IN3060/4060 – Semantic Technologies – Spring 2021

Lecture 2: Resource Description Framework (RDF)

Jieying Chen

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Department of Informatics

University of Oslo

Today's Plan

1. Introduction
2. RDF data model
   - Technicalities
   - Features
3. RDF serialisations
4. RDF vocabularies
5. RDF on the web
6. Subtleties
7. Summary

Mandatory exercises

- First oblig published today (22.01) after lecture.
- Topic RDF.
- Hand in by next Friday (29.01).
- Same schedule for the other small obligs:
  - #2 (29.01 – 05.02),
  - #3 (05.02 – 12.02), and
  - #4 (19.02 – 05.03).
- The larger obligs with two possible attempts:
  - #5 (05.03 – 19.03) and
  - #6 (26.03 – 16.04).
- And one short oblig about OTTR
  - #7 (07.05 – 14.05).
- See *obliger* on the semester page.
- Mr. Oblig.

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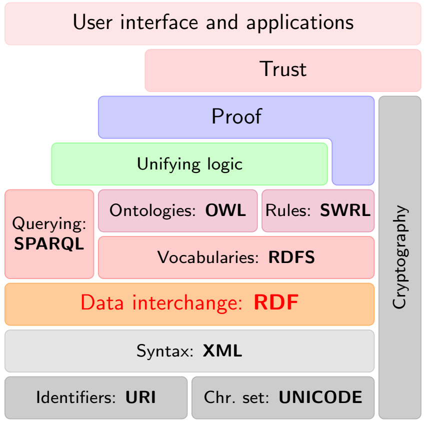
RDF: W3C Overview

- *The Resource Description Framework* (RDF) is a standard model for data interchange on the Web.
- It has features that facilitate data merging even if the underlying schemas differ.
- It extends the linking structure of the Web to use URIs to name the relationship between things as well as the two ends of the link.
- Thus allows data to be mixed, exposed, and shared across different applications.
- This linking structure forms a directed, labelled graph.
- This graph view is the easiest possible mental model for RDF and is often used in easy-to-understand visual explanations.

Adapted from `http://w3c.org/RDF`.

Semantic Web Stack

- Central block in the SW stack.
- First “semantic” block in stack.
- In the course we will explore:
  - RDF
  - SPARQL
  - RDFS/OWL
  - Logic
  - Applications



RDF, essential ‘abouts’:

- The *Resource Description Framework* was initially intended for annotation of web-accessible resources (1999).
- It has since developed into a general purpose language for describing structured information—on the web or elsewhere.
- The goal of RDF is to enable applications to exchange data on the Web in a meaning-preserving way.
- It is considered the basic representation format underlying the Semantic Web.

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RDF Triples

- All information in RDF is expressed using a *triple* pattern.
- A triple consists of a subject, a predicate, and an object.
  Examples:

subject	predicate	object
Norway	has capital	Oslo
Norway	has king	King Harald
King Harald	born year	1937

- Another word for an RDF triple is a *statement* or *fact*.
- The elements of an RDF triple are either
  - *URI references*,
  - *literals*, or
  - *blank nodes*.

Uniform Resource Identifiers (URIs)

- RDF (Resource Description Framework) talks about *resources*.
  - Almost anything is a resource.
- Resources are identified by URIs (Uniform Resource Identifiers).
- E.g., in `dbpedia.org`:

Norway:	`http://dbpedia.org/resource/Norway`
has capital:	`http://dbpedia.org/ontology/capital`
Oslo:	`http://dbpedia.org/resource/Oslo`
has king:	`http://dbpedia.org/ontology/leader`
King Harald:	`http://dbpedia.org/resource/Harald_V_of_Norway`

- As identifiers, think of them as just strings (on a special format).
  - Not necessarily dereferenceable.

URI $\not\subseteq$ URL

URLs are not the only URIs:

- ISBN:
  `urn:isbn:0-486-27557-4`
- Geo:
  `geo:37.786971,-122.399677`
- Mail:
  `mailto:jieyingc@ifi.uio.no`
- and many many more . . .

