

4th Summer Datathon on Linguistic Linked Open Data (SD-LLOD-22)

May 30th to June 3rd 2022 at Residencia Lucas Olazábal of Universidad Politécnica de Madrid, Cercedilla, Spain

Introduction to Semantic Web Technologies

Julia Bosque-Gil (former: University of Zaragoza, Spain)
Thierry Declerck (DFKI, Germany & ACDH-CH, Austria)



The World Wide Web

- Focuses on *documents* (web of hypertext, written in HTML)
- Links are established between those documents
- Humans can extract and interpret the meaning of the content in those documents...but this is not so easy for machines






The World Wide Web

The Web of Data

- Documents
 - Focuses on data, which are described in RDF
- Links are established between those documents
 - Links are established between the data: Easier sharing and discovery
- Humans can extract and interpret the meaning of the content in those documents...but this is not so easy for machines
 - Meaning processable by machines

Introduction

The web of documents vs the web of data: An example from DBpedia. The request for “<https://dbpedia.org/resource/Lisbon>” is leading by default to “<https://dbpedia.org/page/Lisbon>” (human readable), but with a specific request one can be directed to <https://dbpedia.org/data/Lisbon> (machine readable)

https://dbpedia.org/page/Lisbon	
	 Browse using -  Formats -
	 Faceted Browser  Sparql Endpoint
<h2>About: Lisbon</h2>	
An Entity of Type : <i>Capital city</i> , from Named Graph : http://dbpedia.org , within Data Space : dbpedia.org	
<p>Lisbon (; Portuguese: Lisboa; [liʒˈboɐ] ()) is the capital and the largest city of Portugal, with an estimated population of 505,526 within its administrative limits in an area of 100.05 km². Lisbon's urban area extends beyond the city's administrative limits with a population of around 2.8 million people, being the 10th-most populous urban area in the European Union. About 3 million people live in the Lisbon metropolitan area, which represents approximately 27% of the country's population. It is mainland Europe's westernmost capital city and the only one along the Atlantic coast. Lisbon lies in the western Iberian Peninsula on the Atlantic Ocean and the River Tagus. The westernmost portions of its metro area, the Portuguese Riviera, form the westernmost point of Continental Europe, culmin</p>	
Property	Value
dbo:PopulatedPlace/areaMetro	▪ 3015.24
dbo:PopulatedPlace/areaTotal	▪ 100.05
dbo:PopulatedPlace/areaUrban	▪ 1376.0
dbo:abstract	<p>■ Lisbon (; Portuguese: Lisboa; [liʒˈboɐ] ()) is the capital and the largest city of Portugal, with an estimated population of 505,526 within its administrative limits in an area of 100.05 km². Lisbon's urban area extends beyond the city's administrative limits with a population of around 2.8 million people, being the 10th-most populous urban area in the European Union. About 3 million people live in the Lisbon metropolitan area, which represents approximately 27% of the country's population. It is mainland Europe's westernmost capital city and the only one along the Atlantic coast. Lisbon lies in the western Iberian Peninsula on the Atlantic Ocean and the River Tagus. The westernmost portions of its metro area, the Portuguese Riviera, form the westernmost point of Continental Europe, culminating at Cabo da Roca. Lisbon is recognised as an alpha-level global city because of its importance in finance, commerce, media, entertainment, arts, international trade, education and tourism. Lisbon is one of two Portuguese cities (alongside Porto) to be recognised as a global city. It is one of the major economic centres on the continent, with a growing financial sector and one of the largest container ports on Europe's Atlantic coast. Additionally, Humberto Delgado Airport served 29 million passengers in 2016, being the busiest airport in Portugal, the 3rd busiest in the Iberian Peninsula and the 20th busiest in Europe. The motorway network and the high-speed rail system of Alfa Pendular links the main cities of Portugal to Lisbon. The city is the 9th-most-visited city in Southern Europe, after Rome, Istanbul, Barcelona, Milan, Venice, Madrid, Florence and Athens, with 3,320,300 tourists in 2017. The Lisbon region has a higher GDP PPP per capita than any other region in Portugal. Its GDP amounts to US\$96.3 billion and thus \$32,434 per capita. The city occupies the 40th place of highest gross earnings in the world. Most of the headquarters of multinational corporations in Portugal are located in the Lisbon area. It is also the political centre of the country, as its seat of government and residence of the head of state. Lisbon is one of the oldest cities in the world, and the second-oldest European capital city (after Athens), predating other modern European capitals by centuries. Julius Caesar made it a municipium called Felicitas Julia, adding to the name Olisippo. Ruled by a series of Germanic tribes from the 5th century, it was captured by the Moors in the 8th century. In 1147, the Crusaders under Afonso Henriques reconquered the city and since then it has been the political, economic and cultural center of Portugal. ^(en)</p>
dbo:areaCode	▪ (+351) 21 XXX-XXXX
dbo:areaMetro	▪ 3015240000.000000 (xsd:double)
dbo:areaTotal	▪ 100050000.000000 (xsd:double)
dbo:areaUrban	▪ 1376000000.000000 (xsd:double)
dbo:country	▪ dbr:Portugal
dbo:demonym	<ul style="list-style-type: none"> ▪ Lisboeta ^(en) ▪ Olisiponense ^(en) ▪ Alfacinha ^(colloquial) ^(en)

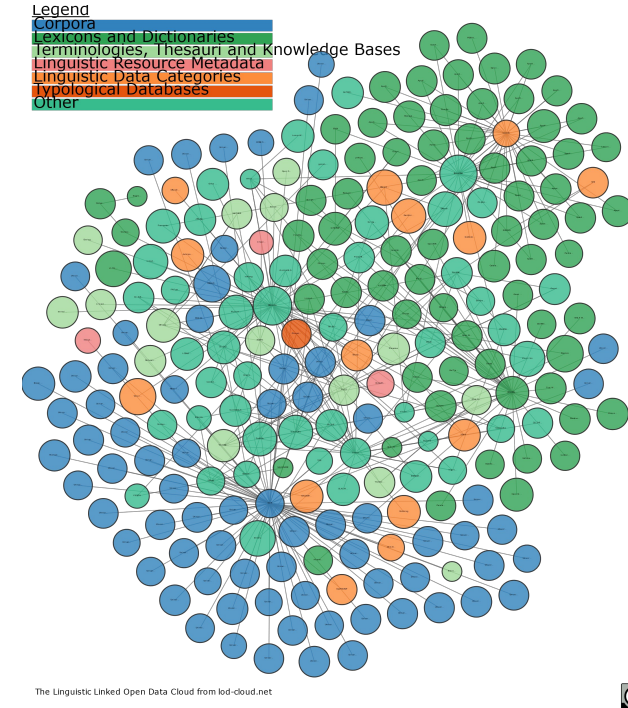
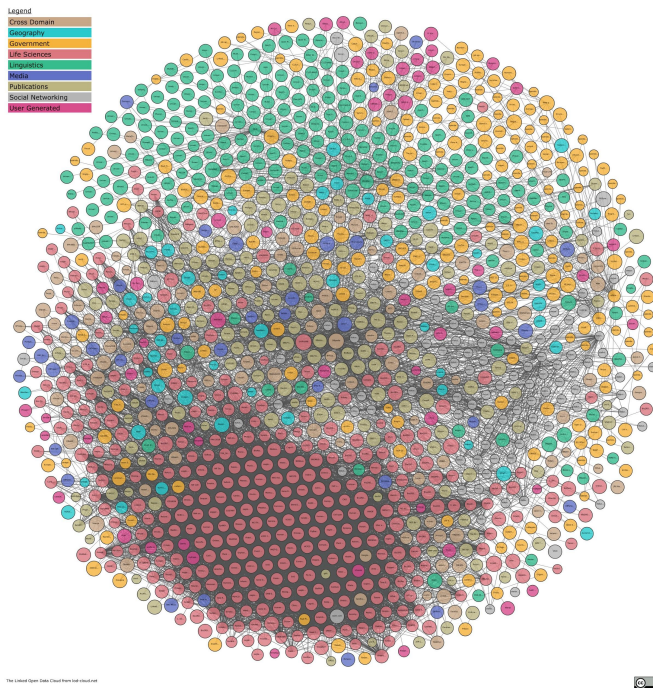
```

sparc2_2021-07-02_17-02-09Z (2) - Editor
Datei Bearbeiten Format Ansicht Hilfe
<?xml version="1.0" encoding="utf-8" ?>
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  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:foaf="http://xmlns.com/foaf/0.1/"
  xmlns:skos="http://www.w3.org/2004/02/skos/core#"
  xmlns:dbp="http://dbpedia.org/property/"
  xmlns:geo="http://www.w3.org/2003/01/geo/wgs84_pos#"
  xmlns:dbo="http://dbpedia.org/ontology/"
  xmlns:dct="http://purl.org/dc/terms/"
  xmlns:georss="http://www.georss.org/georss/"
  xmlns:schema="http://schema.org/"
  xmlns:prov="http://www.w3.org/ns/prov#"
  xmlns:ns12="http://dbpedia.org/ontology/PopulatedPlace/" >
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  </rdf:Description>
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  </rdf:Description>
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  </rdf:Description>
  <rdf:Description rdf:about="http://dbpedia.org/resource/1943_in_aviation">
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  </rdf:Description>
  <rdf:Description rdf:about="http://dbpedia.org/resource/1944_in_Ireland">
    <db:wikiPageWikilink rdf:resource="http://dbpedia.org/resource/Lisbon" />
  </rdf:Description>
  <rdf:Description rdf:about="http://dbpedia.org/resource/1946_Birthday_Honours">
    <db:wikiPageWikilink rdf:resource="http://dbpedia.org/resource/Lisbon" />
  </rdf:Description>
  <rdf:Description rdf:about="http://dbpedia.org/resource/1946_in_aviation">
    <db:wikiPageWikilink rdf:resource="http://dbpedia.org/resource/Lisbon" />
  </rdf:Description>
  <rdf:Description rdf:about="http://dbpedia.org/resource/1947_in_Portugal">
    <db:wikiPageWikilink rdf:resource="http://dbpedia.org/resource/Lisbon" />
  </rdf:Description>
  <rdf:Description rdf:about="http://dbpedia.org/resource/1947_in_aviation">
    <db:wikiPageWikilink rdf:resource="http://dbpedia.org/resource/Lisbon" />
  </rdf:Description>

```

Introduction

Our lectures introduce to those concepts that are central to the „Web of Data“, with a focus on language data. The web of data is best represented by the Linked Data cloud, while a subset of this cloud is built by the Linguistic Linked Data cloud



What are the principles behind those clouds, how do we represent the data?

