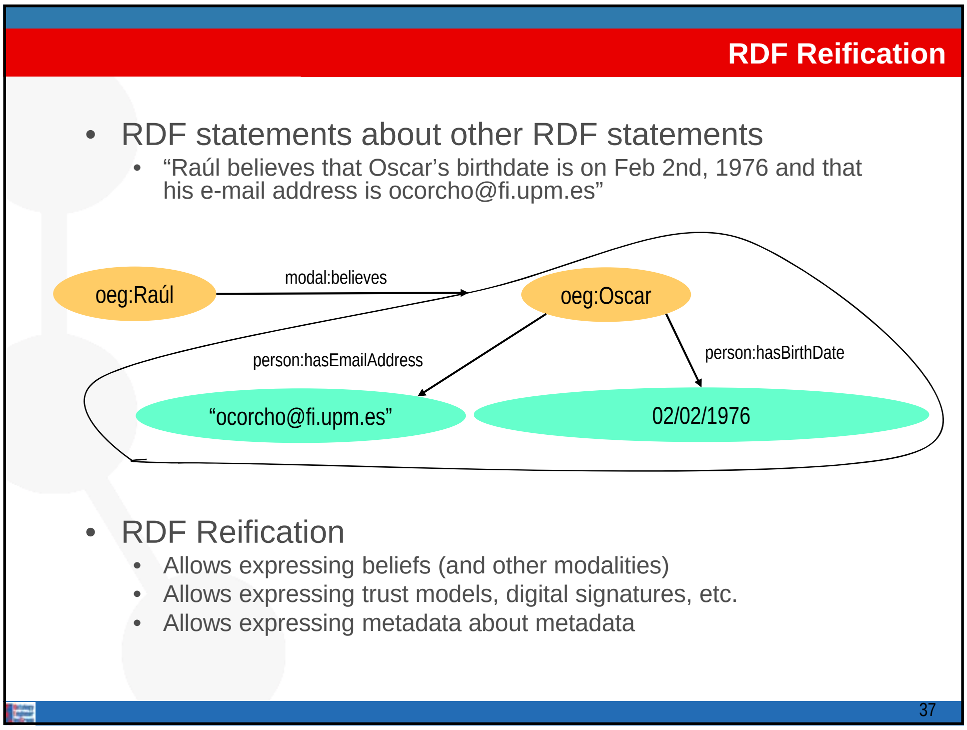
rdf:Seq

rdf:_1

rdf:_2

“ocorcho@fi.upm.es”

“oscar.corcho@upm.es”

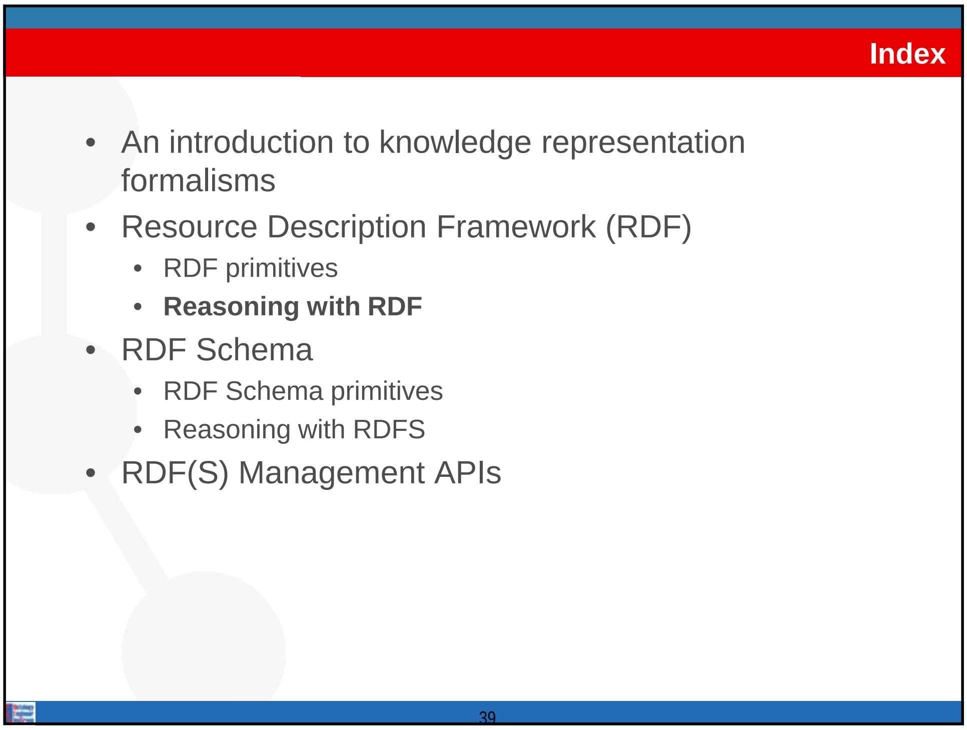


RDF Reification

- RDF statements about other RDF statements
  - “Raúl believes that Oscar’s birthdate is on Feb 2nd, 1976 and that his e-mail address is ocorcho@fi.upm.es”

oeg:Raúl
modal:believes
oeg:Oscar
person:hasEmailAddress
person:hasBirthDate
“ocorcho@fi.upm.es”
02/02/1976

- RDF Reification
  - Allows expressing beliefs (and other modalities)
  - Allows expressing trust models, digital signatures, etc.
  - Allows expressing metadata about metadata



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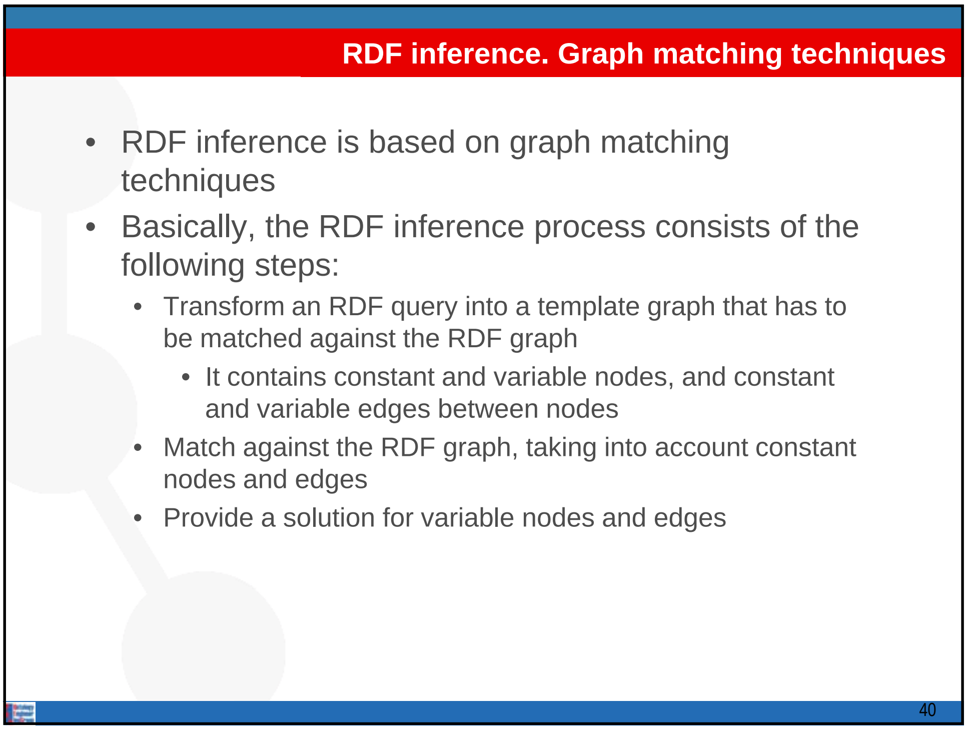
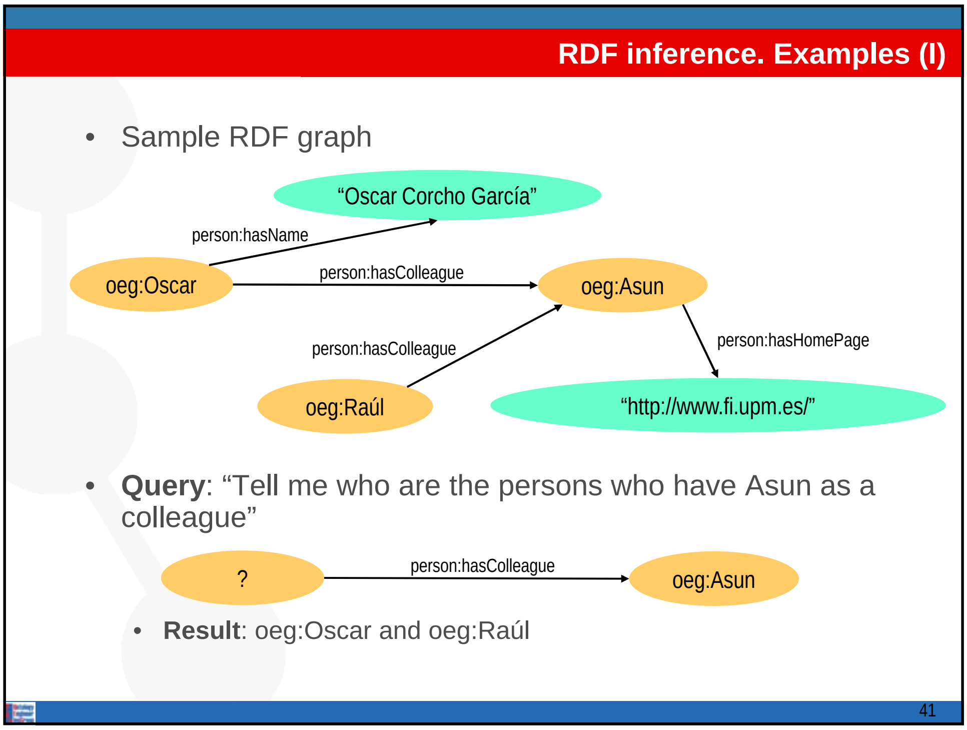