URIs and QNames

- URIs are often long and hard to read and write.
- Most serialisations use an abbreviation mechanism.
  - Define “prefixes”, “namespaces”.
- E.g., in Turtle serialisation:

```
@prefix dbp:  <http://dbpedia.org/resource/> .
@prefix dbp-ont:  <http://dbpedia.org/ontology/> .
```

- A *QName* like `dbp:Oslo` stands for `http://dbpedia.org/resource/Oslo`
- Remember: It’s all just URIs!

URIs and data

- We can then state that Norway's capital is Oslo as:

  `<http://dbpedia.org/resource/Norway> <http://dbpedia.org/ontology/capital> <http://dbpedia.org/resource/Oslo> .`

- Or use prefixes:

  `dbp:Norway dbp-ont:capital dbp:Oslo .`

- But what if we want to state that Oslo's population is 629313?
- We cannot have one URI for every integer, decimal number, string etc.

Literals

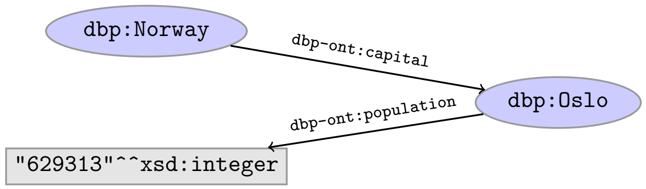
- Literals are used to represent data values.
- All literals have a datatype.
- Datatypes are also resources, referenced via URIs, and written as:
  `dbp:Oslo dbp-ont:population "629313"^^xsd:integer .`
- However, if nothing is written, it is assumed to be a string:
  `dbp:Oslo dbp-ont:officialName "Oslo" .`
  Is short for
  `dbp:Oslo dbp-ont:officialName "Oslo"^^xsd:string .`
- One can also specify the language of a string using a *language tag*:
  `dbp:Norway rdfs:label "Norge"@no .`
  `dbp:Norway rdfs:label "Norwegen"@de .`

RDF Graphs

- An *RDF graph* is a set of triples. E.g.,

  ```
  dbp:Norway  dbp-ont:capital     dbp:Oslo .
  dbp:Oslo    dbp-ont:population  "629313"^^xsd:integer .
  ```

  is an RDF graph containing two triples.
- RDF graphs are often represented as a directed labelled graph:

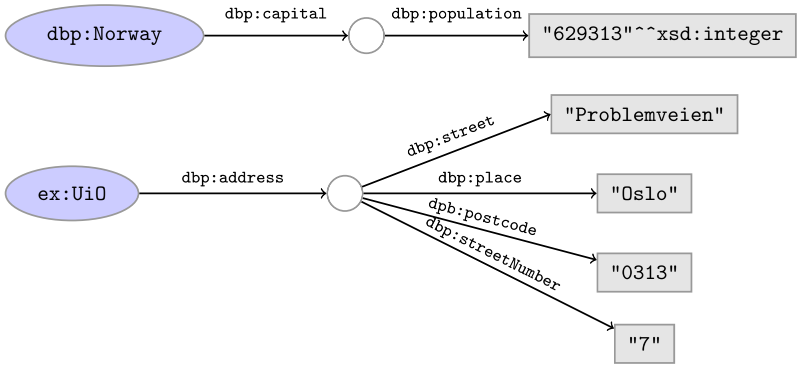


Problems

- Can all knowledge be nicely represented with only triples containing URIs and literals?
- What if we didn't know what the capital of Norway was, only that it has a population of 629313 people?
  dbp:Norway dbp-ont:hasCapitalWithPopulation "629313"^^xsd:integer .
- What if we want to model something which is not nicely represented as one URI, e.g. an address?
- UiO has the address "Problemveien 7 0313 Oslo". How should we model this? As a literal?
  dbp:UiO dbp-ont:hasAddress "Problemveien 7 0313 Oslo" .
- As several literals?
  dbp:UiO dbp-ont:addressPlace "Oslo" .
  dbp:UiO dbp-ont:addsressStreet "Problemveien" .
  dbp:UiO dbp-ont:addressStreetNumber "7" .
  dbp:UiO dbp-ont:addressPostcode "0313" .

