RDF
Resource Description Framework

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- The RDF graph model
- RDF in XML and N3
- Blank nodes
- Representing collections
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A Graph Model for KR

RDF graphs express knowledge about resources

> a resource is anything that can be identified (a web page, a person, a country, an abstraction, ...)

The basic unit of knowledge is the triple

(subject, predicate, object)

It represents the fact that a relation (predicate) holds between the subject and the object.

Examples

Vaud is a neighbour of Geneva

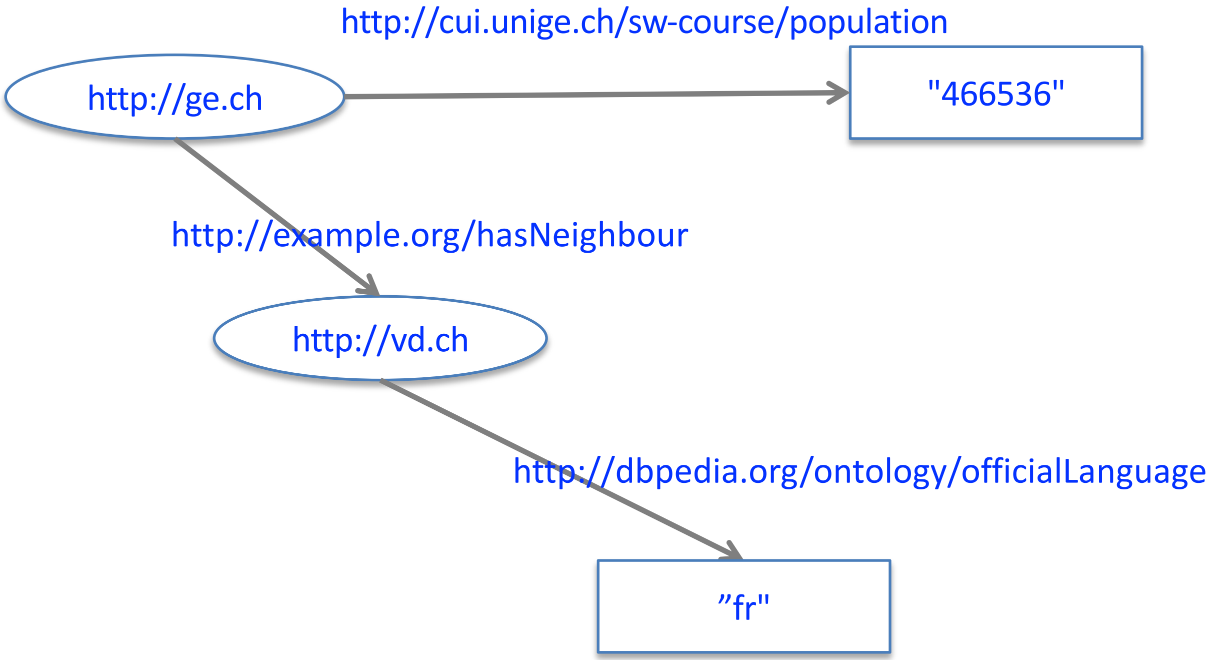
(http://ge.ch http://example.org/hasNeighbour http://vd.ch)

The official language of Vaud is French

(http://vd.ch http://dbpedia.org/ontology/officialLanguage “fr”)

