UNIVERSITÄT
MANNHEIM

Semantic Web Technologies
Linked Open Data &
Semantic Web Programming

Heiko Paulheim

Overview

- Linked Open Data
  - Principles
  - Examples
  - Vocabularies
- Microdata & schema.org
- Introduction to Semantic Web Programming with rdflib & Jena

Linked Open Data

- What we've got to know up to now
  - RDF as a universal language for describing things
  - RDF Schema for describing vocabularies (i.e., classes and properties)

- Linked Open Data
  - uses those techniques
  - for providing open data

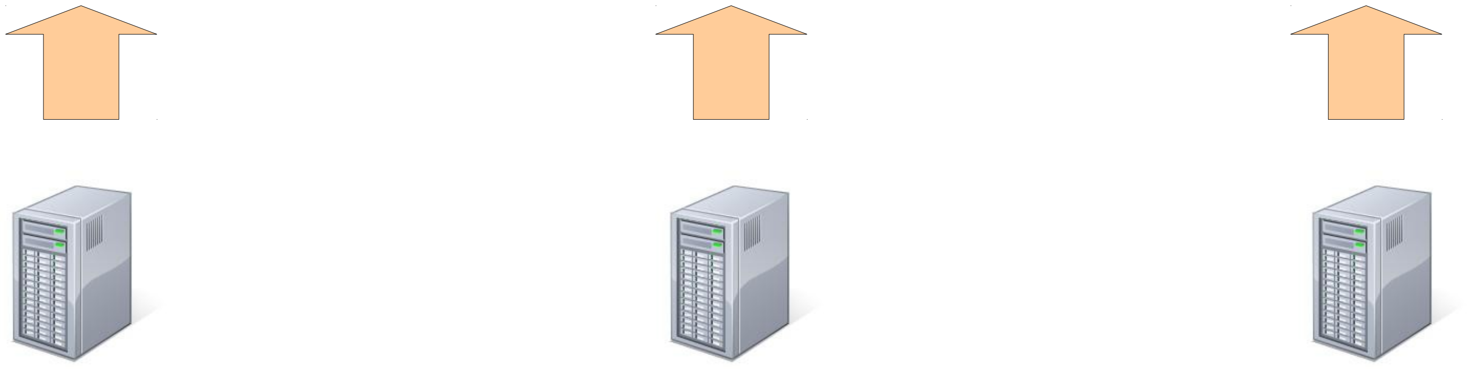
- The Linked Open Data Cloud
  - has nothing to do with cloud computing
  - is a big, freely available collection of knowledge

Why “Linked” Open Data?

```
:p a :Physician .
:p :hasDegree "Dr." .
:p :hasName "Mark Smith" .
:p :hasAddress :a .
:a :street "Main Street" .
:a :number "14"^^xsd:int .
:a :city "Smalltown" .
:p :hasOpeningHours [
  a rdf:Bag ;
  [ :day :Monday;
    :from "9"^^xsd:int;
    :to "11"^^xsd:int;
  ]
  ...
```

```
:s a :City .
:s :name "Smalltown" .
:s :lat "49.86"^^xsd:double .
:s :long "8.65"^^xsd:double .
:s :district "Birmingham" .
...
```

```
:d a :District .
:d :name "Birmingham" .
:d :pop "347891"^^xsd:int .
:d :locatedIn "England" .
...
```



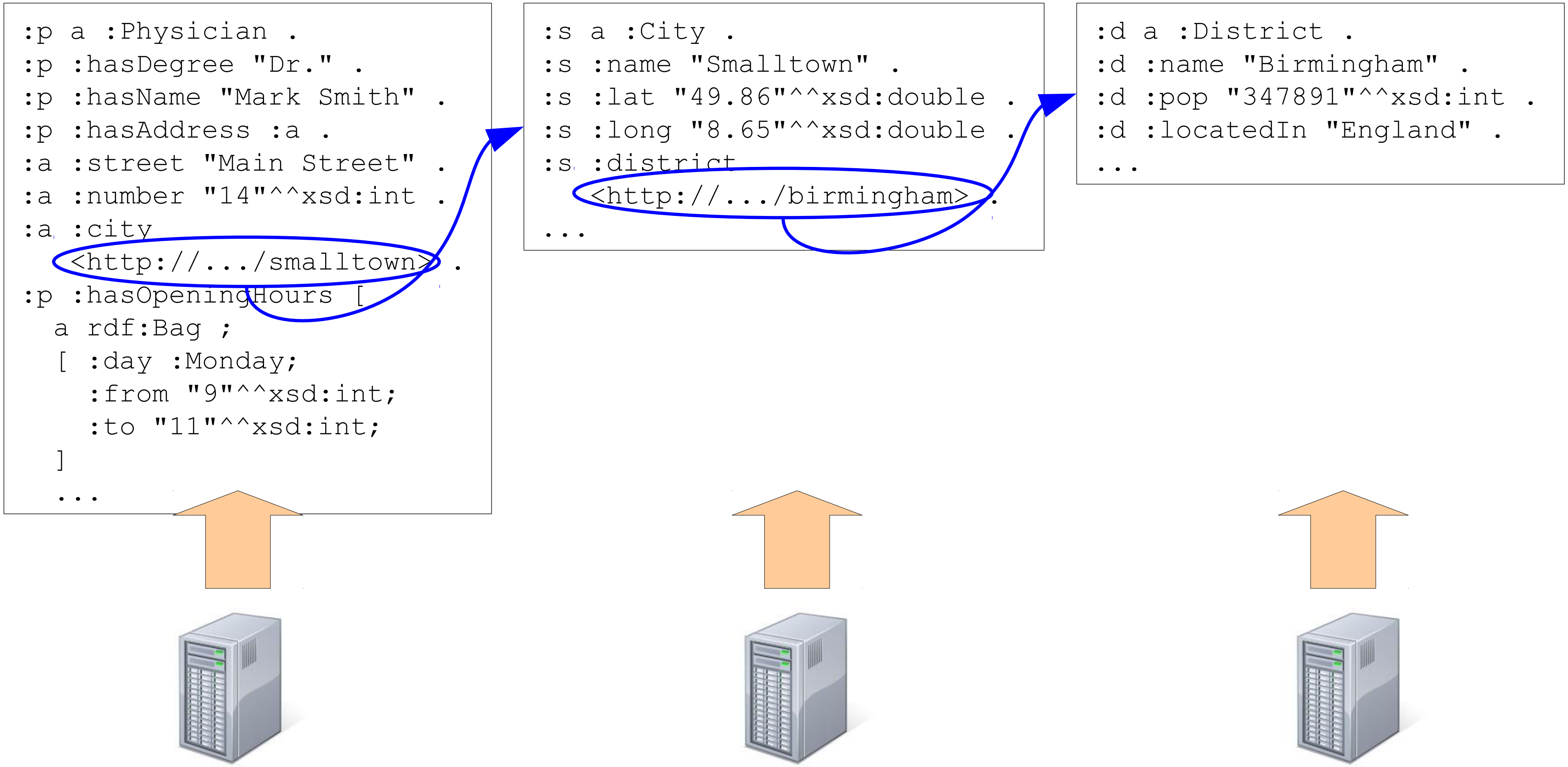
Why “Linked” Open Data?