Blank nodes

- Blank nodes are like resources without a URI.
- Use when resource is unknown, or has no (natural) identifier. E.g.:



RDF Triple Grammar

- Literals and blank nodes may not appear everywhere in triples:

	s	p	o
• URI references may occur in all positions	✔	✔	✔
• Literals may only occur in object position	✘	✘	✔
• Blank nodes may not occur in predicate position	✔	✘	✔

- Why?
  - Literals are just values, no relationships from literals allowed.
  - Blank nodes in predicate position deemed “too meaningless” and confusing.

Why URIs?

- URIs naturally have a “global” scope, unique throughout the web.
  - Contrasts to, e.g., keys in rel. DB which are unique within a table.
  - Helps to avoid name clashes.
  - Example: merging two product catalogues.
    `http://www.abc-company.com/category/item/123`
    `http://www.xyz-company.com/product/123`
- URLs are also addresses.
  - Exploit the well-functioning machinery of web browsing.
  - Find data by following data identifiers, i.e., URIs.
- *“A web of data.”*

Why triples?

- Any information format can be transformed to triples.
  - Examples:

Tabular (spreadsheets, DBs):	row	column	cell
Trees (XML):	parent	path	child

- Relationships are made explicit and elements in their own right.
  - The predicate, i.e., the relationship, is an element in the triple.
  - Unlike DB columns and binary predicates.
  - Can be described in RDF.
  - “Self-documenting”.
- Again, *“A web of data”*.

Why graphs?

- A single, but highly versatile, format.
  - Everything is on the same format: triples!
- Since RDF graphs are just sets of triples, basic set operations are well-defined.
- Merging RDF graphs? Just take their union!
  - With tabular data, table dimensions must match.
  - With trees, a node can only have one parent.
  - Note that graphs need not be connected.
- Extending an RDF graph? Just add more triples!
  - Need not redefine the database table, or
  - to restructure the XML schema.

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RDF Serialisations

There are many serialisations for the RDF data model:

RDF/XML the W3C standard. Complicated!

```
<?xml version="1.0"?>
<rdf:RDF xmlns:dbp="http://dbpedia.org/resource/"
 xmlns:foaf="http://xmlns.com/foaf/0.1/"
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns\#">
  <rdf:Description rdf:about="http://dbpedia.org/resource/Harald_V_of_Norway">
    <foaf:name>Harald V</foaf:name>
  </rdf:Description>
</rdf:RDF>
```

Turtle convenient, human readable/writable—our choice.

```
@prefix dbp: <http://dbpedia.org/resource/> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

dbp:Harald_V_of_Norway foaf:name "Harald V" .
```

N-triples one triple per line. No abbreviations.

```
<http://dbpedia.org/resource/Harald_V_of_Norway> <http://xmlns.com/foaf/0.1/name> "Harald V" .
```

Others N3, TriX, TriG, RDF/JSON, . . .

Turtle: URI references and triples

Full URIs are surrounded by < and >:

```
<http://dbpedia.org/resource/Oslo>
```

Statements are triples terminated by a period:

```
<http://dbpedia.org/resource/Oslo>
   <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
      <http://dbpedia.org/ontology/Place> .
```

Use ‘a’ to abbreviate rdf:type:

```
<http://dbpedia.org/resource/Oslo>
   a  <http://dbpedia.org/ontology/Place> .
```

Turtle allows any non-zero amount of space between elements in triples.

Turtle: Namespaces

QNames are written without any special characters.