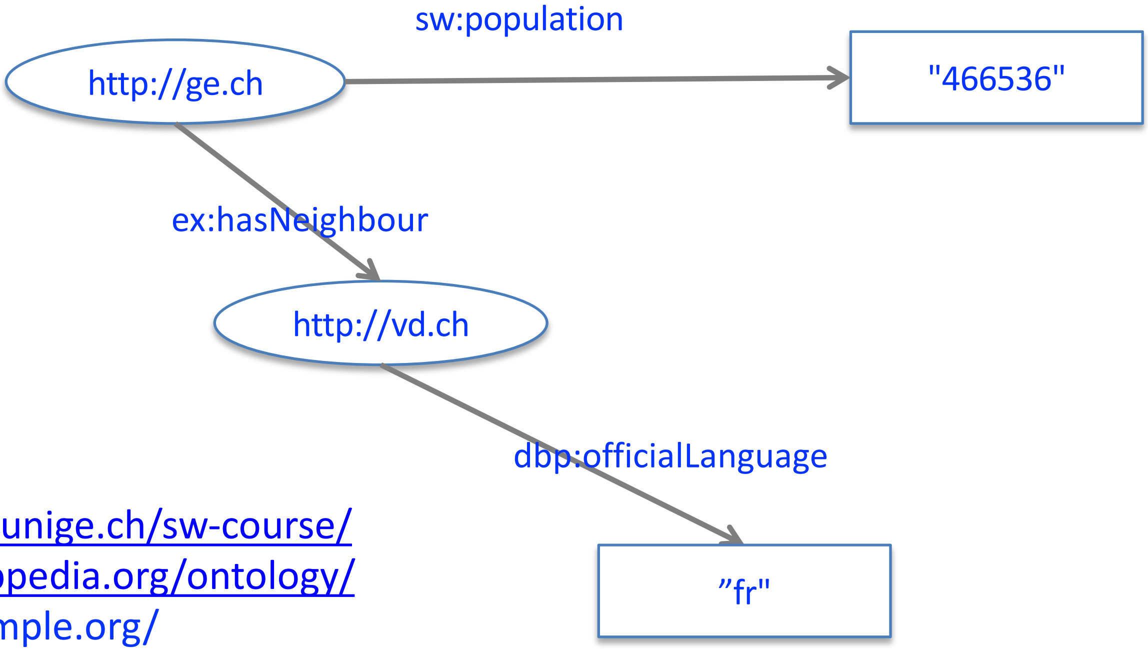
The object may be a literal value

The triples form the edges of a knowledge graph


http://cui.unige.ch/sw-course/population
http://ge.ch
"466536"
http://example.org/hasNeighbour
http://vd.ch
http://dbpedia.org/ontology/officialLanguage
”fr"

Use of prefixes

To simplify the expression of the graphs



sw: http://cui.unige.ch/sw-course/
dbp: http://dbpedia.org/ontology/
ex: http://example.org/

Literals

A lexical form that identifies a value in a value space

strings

"value"

string in a specific language

"value"@language

typed value

"value"^^type

Examples

XML Standard Types

prefix xsd: http://www.w3.org/2001/XMLSchema#

"Scrabble"
"vi povas legi ĉi tiun tekston"@eo
"567"^^xsd:number
"true"^^xsd:boolean
"2002-10-10T12:00:00+02:00"^^xsd:dateTime

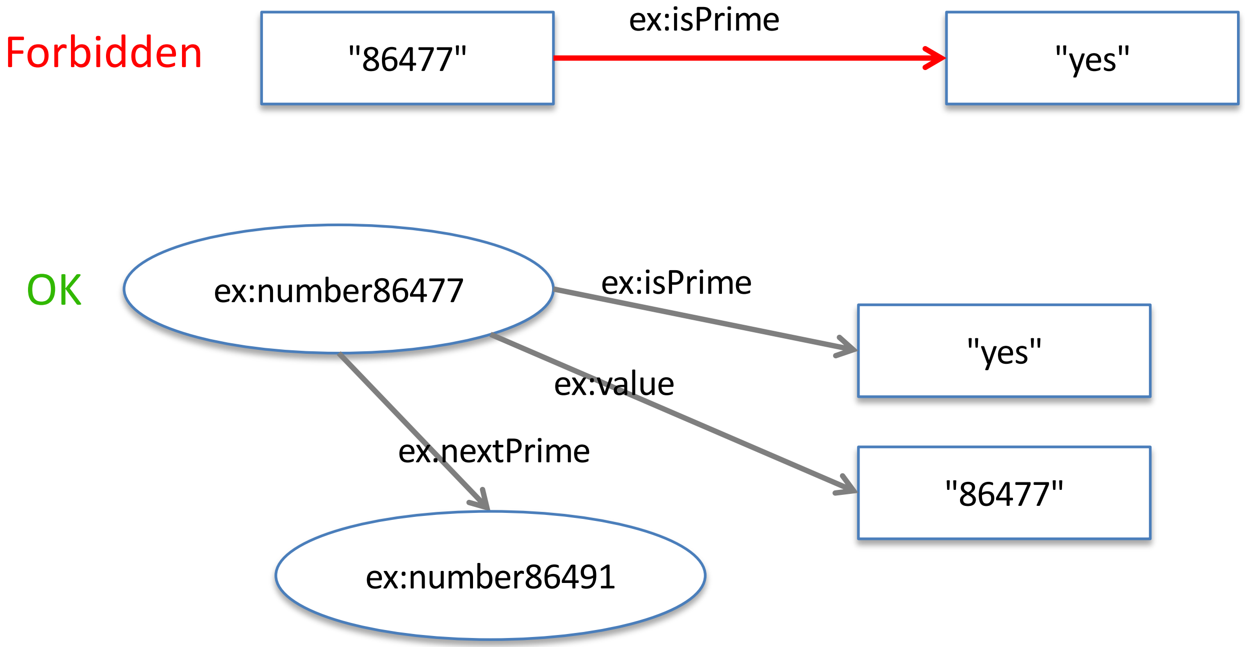
XML builtin datatypes are of common use, but not mandatory

prefix my: http://cui.unige.ch/TypeSystem#

"4.5+3i+2j-5k"^^my:quaternion

Restriction on literal nodes

Remark. A literal may not be the subject of a triple (values cannot be described, they are supposed to be known)



Exercises

1. Draw an RDF graph that represents the following situation

- Bob has a cat. The name of this cat is Felix and he is 6 years old. Felix has two friends: Tiger and Einstein.

