Aalto University
School of Science

SeCo

RDF and RDF Schema

ME-E4300 Semantic Web, 16.1.2019

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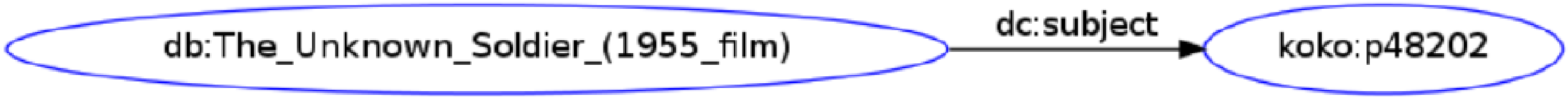
Outline

- RDF data model
- RDF syntax
- RDF Schema (RDFS)
- RDF(S) semantics

RDF data model

Key idea: triple

”subject” ”predicate” ”object”



Namespaces:
koko: http://www.yso.fi/onto/koko/
db: http://dbpedia.org/resource/
dc: http://purl.org/dc/elements/1.1/

RDF data model and relational databases

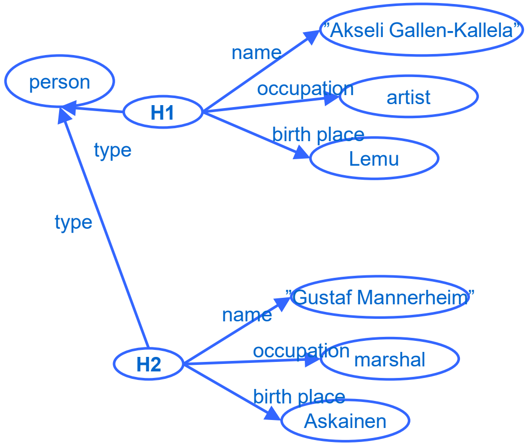
- Information is often available as tables in relational databases or CSV files

- RDF is a set of triples
  - n-ary information can be represented as triples

- RDF is a data model: directed named graph

person	name	occupation	birth place	…
H1	Akseli Gallen-Kallela	artist	Lemu	
H2	Gustaf Mannerheim	marshal	Askainen	
…				

subject	predicate	object
H1	type	person
H1	name	Akseli Gallen-Kallela
H1	occupation	artist
H1	birth place	Lemu
H2	type	person
H2	name	Gustaf Mannerheim
H2	occupation	marshal
H2	birth place	Askainen



RDF data model: fundamental concepts

- Literals
- Resources (and their identifiers)
- Statements (triples)
- Graphs
- Datasets and quads

Literals

data values

Literals

Literal is data encoded as a string

- ”Suomi”, ”Last waltz in Paris”

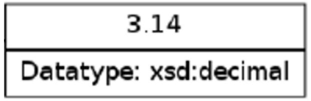
Literal value can be accompanied with a XML language tag:

- ”Suomi”@fi, ”Last waltz in Paris”@en

Literal value can be accompanied with a datatype (XML Schema)

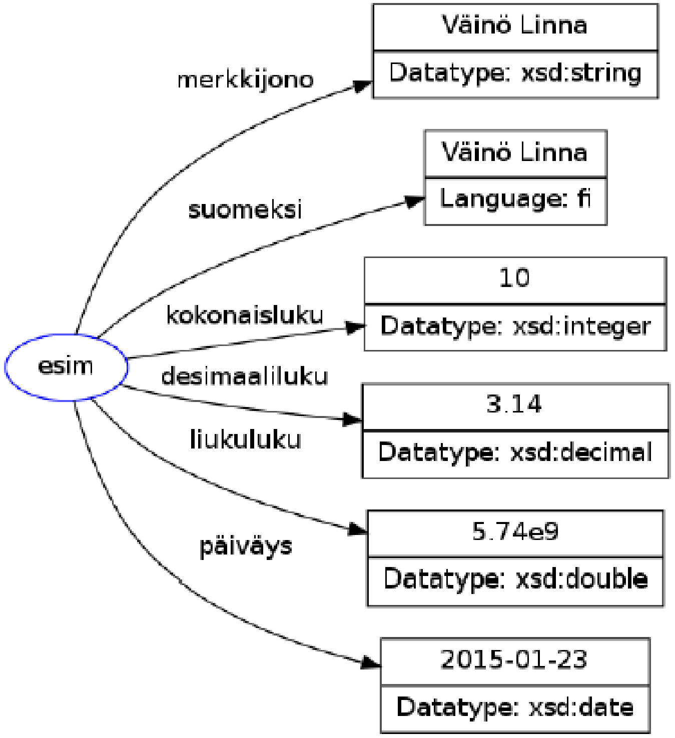
- "-5"^^xsd:integer, "4.2E9"^^xsd:double
- Abbreviated: -5, 4.2E9
- Default datatype: ”Suomi”^^xsd:string

Visualized typically as a rectangle in an RDF graph



Example

```
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix : <http://koe.fi> .

:esim
   :merkkijono "Väinö Linna"^^xsd:string ;
   :suomeksi "Väinö Linna"@fi ;
   :kokonaisluku "10"^^xsd:integer ;
   :desimaaliluku "3.14"^^xsd:decimal ;
   :liukuluku "5.74e9"^^xsd:double ;
   :päiväys "2015-01-23"^^xsd:date .
```



Namespaces:
xsd: http://www.w3.org/2001/XMLSchema#
http://koe.fi

Resources and identifiers

for identifying resources globally

Global identifiers for resources

URL: Uniform Resource Locator

- Specialization of URI that also describes its primary access mechanism (e.g., its network location in HTTP)

URI: Uniform Resource Identifier

- Identifier that conforms syntactically to some **URI scheme**
  - *E.g., ftp, http, https, mailto, urn, oid, xmpp, …*
- (Note change in nomenclature: Universal -> Uniform)

URN: Uniform Resource Name

- Specialization of URI that only specifies its name

IRI: Internationalized Resource Identifier

- Generalization of URI based on Unicode character set
- URL encoding not needed

Examples

URL: Uniform Resource Locator

- http://www.aalto.fi/fi/research/
- http://www.ask.com/web?qsrc=1&o=0&l=dir&q=Capital+of+Finland&qo=serpSearchTopBox
- http://urn.fi/urn:isbn:978-952-10-4171-6