RDF inference. Graph matching techniques

- RDF inference is based on graph matching techniques
- Basically, the RDF inference process consists of the following steps:
  - Transform an RDF query into a template graph that has to be matched against the RDF graph
    - It contains constant and variable nodes, and constant and variable edges between nodes
  - Match against the RDF graph, taking into account constant nodes and edges
  - Provide a solution for variable nodes and edges



RDF inference. Examples (I)

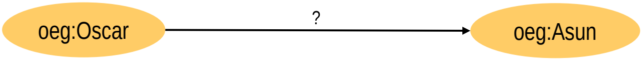
- Sample RDF graph

- **Query**: "Tell me who are the persons who have Asun as a colleague"

  - **Result**: oeg:Oscar and oeg:Raúl

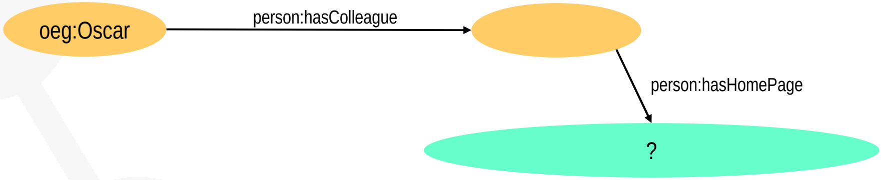
RDF inference. Examples (II)

- **Query**: "Tell me which are the relationships between Oscar and Asun"



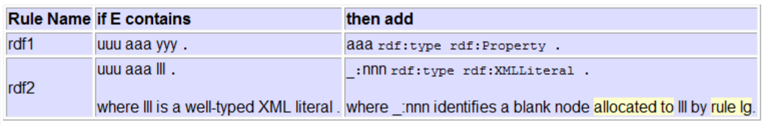
  - **Result**: oeg:hasColleague

- **Query**: "Tell me the homepage of Oscar colleagues"

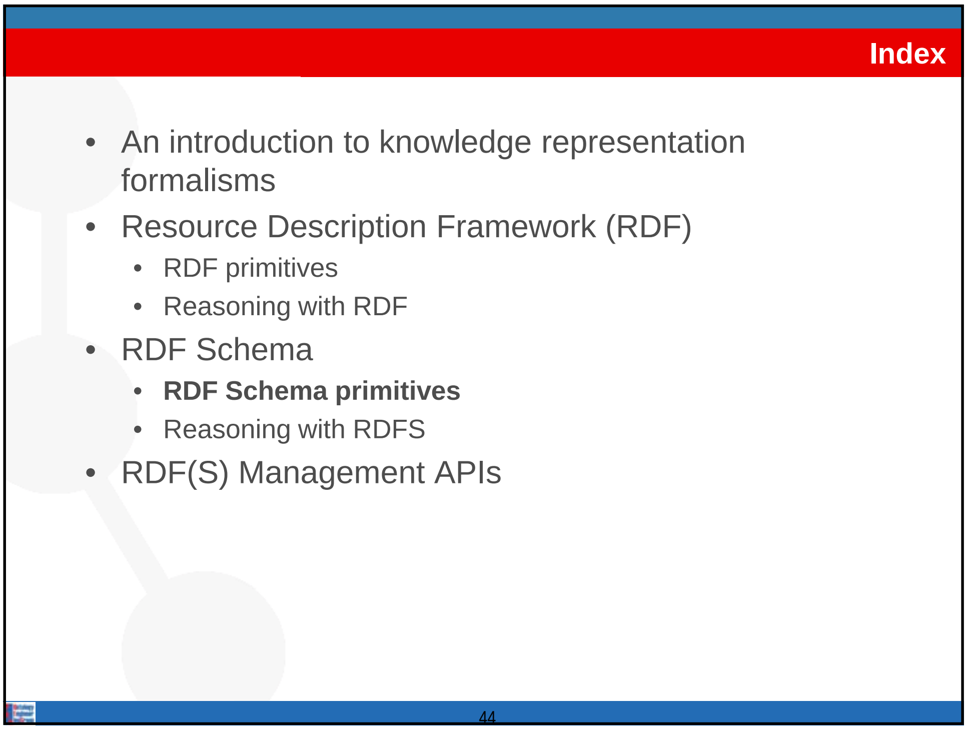


  - **Result**: "http://www.fi.upm.es/"

RDF inference. Entailment rules



Rule Name	if E contains	then add
rdf1	uuu aaa yyy .	aaa `rdf:type rdf:Property .`
rdf2	uuu aaa lll . where lll is a well-typed XML literal .	_:nnn `rdf:type rdf:XMLLiteral .` where _:nnn identifies a blank node allocated to lll by rule lg.



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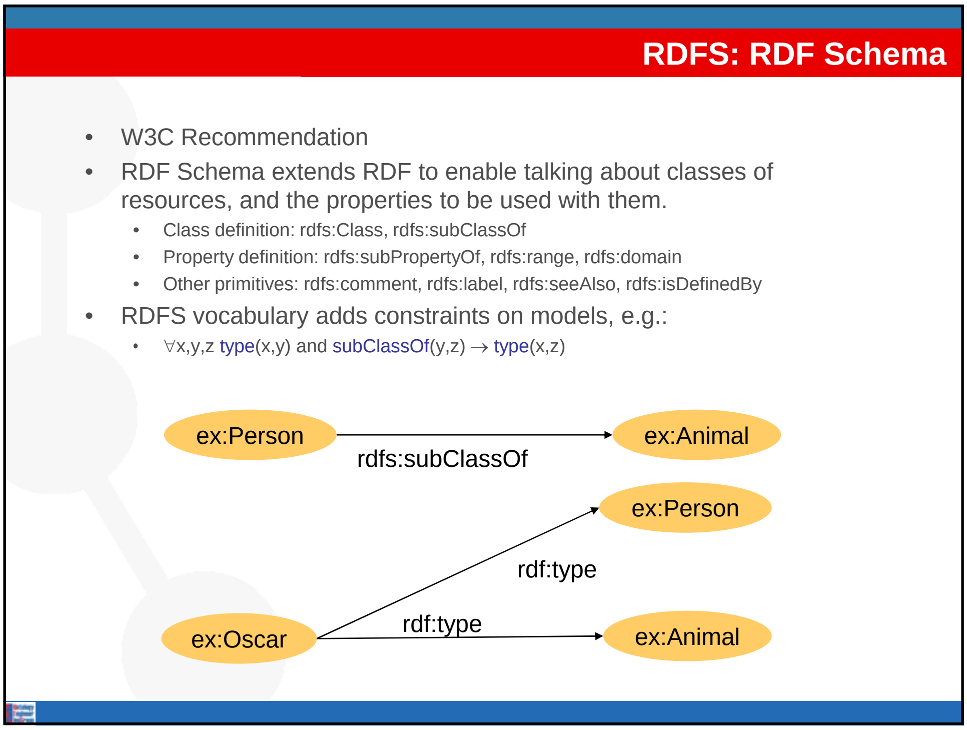


RDFS: RDF Schema

- W3C Recommendation
- RDF Schema extends RDF to enable talking about classes of resources, and the properties to be used with them.
  - Class definition: rdfs:Class, rdfs:subClassOf
  - Property definition: rdfs:subPropertyOf, rdfs:range, rdfs:domain
  - Other primitives: rdfs:comment, rdfs:label, rdfs:seeAlso, rdfs:isDefinedBy
- RDFS vocabulary adds constraints on models, e.g.:
  - $\forall$x,y,z type(x,y) and subClassOf(y,z) $\rightarrow$ type(x,z)