Linked Data Principles

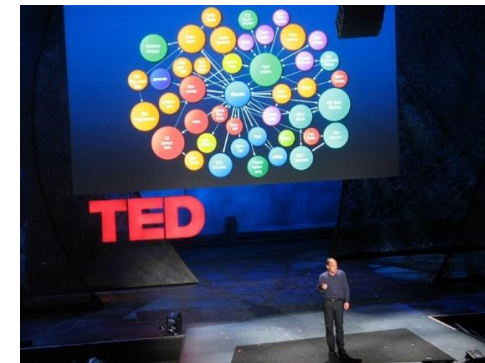
- 1 Use **URIs** as names for things
- 2 Use **HTTP URIs** so that people can look up those names
- 3 When someone looks up a URI, provide useful **information** (using the standards: RDF*, SPARQL)
- 4 Include **links** to other URIs, so that they can discover more things.

<http://www.w3.org/DesignIssues/LinkedData.html>



Checking the compliance to the Linked Data principles

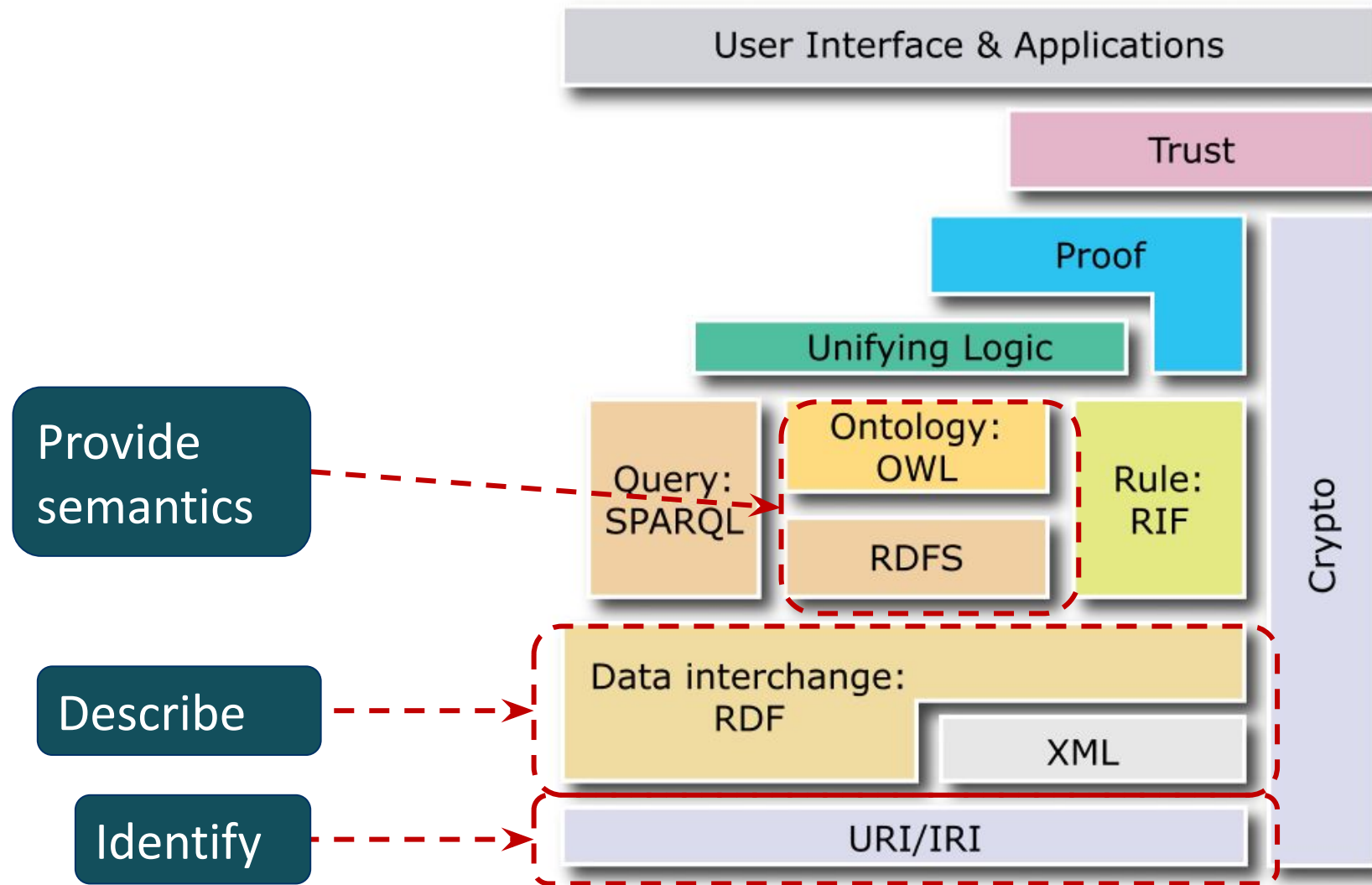
<http://www.w3.org/DesignIssues/LinkedData.html>



Consult the inspiring TED-2009 talk by Tim Berners Lee

https://www.ted.com/talks/tim_berniers_lee_the_next_web?language=en

URIs, RDF, RDF(s) within the Semantic Web Stack



‘A visual representation of the semantic web's structure, often referred to as "layer cake", taken from:
http://webservices.itcs.umich.edu/mediawiki/DigitalRhetoricCollaborative/index.php/Image:Semantic_Web_Stack.png

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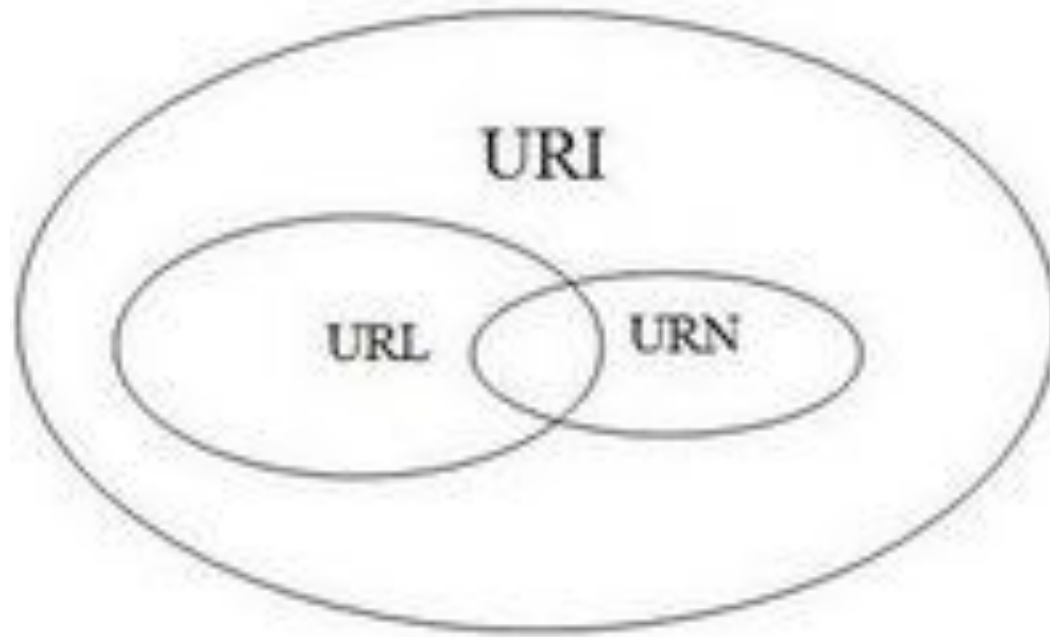
Resource Description Framework (RDF)

Julia Bosque-Gil (University of Zaragoza, Spain)
Thierry Declerck (DFKI, Germany & ACDH-CH, Austria)

What is a URI?

- Uniform Resource Identifier (URI) is a **unique identifier** used by web technologies
- **Some URIs** provide a means of **locating and retrieving** information resources on a network → these are **Uniform Resource Locators (URLs)**.
- Other URIs provide only a unique name, without a means of locating or retrieving the resource or information about it → **Uniform Resource Names (URNs)**.
- The specifications of **Internationalized Resource Identifiers (IRI)** **extend** the definition of URIs → IRIs can handle **character** sets such as Kanji rather than being restricted to ASCII

What is a URI?



<https://prateekvjoshi.com/2014/02/22/url-vs-uri-vs-urn/>

What is RDF?

- The Resource Description Framework (RDF) is a recommendation of the World Wide Web Consortium (W3C).
- It is *a standard model for data interchange on the Web*.
- Published specifications:
 - 1st specification → 1999
 - 2nd specification (RDF 1.0) → 2004
 - 3rd and **current** (RDF 1.1) → 2014
- RDF Primer:
<https://www.w3.org/TR/2014/NOTE-rdf11-primer-20140624/>

“The Resource Description Framework (RDF) is a framework for expressing information about resources. Resources can be anything, including documents, people, physical objects, and abstract concepts.”

What is RDF

Tim Berners-Lee on RDF, in “A Short History of ‘Resource’ in web architecture”:

*“When RDF was first developed, **it was motivated by the need for data about resources very much in the online information sense: data about documents, or 'metadata'.** In fact it was designed to be able to describe anything, but many early users of RDF referred to it as metadata technology. RDF used the word “resource” rather awkwardly in fact as it turned out. In the beginning, many of the things being described were documents, and so the online information meaning of resource made sense. **But in fact in RDF the resource was allowed to be anything at all.** A class, `rdf:Resource` even used the term as the universal class of all things. A little later, the Web Ontology Language decided to use *Thing* for that.”* [Emphasis added]

What is RDF

Tim Berners-Lee on RDF, in “A Short History of ‘Resource’ in web architecture”:

*“RDF came along in what I think was a neat way. It used completely existing web protocol extension devices to introduce **a new system** which was fundamentally different from the old HTTP+HTML one. **The HTML web was a hypertext model, which pages and anchors. The RDF model was a knowledge representation one of arbitrary things. It did this by using the fact that a new language can define whatever it likes as what a local identifier denotes.** A graphic language might use local identifier to denote lines and points. **HTML used local identifiers to identify hypertext anchors. RDF used them to identify arbitrary concepts, people, whatever**”* [Emphasis added]

If RDF can identify and represent „arbitrary concepts, people, whatever”...