- Information is scattered on the Web
  - that also holds for the Semantic Web
  - “information silos”

- HTML has a concept for interlinking scattered information
  - known as *hyperlink*
  - More information at <a href="http://www.w3.org">W3C</a>

- Linked Open Data uses that principle, too

Why “Linked” Open Data?



```
:p a :Physician .
:p :hasDegree "Dr." .
:p :hasName "Mark Smith" .
:p :hasAddress :a .
:a :street "Main Street" .
:a :number "14"^^xsd:int .
:a :city
   <http://.../smalltown> .
:p :hasOpeningHours [
   a rdf:Bag ;
   [ :day :Monday;
     :from "9"^^xsd:int;
     :to "11"^^xsd:int;
   ]
   ...
```

```
:s a :City .
:s :name "Smalltown" .
:s :lat "49.86"^^xsd:double .
:s :long "8.65"^^xsd:double .
:s :district
   <http://.../birmingham> .
...
```

```
:d a :District .
:d :name "Birmingham" .
:d :pop "347891"^^xsd:int .
:d :locatedIn "England" .
...
```

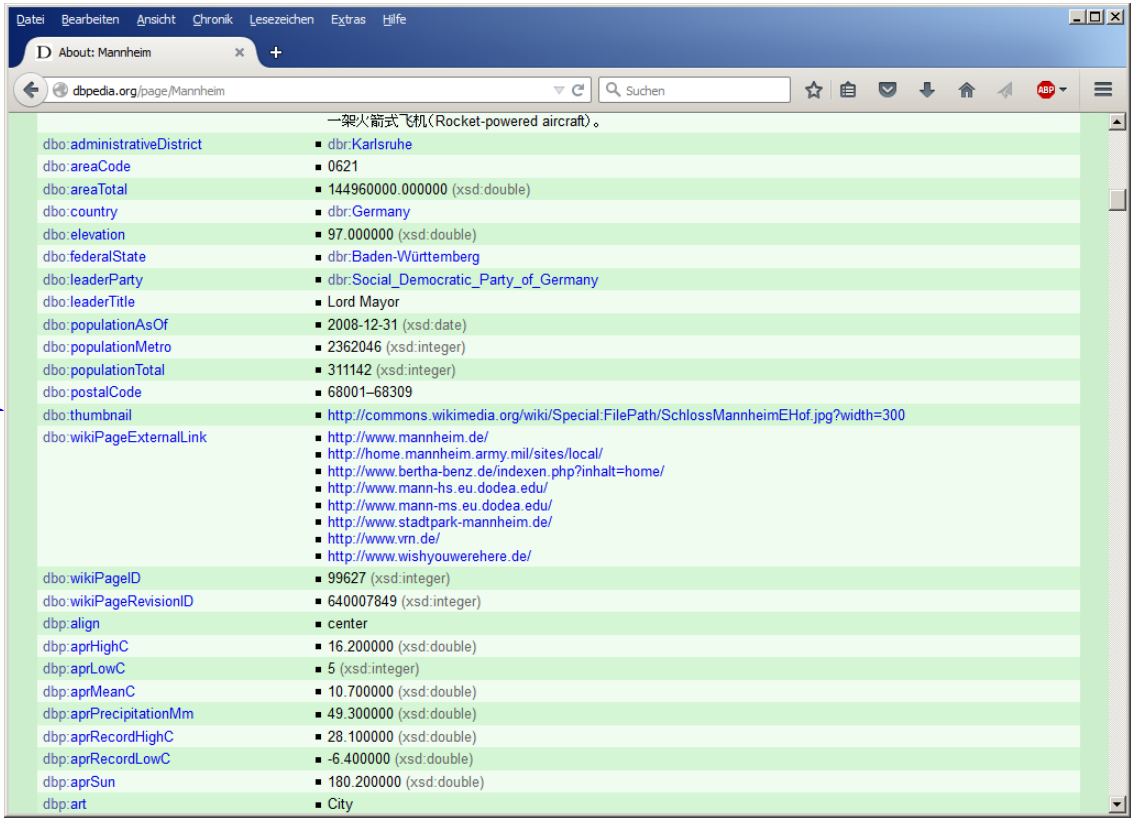
Why “Linked” Open Data?

- Linked Open Data is RDF data
  - which is provided in a distributed manner

- URIs
  - have been used as simple identifiers so far
  - in LOD: links to data
    - resolvable!
    - "dereferencable URIs" (URLs)
    - can be used together with content negotiation, RDFa, etc.