URI: Uniform Resource Identifier

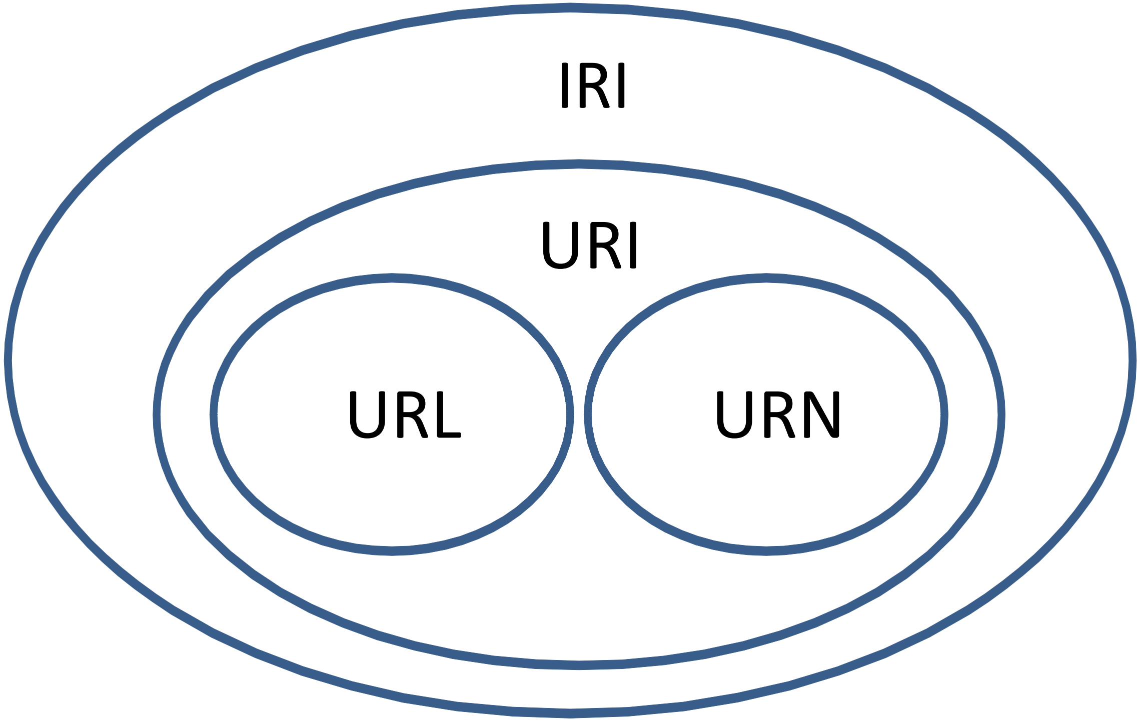
- http://dbpedia.org/resource/Helsinki

URN: Uniform Resource Name

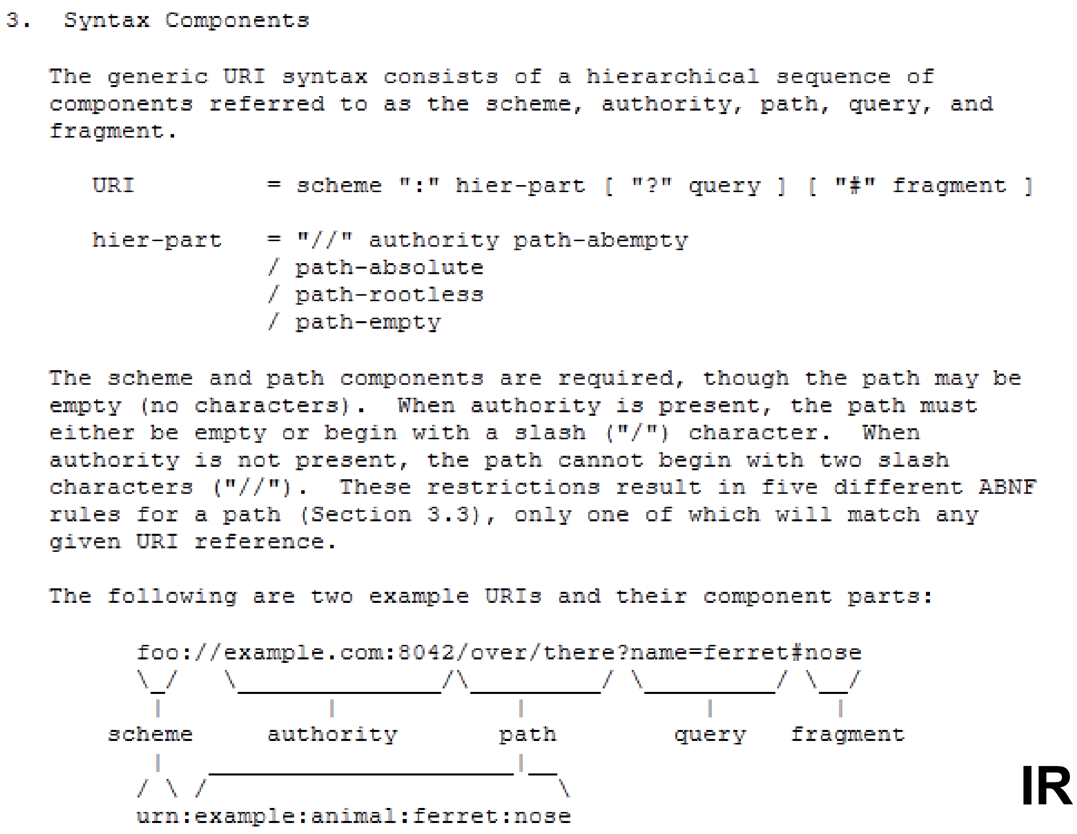
- urn:isbn:978-952-10-4171-6

IRI: Internationalized Resource Identifier

- http://fi.wikipedia.org/wiki/Väinö_Linna


IRI
URI
URL
URN

IRI/URI syntax



3. Syntax Components

The generic URI syntax consists of a hierarchical sequence of components referred to as the scheme, authority, path, query, and fragment.

```
   URI         = scheme ":" hier-part [ "?" query ] [ "#" fragment ]

   hier-part   = "//" authority path-abempty
               / path-absolute
               / path-rootless
               / path-empty
```

The scheme and path components are required, though the path may be empty (no characters). When authority is present, the path must either be empty or begin with a slash ("/") character. When authority is not present, the path cannot begin with two slash characters ("//"). These restrictions result in five different ABNF rules for a path (Section 3.3), only one of which will match any given URI reference.

The following are two example URIs and their component parts:

```
      foo://example.com:8042/over/there?name=ferret#nose
      \_/   \______________/\_________/ \_________/ \__/
       |           |            |            |        |
    scheme     authority       path        query   fragment
       |   _____________________|__
      / \ /                        \
      urn:example:animal:ferret:nose
```

IRI: IETF RFC 3987

URI schemes

- Particular syntactic types of URIs with an agreed interpretation
- Standardized by IANA Internet Assigned Numbers Authority
  - *Tens of URI schemes are available:*
    - ftp, http, mailto, urn, oid, xmpp, …
- Semantic Web advocates the use of HTTP URI/IRIs (URLs)
  - *HTTP URIs not only identify things but are addresses, too*
  - *Type URI in a browser and you get useful info back!*

Blank nodes

locally identified nodes

Nodes can also be ”blank nodes”

RDF graphs may have unique blank nodes (bnodes, anonymous nodes)

- Node ID used only locally in an RDF graph
- Can be represented in RDF syntax, e.g. (Turtle), as: _:*name or []*
  - *_:a _:cat [] […]*
- No need for an IRI for external reference

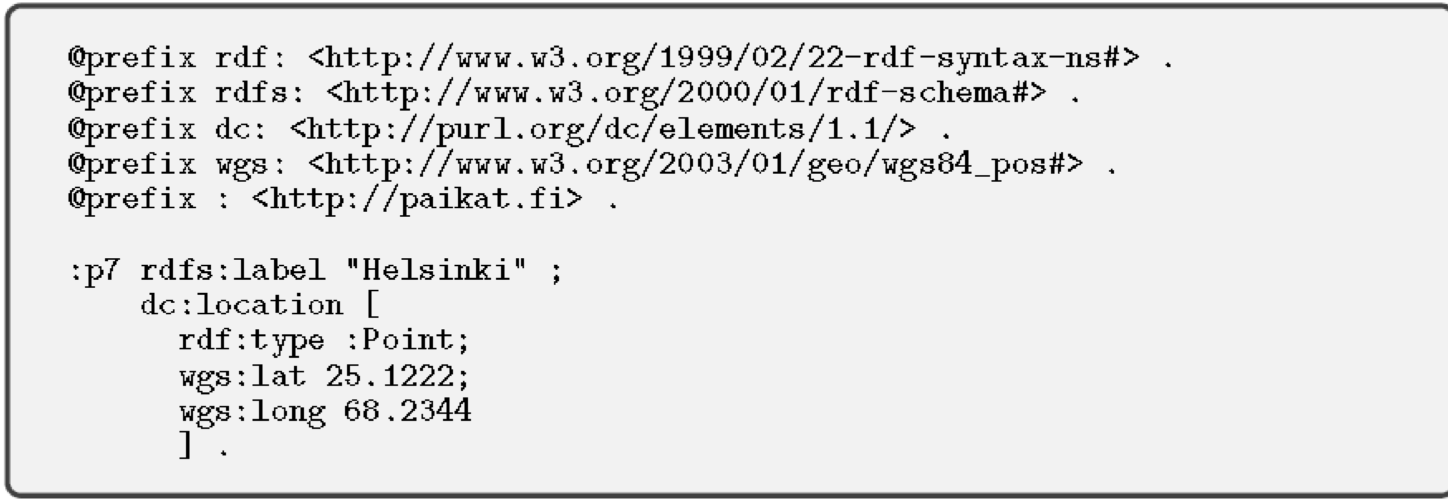
Blank nodes arise from embedded descriptions

- Systems can generate new distinct IRIs automatically (Skolemization)

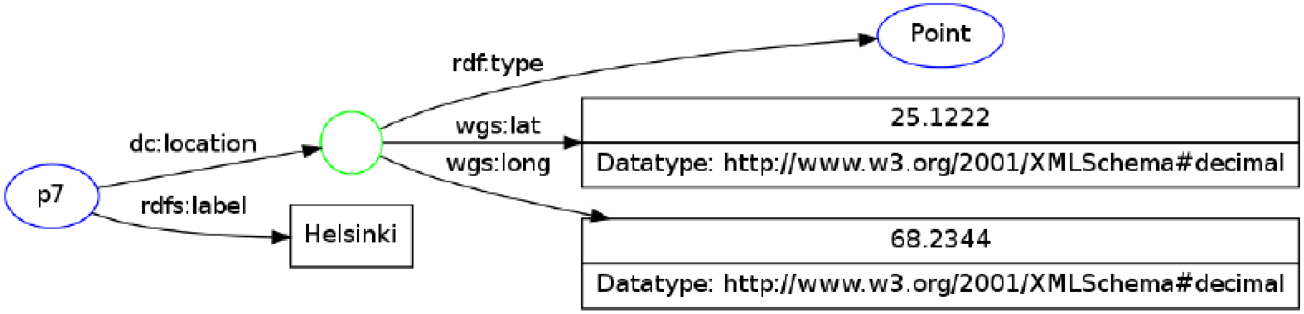
Considered an annoying feature but needed, too

- Must be disambiguated when combining graphs
- Names may change when writing/reading graphs

Example



```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix wgs: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
@prefix : <http://paikat.fi> .

:p7 rdfs:label "Helsinki" ;
    dc:location [
      rdf:type :Point;
      wgs:lat 25.1222;
      wgs:long 68.2344
      ] .
```

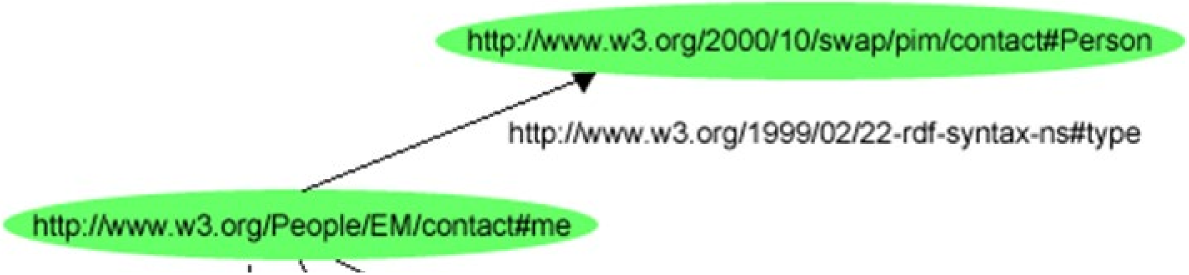


Point
rdf:type
25.1222
wgs:lat
Datatype: http://www.w3.org/2001/XMLSchema#decimal
dc:location
wgs:long
p7
rdfs:label
Helsinki
68.2344
Datatype: http://www.w3.org/2001/XMLSchema#decimal

Namespaces:
rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs: http://www.w3.org/2000/01/rdf-schema#
dc: http://purl.org/dc/elements/1.1/
wgs: http://www.w3.org/2003/01/geo/wgs84_pos#
http://paikat.fi

Resource identifiers: summary

- Used for giving an identity to a resource, so that the resource can be described and referred to
- In RDF graphs, URI/IRIs are nodes (visualized typically as ovals) and arcs
  - *URI/IRI node can be a start or end node of an arc*
  - *The start node of an arc is either an IRI or blank node*
  - *The end node can be an IRI, blank node, or literal data*
  - *The arc always has an URI/IRI*
- An arc attaches a property with some value to a node
- Entity – attribute – value model


http://www.w3.org/2000/10/swap/pim/contact#Person
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://www.w3.org/People/EM/contact#me