2. Add the facts

- Bob is married with Alice since 2008-08-01
- Bob has two other cats

Practical syntax for RDF

How to represent a RDF graph with characters (in a text file)

RDF data can be expressed with different notations

- XML (for machine interchange)
- N3 and Turtle (human readable)
- JSON-LD

XML Syntax

Principle: there are alternating node and property elements

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:sw="http://cui.unige.ch/sw-course/">
<rdf:Description rdf:about="http://cui.unige.ch/sw-course/Geneva">
   <sw:population>466536</sw:population>
   <sw:neighbour>
      <rdf:Description
         rdf:about="http://cui.unige.ch/sw-course/Vaud">
      </rdf:Description>
   </sw:neighbour>
</rdf:Description>
 ...
</rdf:RDF>
```

N3 notation

An N3 file has

1. prefix definitions
2. triples

```
@prefix sw: <http://cui.unige.ch/sw-course/> .
@prefix xsd: <http://www.w3c.org/2001/XMLSchema#> .
sw:Geneva sw:population "466536"^^xsd:integer .
sw:Geneva sw:neighbour sw:Vaud .
sw:Vaud sw:official-language <http://id.loc.gov/vocabulary/iso639-2/fra> .
```

Turtle: Abbreviations

subject pred$_1$ obj$_1$; pred$_2$ obj$_2$; … ; pred$_n$ obj$_n$.

for

subject pred$_1$ obj$_1$. subject pred$_2$ obj$_2$. … . subject pred$_n$ obj$_n$.

```
sw:Geneva
   sw:population "466536"^^xsd:integer ;
   sw:neighbour sw:Vaud .
```

Turtle: Abbreviations

subject predicate obj$_1$, obj$_2$, … , obj$_n$.

for

subject predicate obj$_1$. subject predicate obj$_2$. … . subject predicate obj$_n$.

```
sw:Vaud sw:neighbour
  sw:Geneva , sw:Fribourg , sw:Valais ,
  sw:Neuchatel , sw:Bern .
```

JSON-LD

```
{
“graph”: [
  { "@id" : "http://ge.ch",
    "http://cui.unige.ch/ex#neighbour" : {"@id" : "http://vd.ch"},
    "http://cui.unige.ch/ex#population" : "466536"
  },
  { "@id" : "http://vd.ch",
    "http://cui.unige.ch/ex#official-language" : ”fr"
  }]
}
```

JSON-LD – with typed values

```
{
“graph”: [
{ "@id" : "http://ge.ch",
  "http://cui.unige.ch/ex#neighbour" : {"@id" : "http://vd.ch"},
  "http://cui.unige.ch/ex#population" : {
           "@type" : "http://www.w3.org/2001/XMLSchema#integer",
           "@value" : "466536"
            }
},
{ "@id" : "http://vd.",
  "http://cui.unige.ch/ex#official-language" : "fr"}
}]
}
```

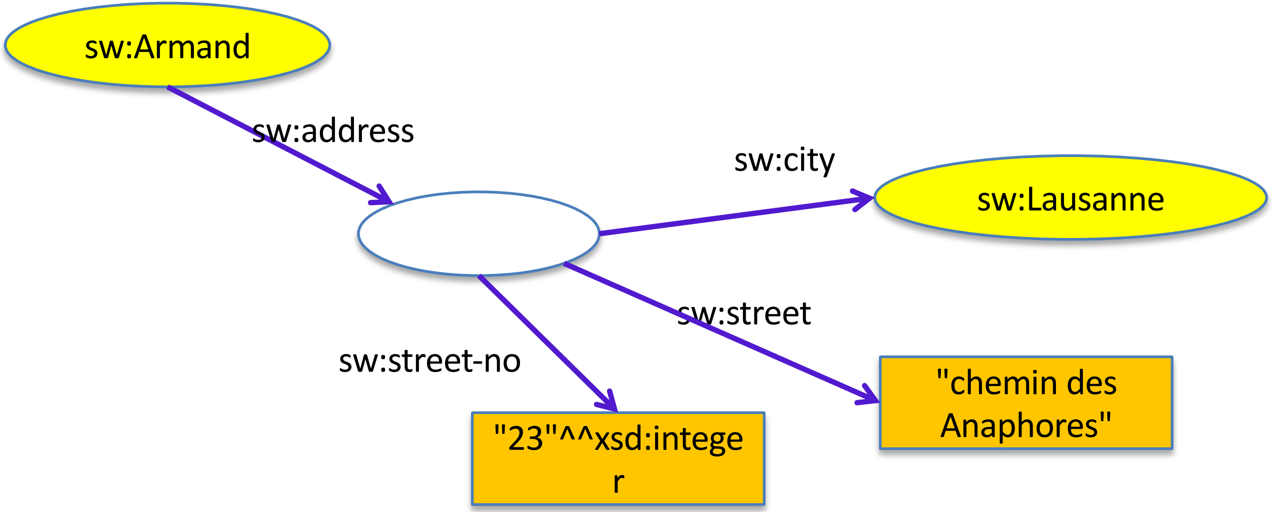
JSON-LD – with context