Namespace prefixes are declared with `@prefix`:

```
@prefix dbp: <http://dbpedia.org/resource/> .

dbp:Oslo a <http://dbpedia.org/ontology/Place> .
```

A default namespace may be declared:

```
@prefix dbp: <http://dbpedia.org/resource/> .
@prefix : <http://dbpedia.org/ontology/> .

dbp:Oslo a :Place .
```

Turtle: Literals

Literal values are enclosed in double quotes:

```
@prefix dbp: <http://dbpedia.org/resource/> .
@prefix : <http://dbpedia.org/ontology/> .

dbp:Norway :officialName "Norge" .
```

Possibly with type or language information:

```
dbp:Norway rdfs:label "Norge"@no .
dbp:Oslo :population "629313"^^xsd:integer .
```

Numbers and booleans may be written without quotes:

```
dbp:Oslo :population 629313 .
dbp:Oslo :isCapital true .
```

Turtle: Statements sharing elements

Instead of:

```
dbp:Oslo rdf:type dbo:City .
dbp:Oslo :officialName "Oslo" .
dbp:Oslo :population 629313 .
```

. . . statements may share a subject with ‘;’:

```
dbp:Oslo rdf:type dbo:City ;
         :officialName "Oslo" ;
         :population 629313 .
```

Turtle: Statements sharing elements

Instead of:

```
dbp:Norway rdfs:label "Norway"@en .
dbp:Norway rdfs:label "Norwegen"@de .
dbp:Norway rdfs:label "Norge"@no .
```

. . . statements may share subject and predicate with ‘,’:

```
dbp:Norway rdfs:label "Norway"@en ,
                      "Norwegen"@de ,
                      "Norge"@no .
```

. . . and in combination:

```
dbp:Norway rdfs:label "Norway"@en, "Norwegen"@de, "Norge"@no ;
           :capital dbp:Oslo .
```

Turtle: Blank nodes

Blank nodes are designated with underscores or `[...]`.

Norway has a capital with population 629313:

```
dbp:Norway :capital _:someplace .
_:someplace :population 629313 .
```

There is a place with official name Oslo:

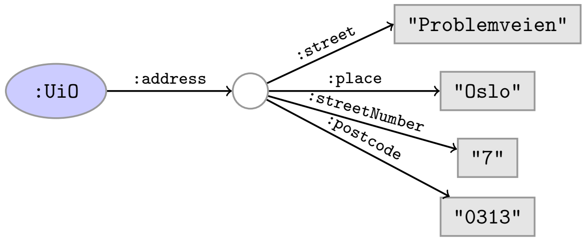
```
[] a :Place ;
   :officialName "Oslo" .
```

UiO has address Problemveien 7, 0313 Oslo:

```
:UiO :address [ :street "Problemveien" ;
                :streetNumber "7";
                :place "Oslo" ;
                :postcode "0313" ] .
```

Question

The blank node here:



has no ‘name.’

Why does Turtle use ‘blank node identifiers’ like `_:someplace`?

Answer: makes it easy to use same node in several triples.

Turtle: Other things

Use ‘#’ to comment:

```
# This is a comment.
dbp:Oslo a dbpont:Place . # This is another comment.
```

Use ‘\’ to escape special characters:

```
:someGuy :foaf:name "James \"Mr. Man\" Olson" .
```

Turtle specification: `http://www.w3.org/TR/turtle/`.

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Vocabularies

- Families of related notions are grouped into *vocabularies*.
- Usually the same namespace/prefix is shared.
- Some important, well-known namespaces—and prefixes:

  `rdf:` `<http://www.w3.org/1999/02/22-rdf-syntax-ns#>` – RDF
  `rdfs:` `<http://www.w3.org/2000/01/rdf-schema#>` – RDF Schema
  `foaf:` `<http://xmlns.com/foaf/0.1/>` – Friend of a friend
  `dcterms:` `<http://purl.org/dc/terms/>` – Dublin Core
- Usually, a description is published at the namespace base URI.
- Note that the prefix is not standardised.
  - However, in practice many are.
  - `@prefix rdf: <http://xmlns.com/foaf/0.1/>` would be highly irregular.