Statements

asserting information

Statement

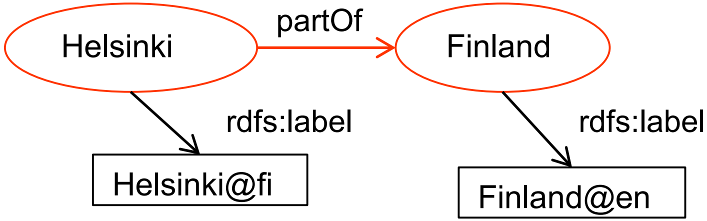
Statement asserts a relationship (property) between two resources

- E.g., ”Helsinki is part of Finland”

Statement is represented as a triple

- <resource, property, property_value>
  <subject, predicate, object>

RDF graph = set of statements



Subject	Predicate	Object
1. Helsinki	partOf	Finland
2. Helsinki	rdfs:label	Helsinki@fi
3. Finland	rdfs:label	Finland@en

Statement characteristics

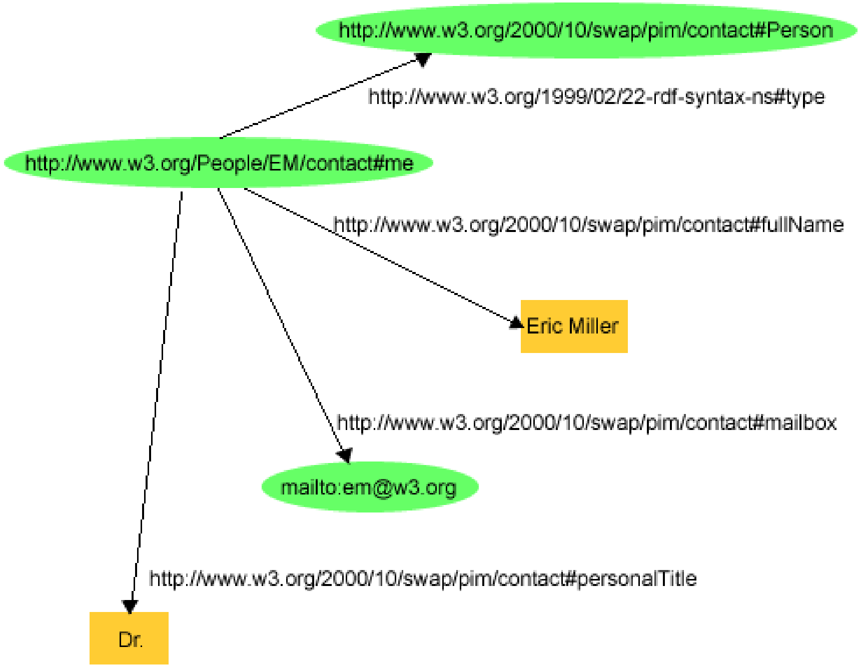
Subject is an IRI or blank node

Predicate is an IRI (blank node is not reasonable predicate)

Object is an IRI, literal, or blank node

- Literals are used only as property values

Example


http://www.w3.org/2000/10/swap/pim/contact#Person
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://www.w3.org/People/EM/contact#me
http://www.w3.org/2000/10/swap/pim/contact#fullName
Eric Miller
http://www.w3.org/2000/10/swap/pim/contact#mailbox
mailto:em@w3.org
http://www.w3.org/2000/10/swap/pim/contact#personalTitle
Dr.

Are binary predicates enough?

RDF uses only binary properties

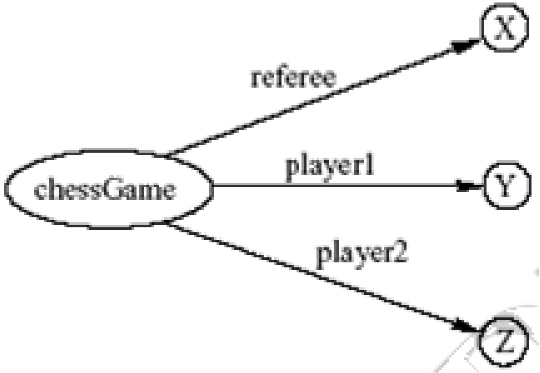
- Often we use predicates with more than 2 arguments

Example problem: referee(X, Y, Z)

- **X** is the referee in a chess game between players **Y** and **Z**

N-ary predicates can be represented by binary ones:

- a new auxiliary resource **chessGame**
- new binary predicates for arguments: **ref**, **player1**, and **player2**



RDF graphs

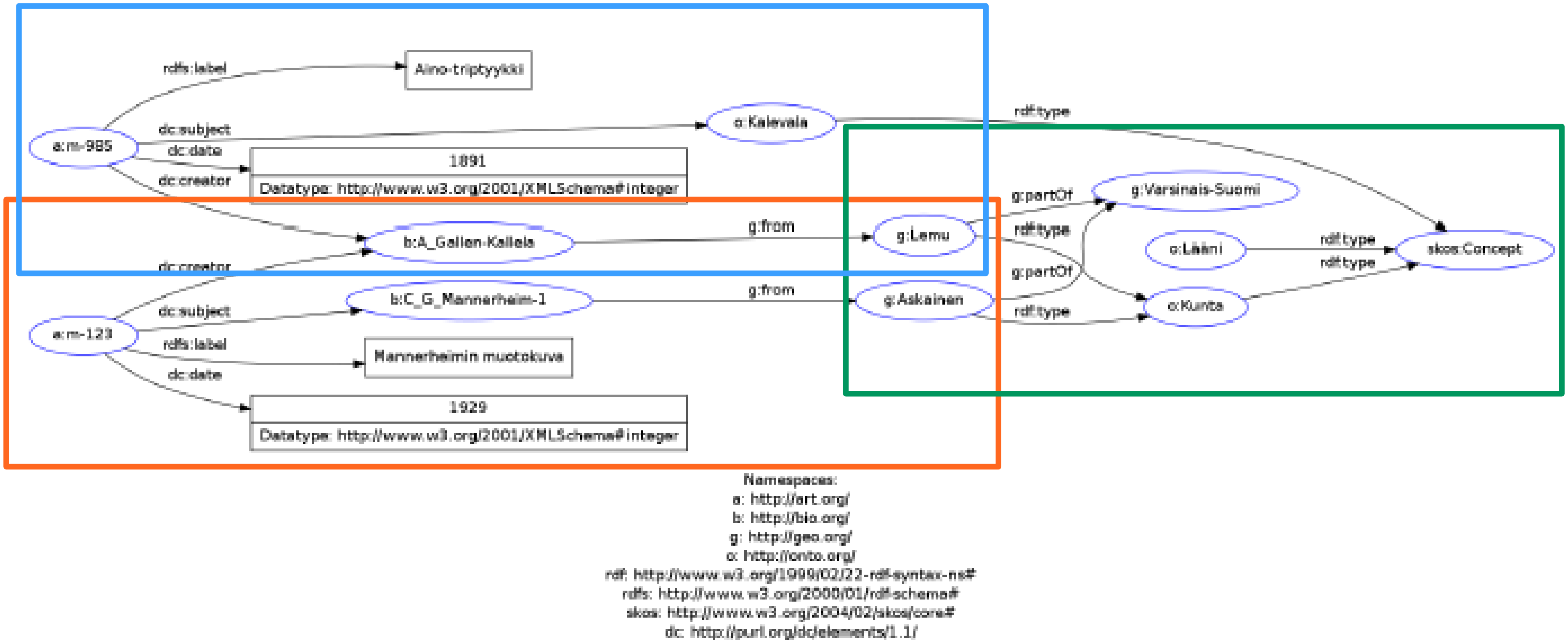
set of triples

RDF graph

RDF graph = set of triples (statements)

- <start node, arc, end node> i.e.
  <subject, predicate, object>

Multiple graphs can be merged with the union operation of set theory



Namespaces:
a: http://art.org/
b: http://bio.org/
g: http://geo.org/
o: http://onto.org/
rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs: http://www.w3.org/2000/01/rdf-schema#
skos: http://www.w3.org/2004/02/skos/core#
dc: http://purl.org/dc/elements/1.1/

Datasets and quads

set of graphs

Datasets, graphs, and quads in RDF 1.1

- **Dataset** consists of a set of **RDF graphs**
  - *Multiple **named graphs** and at most one **unnamed (default) graph***
- Graphs are encode sets of quads, where the 4th position is a graph IRI

  -
    ```
    <http://example.org/spiderman>
    <http://www.perceive.net/schemas/relationship/enemyOf>
    <http://example.org/green-goblin>
    <http://example.org/graphs/spiderman> .
    ```
  - *If the 4th member is omitted, the triple belongs to the default graph*

Quads

Adding the graph information into a triple can be important

- Information modularization
  - *E.g., restricting the search only to a specific graph*
- Representing provenience information
  - *The origin of the statement, the date of the addition into the dataset*
  - *Used, e.g., in the Google Knowledge Graph*
  - *Facilitates the management of contents*

RDF syntax

Serialization

Representing graph as linear text (string)

- E.g., in a file: reading and writing

Alternative serializations for different needs

1. Intuitive for humans to read/write
   - ***N-triples***, *Notation 3*
   - ***Turtle***
   - *TriG, N-Quads*
2. XML-interpretability for machines
   - ***RDF/XML***
   - *Existing XML tools available*
3. For **web** programming
   - ***JSON-LD***
4. Embedding in web pages
   - ***RDFa***
   - *Publishing information for, e.g., search engines*

Intuitive for humans

“Turtle family of RDF languages”

N-Triples

Triple set is serialized in the following form:

```
subject1 predicate1 object1 .
subject2 predicate2 object2 .
...
```

IRIs are enclosed in angle brackets (<>): <iri>:

```
<http://example.org/product2>
<http://www.w3.org/1999/02/22-rdf-syntax#type>
<http://example.org/computer> .
```

- For machines easy to read/write line by line
- For humans difficult to read due to redundancy

Example

```
# Tuntemattoman sotilaan ohjasi Edvin Laine
<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
<http://dbpedia.org/ontology/director> # Ohjaaja-ominaisuus
<http://dbpedia.org/resource/Edvin_Laine> . # Edvin Laine

# Filmin nimi englanniksi
<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
<http://www.w3.org/2000/01/rdf-schema#label> # Nimike
"The Unknown Soldier (1955 film)"@en . # Literaaliarvo

# Tuntemattoman sotilaan aiheena on sota
<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
<http://purl.org/dc/elements/1.1/subject> #Aihe
<http://www.yso.fi/onto/koko/p48202> . # "Sota" KOKO:ssa
```

Notation 3 (N3)

- Easier to read, compact way for serializing RDF information
- Developed by Tim Berners-Lee, however *no* W3C recommendation status
- Namespace prefixes are first introduced in the beginning of the file, e.g.

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

- Then the triples are encoded, e.g.