```
{
"@context": {"@vocab" : "http://cui.unige.ch/ex#"},
“graph”: [
{ "@id" : ”http://ge.ch",
  "neighbour" : {"@id" : ”http://vd.ch"},
  "population" : {
          "@type" : "http://www.w3.org/2001/XMLSchema#integer",
          "@value" : "466536"
           }
},
{ "@id" : ”http://vd.ch",
  "official-language" : {"@id" : "fra"}
}]
}
```

Blank nodes

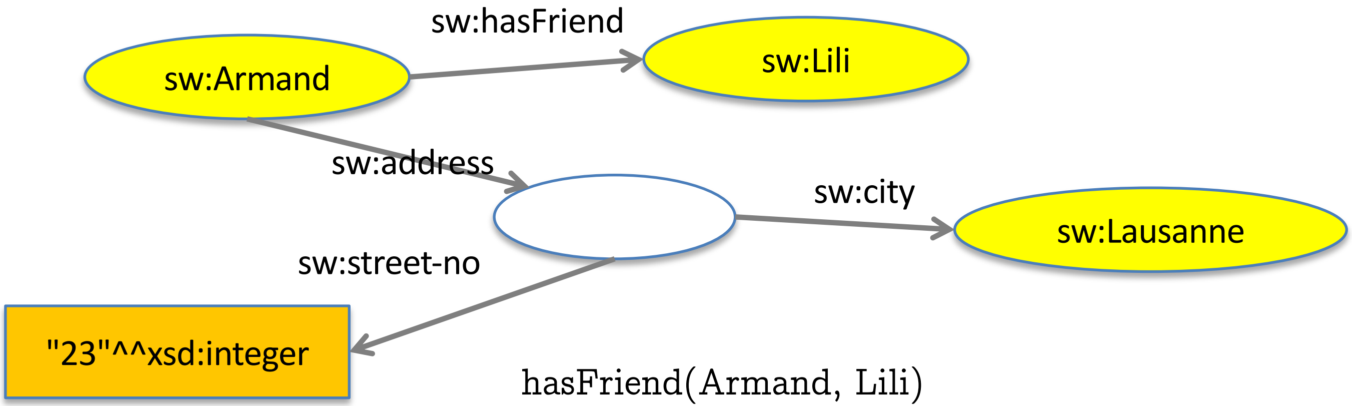
- Nodes that are anonymous, not identified by a URI
- Only locally identified

"The address of Armand is 23 chemin des Anaphores, Lausanne"



Blank nodes – logical interpretation

blank nodes are existentially quantified variables



hasFriend(Armand, Lili)

∧

∃x(address(Armand, x) ∧ city(x, Lausanne) ∧ street-no(x, 23)

!! Not the standard semantics of RDF !!

In Turtle, with the _: prefix

```
@prefix sw: <http://cui.unige.ch/sw-course/> .
@prefix xsd: <http://www.w3c.org/2001/XMLSchema#> .

sw:Armand sw:address _:aa .
_:aa sw:street "chemin des Anaphores" .
_:aa sw:street-no "23"^^xsd:integer .
_:aa sw:city sw:Lausanne .
```

_:aa acts like an internal variable, within the RDF file/graph. It is invisible from the outside (no URI).

Possible abbreviation: [blank node description]

```
sw:Armand sw:address
  [sw:street "chemin des Anaphores" ;
   sw:street-no "23"^^xsd:integer ;
   sw:city sw:Lausanne] .
```

In JSON-LD

```
{"@context" : {
  "sw" : "http://cui.unige.ch/sw-course/",
  "xsd" : "http://www.w3.org/2001/XMLSchema#"
},
"@id": "http://example.org/graphs/73",
"@graph": [
  {"@id" : "sw:Armand",
   "sw:address" : {"@id": "_:aa"}},