ex:Person

rdfs:subClassOf

ex:Animal

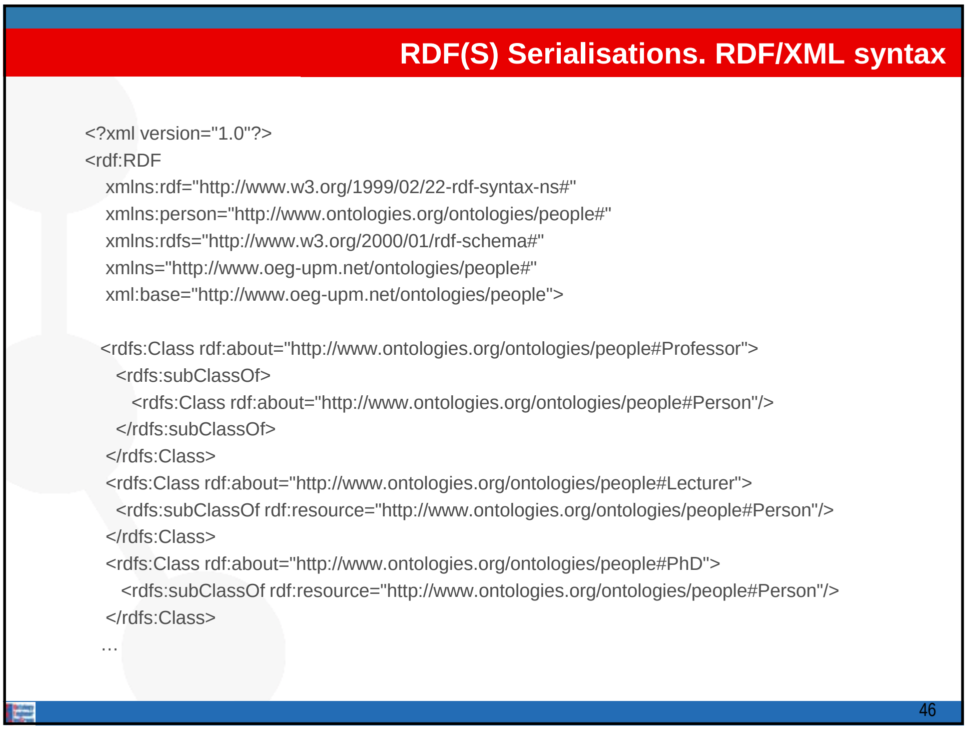
ex:Person

rdf:type

ex:Oscar

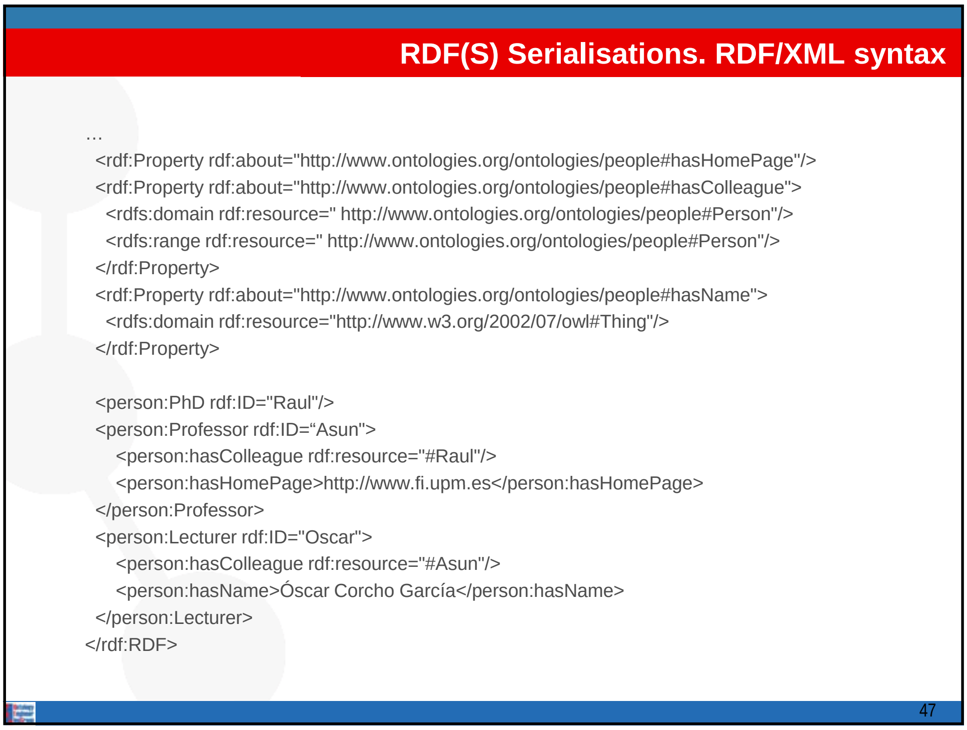
rdf:type

ex:Animal



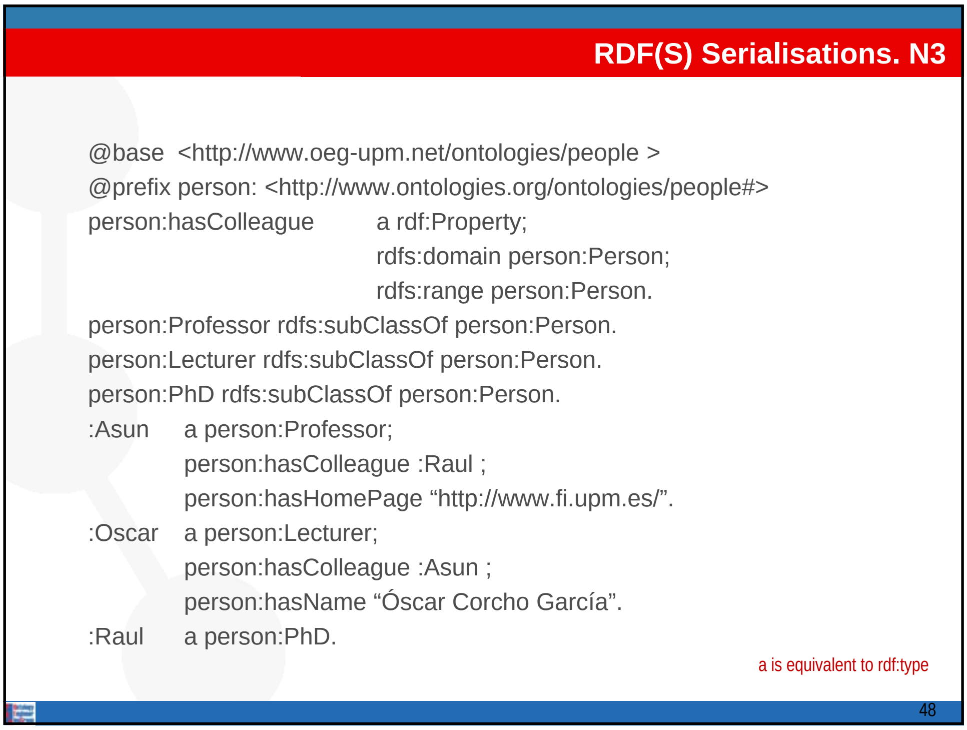
RDF(S) Serialisations. RDF/XML syntax

```
<?xml version="1.0"?>
<rdf:RDF
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:person="http://www.ontologies.org/ontologies/people#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
   xmlns="http://www.oeg-upm.net/ontologies/people#"
   xml:base="http://www.oeg-upm.net/ontologies/people">

  <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#Professor">
    <rdfs:subClassOf>
      <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#Person"/>
    </rdfs:subClassOf>
   </rdfs:Class>
   <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#Lecturer">
    <rdfs:subClassOf rdf:resource="http://www.ontologies.org/ontologies/people#Person"/>
   </rdfs:Class>
   <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#PhD">
     <rdfs:subClassOf rdf:resource="http://www.ontologies.org/ontologies/people#Person"/>
   </rdfs:Class>
  …
```



RDF(S) Serialisations. RDF/XML syntax

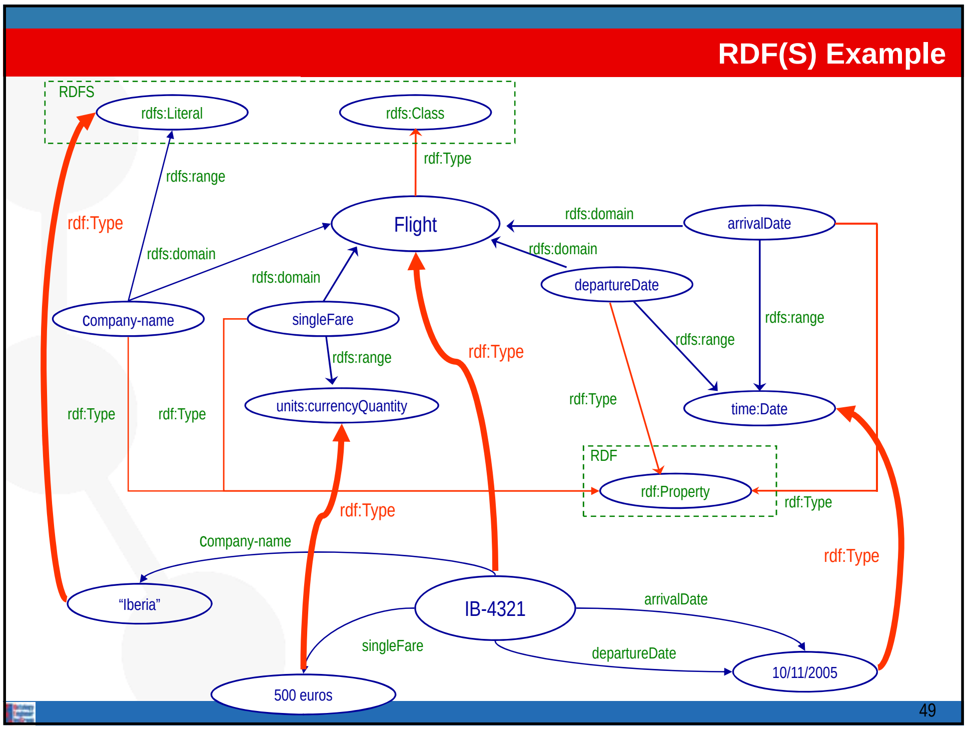
```
…
 <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasHomePage"/>
 <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasColleague">
   <rdfs:domain rdf:resource=" http://www.ontologies.org/ontologies/people#Person"/>
   <rdfs:range rdf:resource=" http://www.ontologies.org/ontologies/people#Person"/>
 </rdf:Property>
 <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasName">
   <rdfs:domain rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
 </rdf:Property>

 <person:PhD rdf:ID="Raul"/>
 <person:Professor rdf:ID=“Asun">
    <person:hasColleague rdf:resource="#Raul"/>
    <person:hasHomePage>http://www.fi.upm.es</person:hasHomePage>
 </person:Professor>
 <person:Lecturer rdf:ID="Oscar">
    <person:hasColleague rdf:resource="#Asun"/>
    <person:hasName>Óscar Corcho García</person:hasName>
 </person:Lecturer>
</rdf:RDF>
```



RDF(S) Serialisations. N3

```
@base  <http://www.oeg-upm.net/ontologies/people >
@prefix person: <http://www.ontologies.org/ontologies/people#>
person:hasColleague         a rdf:Property;
                            rdfs:domain person:Person;
                            rdfs:range person:Person.
person:Professor rdfs:subClassOf person:Person.
person:Lecturer rdfs:subClassOf person:Person.
person:PhD rdfs:subClassOf person:Person.
:Asun     a person:Professor;
          person:hasColleague :Raul ;
          person:hasHomePage “http://www.fi.upm.es/”.
:Oscar    a person:Lecturer;
          person:hasColleague :Asun ;
          person:hasName “Óscar Corcho García”.
:Raul     a person:PhD.
```

a is equivalent to rdf:type



RDF(S) Example

RDFS

rdfs:Literal

rdfs:Class

rdf:Type

rdfs:range

rdf:Type

Flight

rdfs:domain

arrivalDate

rdfs:domain

rdfs:domain

rdfs:domain

departureDate

Company-name

singleFare

rdfs:range

rdfs:range

rdfs:range

rdf:Type

units:currencyQuantity

rdf:Type

rdf:Type

rdf:Type

time:Date

RDF

rdf:Property

rdf:Type

rdf:Type

Company-name

rdf:Type

“Iberia”