```
o:product1 rdf:type o:computer .
```

- Subject doesn't have to be repeated, e.g.

```
o:product3 rdf:type o:computer ;
           o:brand o:apple .
```

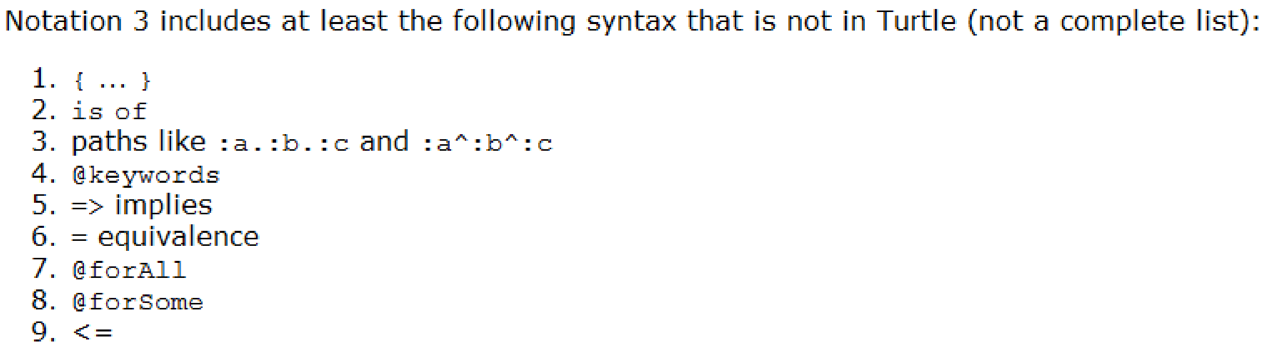
- Blank nodes

```
o:product4 rdf:type [ o:brand "Nokia" ] .
```

- Also other syntactic sugar available

Turtle – Terse RDF Triple Language

- Extends the N-Triples notation
- Subset of Notation 3, non-valid RDF extensions discarded

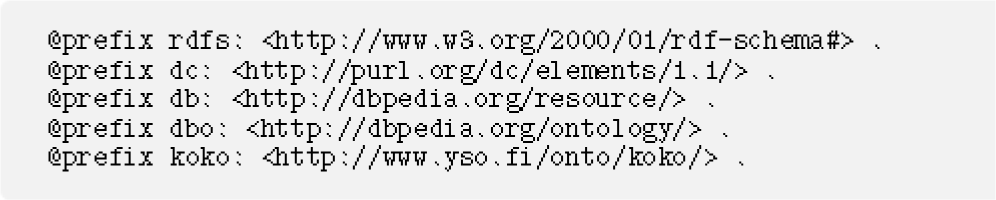


Notation 3 includes at least the following syntax that is not in Turtle (not a complete list):

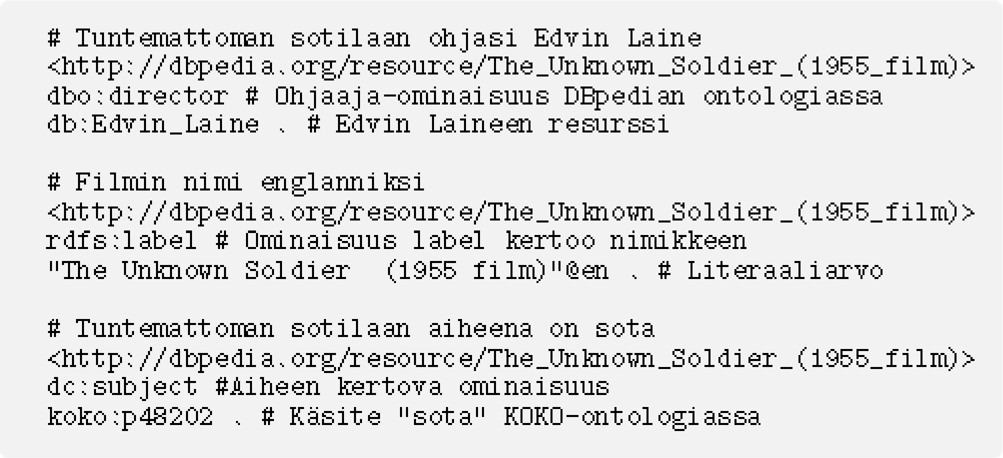
1. `{ ... }`
2. `is of`
3. paths like `:a.:b.:c` and `:a^:b^:c`
4. `@keywords`
5. => implies
6. = equivalence
7. `@forAll`
8. `@forSome`
9. `<=`

- Used in SPARQL query patterns
- Recommended human-readable RDF notation

Turtle simpifies N-triples: Examples



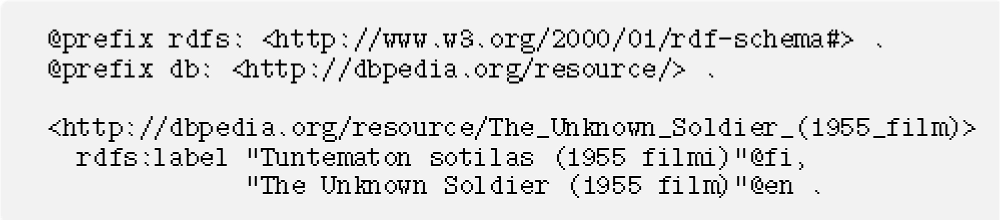
```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix db: <http://dbpedia.org/resource/> .
@prefix dbo: <http://dbpedia.org/ontology/> .
@prefix koko: <http://www.yso.fi/onto/koko/> .
```



```
# Tuntemattoman sotilaan ohjasi Edvin Laine
<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
dbo:director # Ohjaaja-ominaisuus DBpedian ontologiassa
db:Edvin_Laine . # Edvin Laineen resurssi

# Filmin nimi englanniksi
<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
rdfs:label # Ominaisuus label kertoo nimikkeen
"The Unknown Soldier  (1955 film)"@en . # Literaaliarvo

# Tuntemattoman sotilaan aiheena on sota
<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
dc:subject #Aiheen kertova ominaisuus
koko:p48202 . # Käsite "sota" KOKO-ontologiassa
```

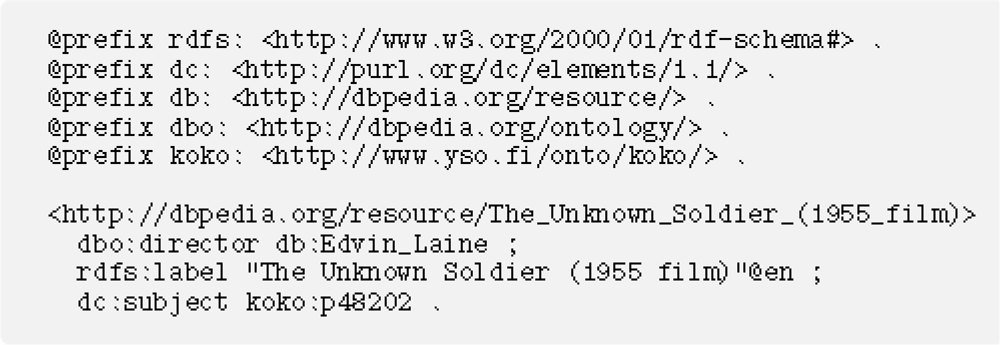
Using namespaces

Multiple property values



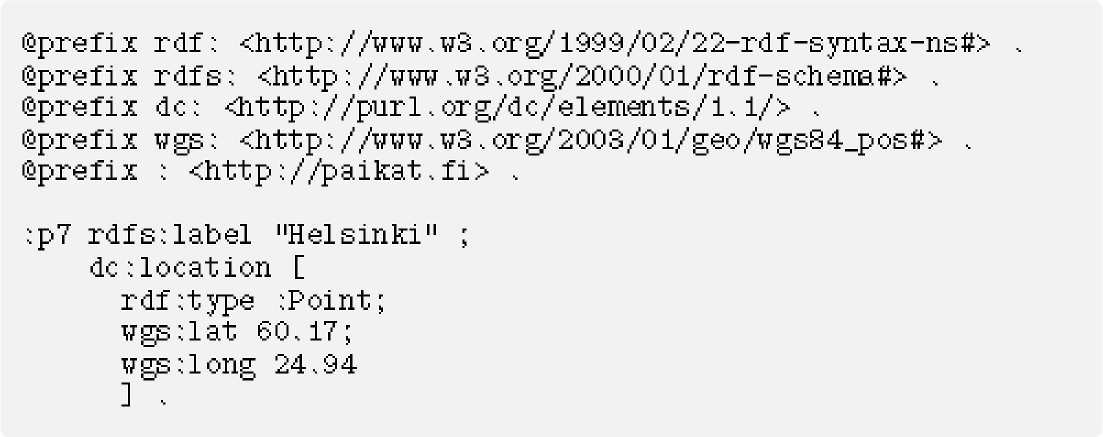
```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix db: <http://dbpedia.org/resource/> .