Why “Linked” Open Data?

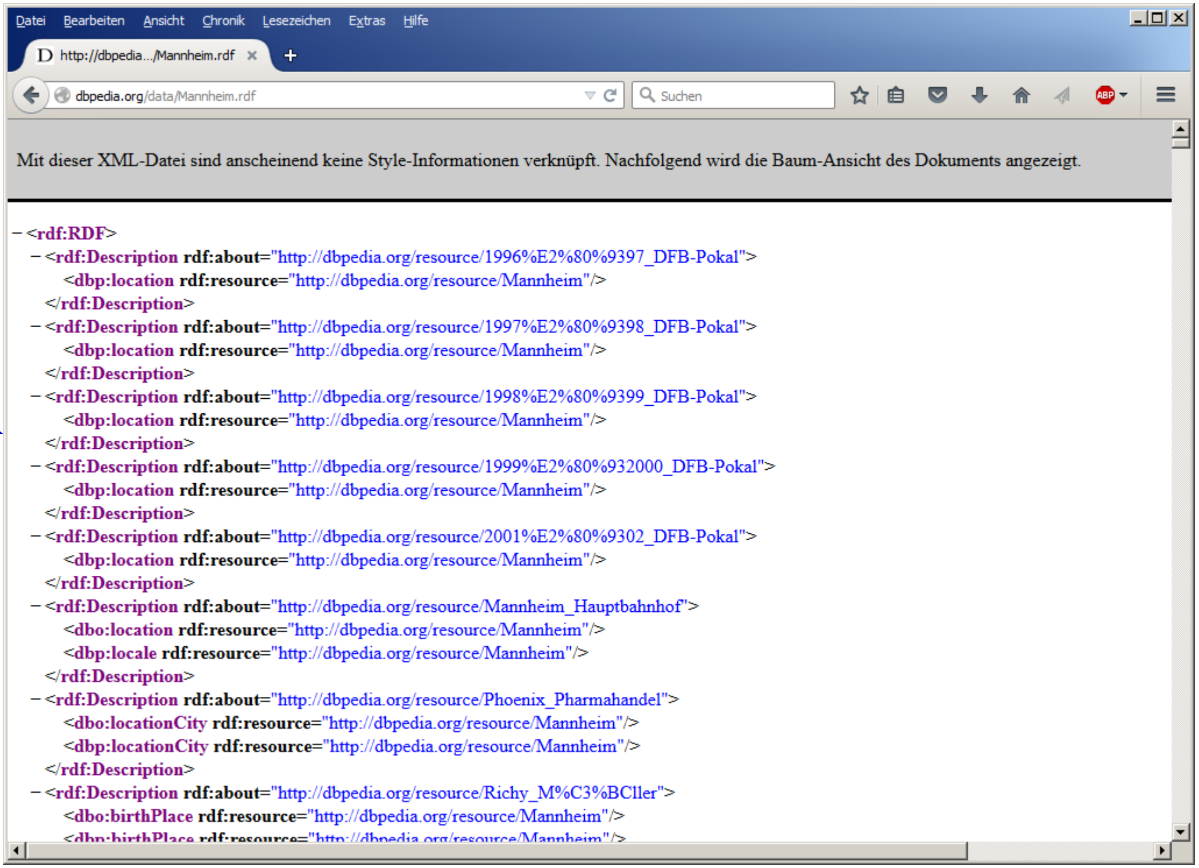
- Example:
  - <#Heiko> :worksIn <http://dbpedia.org/resource/Mannheim> .



	一架火箭式飞机（Rocket-powered aircraft）。
dbo:administrativeDistrict	▪ dbr:Karlsruhe
dbo:areaCode	▪ 0621
dbo:areaTotal	▪ 144960000.000000 (xsd:double)
dbo:country	▪ dbr:Germany
dbo:elevation	▪ 97.000000 (xsd:double)
dbo:federalState	▪ dbr:Baden-Württemberg
dbo:leaderParty	▪ dbr:Social_Democratic_Party_of_Germany
dbo:leaderTitle	▪ Lord Mayor
dbo:populationAsOf	▪ 2008-12-31 (xsd:date)
dbo:populationMetro	▪ 2362046 (xsd:integer)
dbo:populationTotal	▪ 311142 (xsd:integer)
dbo:postalCode	▪ 68001–68309
dbo:thumbnail	▪ http://commons.wikimedia.org/wiki/Special:FilePath/SchlossMannheimEHof.jpg?width=300
dbo:wikiPageExternalLink	▪ http://www.mannheim.de/ ▪ http://home.mannheim.army.mil/sites/local/ ▪ http://www.bertha-benz.de/indexen.php?inhalt=home/ ▪ http://www.mann-hs.eu.dodea.edu/ ▪ http://www.mann-ms.eu.dodea.edu/ ▪ http://www.stadtpark-mannheim.de/ ▪ http://www.vrn.de/ ▪ http://www.wishyouwerehere.de/
dbo:wikiPageID	▪ 99627 (xsd:integer)
dbo:wikiPageRevisionID	▪ 640007849 (xsd:integer)
dbp:align	▪ center
dbp:aprHighC	▪ 16.200000 (xsd:double)
dbp:aprLowC	▪ 5 (xsd:integer)
dbp:aprMeanC	▪ 10.700000 (xsd:double)
dbp:aprPrecipitationMm	▪ 49.300000 (xsd:double)
dbp:aprRecordHighC	▪ 28.100000 (xsd:double)
dbp:aprRecordLowC	▪ -6.400000 (xsd:double)
dbp:aprSun	▪ 180.200000 (xsd:double)
dbp:art	▪ City

Why “Linked” Open Data?

- Example:
  - <#Heiko> :worksIn <http://dbpedia.org/resource/Mannheim> .