IB-4321

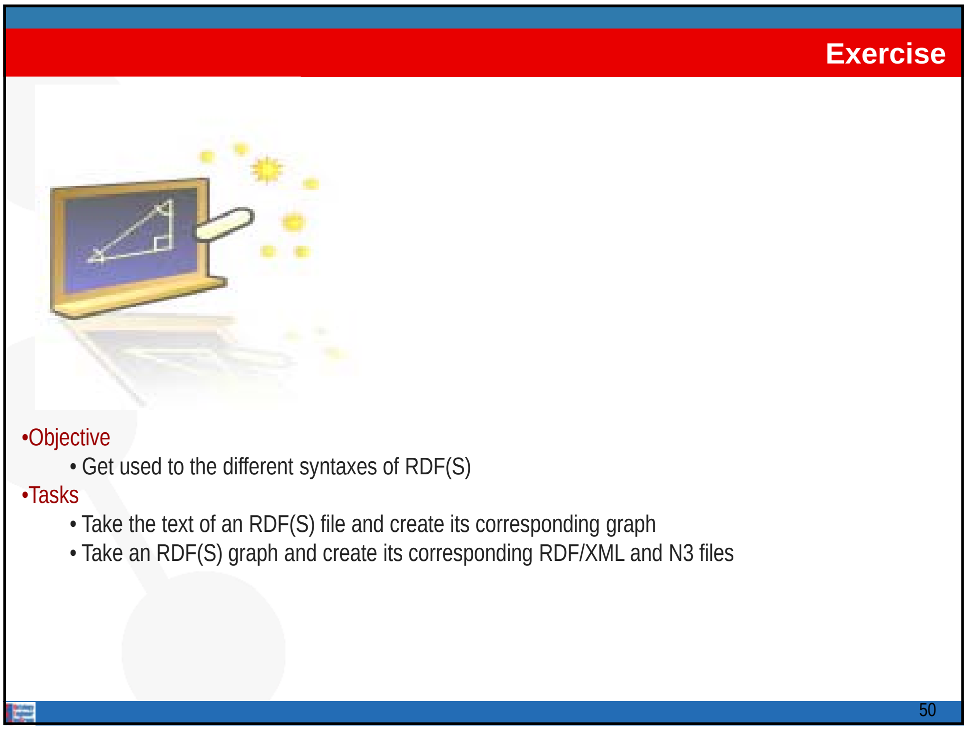
arrivalDate

singleFare

departureDate

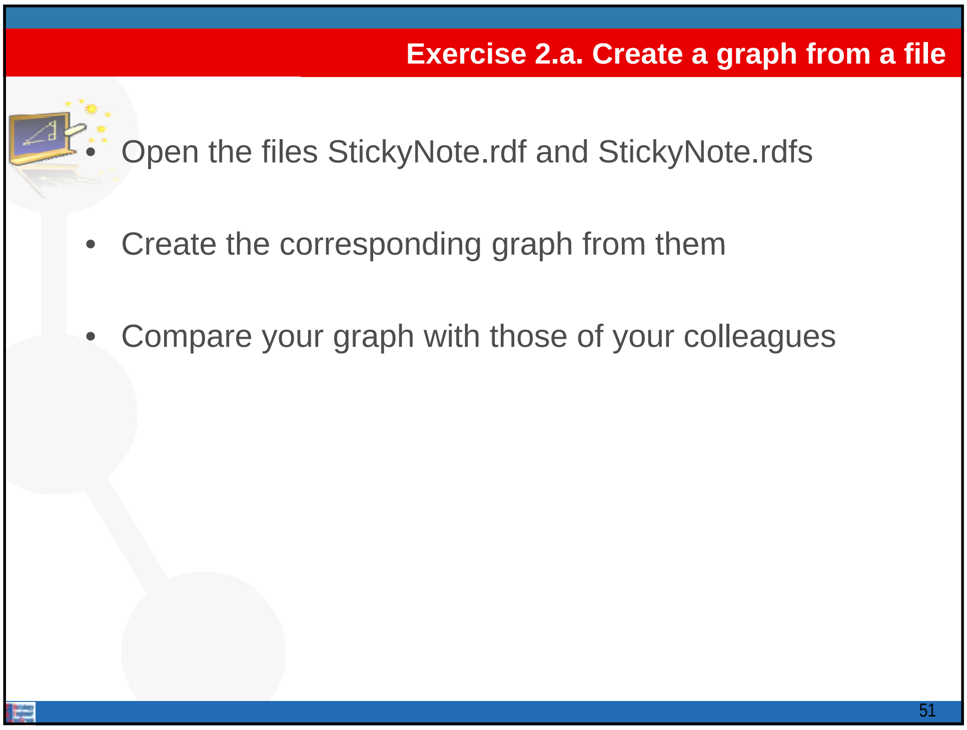
10/11/2005

500 euros



Exercise

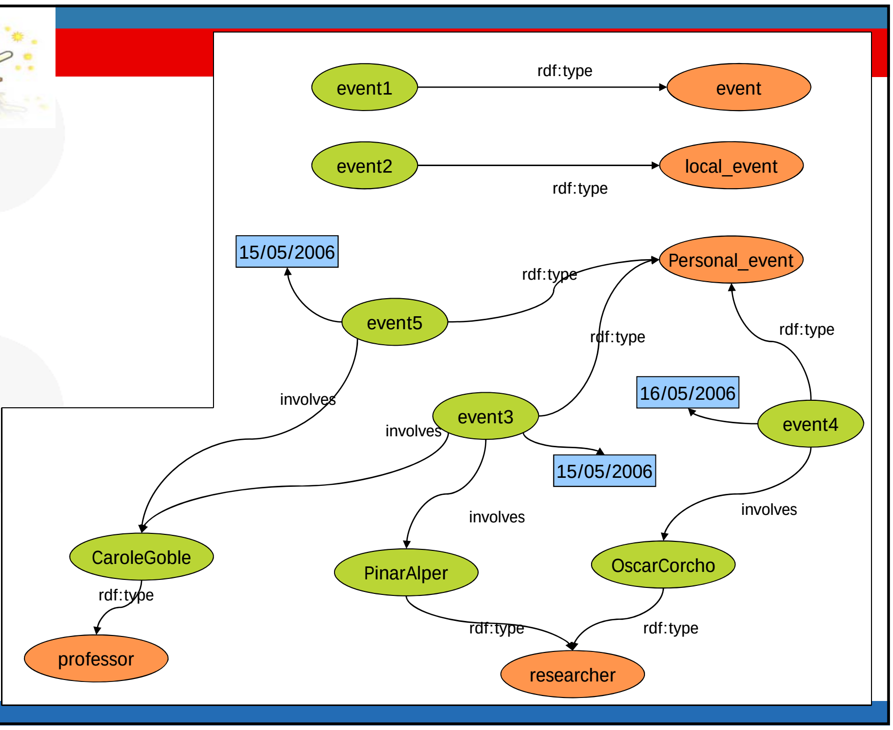
- Objective
  - Get used to the different syntaxes of RDF(S)
- Tasks
  - Take the text of an RDF(S) file and create its corresponding graph
  - Take an RDF(S) graph and create its corresponding RDF/XML and N3 files



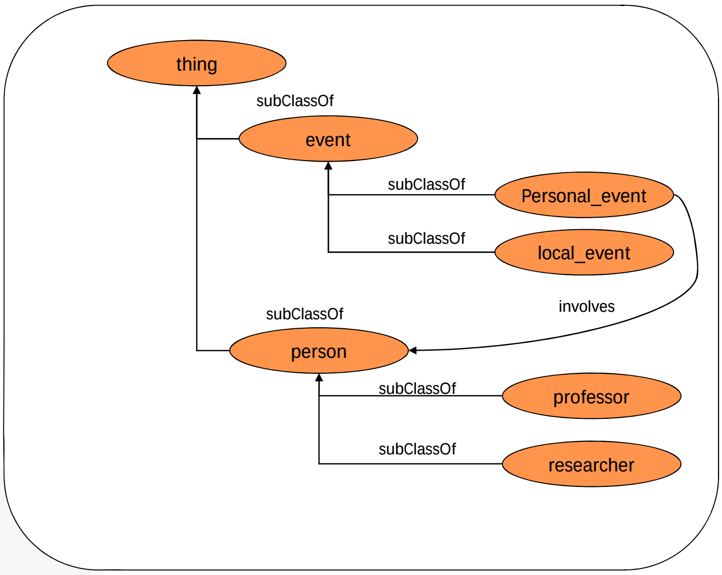
Exercise 2.a. Create a graph from a file

- Open the files StickyNote.rdf and StickyNote.rdfs
- Create the corresponding graph from them
- Compare your graph with those of your colleagues