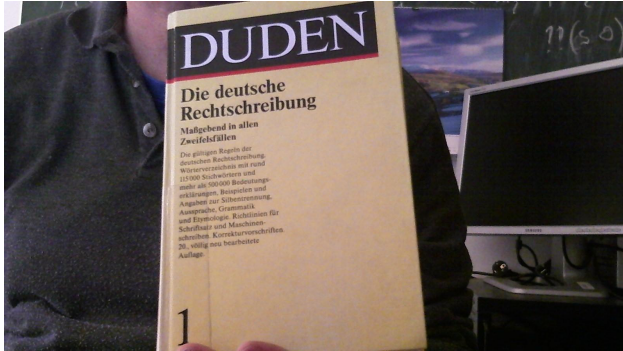


it should also be able to identify and represent any type of linguistic data!

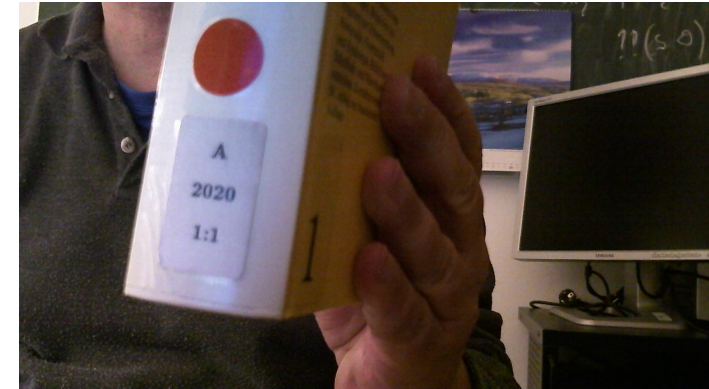
What is a Resource (in RDF)?

- Any thing one can identify (not only Web *locations*):
 - identified by the use of **Uniform Resource Identifiers (URIs)**
 - while a URI can identify a resource on the web, this resource is not necessarily retrievable
- A **resource** can thus be...
 - an object (a book, etc.)
 - a concept (for example “learning”)
 - a person (for example “Sara Carvalho”),
 - an event (for example “Lisbon Summer School in Linguistics 2021”),
 - a webpage (for example “<https://clunl.fcsh.unl.pt/en/lisbon-summer-school-in-linguistics-2021/>”)
 - a word (for example *School*)
 -

Identifying Resources



“my” concrete book: Duden 1



The catalogue number of our library, for “my” book

ISBN 3-411-04010-6

The ISBN number for this edition of the Duden 1 book. This is a unique resource name (URN)



https://en.wikipedia.org/wiki/International_Standard_Book_Number

I can create a URI for my resource

<https://www.example.org/Mybook>

Example Domain

“This domain is for use in illustrative examples in documents. You may use this domain in literature without prior coordination or asking for permission.” (<http://www.example.org/>)

Identifying Resources: Person, Webpage



http://example.org/Person#Sara_Carvalho

Sara Micaela Pereira Carvalho

ESTGA

Category: Professor Adjunto
Cabinet: 7.1.6
Extension: 41141
External Phone: 234611500



sara.carvalho@ua.pt



Short cv

Sara Carvalho holds a PhD in Linguistics (Lexicology, Lexicography and Terminology) and in Sciences de l'Information et de la Communication. Her thesis, entitled "A terminological approach to knowledge organization within the scope of endometriosis: the EndoTerm project", was developed within the scope of a co-tutelle agreement between the Universidade NOVA de Lisboa and the Communauté Université Grenoble Alpes. She holds an MA in German Studies – specialization in German Linguistics – from the University of Aveiro (UA), and graduated in Modern Languages and Literature (English and German Studies) at the Faculty of Humanities – University of Coimbra.

She is currently a researcher at the Linguistics Research Centre of the Universidade NOVA de Lisboa (CLUNL) and a collaborator at the Languages, Literatures and Cultures Research Centre of the University of Aveiro (CLLC). In addition, she is a member of the ISO/TC 37/SC 4/WG 4, entitled "Lexical resources", and of the COST Action 18209 - European network for Web-centred linguistic data science, where she leads WG4 - Use cases and applications. She is also part of the Business English Special Interest Group (BESIG), from the International Association of Teachers of English as a Foreign Language (IATEFL), and participated in Working Group 2 (Retro-digitized dictionaries) at the European Network of e-Lexicography (ENeL).

She has been teaching at the Águeda School of Technology and Management (ESTGA) - University of Aveiro (UA) since 2002, namely in the fields of Languages for Specific Purposes (English and German) and translation technologies. Since 2013, she has also been responsible for the curricular unit of German Linguistics at the Department of Languages and Cultures (UA).

research areas

terminology and ontologies, medical terminology, e-lexicography, language teaching for specific purposes

<https://www.ua.pt/en/p/10320064>

What is a description (RDF)?

- An association of simple properties (called predicates) and property values to the identified resource, pointing to other resources or to literals (examples to come)
- This also helps in **classifying** resources
- RDF properties help to **describe** (or “**represent**”) resources in a formal way, using Semantic Web technologies.

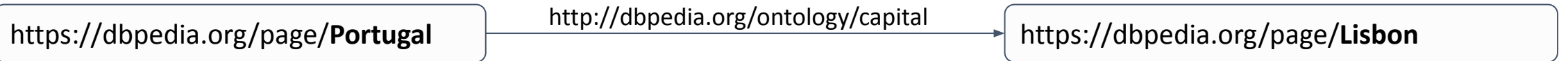


*Identify a resource (with a URI) and associate to it properties pointing to other resources (URIs) or to literal values: **This is the basis of the RDF Data Model***

The Structure of the RDF Data model: RDF triples

- Core structure of the RDF data model: **RDF triple**
- A simple way to make statements about resources:

<subject, predicate, object>



Describing a Person Resource and linking it to a Webpage Resource



Sara Micaela Pereira Carvalho

ESTGA

Category: Professor Adjunto
Cabinet: 7.1.6
Extension: 41141
External Phone: 234611500

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research areas

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sara.carvalho@ua.pt



Subject = http://example.org/Person#Sara_Carvalho

Predicate = <http://example.org/hasWebpage>

Object = <https://www.ua.pt/en/p/10320064>

~~http://example.org/Person#Sara_Carvalho~~

hasBirthDate ...

livesIn ...

hasPosition ...

hasWebpage

<https://www.ua.pt/en/p/10320064>

Interlinking a Person Resource and a Webpage Resource



Sara Micaela Pereira Carvalho

ESTGA

Category: Professor Adjunto
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research areas

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sara.carvalho@ua.pt
in

Subject = http://example.org/Person#Sara_Carvalho
Predicate = <http://example.org/hasWebpage>
Object = <https://www.ua.pt/en/p/10320064>

Subject = <https://www.ua.pt/en/p/10320064>
Predicate = <http://example.org/isAbout>
Object = http://example.org/Person#Sara_Carvalho

http://example.org/Person#Sara_Carvalho

hasBirthDate ...

livesIn ...

hasPosition ...

hasWebpage

<https://www.ua.pt/en/p/10320064>

hasCreationDate

usesHtmlVersion ...

hasLanguage ...

isAbout

RDF Resources: introducing rdf:type



http://example.org/Person#Sara_Carvalho

is_a Person

hasBirthDate ...

livesIn ...

hasPosition ...

hasWebpage

Expressing the fact that the resource “Sara Carvalho” is an instance of a class called “Person”.

More on “classes” and “instances” in the sessions on “RDF Schema” and “OWL”

Subject = http://example.org/Person#Sara_Carvalho

Predicate = <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>

Object = <http://xmlns.com/foaf/0.1/Person>

RDF: A graph-based Data Model

A set of such triples is called **an RDF graph**. An RDF graph can be visualized as a node and directed-arc diagram, in which each triple is represented as a node-arc-node link.
(<https://www.w3.org/TR/rdf11-concepts/#data-model>)



A Graph for “Mybook”

A simple RDF Statement and its representation as an RDF Triple

A subject node

`https://www.example.org/book#Mybook`

A predicate arc/edge

`http://purl.org/dc/terms/publisher`
Existing property (URI)

An object node

`https://www.duden.de/`

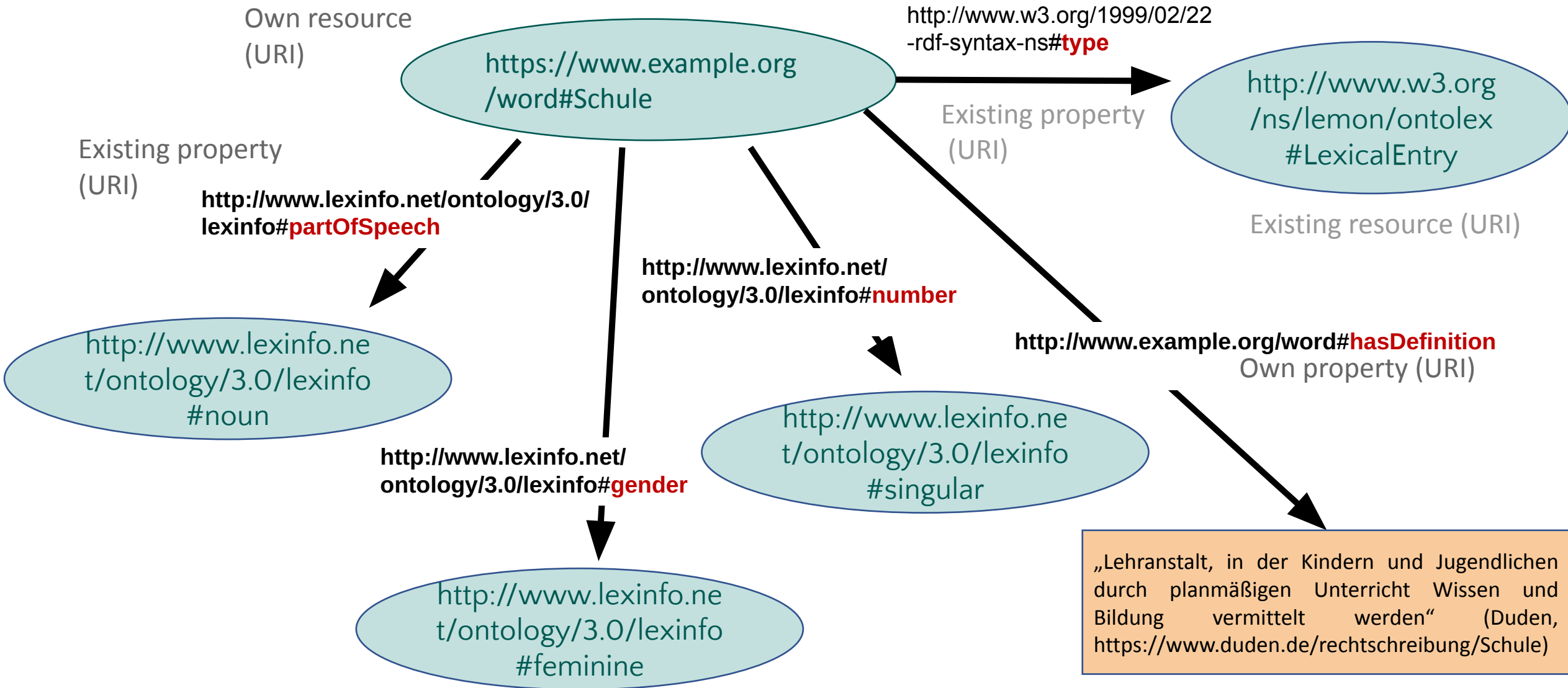
The graph as a “triple”:

`http://www.example.org/mybook`
subject

`http://purl.org/dc/terms/publisher`
predicate

`https://www.duden.de/`
object

A lexicographic Entry in RDF



Some Restrictions on the Elements of a Triple

The **Subject** of a RDF statement is a **URI/IRI** (or a Blank Node, described later)

The **Predicate** of a RDF statement is a **URI/IRI**

The **Object** of a RDF statement is a **URI/IRI, or a literal** (or a Blank Node, described later)

`https://www.example.org/book#Mybook`

Subject

`http://purl.org/dc/terms/publisher`

Predicate

`https://www.duden.de/`

Object

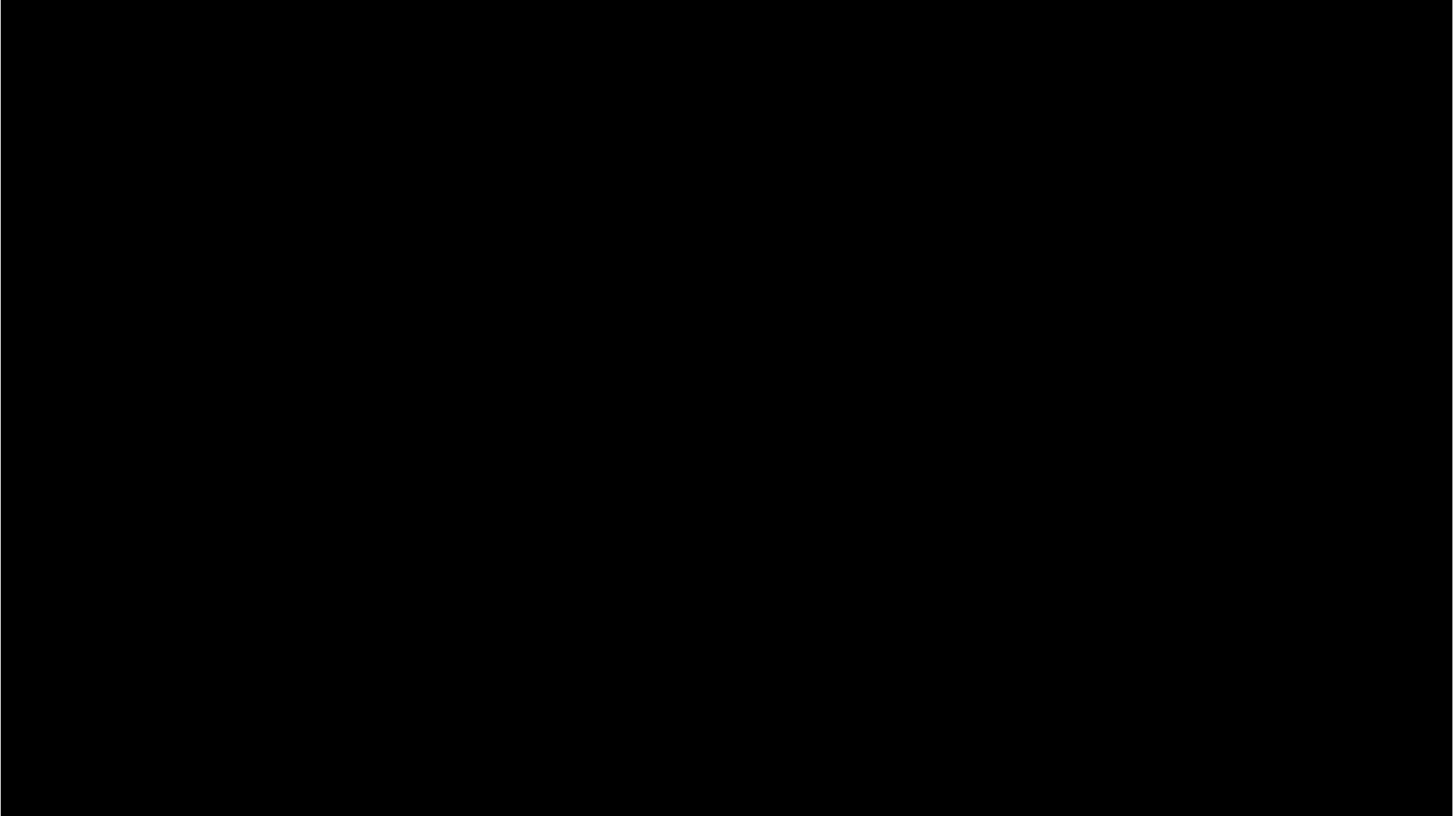
`https://www.example.org/book#Mybook`

`http://www.example.org/hasfPages`

831

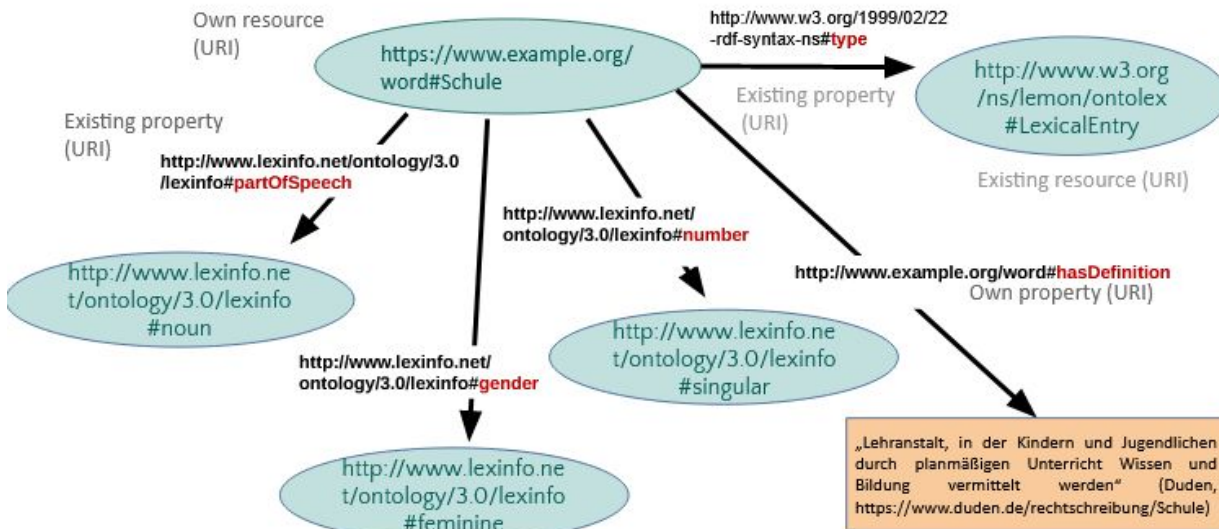
More examples in the animation on the next slide:

Some Restrictions on the Elements of a Triple (2)



Details on this Graph (previous slide)

A lexicographic Entry in RDF



- **Green ellipses** → URI values (resources) of the **subject** and **object** of properties
- **Arrows** → **properties**, labeled with URIs
- The orange **rectangle** → a **literal** value of a property
- We reused the vocabularies of existing ontologies/models for linguistic data: **Lexinfo** and **OntoLex**
 - More details on this topic in the next lectures.

The “Schule” Entry as a Set of Triples

- NOT machine-readable
- Verbose (subject repeated 5 times!)

<https://www.example.org/word#Schule> ; <http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
<http://www.w3.org/ns/lemon/ontolex#LexicalEntry>

<https://www.example.org/word#Schule> ; <http://www.lexinfo.net/ontology/3.0/lexinfo#partOfSpeech>
<http://www.lexinfo.net/ontology/3.0/lexinfo#noun>

<https://www.example.org/word#Schule> ; <http://www.lexinfo.net/ontology/3.0/lexinfo#gender>
<http://www.lexinfo.net/ontology/3.0/lexinfo#feminine>

<https://www.example.org/word#Schule> ; <http://www.lexinfo.net/ontology/3.0/lexinfo#number>
<http://www.lexinfo.net/ontology/3.0/lexinfo#singular>

<https://www.example.org/word#Schule> ; <http://www.example.org/word#hasDefinition>

“Lehranstalt, in der Kindern und Jugendlichen durch planmäßigen Unterricht Wissen und Bildung vermittelt werden” (Duden, <https://www.duden.de/rechtschreibung/Schule>)

The need of a syntax to make the RDF Data Model machine-readable and interpretable: RDF Serialization

Serializations of RDF Data Models

- “In computing, **serialization** (US spelling) or **serialisation** (UK spelling) is **the process of translating a data structure or object state into a format that can be stored [..] or transmitted [...]** and reconstructed later (possibly in a different computer environment)” (<https://en.wikipedia.org/wiki/Serialization>). [Emphasis added]
- There are a number of serialization formats for RDF [1]

*We concentrate in this school on **Turtle** [2], which stands for “Terse RDF Triple Language”.*

[1] <https://www.w3.org/TR/rdf11-primer/#section-graph-syntax>

[2] <https://www.w3.org/TR/turtle/>

A text-based syntax for storing and exchanging RDF Models/Graphs

Writing Turtle:

1. We want to shorten the URIs, to make the models also (a bit) human-readable. We use for this “**namespaces**”:

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

```
@prefix ontollex: <http://www.w3.org/ns/lemon/ontollex#> .
```

```
@prefix lexinfo: <http://www.lexinfo.net/ontology/3.0/lexinfo#> .
```

```
@prefix ex: <http://www.example.org/word#> .
```

...leading to:

```
ex:Schule rdf:type ontollex:LexicalEntry .
```

```
ex:Schule lexinfo:number lexinfo:singular .
```

```
ex:Schule ex:hasDefinition “Lehranstalt, in der Kindern und Jugendlichen durch planmäßigen Unterricht Wissen und Bildung vermittelt werden (Duden)” .
```

Expressions like “lexinfo:number ” are called “qualified names” (QName) → shorthand for the full URI: “lexinfo:number ” stands for “http://www.lexinfo.net/ontology/3.0/lexinfo#number”

A text-based syntax for storing and exchanging RDF Models/Graphs

Writing Turtle:

2. We want to reduce redundancy and **mention the subject only once**.
Properties associated with the subject are “;”- separated. The graph is closed with “.”