  {"@id": "_:aa" ,
    "sw:street" : "chemin des Anaphores",
    "sw:street-no" : {"@type": "xsd:integer", "@value" : "33"},
    "sw:city" : "sw:Lausanne"
  }]
}
```

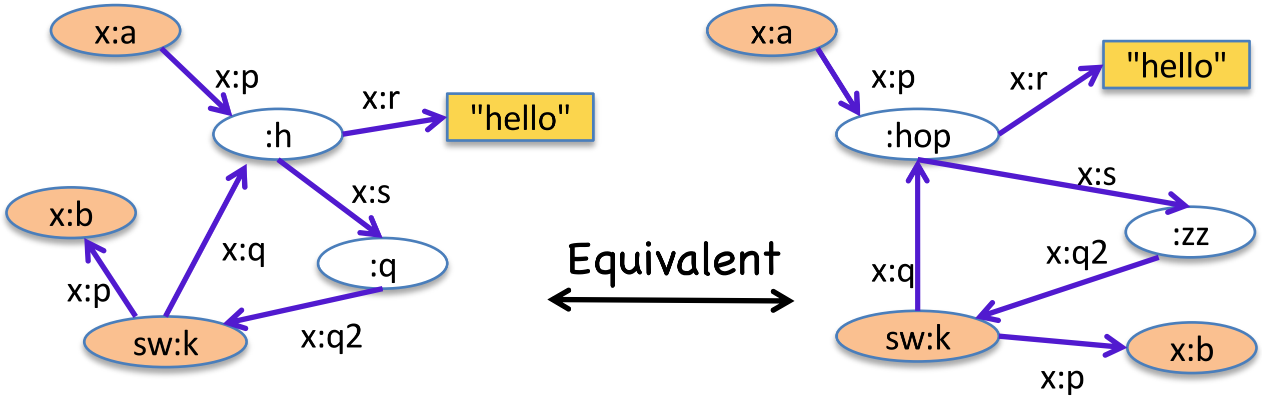
In JSON-LD

```
{
"@context" : {
 "sw" : "http://cui.unige.ch/sw-course/",
 "xsd" : "http://www.w3.org/2001/XMLSchema#”
}

{"@id" : "sw:Armand",
 "sw:address" : {
           "sw:street” : "chemin des Anaphores",
          "sw:street-no” : {"@type" : ”xsd:integer", "@value" : "466536"}
           "sw:city" : "sw:Lausanne"
  }
}}
```

Graph equivalence

- The internal identifiers of blank node are interchangeable
- Two RDF graphs have the same meaning if their only differences are the blank node identifiers.



Graph equivalence

The official definition

Two RDF graphs *G* and *G'* are equivalent if there is a bijection *M* between the sets of nodes of the two graphs, such that:

- *M* maps blank nodes to blank nodes.
- *M*(*lit*)=*lit* for all RDF literals *lit* which are nodes of *G*.
- *M*(*uri*)=*uri* for all RDF URI references *uri* which are nodes of *G*.
- The triple (*s*, *p*, *o*) is in *G* iff (*M*(*s*), *p*, *M*(*o*)) is in *G'*

In fact, *M* shows how each blank node in *G* can be replaced with a new blank node to obtain *G'*.

RDF standard vocabulary

A standard vocabulary for defining

- resource typing
- data structures (containers and collections)
- RDF graph schemas
  - resource classification (schemas)
  - constraints on properties

This vocabulary has URIs of the form

http://www.w3.org/1999/02/22-rdf-syntax-ns#*name*

the usual prefix definition is

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

rdf:type

Assign a type to a resource

- Felix *is a* cat and Joe *is a* mouse

```
ex:Felix rdf:type ex:Cat
ex:Joe rdf:type ex:Mouse
```

- My car is red (a set-theoretical view)