Mit dieser XML-Datei sind anscheinend keine Style-Informationen verknüpft. Nachfolgend wird die Baum-Ansicht des Dokuments angezeigt.

```
– <rdf:RDF>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/1996%E2%80%9397_DFB-Pokal">
      <dbp:location rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/1997%E2%80%9398_DFB-Pokal">
      <dbp:location rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/1998%E2%80%9399_DFB-Pokal">
      <dbp:location rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/1999%E2%80%932000_DFB-Pokal">
      <dbp:location rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/2001%E2%80%9302_DFB-Pokal">
      <dbp:location rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/Mannheim_Hauptbahnhof">
      <dbo:location rdf:resource="http://dbpedia.org/resource/Mannheim"/>
      <dbp:locale rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/Phoenix_Pharmahandel">
      <dbo:locationCity rdf:resource="http://dbpedia.org/resource/Mannheim"/>
      <dbp:locationCity rdf:resource="http://dbpedia.org/resource/Mannheim"/>
    </rdf:Description>
  – <rdf:Description rdf:about="http://dbpedia.org/resource/Richy_M%C3%BCller">
      <dbo:birthPlace rdf:resource="http://dbpedia.org/resource/Mannheim"/>
      <dbp:birthPlace rdf:resource="http://dbpedia.org/resource/Mannheim"/>
```

HTML Links vs. Links in Linked Open Data

- Compare

  ```
  Heiko works in <a href="http://www.mannheim.de">Mannheim</a>.
  ```

  to

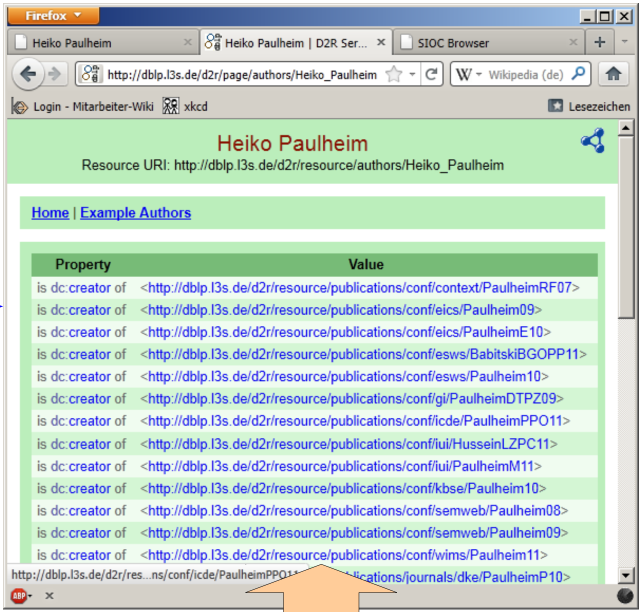
  ```
  :Heiko :worksIn <http://dbpedia.org/resource/Mannheim> .
  ```

- Observation:
  - Links in Linked Open Data are always *explicitly* typed
  - The semantics of the link is thus interpretable
    - given that the predicate is defined in a schema

Links in Linked Open Data

- Important special case: owl:sameAs*

```
:Heiko
  owl:sameAs
  <http://dblp.l3s.de/d2r/page/
   authors/Heiko_Paulheim>
```



http://dblp.l3s.de/d2r/page/authors/Heiko_Paulheim

Heiko Paulheim

Resource URI: http://dblp.l3s.de/d2r/resource/authors/Heiko_Paulheim

Home | Example Authors

Property	Value
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/context/PaulheimRF07>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/eics/Paulheim09>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/eics/PaulheimE10>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/esws/BabitskiBGOPP11>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/esws/Paulheim10>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/gi/PaulheimDTPZ09>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/icde/PaulheimPPO11>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/iui/HusseinLZPC11>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/iui/PaulheimM11>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/kbse/Paulheim10>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/semweb/Paulheim08>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/semweb/Paulheim09>
is dc:creator of	<http://dblp.l3s.de/d2r/resource/publications/conf/wims/Paulheim11>
	lications/journals/dke/PaulheimP10>

http://dblp.l3s.de/d2r/res...ns/conf/icde/PaulheimPPO11

* We don't know OWL yet, never mind, we'll get to that...

Links in Linked Open Data

- Important special case: `owl:sameAs`*
- Links two *identical* resources
  - This is required due to the non-unique naming assumption

- One of the most commonly misused concepts in the Semantic Web...
- Use:
  - Two datasets with information about the same person
- Abuse:
  - A dataset with information about a person and the person's homepage
  - The Starbucks in O7 and the company Starbucks
  - The state and the city of Hamburg
  - The parliament as an institution and the parliament as a building

* We don't know OWL yet, never mind, we'll get to that...

Links in Linked Open Data

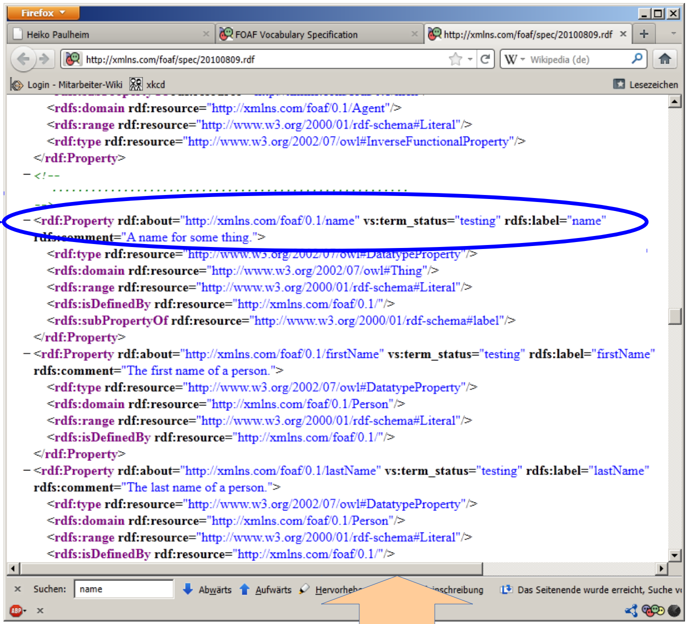
- Alternatives to abusing `owl:sameAs*`
  - General link to other resources
    `rdfs:seeAlso`
  - Link to (HTML) homepage:
    e.g., `foaf:homepage`

* We don't know OWL yet, never mind, we'll get to that...