`https://www.example.org/word#Schule`

`rdf:type ontalex:LexicalEntry ;`

`lexinfo:number lexinfo:singular ;`

`lexinfo:gender lexinfo:feminine ;`

`lexinfo:partOfSpeech lexinfo:noun ;`

`ex:hasDefinition “Lehranstalt, in der Kindern und Jugendlichen durch planmäßigen Unterricht
 Wissen und Bildung vermittelt werden”@de-DE .`

A text-based syntax for storing and exchanging RDF Models/Graphs

Writing Turtle:

3. Another Turtle simplification consist in abbreviating **rdf:type** to **“a”**:

`https://www.example.org/word#Schule`

`a ontalex:LexicalEntry ;`

`lexinfo:number lexinfo:singular ;`

`lexinfo:gender lexinfo:feminine ;`

`lexinfo:partOfSpeech lexinfo:noun ;`

`ex:hasDefinition “Lehranstalt, in der Kindern und Jugendlichen durch planmäßigen Unterricht Wissen und Bildung vermittelt werden”@de-DE .`

Files containing an RDF model serialized with the Turtle syntax are commonly using the extension **“*.ttl”**

Serializations of RDF Data Models

- RDF/XML:
 - XML-based syntax
 - First proposed format
- Turtle:
 - Compact and aimed at human-readable
- N-Triples
 - Easy to parse, line-based, but not as compact as Turtle
- N-Quads
 - Superset of N-triples, used to serialize multiple RDF graphs
- JSON-LD
 - JSON-based
- N3 or Notation3
 - Similar to Turtle and supports inference rule definition

RDF/XML (abbreviated example)

```
<rdf:RDF>
```

```
  <rdf:Description rdf:about="http://dbpedia.org/resource/Lisbon">
```

```
    <rdf:type rdf:resource="http://dbpedia.org/ontology/City"/>
```

```
    <rdf:type rdf:resource="http://dbpedia.org/class/yago/Region108630985"/>
```

```
    <rdf:type rdf:resource="http://dbpedia.org/class/yago/Town108665504" />
```

```
      <rdf:type rdf:resource="http://schema.org/City" />
```

```
      <rdf:type rdf:resource="http://schema.org/Place" />
```

```
      <rdfs:label xml:lang="sv">Lissabon</rdfs:label>
```

```
      <rdfs:label xml:lang="ko">리스본</rdfs:label>
```

```
      <rdfs:label xml:lang="nl">Lissabon</rdfs:label>
```

```
      <rdfs:label xml:lang="en">Lisbon</rdfs:label>
```

```
      <rdfs:comment xml:lang="en">
```

Lisbon (; Portuguese: Lisboa; [liʒˈboɐ] ()) is the capital and the largest city of Portugal, with an estimated population of 505,526 within its administrative limits in an area of 100.05 km². Lisbon's urban area extends beyond the city's administrative limits with a population of around 2.8 million people, being the 10th-most populous urban area in the European Union. ... </rdfs:comment>

```
      <rdfs:comment xml:lang="el">
```

Η Λισαβόνα ή Λισσαβώνα, (πορτογαλικά: Lisboa (Λισμπόα)), παλαιότερα Ολισσιπόννα, είναι η πρωτεύουσα και η μεγαλύτερη πόλη της Πορτογαλίας. Η Λισαβόνα έχει πληθυσμό 552.700 κατοίκους ενώ η μητροπολιτική (γενικότερη) περιοχή της Λισαβόνας με τα προάστια έχει σχεδόν 3.000.000 κατοίκους (2013). ... </rdfs:comment>

```
      <geo:lat rdf:datatype="http://www.w3.org/2001/XMLSchema#float">38.7253</geo:lat>
```

```
      <geo:long rdf:datatype="http://www.w3.org/2001/XMLSchema#float">-9.15002</geo:long>
```

```
    </rdf:Description>
```

```
</rdf:RDF>
```

JSON-LD (abbreviated example)

```
{ "http://dbpedia.org/resource/Lisbon" : {  
  "http://www.w3.org/1999/02/22-rdf-syntax-ns#type" :  
    [{ "type" : "uri", "value" : "http://schema.org/City" } ,  
     { "type" : "uri", "value" : "http://schema.org/Place" },  
     { "type" : "uri", "value" : "http://dbpedia.org/class/yago/Region108630985 " } [...]  
  ],  
  "http://www.w3.org/2000/01/rdf-schema#label": [  
    { "type" : "literal", "value" : "Lisbona" , "lang" : "it" } ,  
    { "type" : "literal", "value" : "Lissabon" , "lang" : "nl" } ,  
    { "type" : "literal", "value" : "Lisboa" , "lang" : "eu" } ,  
    { "type" : "literal", "value" : "Lisbon" , "lang" : "en" } ,  
    { "type" : "literal", "value" : "Lisboa" , "lang" : "es" }  
  ],  
  "http://www.w3.org/2000/01/rdf-schema#comment" : [  
    { "type" : "literal", "value" : " Lisbon (; Portuguese: Lisboa; [li\u0292\u02C8bo\u0250] ()) is the capital and the largest city of Portugal,  
    with an estimated population of 505,526 within its administrative limits in an area of 100.05 km2. Lisbon's urban area extends  
    beyond the city's administrative limits with a population of around 2.8 million people, being the 10th-most populous urban area  in the  
    European Union. [...] , "lang" : "en" } , [...] ]  
  ],  
  "http://www.w3.org/2003/01/geo/wgs84_pos#lat" : [ { "type" : "literal", "value" : 38.72526550292969 , "datatype" :  
    "http://www.w3.org/2001/XMLSchema#float" } ] ,  
  "http://www.w3.org/2003/01/geo/wgs84_pos#long" : [ { "type" : "literal", "value" : -9.150019645690918  
    , "datatype" : "http://www.w3.org/2001/XMLSchema#float" } ] ,  
  "http://dbpedia.org/property/populationTotal" : [ { "type" : "literal", "value" : 505526 , "datatype" :  
    "http://www.w3.org/2001/XMLSchema#integer" } ].
```

Turtle (abbreviated example)

```
@prefix dbo: <http://dbpedia.org/ontology/> .
@prefix dbr: <http://dbpedia.org/resource/> .
@prefix schema: <http://schema.org/> .
@prefix yago: <http://dbpedia.org/class/yago/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84\_pos#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
```

dbr:Lisbon

```
    rdf:type    schema:City , schema:Place , yago:Marina103721590 , yago:Dock103216828 ,    yago:Landing103638321 ,
wikidata:Q486972 , wikidata:Q515 ;
```

```
    rdfs:label   "Lissabon"@nl , "Lisbon"@en , "Lisboa"@pt ;
```

```
    rdfs:comment "Lisbon (; Portuguese: Lisboa; [li\u0292\u02C8bo\u0250] ()) is the capital and the largest city of Portugal, with an
estimated population of 505,526 within its administrative limits in an area of 100.05 km2. Lisbon's urban area extends beyond the city's
administrative limits with a population of around 2.8 million people, being the 10th-most populous urban area in the European
Union..."@en ;
```

```
    foaf:homepage <http://www.cm-lisboa.pt/> ;
```

```
    geo:lat      "38.7252655029296875"^^xsd:float ;
```

```
    geo:long     "-9.1500196456909179688"^^xsd:float ;
```

```
    .....
```

```
    .
```

RDF Vocabulary Terms

- In www.w3.org/1999/02/22-rdf-syntax-ns# we find the **list of terms** (all realised as a URI, clearly) that can be used for describing elements of the RDF Data Model, or “RDF vocabulary terms in the RDF Namespace”. For example:
 - `rdf:Property` a `rdfs:Class` (`rdfs:Class` to be explained in the next session)
 - `rdf:Statement` a `rdfs:Class`
 - `rdf:type` a `rdf:Property`
 - `rdf:subject` a `rdf:Property` (“The subject of the subject RDF statement”)
 - `rdf:predicate` a `rdf:Property` (“The predicate of the subject RDF statement”)
 - `rdf:object` a `rdf:Property` (“The object of the subject RDF statement.”)
- With those terms (URIs) and some others, one can write RDF statements, in general dealing with **instances of classes** (see the session on RDF Schema)
- But **the RDF Vocabulary Terms are not enough** for describing the classes themselves and the interactions between those. Therefore, the need for RDF Schema Vocabulary Terms

Blank Nodes

- Blank nodes are **nodes** in an RDF Graph, which have **neither a URI/IRI or a literal values**. This applies only to Subject and Object Nodes:

“Blank nodes are treated as simply indicating **the existence of a thing, without using a URI (Uniform Resource Identifier) to identify any particular thing**. This is not the same as assuming that the blank node indicates an 'unknown' URI.” [1]

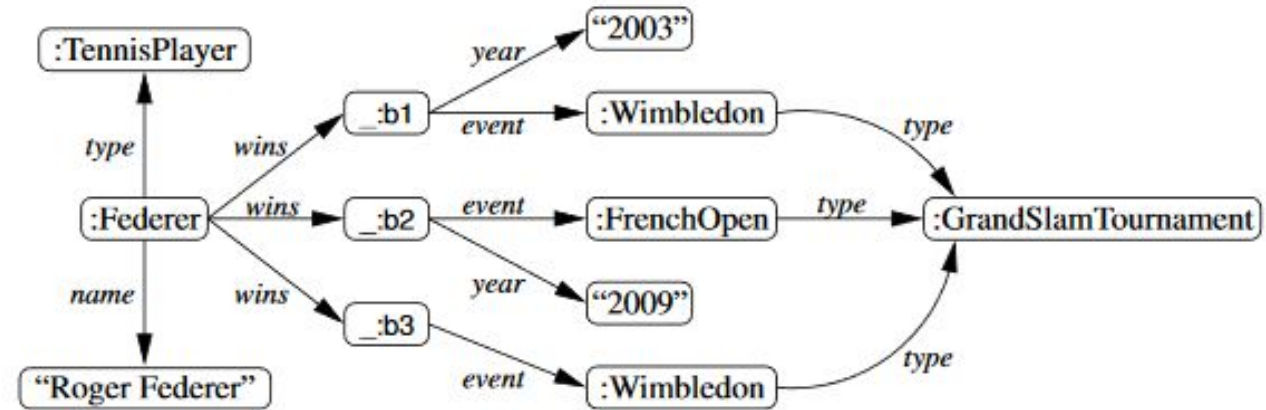


Fig. 1. An RDF graph for our running example. In this graph, URIs are preceded by ':' blank nodes by '_' and literals are enclosed in quotation marks.