```
ex:myCar rdf:type ex:RedThings
```

`ex:myCar ex:color "red"` (generally a better choice)

Containers

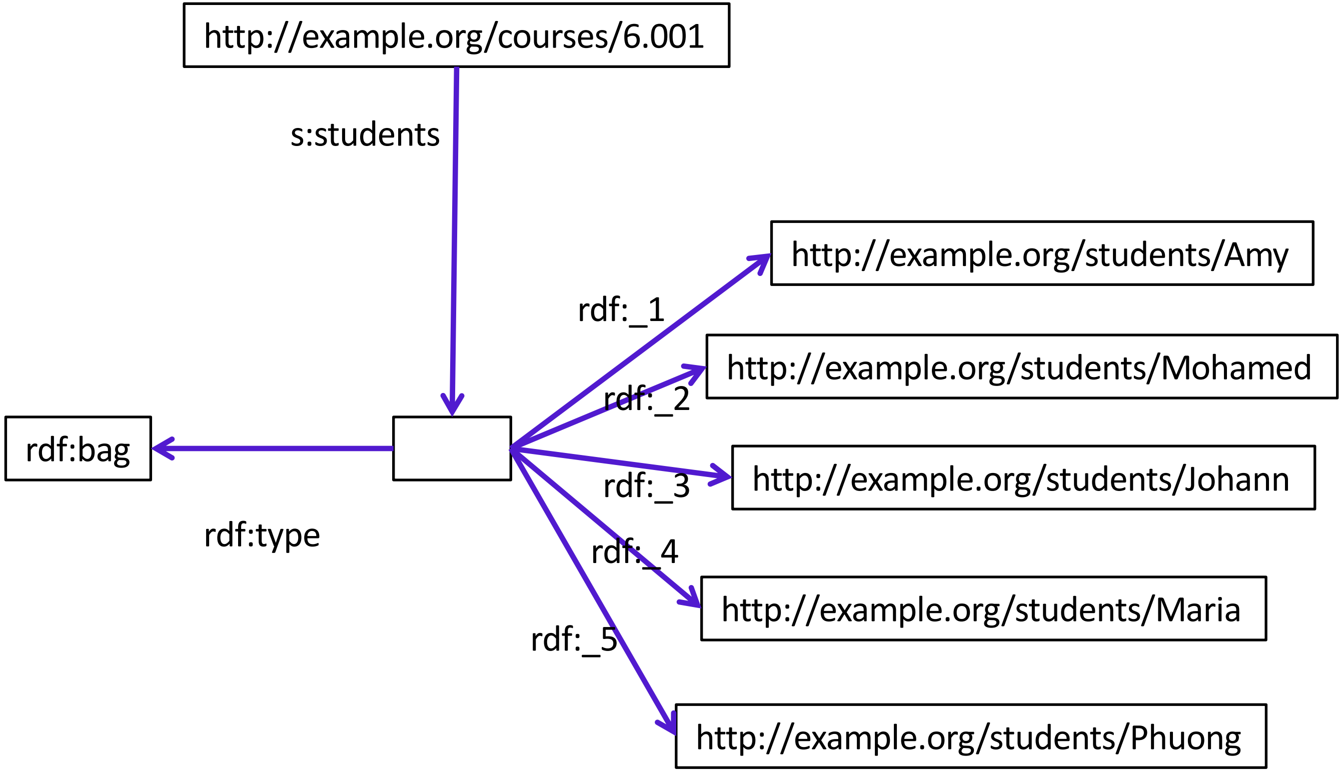
To consider a group of resources as a whole

- assign global properties to the group

Three types of containers

- rdf:Bag (a set with repetitions)
- rdf:Seq (an ordered set)
- rdf:Alt (represents choices)

Properties rdf:_1, rdf:_2, rdf:_3, ... to link a container with its first, second, third, ... member.


http://example.org/courses/6.001
s:students
rdf:_1
http://example.org/students/Amy
http://example.org/students/Mohamed
rdf:_2
rdf:bag
http://example.org/students/Johann
rdf:_3
rdf:type
rdf:_4
http://example.org/students/Maria
rdf:_5
http://example.org/students/Phuong

Remarks

- Bag, Seq, Alt are indications about the intended meaning
- There is not specific way to "close" a container, i.e. to say that is doesn't have any other member.
  - the Bag of students in the previous example may have more than 5 members, in reality

Collections

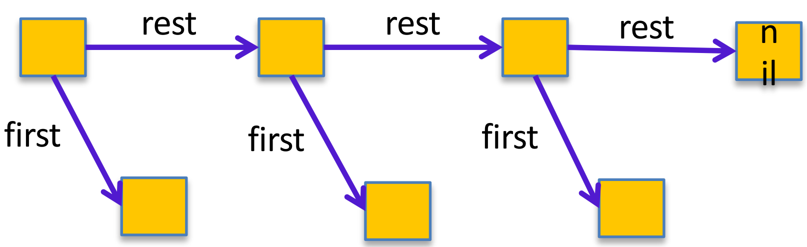
Closed collections: all the members are known

Use the first/rest representation technique:

A collection is made of

- a first element (any resource)
- a rest, which is a collection

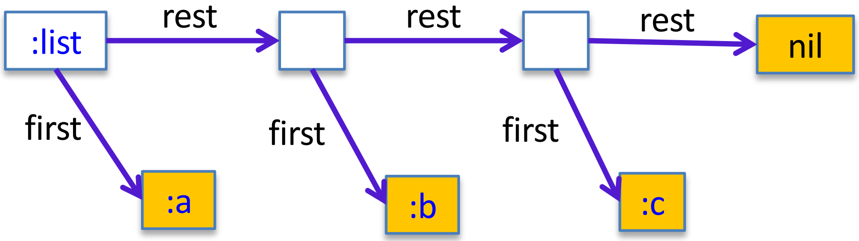
rdf:nil is the empty collection



In Turtle