<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
  rdfs:label "Tuntematon sotilas (1955 filmi)"@fi,
             "The Unknown Soldier (1955 film)"@en .
```

Several properties

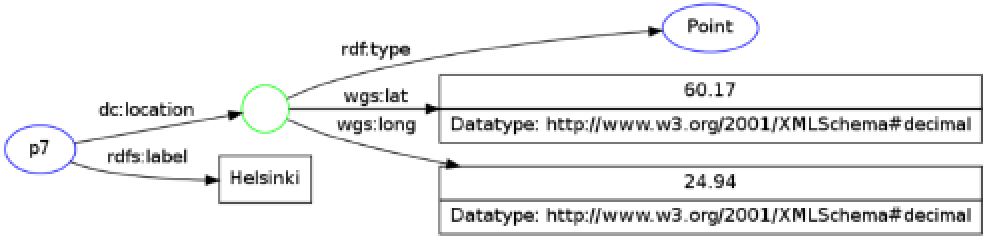


```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix db: <http://dbpedia.org/resource/> .
@prefix dbo: <http://dbpedia.org/ontology/> .
@prefix koko: <http://www.yso.fi/onto/koko/> .

<http://dbpedia.org/resource/The_Unknown_Soldier_(1955_film)>
  dbo:director db:Edvin_Laine ;
  rdfs:label "The Unknown Soldier (1955 film)"@en ;
  dc:subject koko:p48202 .
```

Nesting blank nodes

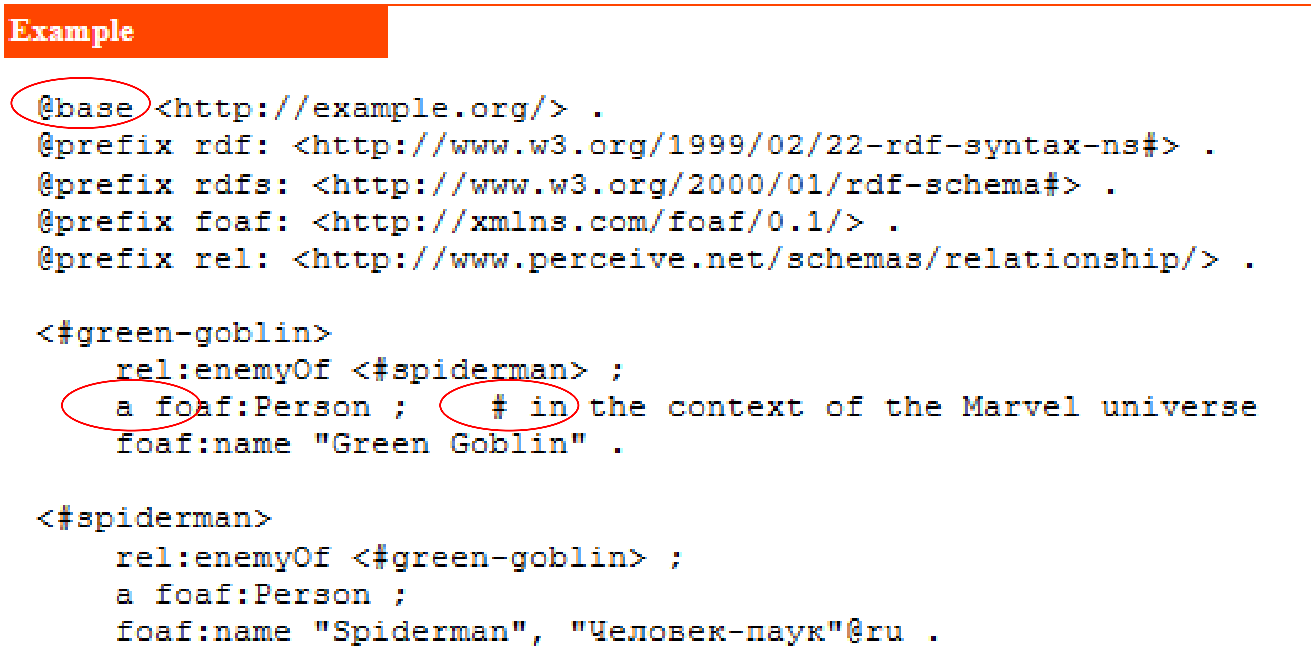


```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix wgs: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
@prefix : <http://paikat.fi> .

:p7 rdfs:label "Helsinki" ;
    dc:location [
      rdf:type :Point;
      wgs:lat 60.17;
      wgs:long 24.94
      ] .
```


Point
rdf:type
60.17
wgs:lat
wgs:long
Datatype: http://www.w3.org/2001/XMLSchema#decimal
dc:location
p7
rdfs:label
Helsinki
24.94
Datatype: http://www.w3.org/2001/XMLSchema#decimal

Namespaces:
rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs: http://www.w3.org/2000/01/rdf-schema#
dc: http://purl.org/dc/elements/1.1/
wgs: http://www.w3.org/2003/01/geo/wgs84_pos#
http://paikat.fi

Turtle – syntactic sugar

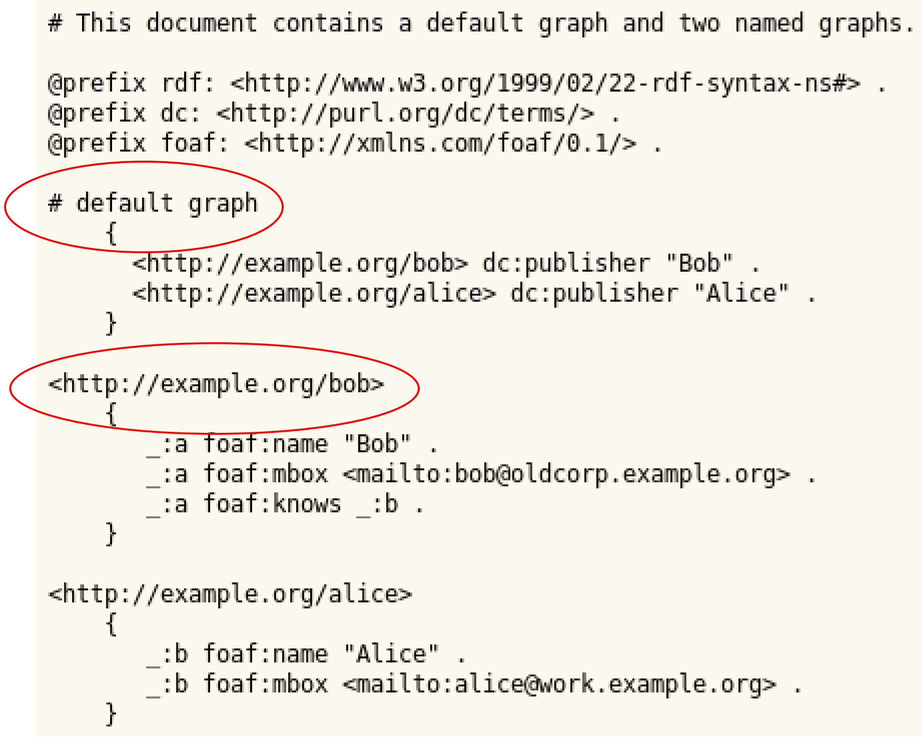


Example

```
@base <http://example.org/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix rel: <http://www.perceive.net/schemas/relationship/> .

<#green-goblin>
    rel:enemyOf <#spiderman> ;
    a foaf:Person ;    # in the context of the Marvel universe
    foaf:name "Green Goblin" .

<#spiderman>
    rel:enemyOf <#green-goblin> ;
    a foaf:Person ;
    foaf:name "Spiderman", "Человек-паук"@ru .
```

TriG

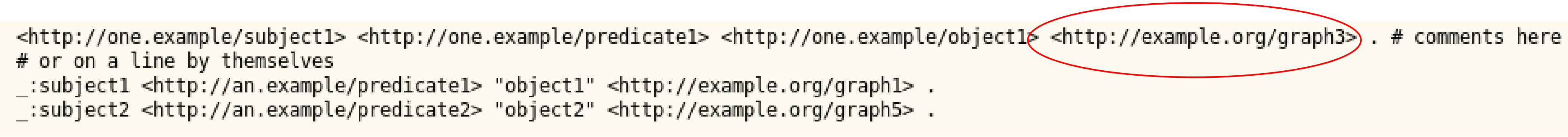
Extends Turtle notation for representing datasets (set of graphs)



```
# This document contains a default graph and two named graphs.