Exercise 2.a. StickyNote.rdf

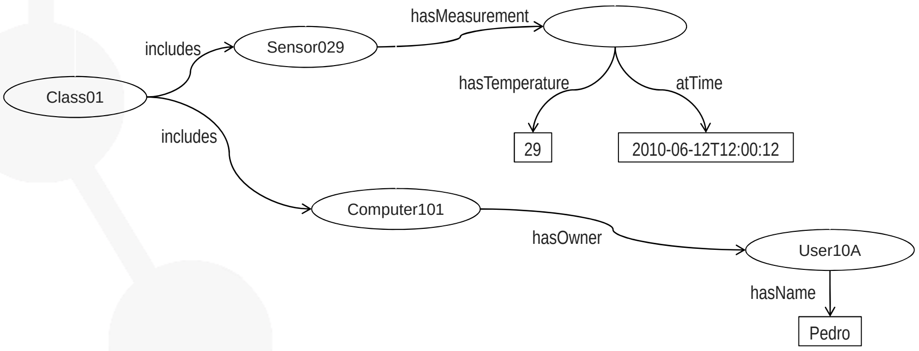


Exercise 2.a. StickyNote.rdfs



Exercise 2.b. Create files from a graph

- Transform the following graph into N3 syntax



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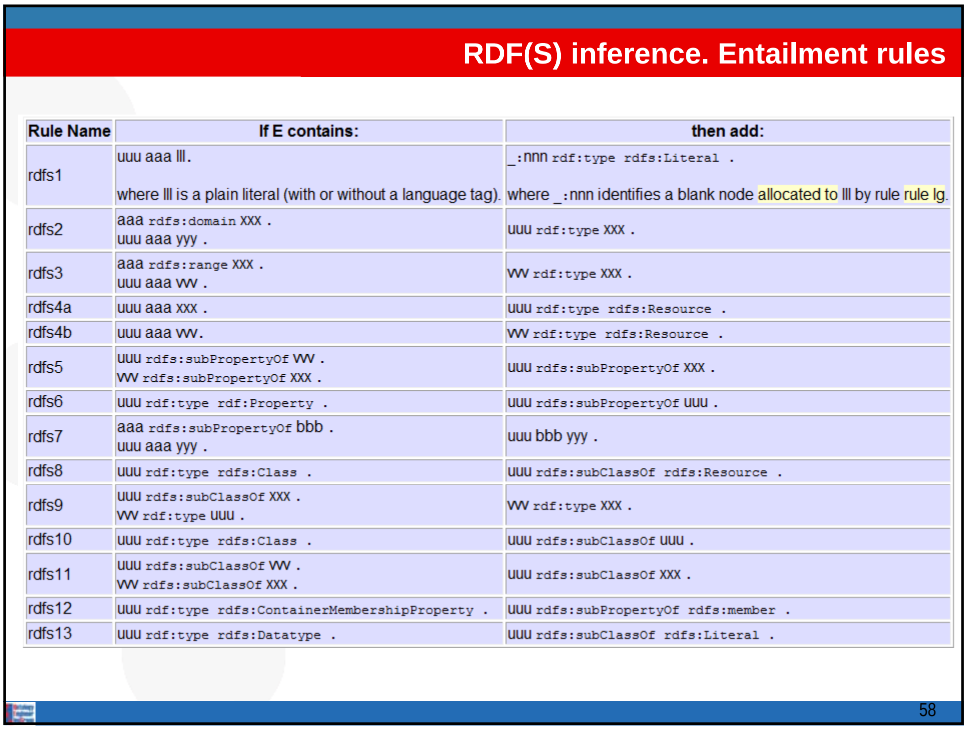
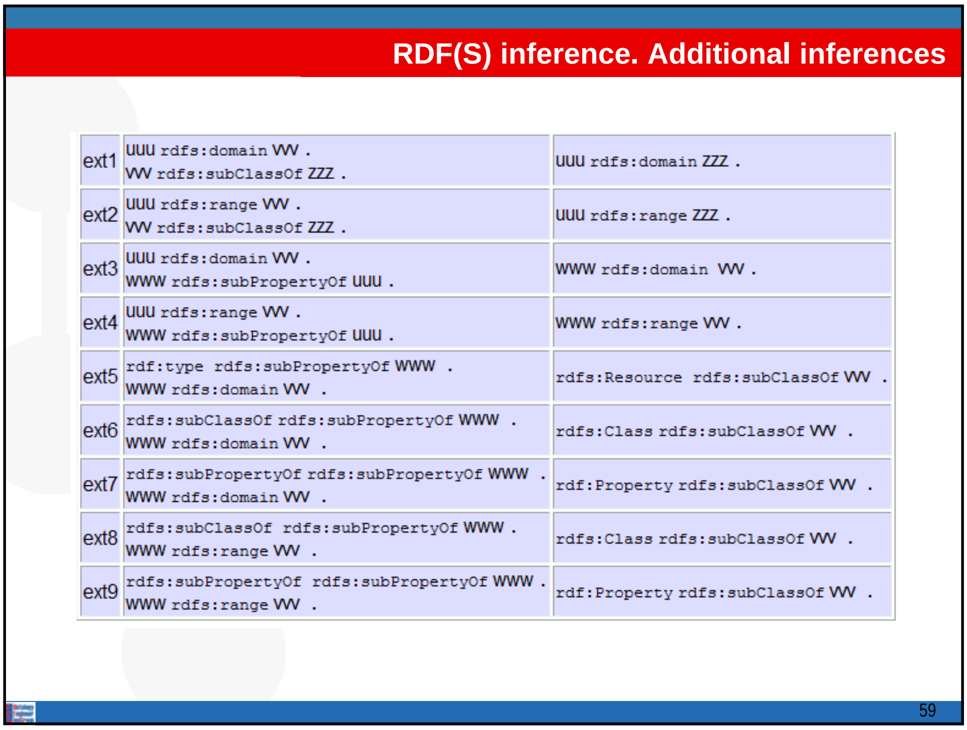


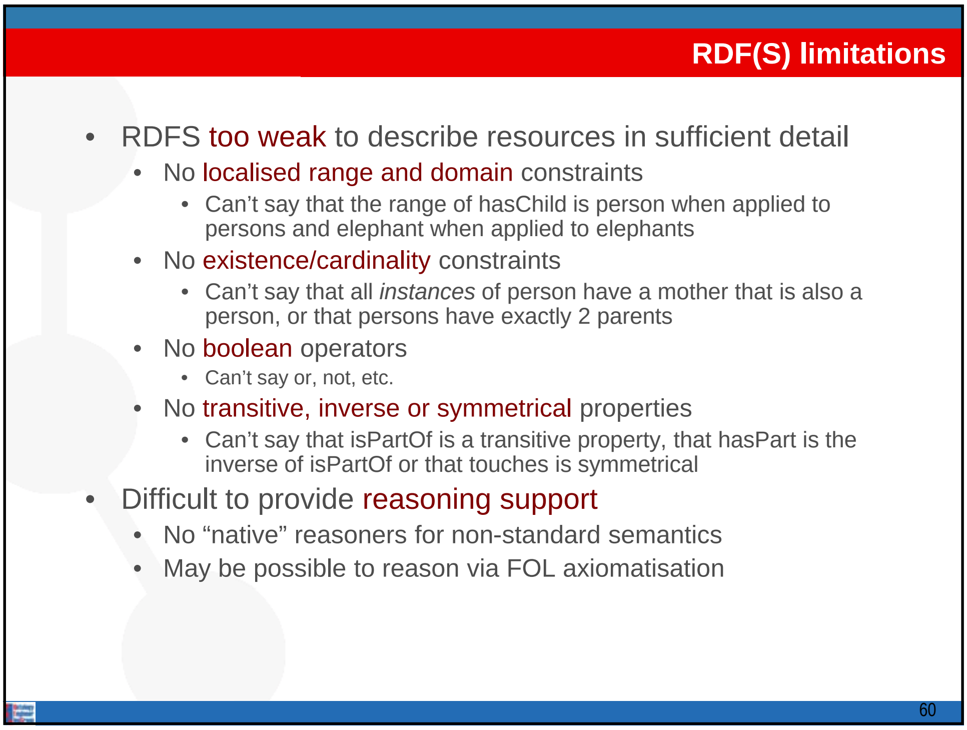
RDF(S) inference. Entailment rules

Rule Name	If E contains:	then add:
rdfs1	uuu aaa lll. where lll is a plain literal (with or without a language tag).	_:nnn rdf:type rdfs:Literal . where _:nnn identifies a blank node allocated to lll by rule rule lg.
rdfs2	aaa rdfs:domain XXX . uuu aaa yyy .	uuu rdf:type XXX .
rdfs3	aaa rdfs:range XXX . uuu aaa vvv .	vvv rdf:type XXX .
rdfs4a	uuu aaa xxx .	uuu rdf:type rdfs:Resource .
rdfs4b	uuu aaa vvv.	vvv rdf:type rdfs:Resource .
rdfs5	uuu rdfs:subPropertyOf vvv . vvv rdfs:subPropertyOf XXX .	uuu rdfs:subPropertyOf XXX .
rdfs6	uuu rdf:type rdf:Property .	uuu rdfs:subPropertyOf uuu .
rdfs7	aaa rdfs:subPropertyOf bbb . uuu aaa yyy .	uuu bbb yyy .
rdfs8	uuu rdf:type rdfs:Class .	uuu rdfs:subClassOf rdfs:Resource .
rdfs9	uuu rdfs:subClassOf XXX . vvv rdf:type uuu .	vvv rdf:type XXX .
rdfs10	uuu rdf:type rdfs:Class .	uuu rdfs:subClassOf uuu .
rdfs11	uuu rdfs:subClassOf vvv . vvv rdfs:subClassOf XXX .	uuu rdfs:subClassOf XXX .
rdfs12	uuu rdf:type rdfs:ContainerMembershipProperty .	uuu rdfs:subPropertyOf rdfs:member .
rdfs13	uuu rdf:type rdfs:Datatype .	uuu rdfs:subClassOf rdfs:Literal .