Linking to a Schema

- Another important special case:
  - linking to a schema
  - luckily, everything is identified by a URI (also properties and classes)

```
:Heiko
  <http://xmlns.com/foaf/0.1/name>
  "Heiko Paulheim" .
```



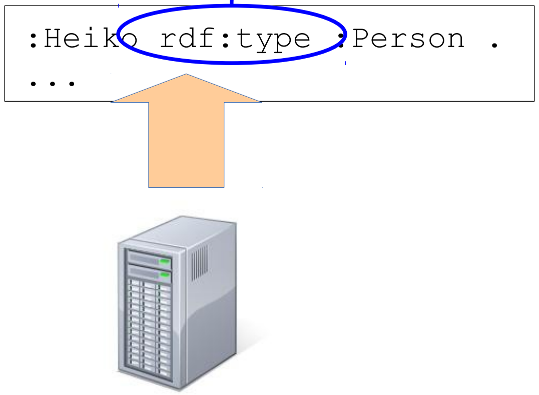
Firefox
Heiko Paulheim
FOAF Vocabulary Specification
http://xmlns.com/foaf/spec/20100809.rdf
http://xmlns.com/foaf/spec/20100809.rdf
Wikipedia (de)
Login - Mitarbeiter-Wiki
xkcd
Lesezeichen
Suchen: name
Abwärts
Aufwärts
Hervorheb
Das Seitenende wurde erreicht, Suche v

```
    <rdfs:domain rdf:resource="http://xmlns.com/foaf/0.1/Agent"/>
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#InverseFunctionalProperty"/>
  </rdf:Property>
- <!--
      ..............................................................
  -->
- <rdf:Property rdf:about="http://xmlns.com/foaf/0.1/name" vs:term_status="testing" rdfs:label="name"
  rdfs:comment="A name for some thing.">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
    <rdfs:domain rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
    <rdfs:isDefinedBy rdf:resource="http://xmlns.com/foaf/0.1/"/>
    <rdfs:subPropertyOf rdf:resource="http://www.w3.org/2000/01/rdf-schema#label"/>
  </rdf:Property>
- <rdf:Property rdf:about="http://xmlns.com/foaf/0.1/firstName" vs:term_status="testing" rdfs:label="firstName"
  rdfs:comment="The first name of a person.">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
    <rdfs:domain rdf:resource="http://xmlns.com/foaf/0.1/Person"/>
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
    <rdfs:isDefinedBy rdf:resource="http://xmlns.com/foaf/0.1/"/>
  </rdf:Property>
- <rdf:Property rdf:about="http://xmlns.com/foaf/0.1/lastName" vs:term_status="testing" rdfs:label="lastName"
  rdfs:comment="The last name of a person.">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
    <rdfs:domain rdf:resource="http://xmlns.com/foaf/0.1/Person"/>
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
    <rdfs:isDefinedBy rdf:resource="http://xmlns.com/foaf/0.1/"/>
```

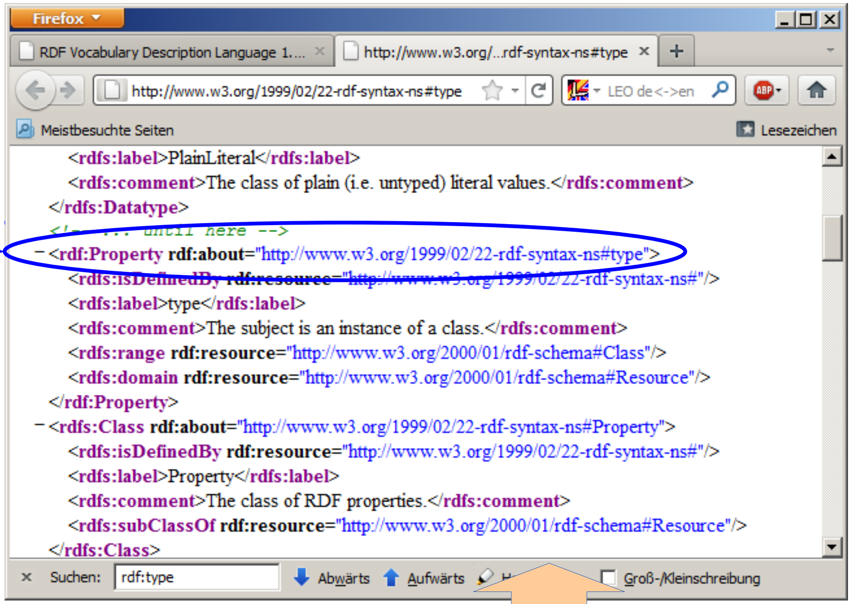
Linking to a Schema

- btw: this also works for “built in” schemas

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



```
:Heiko rdf:type :Person .
...
```