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix dc: <http://purl.org/dc/terms/> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

# default graph
    {
      <http://example.org/bob> dc:publisher "Bob" .
      <http://example.org/alice> dc:publisher "Alice" .
    }

<http://example.org/bob>
    {
       _:a foaf:name "Bob" .
       _:a foaf:mbox <mailto:bob@oldcorp.example.org> .
       _:a foaf:knows _:b .
    }

<http://example.org/alice>
    {
       _:b foaf:name "Alice" .
       _:b foaf:mbox <mailto:alice@work.example.org> .
    }
```

N-Quads

Extends N-Triples notation for representing triples with graph information (line by line)



```
<http://one.example/subject1> <http://one.example/predicate1> <http://one.example/object1> <http://example.org/graph3> . # comments here
# or on a line by themselves
_:subject1 <http://an.example/predicate1> "object1" <http://example.org/graph1> .
_:subject2 <http://an.example/predicate2> "object2" <http://example.org/graph5> .
```

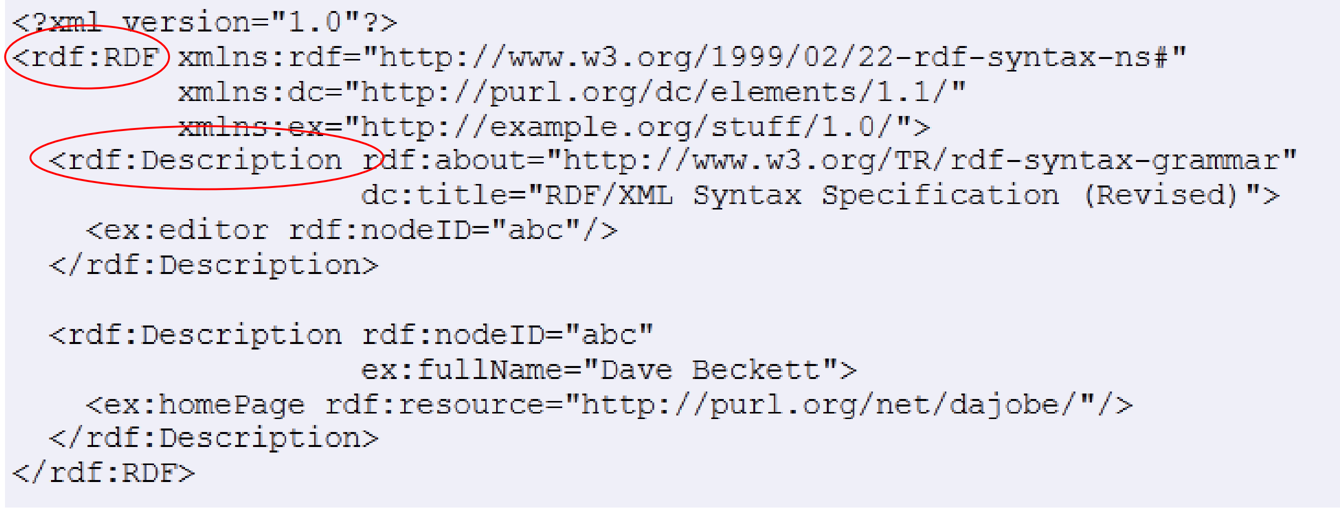
XML-interpretability for machines

RDF/XML

RDF/XML

- XML language for serializing RDF graphs
- Originally the only RDF syntax in the RDF 1.0 recommendation
- Meant for machines, complicated for humans
  - *Existing XML tools available*

Example of RDF/XML



```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/stuff/1.0/">
  <rdf:Description rdf:about="http://www.w3.org/TR/rdf-syntax-grammar"
                   dc:title="RDF/XML Syntax Specification (Revised)">
    <ex:editor rdf:nodeID="abc"/>
  </rdf:Description>

  <rdf:Description rdf:nodeID="abc"
                   ex:fullName="Dave Beckett">
    <ex:homePage rdf:resource="http://purl.org/net/dajobe/"/>
  </rdf:Description>
</rdf:RDF>
```

For web programming

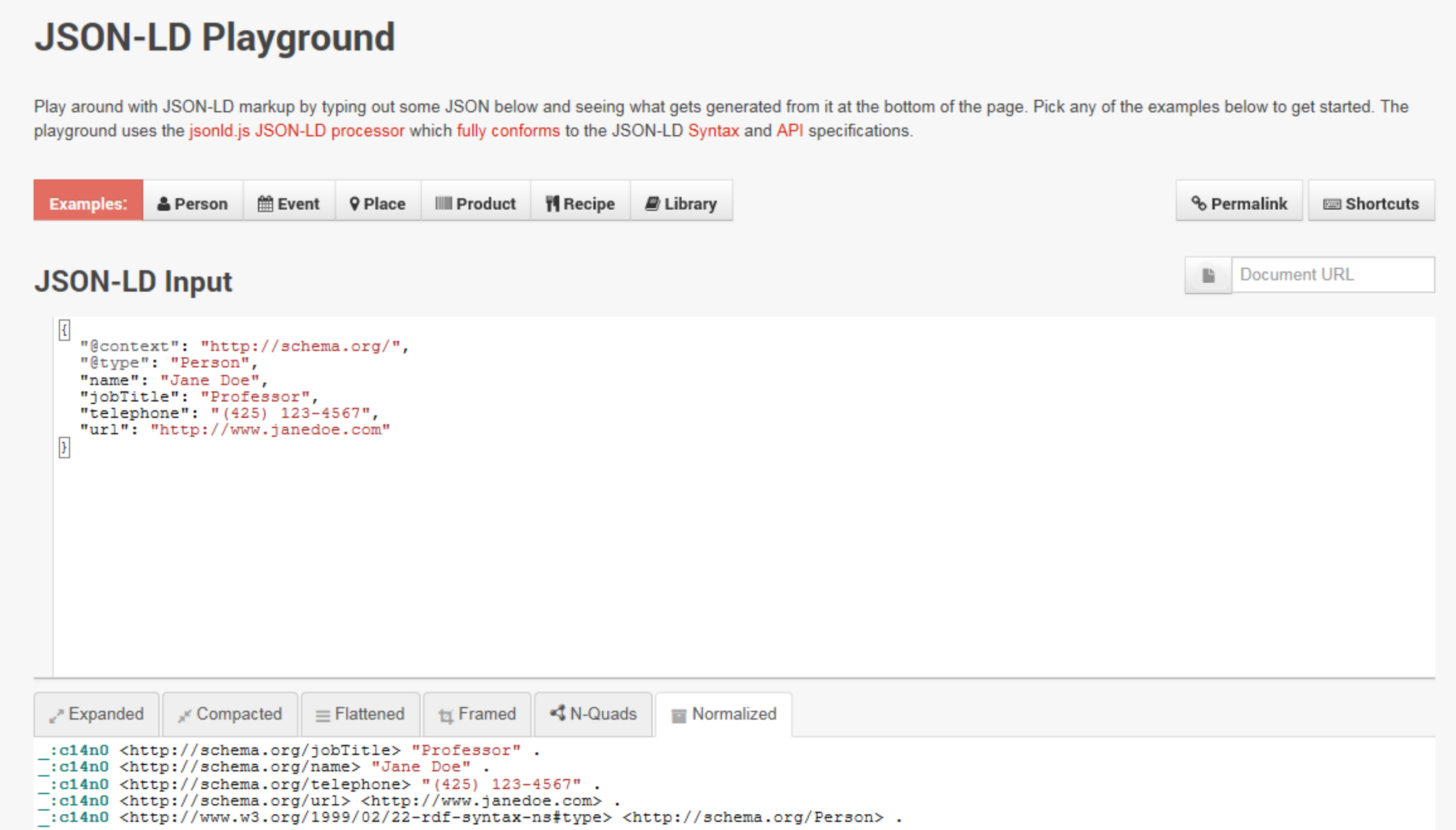
JSON-LD

JSON-LD (JSON Linked Data)

- Human-readable notation with built-in support in programming languages/environments, such as JavaScript, Python
- See also interactive JSON-LD ”playground”

Example of JSON-LD

http://json-ld.org/playground/index.html



JSON-LD Playground

Play around with JSON-LD markup by typing out some JSON below and seeing what gets generated from it at the bottom of the page. Pick any of the examples below to get started. The playground uses the jsonld.js JSON-LD processor which fully conforms to the JSON-LD Syntax and API specifications.

JSON-LD Input

```
{
  "@context": "http://schema.org/",
  "@type": "Person",
  "name": "Jane Doe",
  "jobTitle": "Professor",
  "telephone": "(425) 123-4567",
  "url": "http://www.janedoe.com"
}
```