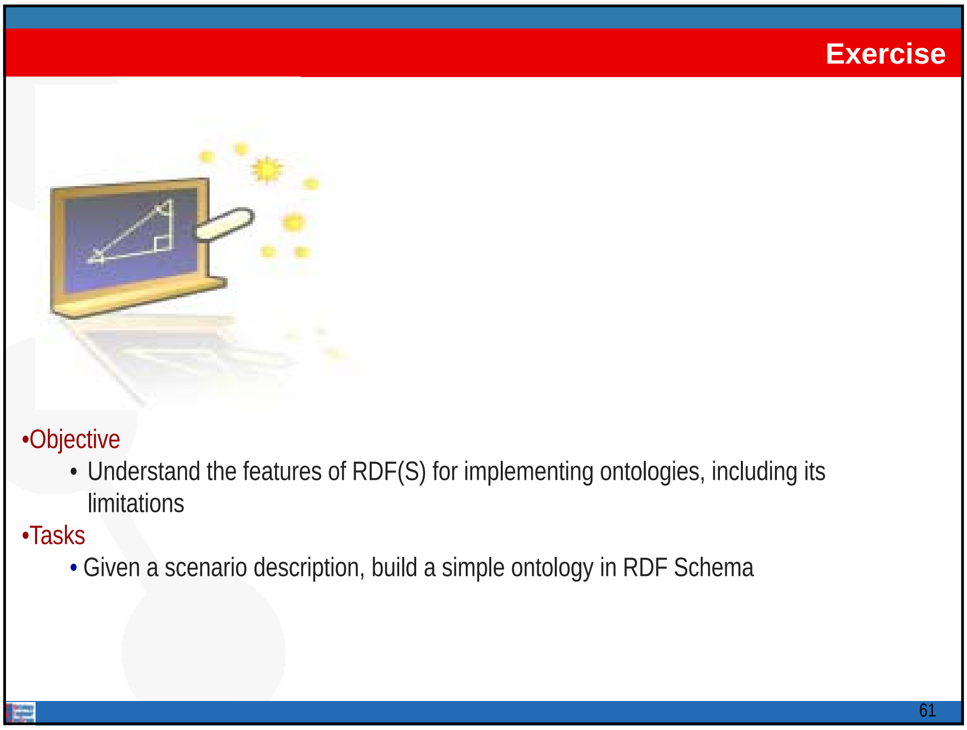
RDF(S) inference. Additional inferences

ext1	uuu rdfs:domain vvv . vvv rdfs:subClassOf zzz .	uuu rdfs:domain zzz .
ext2	uuu rdfs:range vvv . vvv rdfs:subClassOf zzz .	uuu rdfs:range zzz .
ext3	uuu rdfs:domain vvv . www rdfs:subPropertyOf uuu .	www rdfs:domain vvv .
ext4	uuu rdfs:range vvv . www rdfs:subPropertyOf uuu .	www rdfs:range vvv .
ext5	rdf:type rdfs:subPropertyOf www . www rdfs:domain vvv .	rdfs:Resource rdfs:subClassOf vvv .
ext6	rdfs:subClassOf rdfs:subPropertyOf www . www rdfs:domain vvv .	rdfs:Class rdfs:subClassOf vvv .
ext7	rdfs:subPropertyOf rdfs:subPropertyOf www . www rdfs:domain vvv .	rdf:Property rdfs:subClassOf vvv .
ext8	rdfs:subClassOf rdfs:subPropertyOf www . www rdfs:range vvv .	rdfs:Class rdfs:subClassOf vvv .
ext9	rdfs:subPropertyOf rdfs:subPropertyOf www . www rdfs:range vvv .	rdf:Property rdfs:subClassOf vvv .



RDF(S) limitations

- RDFS too weak to describe resources in sufficient detail
  - No localised range and domain constraints
    - Can’t say that the range of hasChild is person when applied to persons and elephant when applied to elephants
  - No existence/cardinality constraints
    - Can’t say that all *instances* of person have a mother that is also a person, or that persons have exactly 2 parents
  - No boolean operators
    - Can’t say or, not, etc.
  - No transitive, inverse or symmetrical properties
    - Can’t say that isPartOf is a transitive property, that hasPart is the inverse of isPartOf or that touches is symmetrical
- Difficult to provide reasoning support
  - No “native” reasoners for non-standard semantics
  - May be possible to reason via FOL axiomatisation



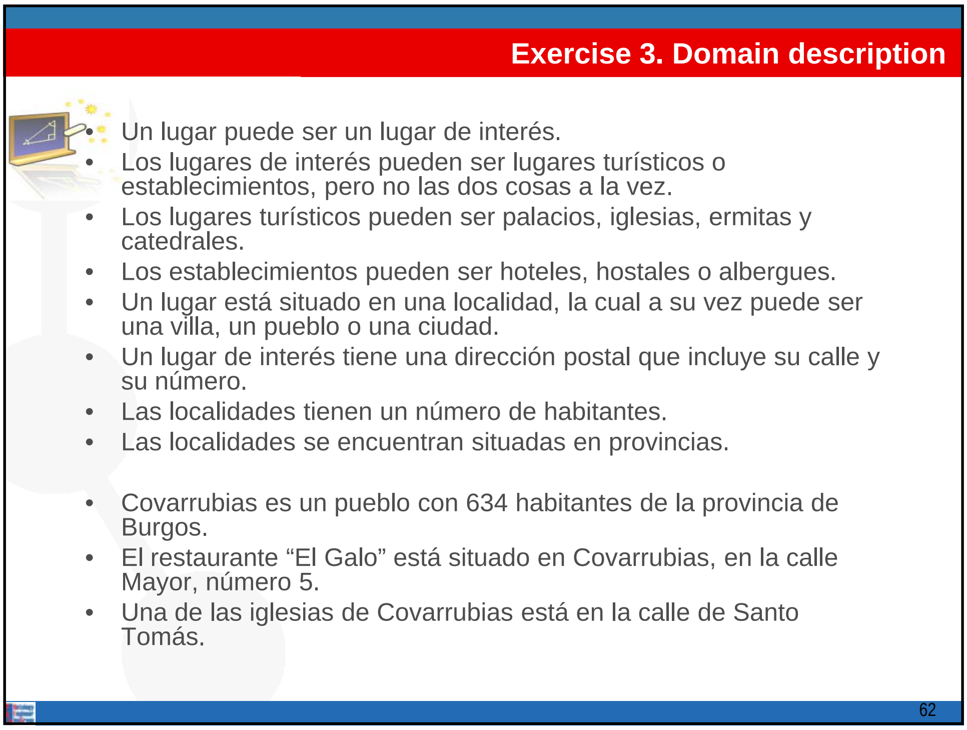
Exercise

•Objective

- Understand the features of RDF(S) for implementing ontologies, including its limitations

•Tasks

- Given a scenario description, build a simple ontology in RDF Schema

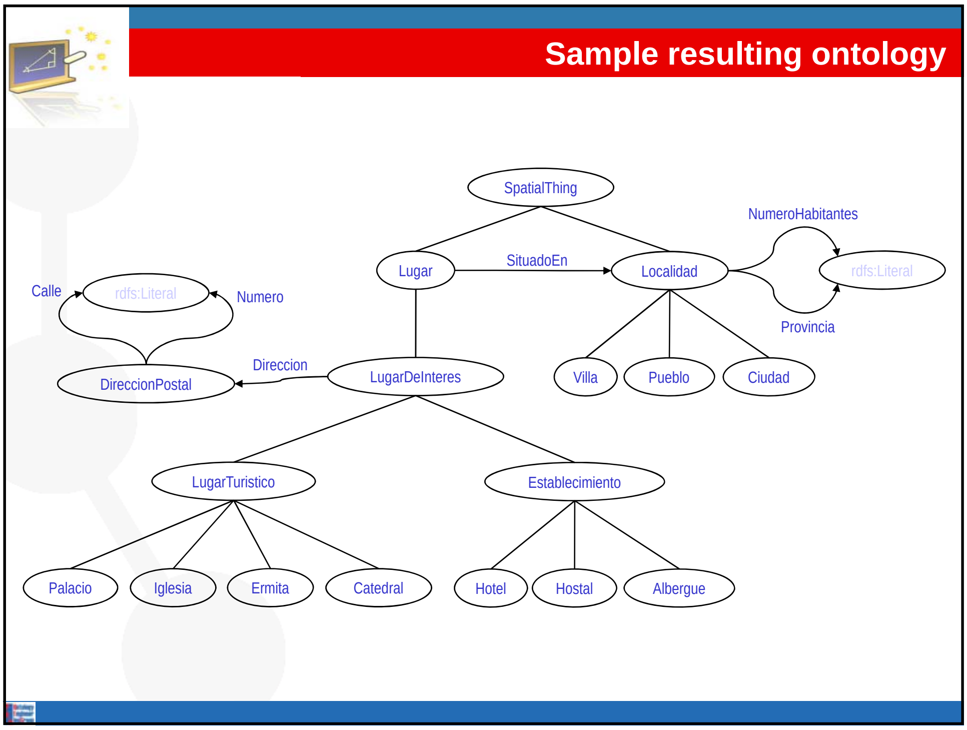


Exercise 3. Domain description

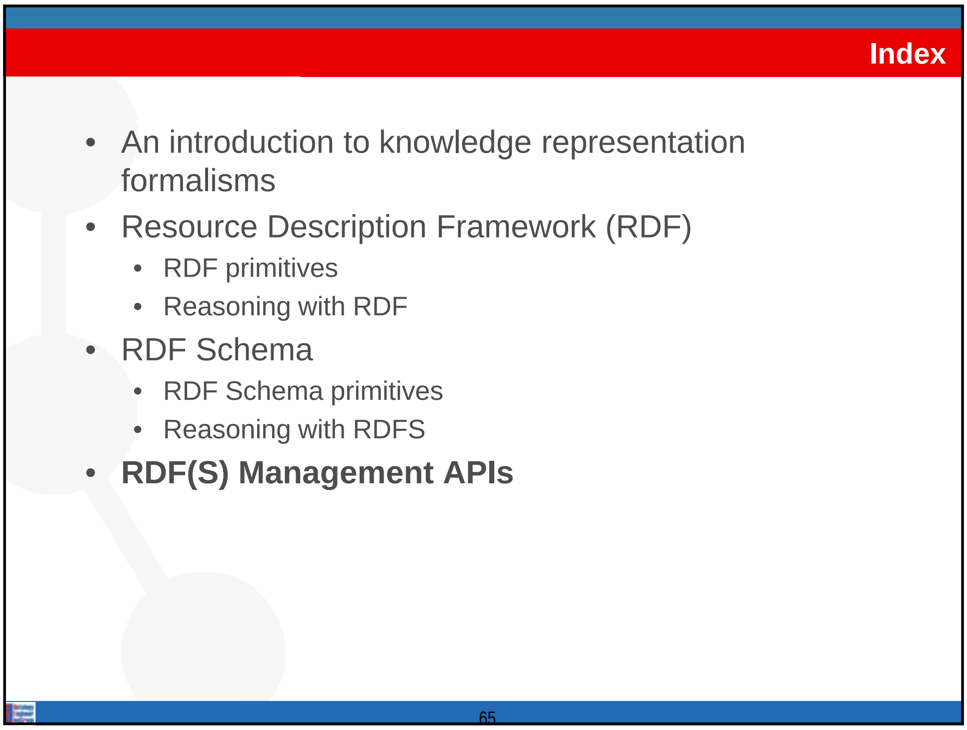
- Un lugar puede ser un lugar de interés.
- Los lugares de interés pueden ser lugares turísticos o establecimientos, pero no las dos cosas a la vez.
- Los lugares turísticos pueden ser palacios, iglesias, ermitas y catedrales.
- Los establecimientos pueden ser hoteles, hostales o albergues.
- Un lugar está situado en una localidad, la cual a su vez puede ser una villa, un pueblo o una ciudad.
- Un lugar de interés tiene una dirección postal que incluye su calle y su número.
- Las localidades tienen un número de habitantes.
- Las localidades se encuentran situadas en provincias.