```
:list rdf:first :a ;
      rdf:rest [rdf:first :b ;
                rdf:rest [rdf:first :c ;
                          rdf:rest rdf:nil]]
```

```
Abbreviated
(:a :b :c)
```



```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix s: <http://example.org/vocab#> .
@prefix c: <http://example.org/courses/> .
@prefix std: <http://example.org/students/>.

c:6.001  s:students  ( std:Amy, std:Mohamed, std:Johann ) .

{
```

Exercise

Represent the following facts

- p1 and p2 are political parties
- c1, c2, c3, c4 were candidates for p1
- d1, d2, d3 were candidates for p2
- c3, c1 have been elected (in this order) for p1
- no one from p2 has been elected
- elected candidates have become members of the parliament (MP)

Reification

How to represent statements about statements?

« Ralph Swick says that Ora Lassila is the creator of the resource http://www.w3.org/Home/Lassila . »

« Albert says that document 345 confirms that Ralph Swick says that Ora Lassila is the creator of the resource http://www.w3.org/Home/Lassila ».

Reification

« Ralph Swick says that Ora Lassila is the creator of the resource
http://www.w3.org/Home/Lassila . »

Something like

Ralph Swick says *X*

X = (http://www.w3.org/Home/Lassila ex:creator "Ora Lassila")

Goal: Reify a statement = consider a triple (statement) as an object

Remark. *res* = *thing* in Latin

Reification

Ralph Swick says that Ora Lassila is the creator of the resource http://www.w3.org/Home/Lassila . »

The rdf standard vocabulary contains a reification vocabulary.

X a:attributedTo "Ralph Swick".