```
_:c14n0 <http://schema.org/jobTitle> "Professor" .
_:c14n0 <http://schema.org/name> "Jane Doe" .
_:c14n0 <http://schema.org/telephone> "(425) 123-4567" .
_:c14n0 <http://schema.org/url> <http://www.janedoe.com> .
_:c14n0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://schema.org/Person> .
```

RDF data validation

- The validity of different RDF syntaxes can be checked with validators
- As part of the validation the serialized representation can be visualized as an RDF graph
- http://www.ldf.fi/service/rdf-grapher/ at Linked Data Finland
- W3C RDF/XML validator
- More validators

RDF Schema (RDFS)

Why RDF Schema?

Introducing classes and individuals (instances)

- A class is a set of individuals
  - *E.g., John and Mary are individuals of class Person*

Introducing constraints on using properties

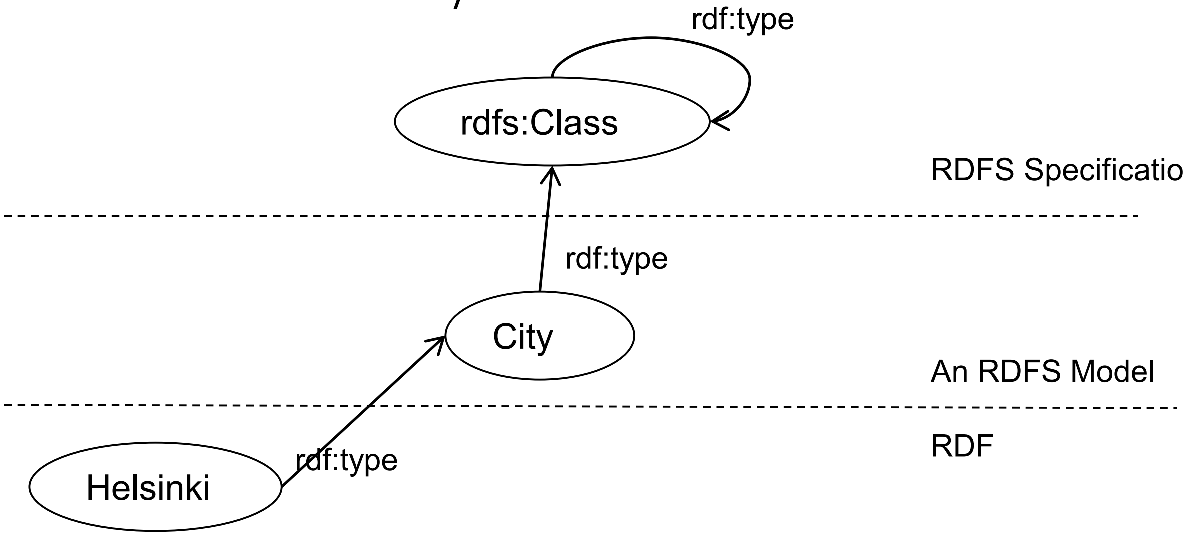
- **Domain** constraint: only certain classes of individuals can have certain properties
  - *E.g., only persons have a social security number*
- **Range** constraint: certain properties may have value of a certain class only
  - *E.g., a person's parent must be a person, too*

Introducing class and property hierarchies

Introducing semantics for validating data and for reasoning

Individuals

- Individual–class relationship is expressed by property **rdf:type**
- Classes are individuals of the (meta)class **rdfs:Class**
- **rdfs:Class** is an instance/individual of itself



Class hierarchies

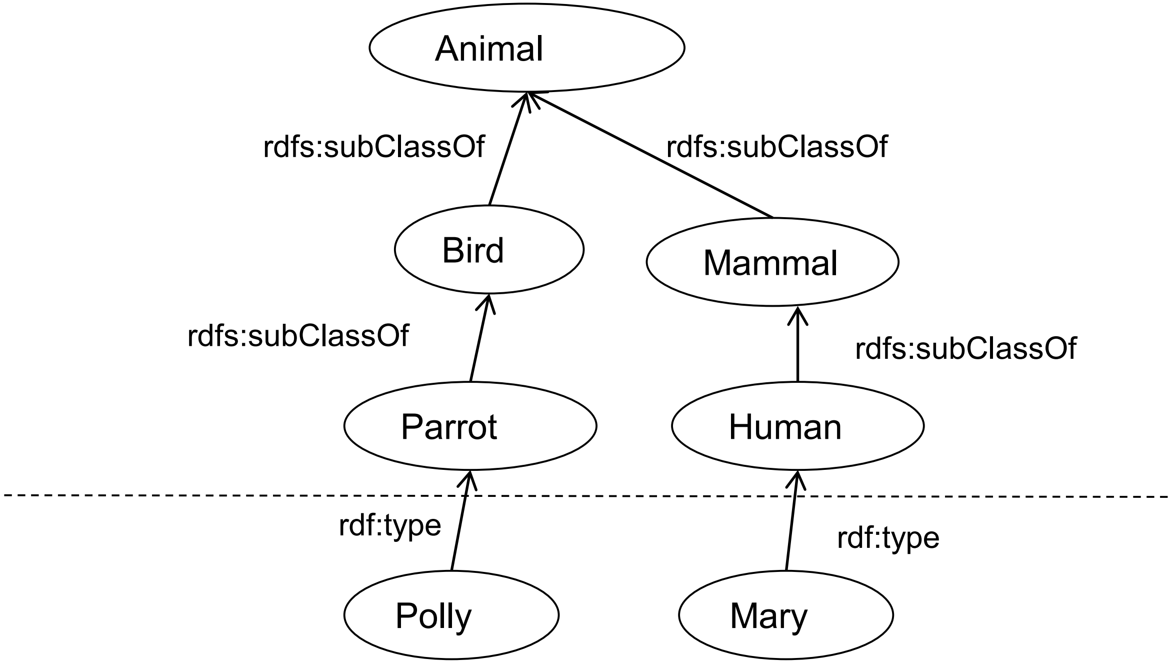
Classes can be organized in hierarchies

- A is a subclass of B if every instance of A is also an instance of B
- Then B is a superclass of A

A class may have multiple superclasses

- Multiple inheritance
- A subclass graph is then not a tree

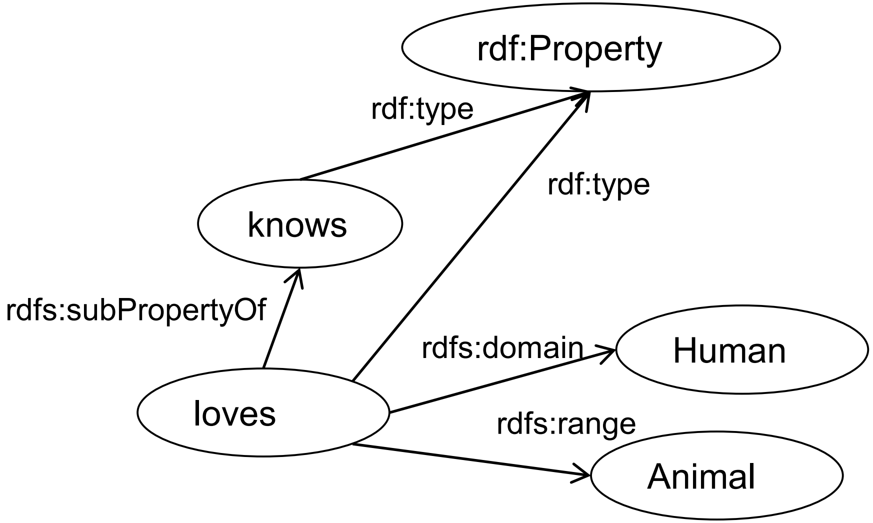
Class hierarchy: rdfs:subClassOf



Properties and constraints

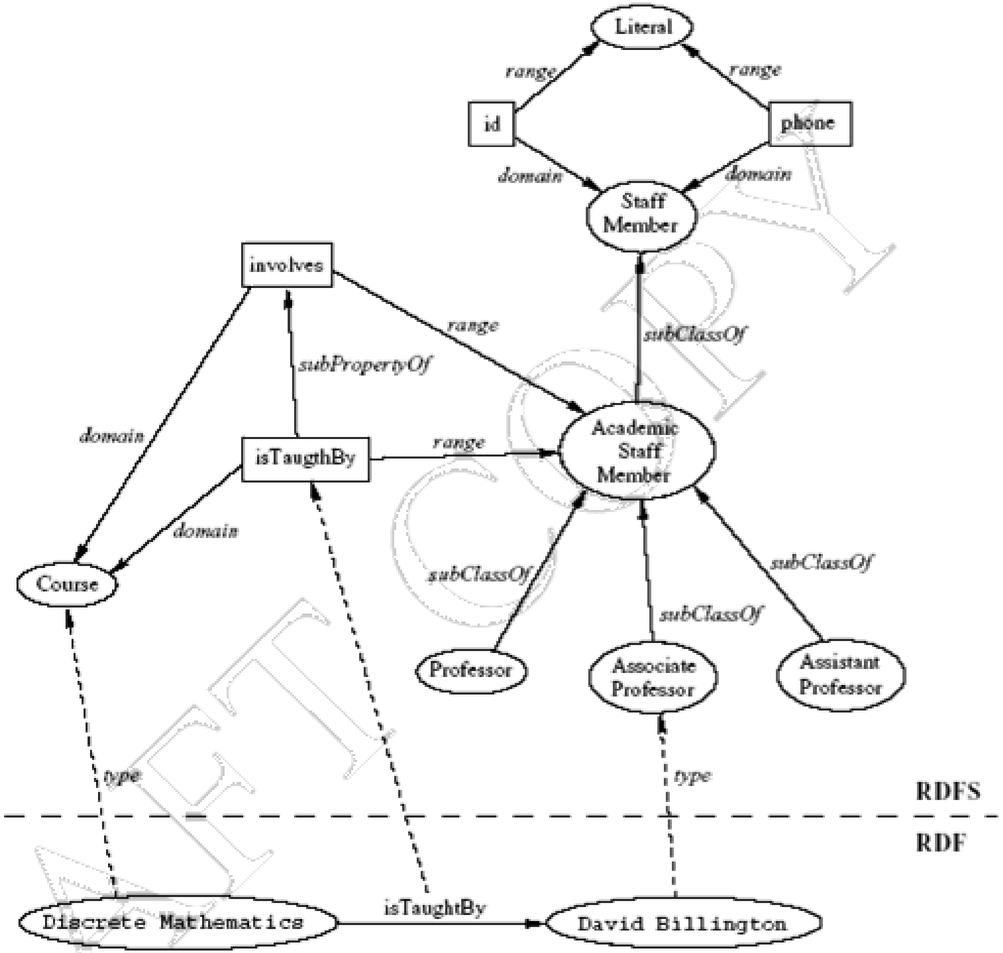
- Property types are individuals of the class **rdf:Property**
- A property may have domain and/or range constraints, expressed by properties **rdfs:domain** and **rdfs:range**

RDF Schema with property constraints and hierarchy-based reasoning



- Constraints: Only humans may love only animals (of any kind)
- Inheritance reasoning:
    - Property hierarchy: Since humans love they also know animals
    - Class hierarchy: Polly (a bird and therefore an animal) can be loved by humans such as Mary

Example (Semantic Web Primer 2nd ed.)

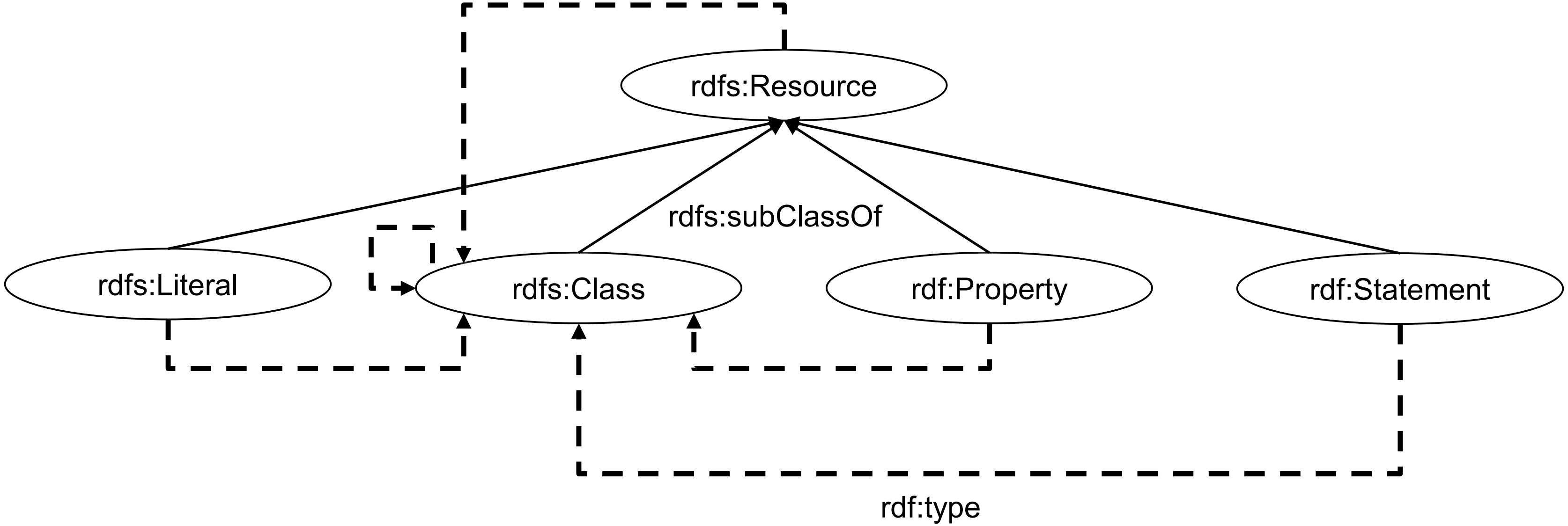


RDF(S) core classes

- **rdfs:Resource**
- **rdfs:Class**
- **rdfs:Literal**
- **rdf:Property**
- **rdf:Statement**

Hierarchy of RDF(S) core classes

These classes form a hierarchy in the RDF(S) specifications written by RDFS itself!



RDF(S) core properties

- **rdf:type**

- **rdfs:subClassOf**
- **rdfs:subPropertyOf**

- **rdfs:domain**
- **rdfs:range**

Other constructs in RDF(S)

Reification mechanism

- For adding metadata to individual triples (statements)
- ”John believes Mary loves Polly”