- Why** using a blank node? For case one think there is **no need to have an identifiable** (e.g., by means of a URI/IRI) node, for example dealing with structured information, also helping in ordering triples.



Taken from: Mallea, M. Arenas, A. Hogan, and A. Polleres. On Blank Nodes. In The Semantic Web--ISWC 2011, pages 421--437. Springer, 2011.

Other Examples for the Use of Blank Nodes: Underspecified Information

Blank nodes

Subjects and objects can also be Blank nodes
Blank nodes can have local identifiers



taken from <https://www.slideshare.net/jelabra/rdf-data-model>

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .  
  
# Someone knows someone else, who has the name "Bob".  
[] foaf:knows [ foaf:name "Bob" ] .
```

taken from <https://www.w3.org/TR/turtle/#BNodes>

On the factuality of RDF Triples: Reification

- It is not possible to contradict an RDF Triple comparing it to another RDF Triple, using only the vocabulary terms of RDF (there is the need for more expressive formalisms).

So, for example for the triples (ex:Portugal, ex:hasCapital, ex:Madrid) and (ex:Portugal, ex:hasCapital, ex:Lisbon)

- But **one can “reify” a triple and create a new RDF Statement**, that “(ex:Portugal, ex:hasCapital, ex:Madrid)” is false (in fact, adding Metadata to an RDF Statement). **In doing so, an RDF statement is being considered itself as a resource, which can be described, adding properties to it.**

Example of Reification

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

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

```
@prefix ex: <http://example.org#> .
```

ex:triple1

```
  rdf:type rdf:Statement ;  
  rdf:subject <https://dbpedia.org/page/Portugal> ;  
  rdf:predicate <http://dbpedia.org/ontology/capital> ;  
  rdf:object <https://dbpedia.org/page/Madrid> .
```

ex:triple2

```
  rdf:type rdf:Statement ;  
  rdf:subject <https://dbpedia.org/page/Portugal> ;  
  rdf:predicate <http://dbpedia.org/ontology/capital> ;  
  rdf:object <https://dbpedia.org/page/Lisbon> .
```

ex:triple1 ex:hasTruthValue “false”

ex:triple2 ex:hasTruthValue “true”



Although Reification could be used for adding metadata to RDF statements, “the RDF reification mechanism is hardly used by RDF applications and even members of the former W3C RDF Core working group, who have designed the mechanism, are recommending not to use it” (Christian Bizer: Quality-Driven Information Filtering in the Context of Web-Based Information Systems. Dissertation, Berlin, Germany, March 2007.)

Example of Reification : Temporal Validity

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
@prefix ex: <http://example.org#/> .
```

ex:triple1

```
rdf:type rdf:Statement ;  
rdf:subject <https://dbpedia.org/page/Lisbon> ;  
rdf:predicate ex:isCapitalOf ;  
rdf:object <https://dbpedia.org/page/  
United\_Kingdom\_of\_Portugal,\_Brazil\_and\_the\_Algarves> .
```

ex:triple2

```
rdf:type rdf:Statement ;  
rdf:subject <https://dbpedia.org/page/Lisbon> ;  
rdf:predicate ex:isCapitalOf ;  
rdf:object <https://dbpedia.org/page/  
First\_Portuguese\_Republic> .
```

ex:triple1 ex:hasTempVal 16.12.1815-29.08.1825

ex:triple2 ex:hasTempVal 5.10.1910-28.05.1926



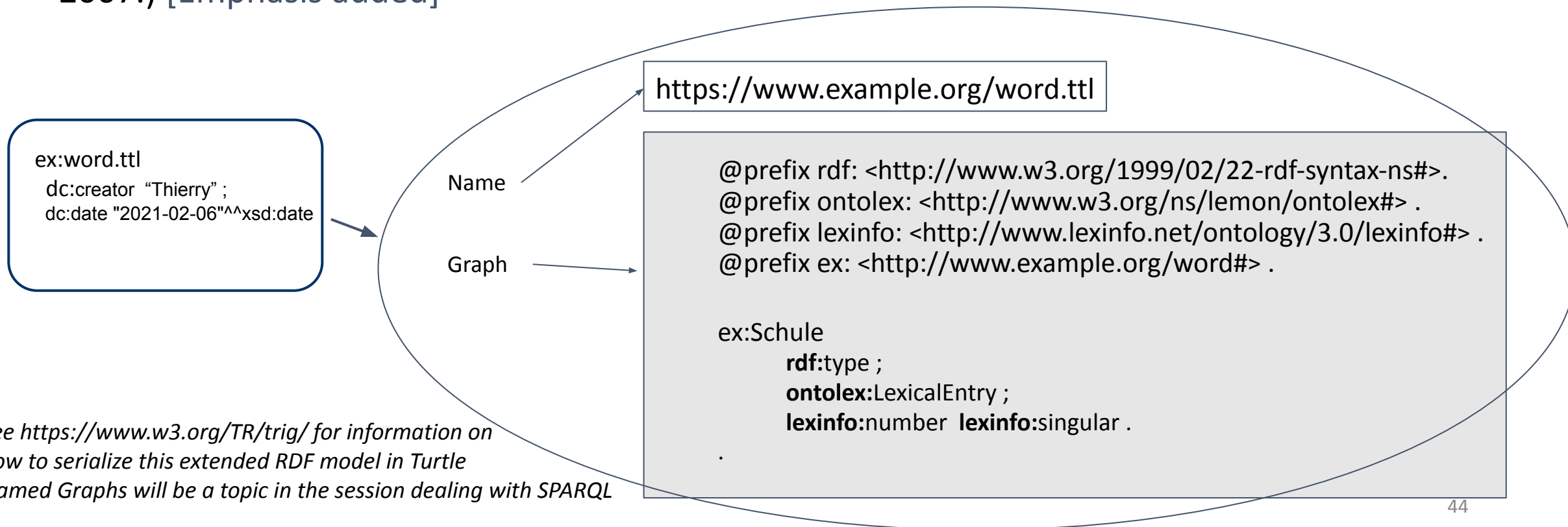
Although Reification could be used for adding metadata to RDF statements, “the RDF reification mechanism is hardly used by RDF applications and even members of the former W3C RDF Core working group, who have designed the mechanism, are recommending not to use it” (Christian Bizer: Quality-Driven Information Filtering in the Context of Web-Based Information Systems. Dissertation, Berlin, Germany, March 2007.)

Drawbacks of RDF Reification

- Although Reification could be used for adding metadata to RDF statements, “the RDF reification mechanism **is hardly used by RDF applications** and even members of the former W3C RDF Core working group, who have designed the mechanism, are recommending not to use it” (Christian Bizer: Quality-Driven Information Filtering in the Context of Web-Based Information Systems. Dissertation, Berlin, Germany, March 2007.)
- “The analysis shows that the RDF data model does not provide an efficient mechanism for representing information together with quality-related meta-information.” (Christian Bizer. Quality-Driven Information Filtering in the Context of Web-Based Information Systems. Dissertation, Berlin, Germany, March 2007.)

Named RDF Graphs

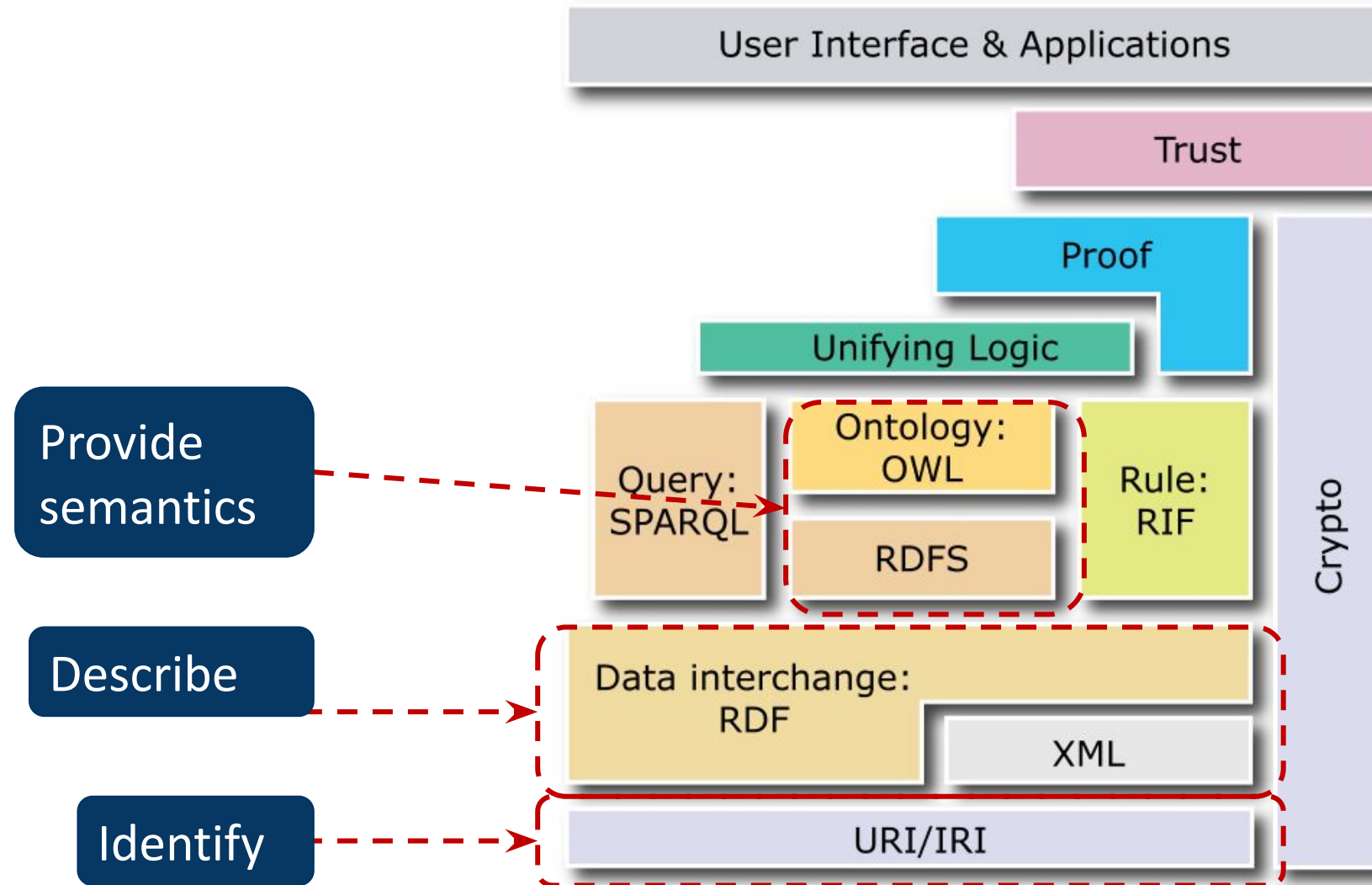
“The Named Graphs data model is a **simple variation of the RDF data model**. The basic idea of the model is to introduce a **graph naming mechanism**, which allows RDF triples to talk about RDF graphs. **A named graph is an entity which consists of an RDF graph and a name in the form of a URI reference.**” (Christian Bizer. Quality-Driven Information Filtering in the Context of Web-Based Information Systems. Dissertation, Berlin, Germany, March 2007.) [Emphasis added]