- Covarrubias es un pueblo con 634 habitantes de la provincia de Burgos.
- El restaurante "El Galo" está situado en Covarrubias, en la calle Mayor, número 5.
- Una de las iglesias de Covarrubias está en la calle de Santo Tomás.

Exercise 3. Sample resulting ontology



Sample resulting ontology



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Sample RDF APIs

- RDF libraries for different languages:
  - Java, Python, C, C++, C#, .Net, Javascript, Tcl/Tk, PHP, Lisp, Obj-C, Prolog, Perl, Ruby, Haskell
  - List in
- Usually related to a RDF repository
- Multilanguage:
  - Redland RDF Application Framework (C, Perl, PHP, Python and Ruby): http://www.redland.opensource.ac.uk/
- Java:
  - Jena: http://jena.sourceforge.net/
  - Sesame: http://www.openrdf.org/
- PHP:
  - RAP - RDF API for PHP: http://www4.wiwiss.fu-berlin.de/bizer/rdfapi/
- Python:
  - RDFLib: http://rdflib.net/
  - Pyrple: http://infomesh.net/pyrple/

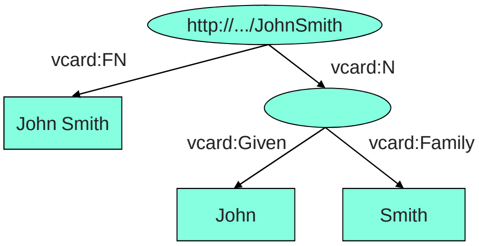
Jena

- Java framework for building Semantic Web applications
- Open source software from HP Labs
- The Jena framework includes:
  - A RDF API
  - An OWL API
  - Reading and writing RDF in RDF/XML, N3 and N-Triples
  - In-memory and persistent storage
  - A rule based inference engine
  - SPARQL query engine

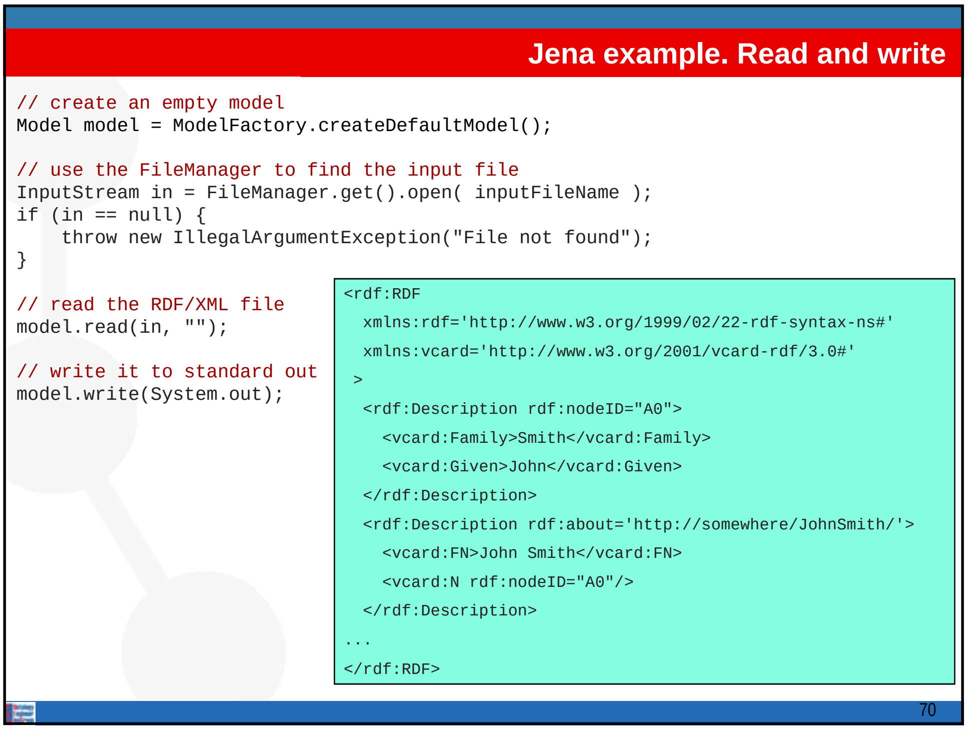
Sesame

- A framework for storage, querying and inferencing of RDF and RDF Schema
- A Java Library for handling RDF
- A Database Server for (remote) access to repositories of RDF data
- Highly expressive query and transformation languages
  - SeRQL, SPARQL
- Various backends
  - Native Store
  - RDBMS (MySQL, Oracle 10, DB2, PostgreSQL)
  - main memory
- Reasoning support
  - RDF Schema reasoner
  - OWL DLP (OWLIM)
  - domain reasoning (custom rule engine)

Jena example. Graph creation



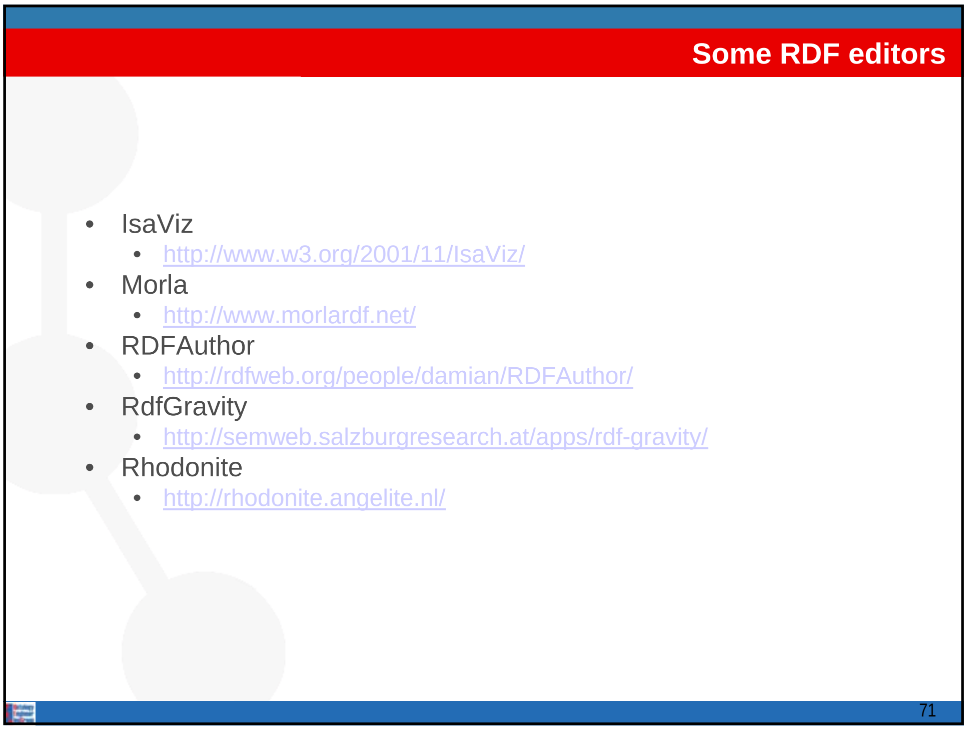
```
// some definitions
String personURI = "http://somewhere/JohnSmith";
String givenName = "John";
String familyName = "Smith";
String fullName = givenName + " " + familyName;
// create an empty
Model Model model = ModelFactory.createDefaultModel();
// create the resource
// and add the properties cascading style
Resource johnSmith = model.createResource(personURI)
    .addProperty(VCARD.FN, fullName)
    .addProperty(VCARD.N, model.createResource()
    .addProperty(VCARD.Given, givenName)
    .addProperty(VCARD.Family, familyName));
```



Jena example. Read and write

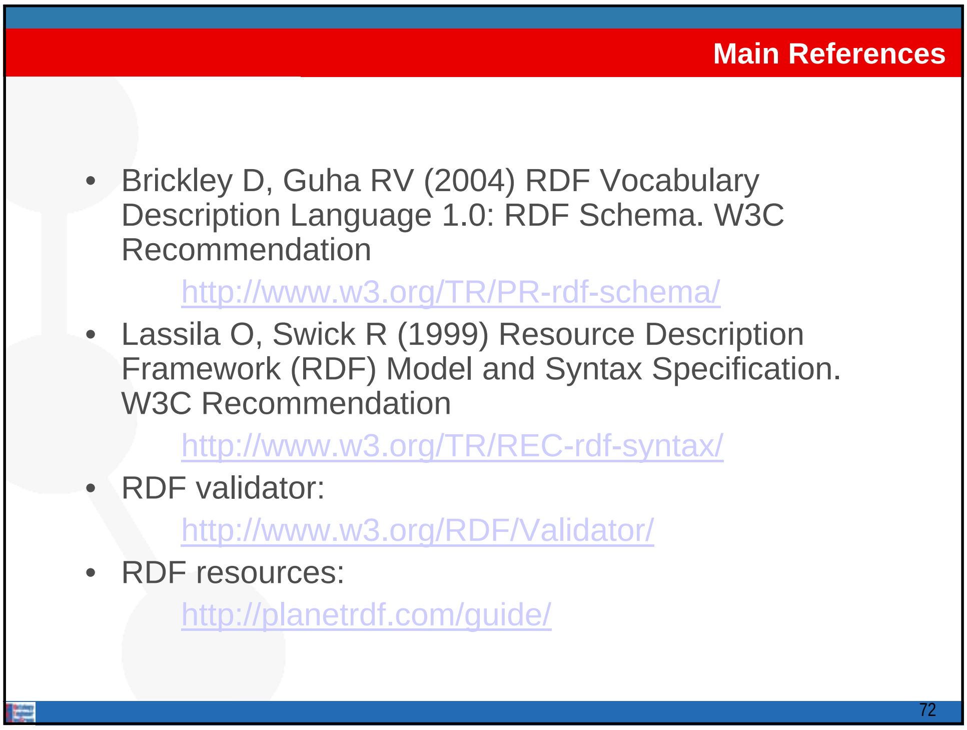
```
// create an empty model
Model model = ModelFactory.createDefaultModel();

// use the FileManager to find the input file
InputStream in = FileManager.get().open( inputFileName );
if (in == null) {
    throw new IllegalArgumentException("File not found");
}

// read the RDF/XML file
model.read(in, "");

// write it to standard out
model.write(System.out);
```

```
<rdf:RDF
  xmlns:rdf='http://www.w3.org/1999/02/22-rdf-syntax-ns#'
  xmlns:vcard='http://www.w3.org/2001/vcard-rdf/3.0#'
 >
  <rdf:Description rdf:nodeID="A0">
    <vcard:Family>Smith</vcard:Family>
    <vcard:Given>John</vcard:Given>
  </rdf:Description>
  <rdf:Description rdf:about='http://somewhere/JohnSmith/'>
    <vcard:FN>John Smith</vcard:FN>
    <vcard:N rdf:nodeID="A0"/>
  </rdf:Description>
...
</rdf:RDF>
```