  -
    ```
    :s1 rdf:type rdfs:Statement;
        rdf:subject :Mary;
        rdf:predicate :loves;
        rdf:object :Polly .
    :John :believe :s1 .
    ```

Collection class rdf:List for representing lists

(:a :b (:c :d) :e)

Container subclasses of rdfs:Container for generic data structures

• **rdf:Bag**	Bags
• **rdf:Seq**	Sequences
• **rdf:Alt**	Alternatives

Other constructs in RDF(S) (2)

Utility properties

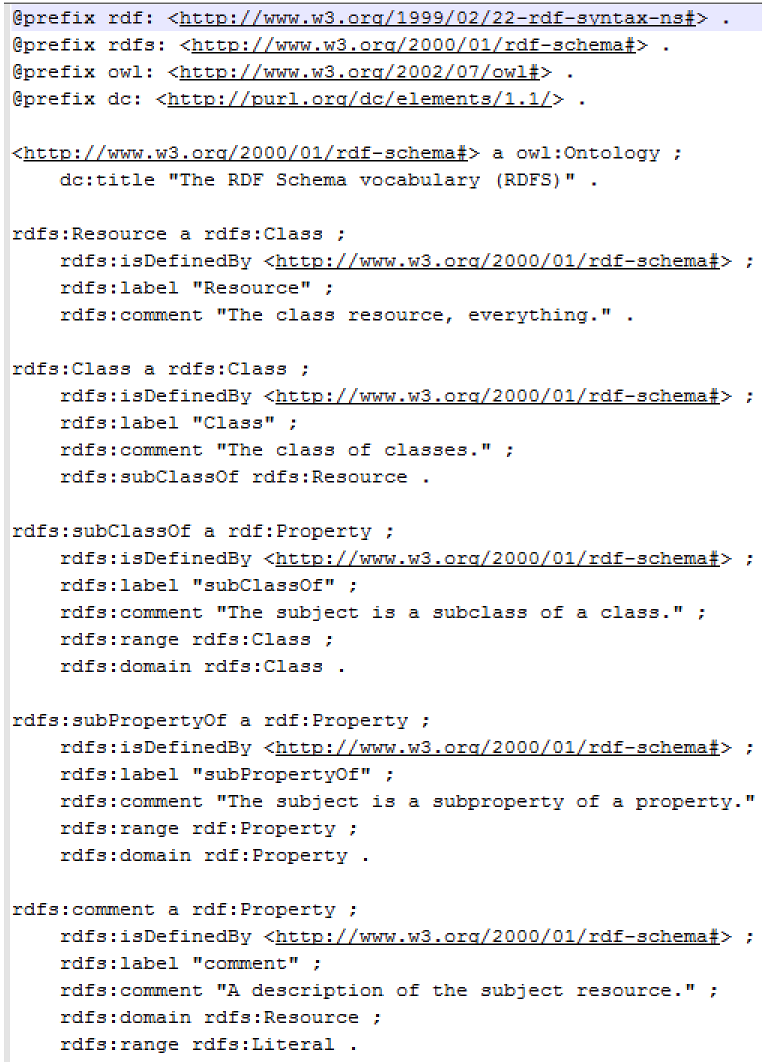
• **rdfs:label**	human-readable label
• **rdfs:comment**	for commenting
• **rdfs:seeAlso**	related explaining resource
• **rdfs:isDefinedBy**	subproperty of **rdfs:seeAlso**

There are also some other primitives in the specifications

RDF(S) specification in RDFS

Namespace IRIs of RDF and RDFS contain the specifications for 1) classes and 2) properties

- http://www.w3.org/1999/02/22-rdf-syntax-ns#
- http://www.w3.org/2000/01/rdf-schema#



```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .

<http://www.w3.org/2000/01/rdf-schema#> a owl:Ontology ;
    dc:title "The RDF Schema vocabulary (RDFS)" .

rdfs:Resource a rdfs:Class ;
    rdfs:isDefinedBy <http://www.w3.org/2000/01/rdf-schema#> ;
    rdfs:label "Resource" ;
    rdfs:comment "The class resource, everything." .

rdfs:Class a rdfs:Class ;
    rdfs:isDefinedBy <http://www.w3.org/2000/01/rdf-schema#> ;
    rdfs:label "Class" ;
    rdfs:comment "The class of classes." ;
    rdfs:subClassOf rdfs:Resource .

rdfs:subClassOf a rdf:Property ;
    rdfs:isDefinedBy <http://www.w3.org/2000/01/rdf-schema#> ;
    rdfs:label "subClassOf" ;
    rdfs:comment "The subject is a subclass of a class." ;
    rdfs:range rdfs:Class ;
    rdfs:domain rdfs:Class .

rdfs:subPropertyOf a rdf:Property ;
    rdfs:isDefinedBy <http://www.w3.org/2000/01/rdf-schema#> ;
    rdfs:label "subPropertyOf" ;
    rdfs:comment "The subject is a subproperty of a property."
    rdfs:range rdf:Property ;
    rdfs:domain rdf:Property .

rdfs:comment a rdf:Property ;
    rdfs:isDefinedBy <http://www.w3.org/2000/01/rdf-schema#> ;
    rdfs:label "comment" ;
    rdfs:comment "A description of the subject resource." ;
    rdfs:domain rdfs:Resource ;
    rdfs:range rdfs:Literal .
```

RDF(S) semantics

RDFS semantics

Based on first-order predicate logic

RDF data can therefore be used for reasoning new data

= Adding new triples in the graph

Two ways of defining the same semantics in logic

- Axiomatic semantics by representing RDF constructs in terms of logical axioms
- Direct inference rule-based semantics
  - *Simpler way*

Axiomatic semantics: an example (Semantic Web Primer)

- An RDF statement (triple) **(R, P, V)** is represented as **PropVal(P, R, V)**
- **Type(R, T)** is a shorthand for **PropVal(type, R, T)**
- **subClassOf** is a property:

  Type(subClassOf, Property)

- **type** can be applied to resources and has a class as its value:

  Type(?r, ?c) → (Type(?r, Resource) ∧ Type(?c, Class))

- If a class C is a subclass of a class C', then all instances of C are also instances of C':

  PropVal(subClassOf, ?c, ?c') ↔
  (Type(?c, Class) ∧ Type(?c', Class) ∧
  ∀?x (Type(?x, ?c) → Type(?x, ?c')))

Semantics based on inference rules

Semantics in terms of RDF triples instead of restating RDF in terms of first-order logic

- Sound and complete inference system
  - *But no need for heavy first-order logic proof system (good for scalability)*

Rule system consists of inference rules of the form:

IF	**E contains certain triples**
THEN	**add to E certain additional triples**

where E is an arbitrary set of RDF triples

Examples of inference rules

IF E contains the triple (?x, ?p, ?y)
THEN E also contains (?p, rdf:type, rdf:Property)

IF E contains the triples (?u, rdfs:subClassOf, ?v)
and (?v, rdfs:subclassOf, ?w)
THEN E also contains the triple (?u, rdfs:subClassOf, ?w)

IF E contains the triples (?x, rdf:type, ?u)
and (?u, rdfs:subClassOf, ?v)
THEN E also contains the triple (?x, rdf:type, ?v)

Examples of inference rules (2)

Any resource **?y** which appears as the value of a property **?p** can be inferred to be a member of the range of **?p**

- This shows that range definitions in RDF Schema are not used to restrict the range of a property, but rather to infer the membership of the range

IF E contains the triples (?x, ?p, ?y)

and (?p, rdfs:range, ?u)

THEN E also contains the triple (?y, rdf:type, ?u)

Summary

- RDF provides a foundation for representing and processing metadata
- RDF has a graph-based data model
- RDF has different syntaxes
- RDF has a decentralized philosophy
  - *Incremental building of knowledge*
  - *Sharing and reusing metadata*

Summary (2)

- RDF is domain-independent
- RDF Schema provides a mechanism for describing specific domains
  - *RDF Schema is a primitive ontology language*
- Key concepts of RDF (Schema) are
  - *Classes and instances*
  - *Type and subclass relations for class hierarchies*
  - *Property and subproperty relations for property hierarchies*
  - *Domain and range restrictions connecting properties and classes*