RDF Schema (RDF-S)

Julia Bosque-Gil (University of Zaragoza, Spain)
Thierry Declerck (DFKI, Germany & ACDH-CH, Austria)

URIs, RDF, RDF(s) within the Semantic Web Stack



'A visual representation of the semantic web's structure, often referred to as "layer cake"', taken from:
http://webservices.itcs.umich.edu/mediawiki/DigitalRhetoricCollaborative/index.php/Image:Semantic_Web_Stack.png

RDF Vocabulary

- RDF Vocabulary → essentially the set of URIs for the edges that make up RDF graphs [1]
- The RDF data model provides **a way to make statements about resources**, it does not make any assumptions about what resource IRIs stand for.
- RDF has a limited vocabulary (set of terms) that is applied mainly for the **purpose of modelling your data as a triple**
- RDF is typically used in combination with vocabularies that provide semantic information about these resources [2]

[1] <https://www.cambridgesemantics.com/blog/semantic-university/learn-rdf/>

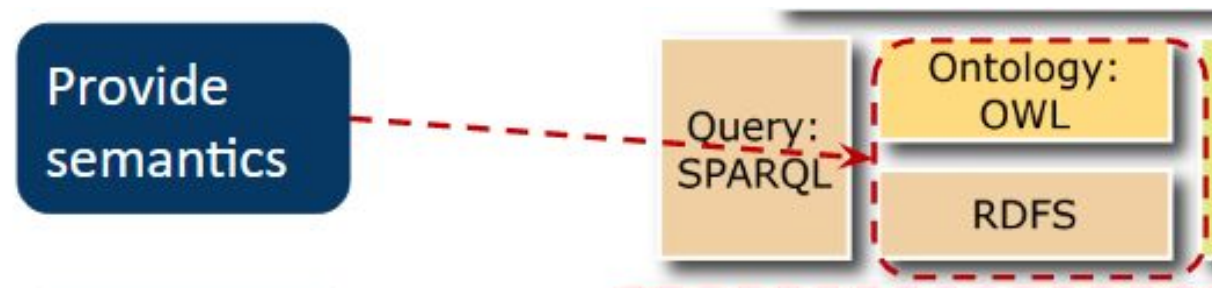
[2] <https://www.w3.org/TR/rdf11-primer/#section-vocabulary>

RDF Schema

- To extend this, RDF provides for a schema that “allows one to define semantic characteristics of RDF data”

“RDF Schema is **a semantic extension of RDF**. It provides mechanisms for describing groups of related resources and the relationships between these resources. RDF Schema is written in RDF [...]. These resources are used to determine characteristics of other resources [...].” [Emphasis added]

(https://www.w3.org/TR/rdf-schema/#ch_introduction)



RDF Schema – or RDF(s)

Construct	Syntactic form	Description
<u>Class</u> (a class)	C <code>rdf:type</code> <code>rdfs:Class</code>	C (a resource) is an RDF class
<u>Property</u> (a class)	P <code>rdf:type</code> <code>rdf:Property</code>	P (a resource) is an RDF property
<u>type</u> (a property)	I <code>rdf:type</code> C	I (a resource) is an instance of C (a class)
<u>subClassOf</u> (a property)	C1 <code>rdfs:subClassOf</code> C2	C1 (a class) is a subclass of C2 (a class)
<u>subPropertyOf</u> (a property)	P1 <code>rdfs:subPropertyOf</code> P2	P1 (a property) is a sub-property of P2 (a property)
<u>domain</u> (a property)	P <code>rdfs:domain</code> C	domain of P (a property) is C (a class)
<u>range</u> (a property)	P <code>rdfs:range</code> C	range of P (a property) is C (a class)

<https://www.w3.org/TR/rdf11-primer/#section-vocabulary>

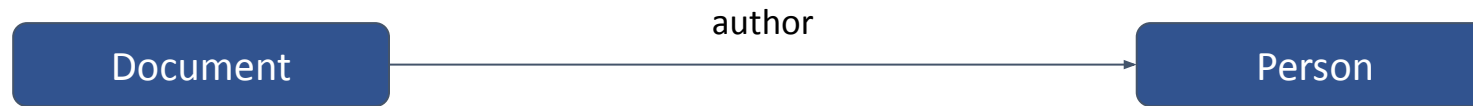
The RDF(s) vocabulary (set of terms) is available at: www.w3.org/2000/01/rdf-schema#

RDF Schema

- The RDF Schema class and property system is **similar to the type systems of object-oriented programming languages** such as Java.
- **BUT:** instead of defining a class in terms of the properties its instances may have, RDF Schema describes properties in terms of the classes of resource to which they apply. This is the role of the **domain and range mechanisms** described in this specification.
 - **ex:author** property with domain **ex:Document** and range **ex:Person** VS. classical object-oriented system class **ex:Book** with an attribute called **ex:author** of type **ex:Person**.

RDF Schema

- **ex:author** property with domain **ex:Document** and range **ex:Person**
VS. classical object-oriented system class **ex:Book** with an attribute called **ex:author** of type **ex:Person**. Using the RDF approach, it is **easy for others to subsequently define additional properties** with a domain of **ex:Document** or a range of **ex:Person**



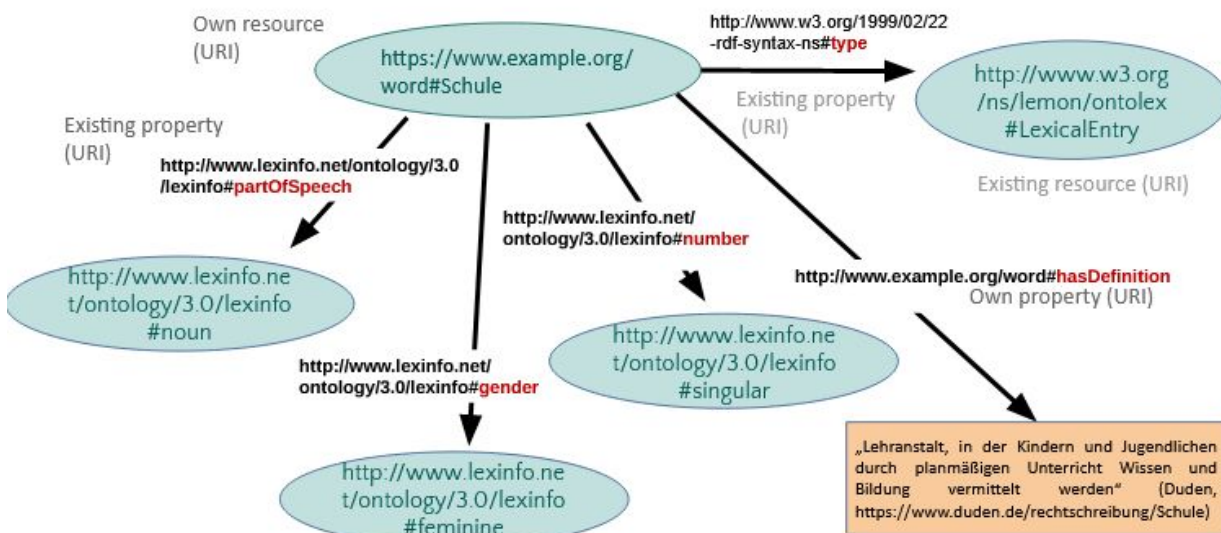
Working on our DUDEN Example

- **Subclasses** of an `ontolex:LexicalEntry` (owl:Class will be explained tomorrow!)