Firefox
RDF Vocabulary Description Language 1....
http://www.w3.org/...rdf-syntax-ns#type
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
LEO de<->en
Meistbesuchte Seiten
Lesezeichen

```
    <rdfs:label>PlainLiteral</rdfs:label>
    <rdfs:comment>The class of plain (i.e. untyped) literal values.</rdfs:comment>
  </rdfs:Datatype>
  <!-- ... until here -->
- <rdf:Property rdf:about="http://www.w3.org/1999/02/22-rdf-syntax-ns#type">
    <rdfs:isDefinedBy rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
    <rdfs:label>type</rdfs:label>
    <rdfs:comment>The subject is an instance of a class.</rdfs:comment>
    <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
    <rdfs:domain rdf:resource="http://www.w3.org/2000/01/rdf-schema#Resource"/>
  </rdf:Property>
- <rdfs:Class rdf:about="http://www.w3.org/1999/02/22-rdf-syntax-ns#Property">
    <rdfs:isDefinedBy rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
    <rdfs:label>Property</rdfs:label>
    <rdfs:comment>The class of RDF properties.</rdfs:comment>
    <rdfs:subClassOf rdf:resource="http://www.w3.org/2000/01/rdf-schema#Resource"/>
  </rdfs:Class>
```

× Suchen: rdf:type
Abwärts
Aufwärts
□ Groß-/Kleinschreibung

Four Principles of Linked Open Data

- The four Principles by Tim Berners-Lee (2006)
  1) Use URIs to identify things
  2) Use derefencable URIs
  3) Provide useful information upon derefencable URIs, use standards
  4) Add links to other datasets

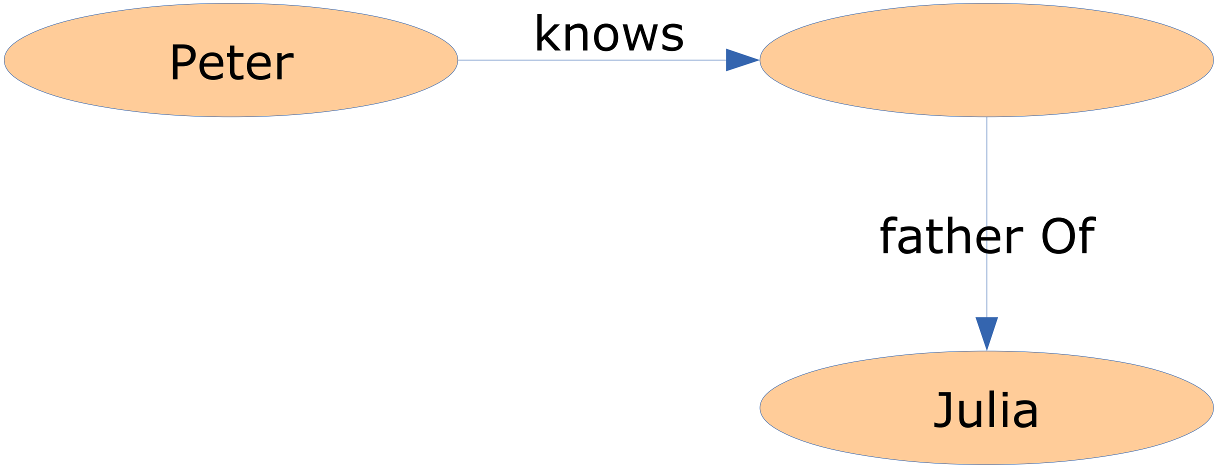
What Data to Serve at a URI?

- Basic principle: provide a complete *RDF molecule* at the URI

- Definition of a complete RDF molecule:
  - All triples that have the URI as a subject or an object
  - Every blank node is connected by at least two predicates