Example vocabularies: RDF, RDFS

Some example resources:

RDF: describing RDF graphs.

- `rdf:Statement`
- `rdf:subject`,
  `rdf:predicate`,
  `rdf:object`
- `rdf:type`

RDFS: describing RDF vocabularies.

- `rdfs:Class`
- `rdfs:subClassOf`,
  `rdfs:subPropertyOf`
- `rdfs:domain`,
  `rdfs:range`
- `rdfs:label`

Examples:

```
dbp:Oslo rdf:type dbp-ont:Place .
dbp:Norway rdfs:label "Norge"@no .
dbp:Capital rdfs:subClassOf dbp:City .
```

Example vocabularies: FOAF, Dublin Core

Some example resources:

FOAF: person data and relations.

- `foaf:Person`
- `foaf:knows`
- `foaf:firstName`,
  `foaf:lastName`,
  `foaf:gender`

Dublin Core: library metadata.

- `dcterms:creator`,
  `dcterms:contributor`
- `dcterms:format`,
  `dcterms:language`,
  `dcterms:licence`

Examples:

```
ifi:jieyingc rdf:type foaf:Person .
ifi:jieyingc foaf:knows ifi:martingi .
ifi:jieyingc dcterms:creator ifi:rdf-lecture .
```

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Where is it?

- In files:
  - In some serialisation: XML/RDF, Turtle, . . .
  - Typically small RDF graphs, i.e., max. a few 100 triples, e.g.,
    - Vocabularies: `http://xmlns.com/foaf/spec/index.rdf`.
    - Tiny datasets: `http://folk.uio.no/martingi/foaf.rdf`.
- From *SPARQL endpoints*:
  - Data kept in a *triple store*, i.e., a database.
  - RDF is served from endpoint as results of *SPARQL queries*.
  - Exposes data (in different formats)
    - with endpoint frontends, e.g., `http://dbpedia.org/resource/Norway`, or
    - by direct SPARQL query: `http://dbpedia.org/sparql`.
- There are many *RDFizers* which convert data to RDF.
  - Tabular files (CSV, Excel): XLWrap.
  - Relational DB: D2RQ (`http://sws.ifi.uio.no/d2rq/`) or R2RML (`https://www.w3.org/TR/r2rml/`).
  - W3C keeps a list: `http://www.w3.org/wiki/ConverterToRdf`.

Creating RDF data and vocabularies

- Designing an easy-to-use and robust namespace is non-trivial.
- Naming is difficult.
- Reuse existing vocabularies if possible. Don't reinvent.
- URIs are also addresses, consider publishing issues when naming.
- Adhere to the policies described in *best practice* documents:
  - Best Practice Recipes for Publishing RDF Vocabularies
    - `http://www.w3.org/TR/2008/NOTE-swbp-vocab-pub-20080828/`
  - Cool URIs for the Semantic Web
    - `http://www.w3.org/TR/cooluris/`
- Use `http://www.example.[com|net|org]` for prototyping and documentation.

Linked Open Data

Tim Berners-Lee's recipe for 5 star web data:

1. Make data available on the Web (any format) under an open license.
2. Make it available as structured data (e.g., Excel, not image scans).
3. Use non-proprietary formats (e.g., CSV instead of Excel).
4. Use URIs to identify data items; make them referable on the Web.
5. Link your data to other's data to provide context.

Adapted from `http://www.w3.org/DesignIssues/LinkedData.html`.

Web of Data

- The point of publishing data as described in this lecture is to have self-describing and self-documenting data.
- Decouples data from applications.
- Lightens the programming burden.
- Semantic Web applications should be/are generic and general purpose, exploiting rich and knowledge intensive data sets.