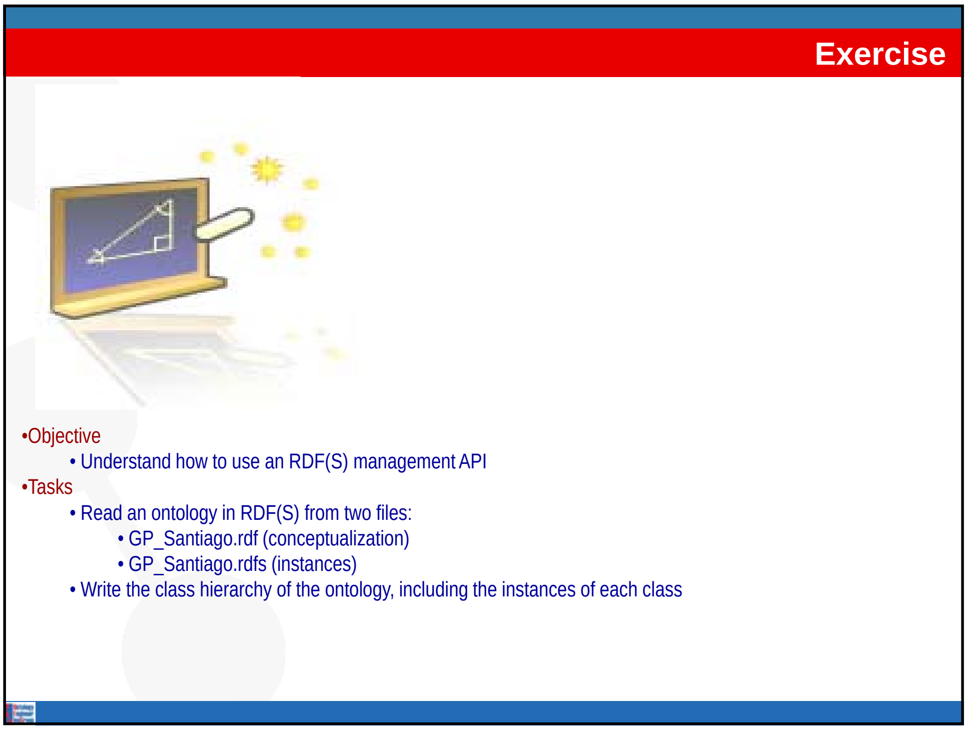
Some RDF editors

- IsaViz
  - http://www.w3.org/2001/11/IsaViz/
- Morla
  - http://www.morlardf.net/
- RDFAuthor
  - http://rdfweb.org/people/damian/RDFAuthor/
- RdfGravity
  - http://semweb.salzburgresearch.at/apps/rdf-gravity/
- Rhodonite
  - http://rhodonite.angelite.nl/



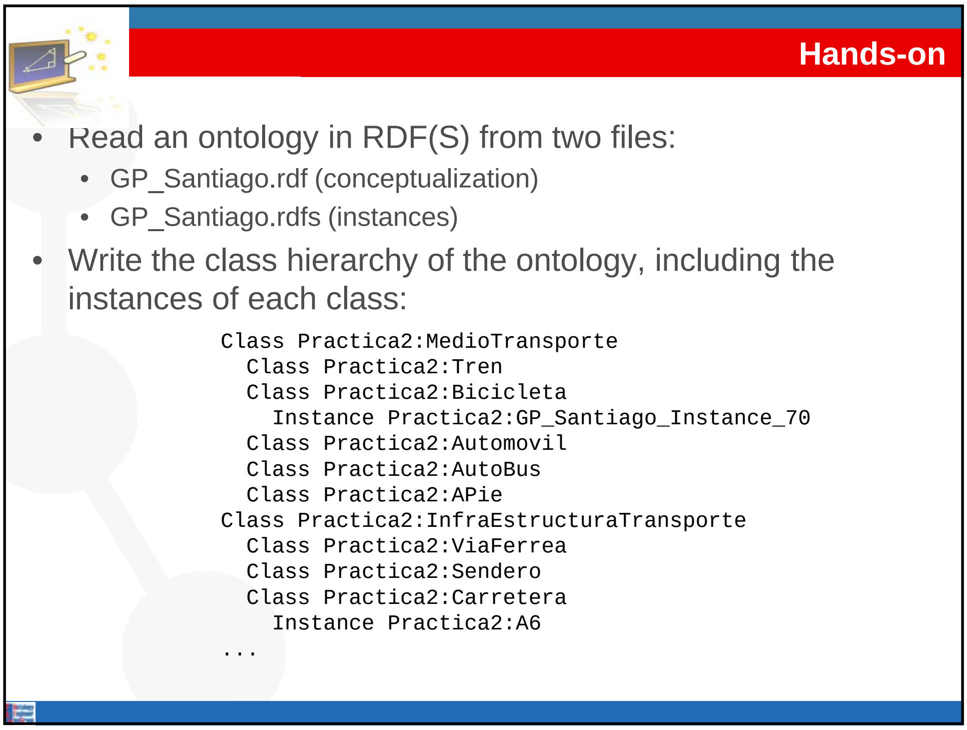
Main References

- Brickley D, Guha RV (2004) RDF Vocabulary Description Language 1.0: RDF Schema. W3C Recommendation
  - http://www.w3.org/TR/PR-rdf-schema/
- Lassila O, Swick R (1999) Resource Description Framework (RDF) Model and Syntax Specification. W3C Recommendation
  - http://www.w3.org/TR/REC-rdf-syntax/
- RDF validator:
  - http://www.w3.org/RDF/Validator/
- RDF resources:
  - http://planetrdf.com/guide/



Exercise

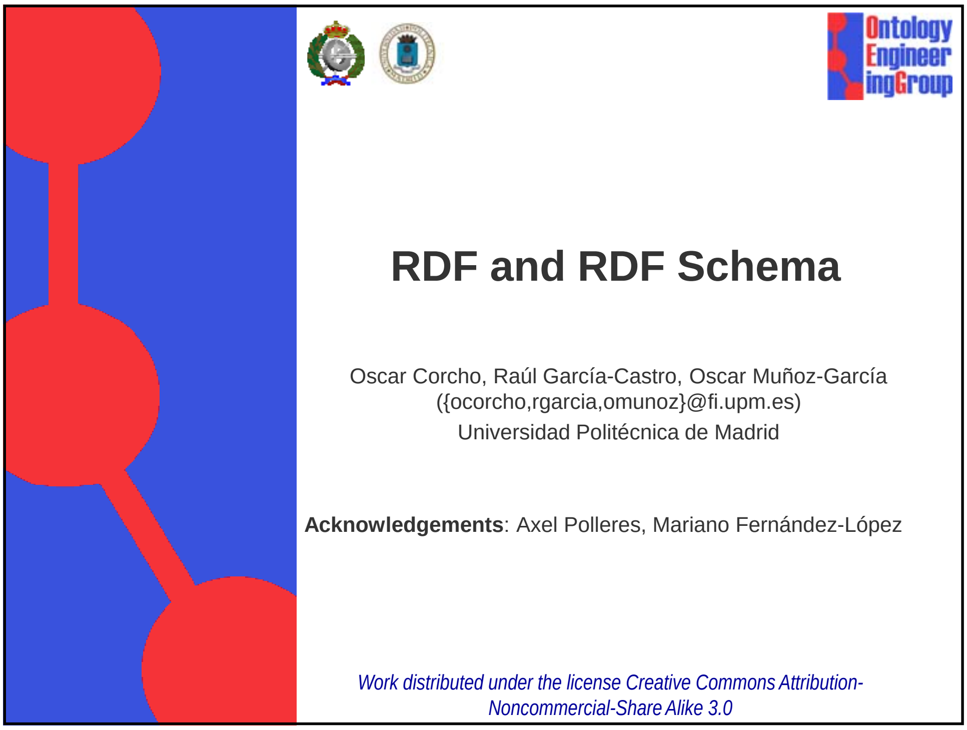
- •Objective
  - • Understand how to use an RDF(S) management API
- •Tasks
  - • Read an ontology in RDF(S) from two files:
    - • GP_Santiago.rdf (conceptualization)
    - • GP_Santiago.rdfs (instances)
  - • Write the class hierarchy of the ontology, including the instances of each class



Hands-on

- Read an ontology in RDF(S) from two files:
  - GP_Santiago.rdf (conceptualization)
  - GP_Santiago.rdfs (instances)
- Write the class hierarchy of the ontology, including the instances of each class:

```
Class Practica2:MedioTransporte
  Class Practica2:Tren
  Class Practica2:Bicicleta
    Instance Practica2:GP_Santiago_Instance_70
  Class Practica2:Automovil
  Class Practica2:AutoBus
  Class Practica2:APie
Class Practica2:InfraEstructuraTransporte
  Class Practica2:ViaFerrea
  Class Practica2:Sendero
  Class Practica2:Carretera
    Instance Practica2:A6
...
```



RDF and RDF Schema

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