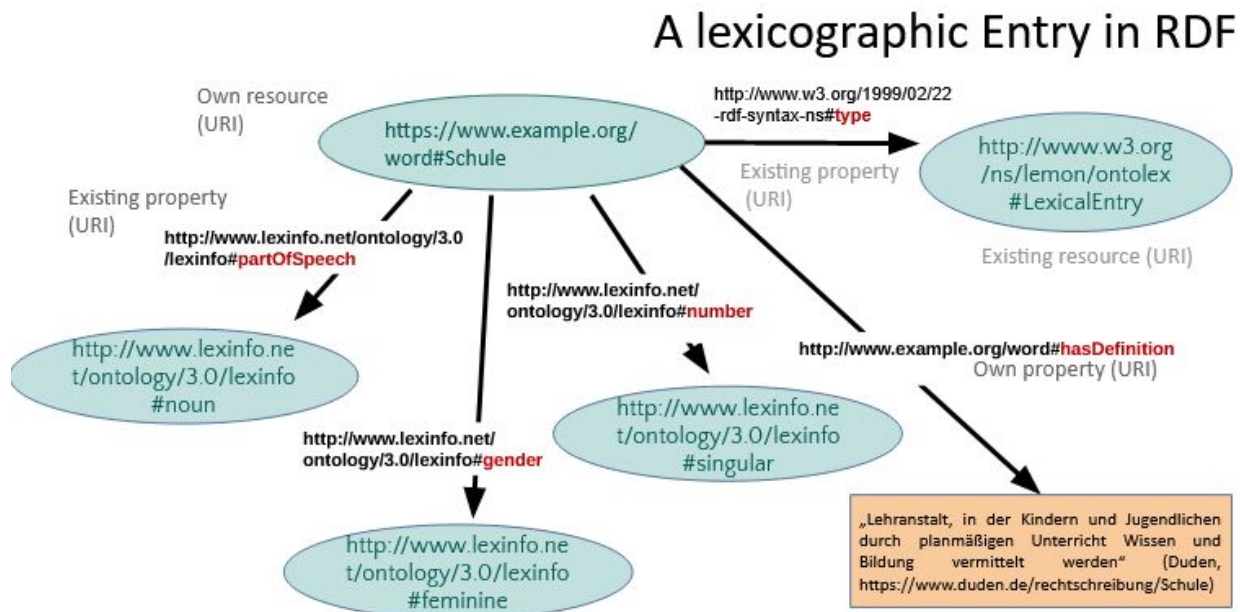
```
ontolex:Word a rdfs:Class;  
  rdfs:subClassOf ontolex:LexicalEntry .  
ontolex:Phrase a rdfs:Class;  
  rdfs:subClassOf ontolex:LexicalEntry .
```

- “Schule” as an **instance** of the “Word” class (and by inference, also an instance of the `LexicalEntry` class)

A lexicographic Entry in RDF



Working on our DUDEN Example



- “Schule” as an **instance** of the “Word” class (and by inference, also an instance of the `LexicalEntry` class)

`ex:Schule a ontolex:Word;`

`lexinfo:number lexinfo:singular;`

`lexinfo:gender lexinfo:feminine .`

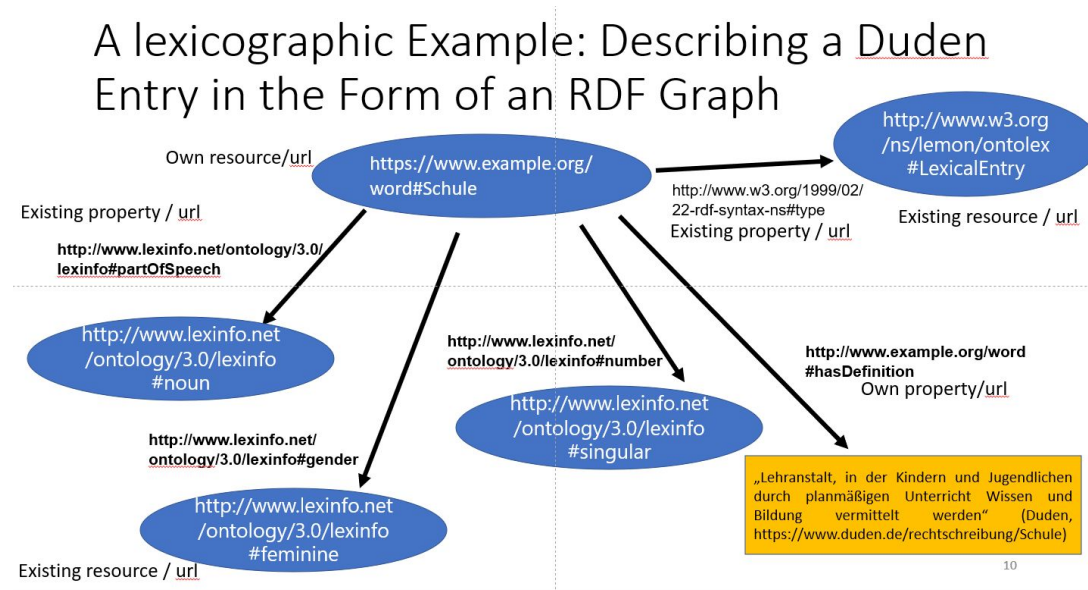
- From the [LexInfo](#) vocabulary we know that **lexinfo:number** is a sub-property of **lexinfo:morphosyntacticProperty**

Working on our DUDEN Example

- From the [LexInfo](#) vocabulary we know that **lexinfo:number** is a sub-property of **lexinfo:morphosyntacticProperty**
- We can specify with **rdfs:domain** for **lexinfo:morphosyntacticProperty** that its subject has to be of type **ontolex:LexicalEntry** and with **rdfs:range** we can be more specific and state that the object of **lexinfo:number** has to be of type **lexinfo:Number**.

```
<owl:ObjectProperty rdf:about="http://www.lexinfo.net/ontology/3.0/lexinfo#number">
  <rdfs:range rdf:resource="http://www.lexinfo.net/ontology/3.0/lexinfo#Number"/>
  <rdfs:subPropertyOf rdf:resource="http://www.lexinfo.net/ontology/3.0/lexinfo#morphosyntacticProperty"/>
  <rdfs:comment xml:lang="en">
    Grammatical category for the variation in form of nouns, pronouns, and any words agreeing with them, depending on how many persons or things are referred to. // In many languages,
    the grammatical distinction that indicates the number of objects referred to by the term or word.
  </rdfs:comment>
  <rdfs:label xml:lang="en">number</rdfs:label>
  <owl:priorVersion rdf:resource="http://www.lexinfo.net/ontology/2.0/lexinfo#number"/>
</owl:ObjectProperty>
```

Working on our Example (2)



- We can specify with **rdfs:domain** for `lexinfo:morphosyntacticProperty` (and so for “`lexinfo:number`”) that its subject has to be of type “`ontolex:LexicalEntry`” and with **rdfs:range** we can be more specific and state that the object of “`lexinfo:number`” has to be of type `lexinfo:Number` (not the capital letter for designating a class, instead of a property). This class has 9 instances: “collective”, “dual”, `massNoun`, “otherNumber”, “paucal”, “plural”, “quadrial”, “singular” and “trial”, out of which we selected “singular”. (See <https://lexinfo.net/ontology/3.0/lexinfo>).

Some more aspects of RDF(S)

- All things described by RDF are called *resources*, and are **instances of the class `rdfs:Resource`**. This is the class of everything. All other classes are subclasses of this class. `rdfs:Resource` is an instance of `rdfs:Class`.
- The class **`rdfs:Literal`** is the **class of literal values** such as strings and integers. Property values such as textual strings are examples of RDF literals. `rdfs:Literal` is an instance of `rdfs:Class`. `rdfs:Literal` is a subclass of `rdfs:Resource`.
- The property **`rdfs:subClassOf`** is an instance of `rdf:Property` that is used **to state that all the instances of one class are instances of another**. A triple of the form: `C1 rdfs:subClassOf C2` states that `C1` is an instance of `rdfs:Class`, `C2` is an instance of `rdfs:Class` and `C1` is a subclass of `C2`. The `rdfs:subClassOf` property is transitive.

RDF(s) Annotation Properties

- RDF(s) introduces a **special type of properties** -> allow the human readable reading and understanding of the “meaning” of classes and properties.
- The values of annotation properties are not inherited from one class to a subclass!
 - **rdfs:label** → to provide a human-readable version of a resource's name
 - **rdfs:comment** → to provide a human-readable description of a resource

Let's check out our **Lisbon** example ([slide 34](#))

- More such annotation properties are available in distinct vocabularies

rdfs:label and rdf:comment

- OWL and RDF(S) rely on **rdfs:label** to capture the relation between a vocabulary element and its (preferred) lexicalization in a given language. This lexicalization provides a lexical anchor that makes the concept, property, individual etc. understandable to a human user.
[1]
- An Example [2] showing how in RDF(s) multilinguality is dealt with for naming concepts/classes:

```
:PhraseElement a rdfs:Class ;  
    rdfs:subClassOf :LemonElement ;  
    rdfs:comment "A terminal node in a phrase structure graph, i.e., a realisable,  
lexical element."@en ;  
    rdfs:label "Elemento del sintagma"@es, "Elément du syntagme"@fr, "Phrase  
element"@en, "Phrase-Element"@de, "Zinselement"@nl .
```

[1] <https://www.w3.org/2016/05/ontolex/#introduction>

[2] Taken and adapted from <http://lemon-model.net/lemon#>

References used in this Session

W3C Resources

<https://www.w3.org/TR/rdf11-primer/#section-vocabulary>
<https://www.w3.org/TR/2014/NOTE-rdf11-primer-20140624/>
<https://www.w3.org/TR/rdf11-concepts/#data-model>
<https://www.w3.org/TR/turtle/>
<https://www.w3.org/TR/rdf11-primer/#section-graph-syntax>
https://www.w3.org/TR/rdf-schema/#ch_introduction
www.w3.org/2000/01/rdf-schema#
<https://www.w3.org/TR/trig/>

Other Web Resources

<http://www.w3.org/DesignIssues/LinkedData.html> (Tim Berners-Lee)
https://www.ted.com/talks/tim_berners_lee_the_next_web?language=en (TED Talk by Tim Berners-Lee, 2009)
<https://www.w3.org/DesignIssues/TermResource.html> (Tim Berners-Lee)
<https://www.cambridgesemantics.com/blog/semantic-university/learn-rdf/>
<https://www.w3.org/2016/05/ontolex/> (OntoLex-Lemon Specification)

Vocabularies

www.w3.org/1999/02/22-rdf-syntax-ns# (RDF)
<http://purl.org/dc/terms/> (Dublin Core)
<https://www.w3.org/ns/lemon/ontolex> (OntoLex-Lemon core module)
<https://lexinfo.net/ontology/3.0/lexinfo> (lexInfo)
<http://xmlns.com/foaf/spec/20140114.rdf> (FOAF -- Friend Of A Friend)

General Literature

Mallea, M. Arenas, A. Hogan, and A. Polleres. On Blank Nodes. In The Semantic Web--ISWC 2011, pages 421--437. Springer, 2011.

Christian Bizer: Quality-Driven Information Filtering in the Context of Web-Based Information Systems. Dissertation, Berlin, Germany, March 2007