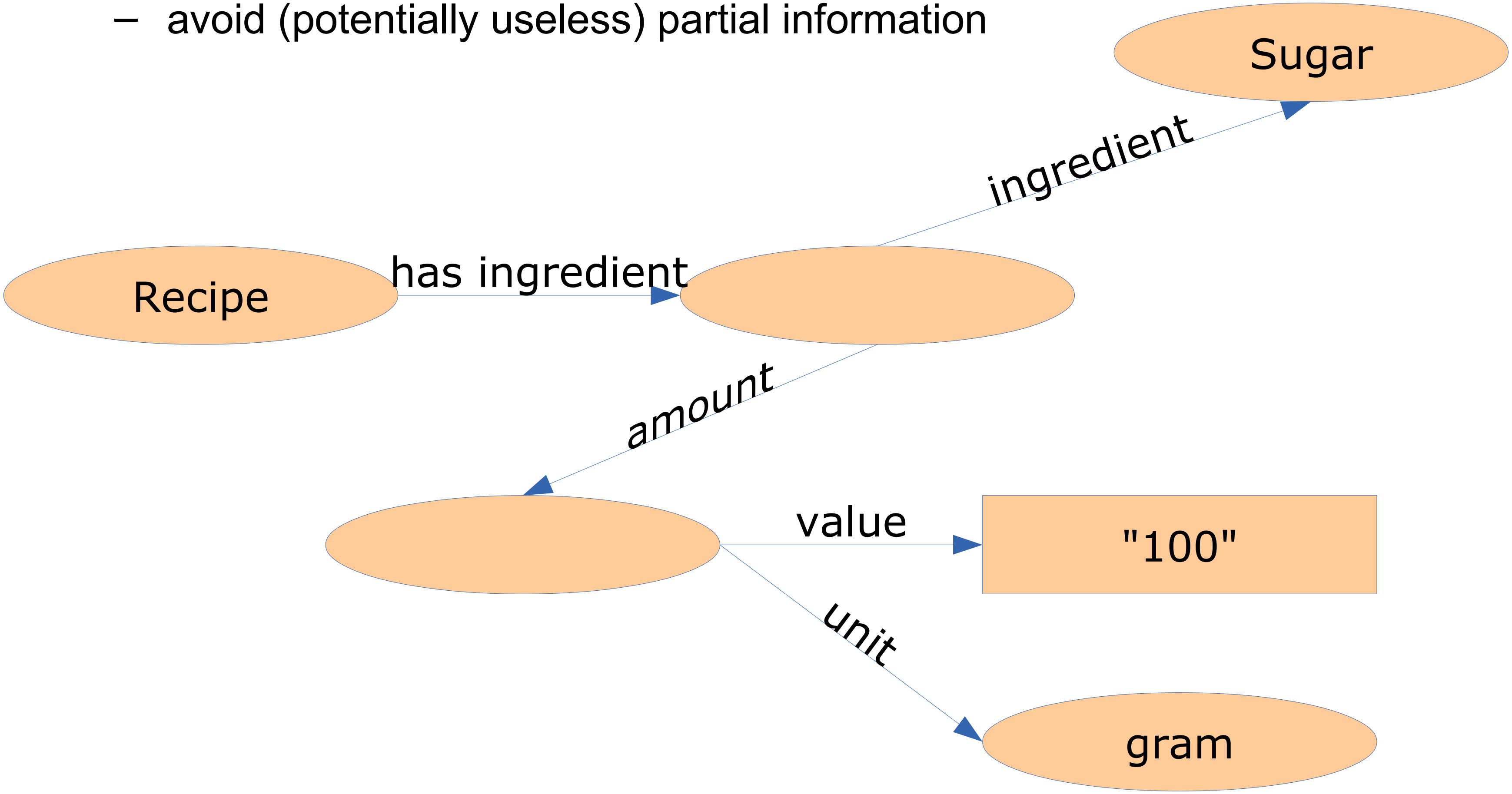
RDF Molecules

- Avoid dead ends in browsing



RDF Molecules

- Recap: Blank Nodes for multi-valued predicates
  - avoid (potentially useless) partial information



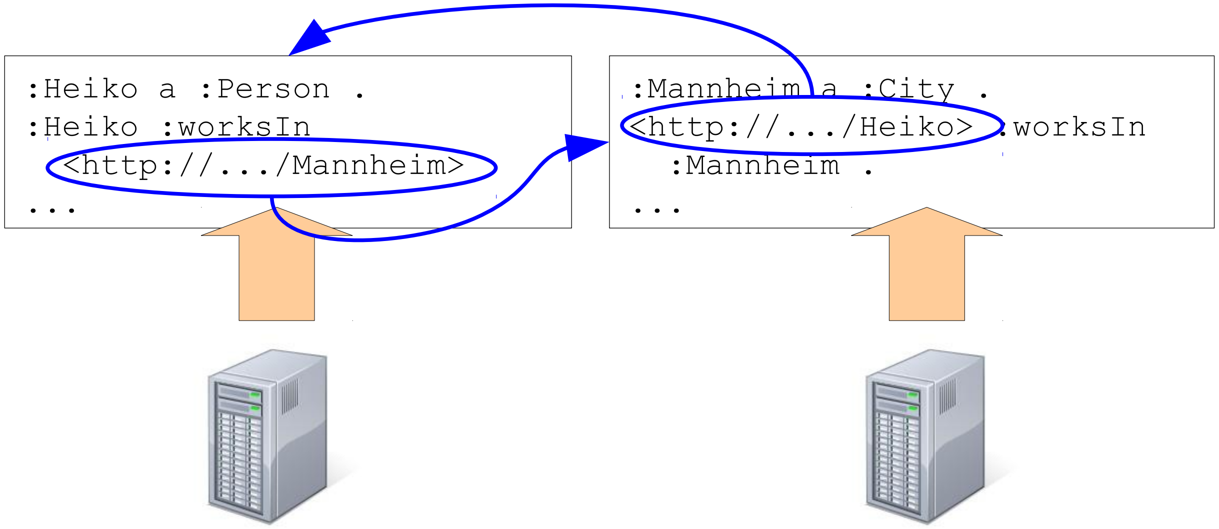
RDF Molecules: Theory and Practice

- Definition of a complete RDF molecule:
  - All triples that have the URI as a subject or an object
  - Every blank node is connected by at least two predicates

- Consequences:
  - Triples are duplicated (in the subject's and the object's molecule)
    - redundancy, depending on serving strategy
  - Molecules can become very big

RDF Molecules: Theory and Practice

- In theory, all triples have to be served
- Pragmatic approach:
  - Which information is interesting for a user?
  - For a person: the city of residence
    - but for a city: all persons who reside here?

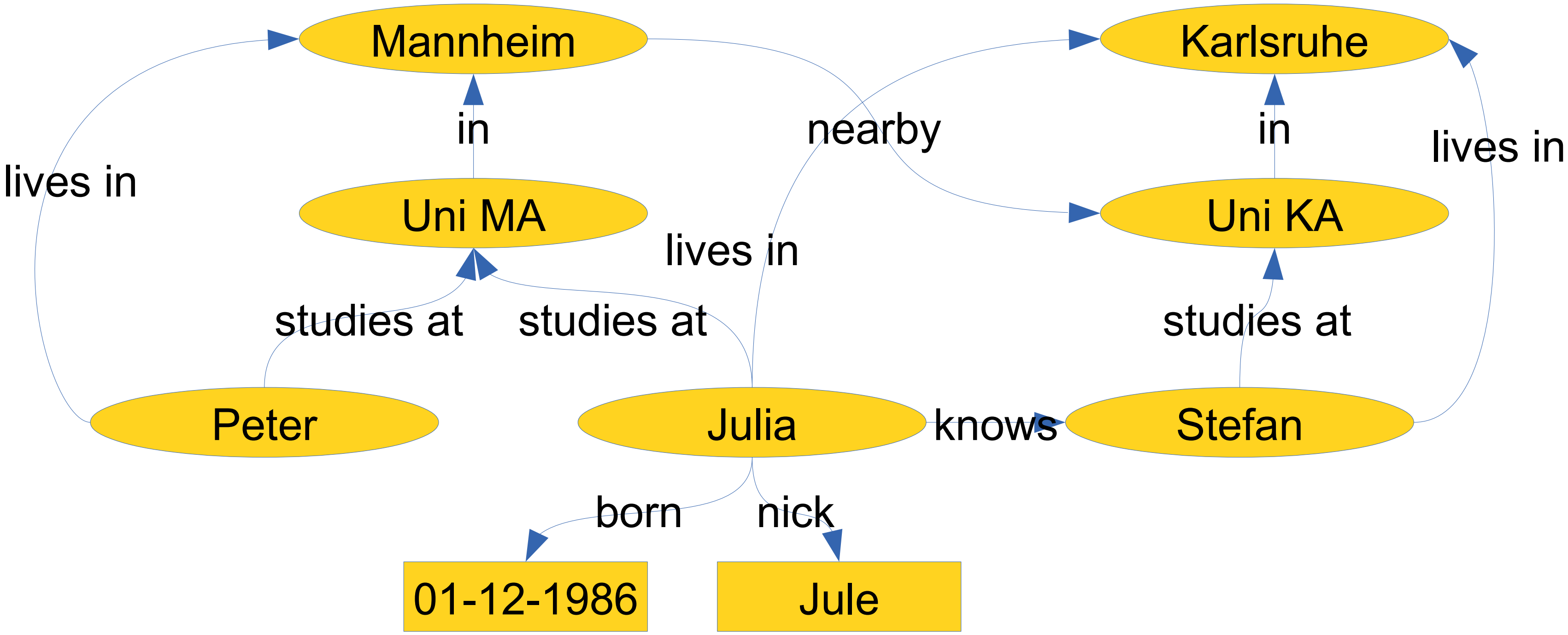


```
:Heiko a :Person .
:Heiko :worksIn
  <http://.../Mannheim>
...
```

```
:Mannheim a :City .
<http://.../Heiko> :worksIn
  :Mannheim .
...
```