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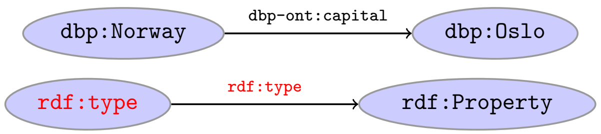
URIs are not necessarily unique

- URIs are just strings, not a "global identification service".
- There is nothing stopping you from using `rdf:type` as the URI for your favourite data item.
- However, don't do that!
- The simple rule of only creating URIs in a namespace domain you control should keep you out of trouble.
  - Again, put data on the URI address.
- *Trust* is an important (and work-in-progress) layer in the SW stack.

RDF graphs are not graphs



- Drawing `dbp:Norway dbp-ont:capital dbp:Oslo` is straight-forward.
- But what about `rdf:type rdf:type rdf:Property`?
- RDF graphs are sets of triples, not graphs.
- The set of nodes, i.e., subjects and object, and edges, i.e., predicates, of an RDF graph need not be disjoint.

Be careful when merging RDF *files*

Merging the two RDF files containing named blank nodes

File 1

```
ifi:martige :owns _:myCar .
_:myCar a  lotus:Esprit .
```

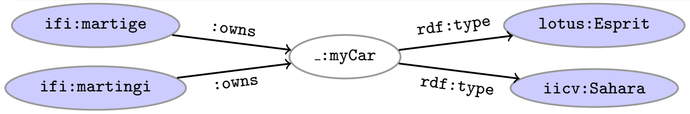
File 2

```
ifi:martingi :owns _:myCar .
_:myCar     a    iicv:Sahara .
```

gives the RDF graph:

File 1 ∪ File 2

```
ifi:martige  :owns _:myCar .
ifi:martingi :owns _:myCar .
_:myCar       a    lotus:Esprit, iicv:Sahara .
```



Rename blank nodes

Renaming _:myCar to _:myCar2 in File 2.

File 1

```
ifi:martige :owns _:myCar .
_:myCar a  lotus:Esprit .
```

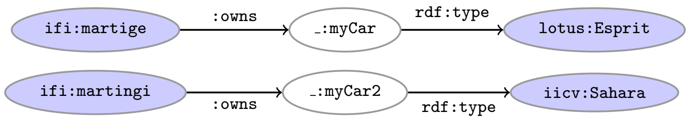
File 2

```
ifi:martingi :owns _:myCar2 .
_:myCar2     a    iicv:Sahara .
```

gives the RDF graph:

File 1 ∪ File 2

```
ifi:martige  :owns _:myCar  .  _:myCar   a  lotus:Esprit .
ifi:martingi :owns _:myCar2 .  _:myCar2  a  iicv:Sahara .
```



More complex statements

We can use triples to form complex statements, e.g.:

Data structures

```
:in3060 :hasLecturers
            [ rdf:first :martingi ;
              rdf:rest [ rdf:first : jieyingc;
                         rdf:rest [ rdf:first :olemholt ;
                                    rdf:rest rdf:nil .
                                  ] .
                       ] .
            ] .
```

Turtle shorthand for lists

```
:in3060 :hasLecturers (:martingi :jieyingc :olemholt ) .
```

More complex statements (cont.)

What if I want to state that “Jieying thinks iOS is better than Linux, but Martin does not.”

Reification, statements describing statements

```
_:s rdf:subject ex:ios ;
    rdf:predicate ex:betterThan ;
    rdf:object ex:linux .

:jieyingc :thinks _:s .
:martingi :thinksNot _:s .
```

Reification allows us to describe agents’ (e.g. people, sensors) beliefs, knowledge, etc. or meta information about a statement, e.g. “added by”, “imestamp”, etc.

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Summary

- RDF is a general format for describing resources.
- Data is represented as triples, consisting of
  - URIs for describing resources,
  - literals for data,
  - blank nodes for unknown data or more complex relationships.
- Sets of triples form RDF graphs.
- Naturally extends the linking structure of the web.
- Allows meta-data as a part of the data.
- Allows data to be easily linked to other datasets.
- Is completely independent of any application.

That’s it for today!

Remember the mandatory assignment.