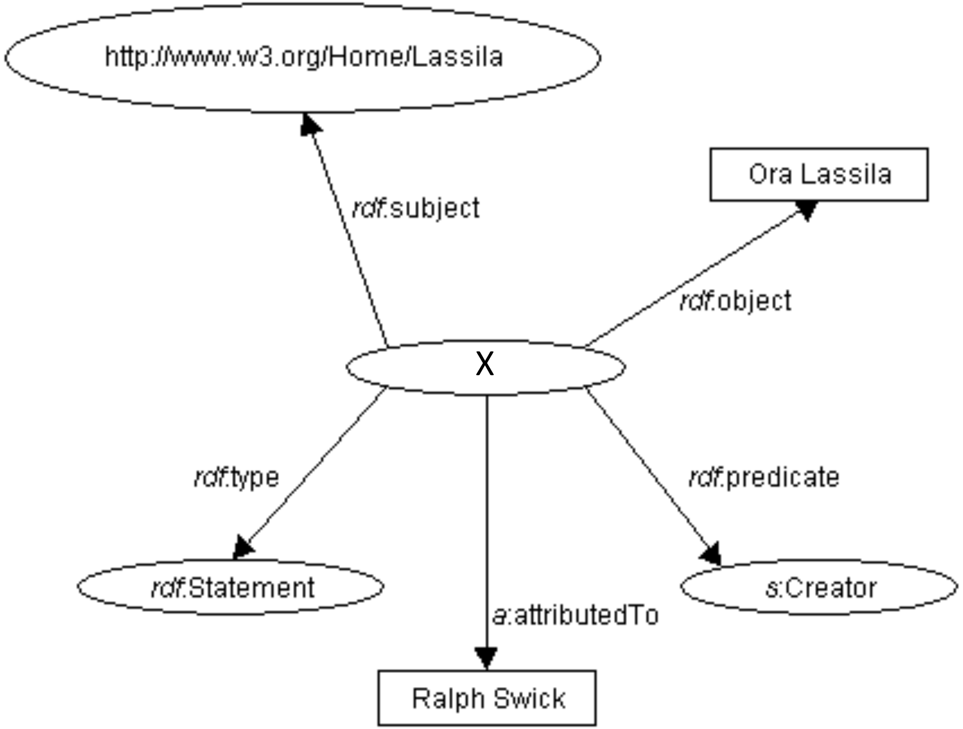
X rdf:type rdf:Statement .

X rdf:predicate s:creator .

X rdf:subject http://www.w3.org/Home/Lassila .

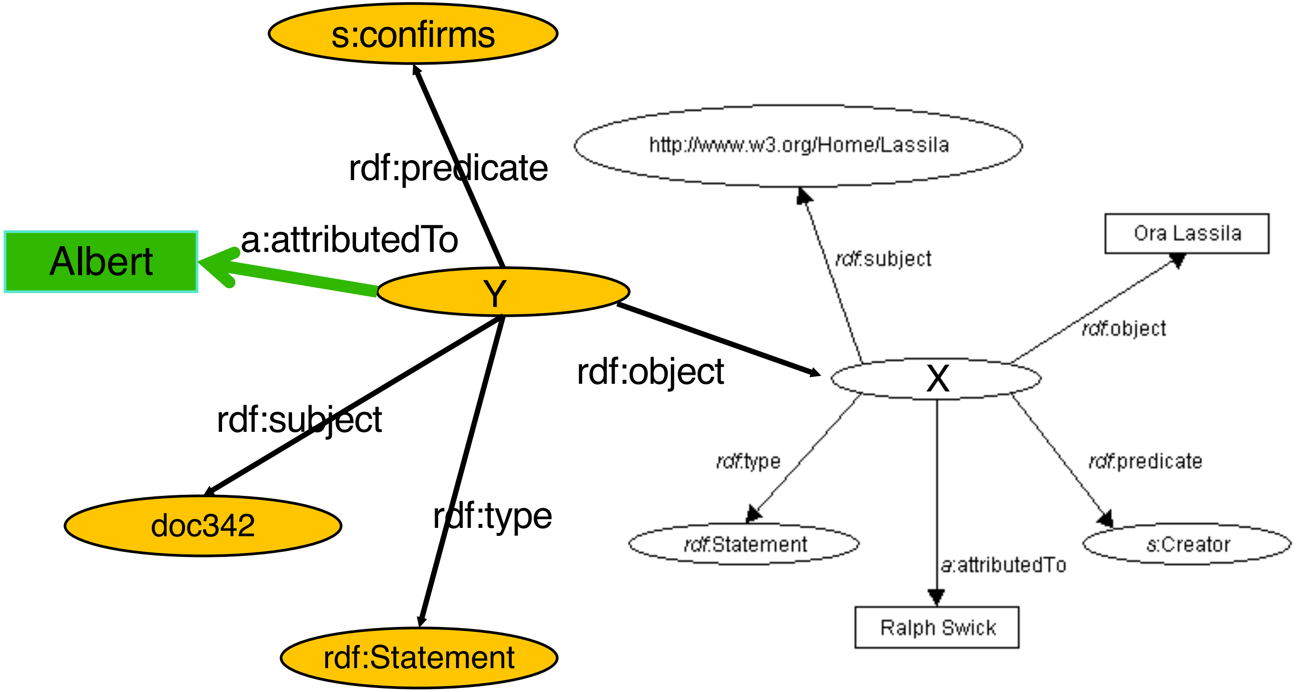
X rdf:object "Ora Lassila" .

Reified statement



A statement about a statement about a statement

Albert says that doc342 confirms that Ralph Swick says that
Ora Lassila is the creator of the resource.

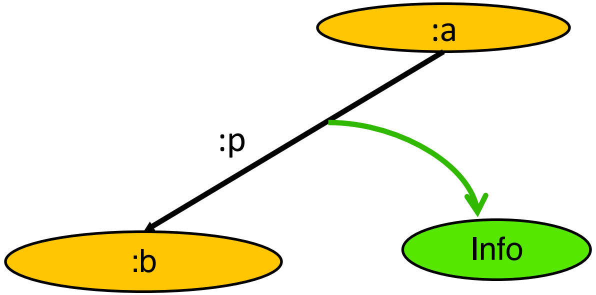


Alternatives to reification

Objective: add information to a triple (metadata)

Use cases:

- define the validity time of a triple
  - “The population of Geneva is 453779 **in 2010**”
- define the validity space (location)
- add provenance information
  - “IBM was founded in 1911 **according to Wikipedia**”
- add confidence or certainty information



Exercise. Find a least two design patterns to add information to triples

Summary

- RDF is a graph data model
  - nodes are either resources (URI), literals, or blank nodes

- There are different syntaxes: XML, N3, ...

- The RDF standard vocabulary helps modeling (among others)
  - the *is_a* (type) relationship
  - collections
  - statements (reification)

Exercises

Find algorithms to

1. transform a spreadsheet (made of cells organized in rows and columns and containing numbers or strings or formulae) into an RDF graph.
2. transform a relational database (made of tables, rows, columns, keys, foreign key) into an RDF graph
3. transform an XML document into an RDF graph

The transformations must be lossless, i.e. it must be possible to go back to the original data.