RDF Molecules: Theory and Practice

- Example Graph



The Five Star Schema

- Five Star Scheme (Tim Berners-Lee, 2010)

  * Available on the web with an open license

  ** Available as machine-readable, structured data

  *** like ** plus using a non-proprietary format

  **** like*** plus using open standards by the W3C

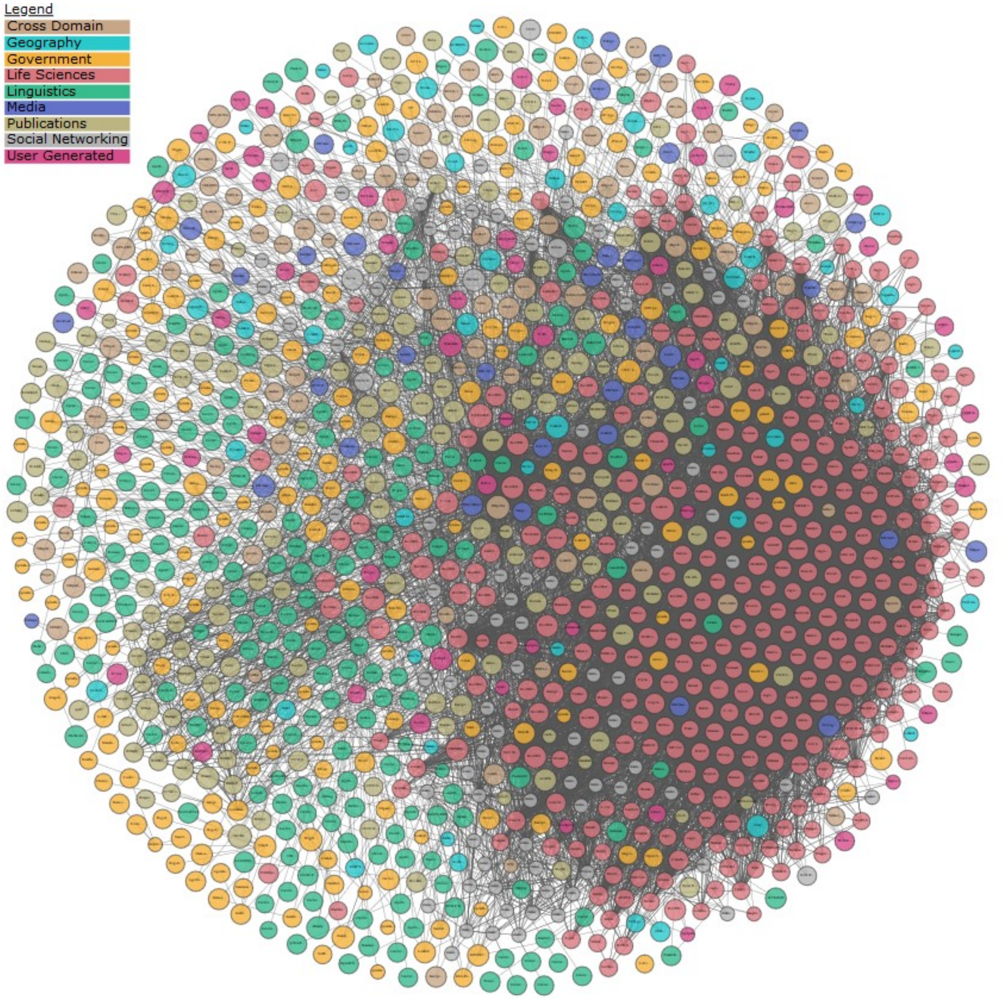
  ***** like **** plus links to other datasets

Linked Open Data Best Practices

- as defined by Heath and Bizer, 2011

1) Provide dereferencable URIs
2) Set RDF links pointing at other data sources
3) Use terms from widely deployed vocabularies
4) Make proprietary vocabulary terms dereferencable
5) Map proprietary vocabulary terms to other vocabularies
6) Provide provenance metadata
7) Provide licensing metadata
8) Provide data-set-level metadata
9) Refer to additional access methods

The Linked Open Data Cloud



http://lod-cloud.net/

The Linked Open Data Cloud from lod-cloud.net

The Linked Open Data Cloud

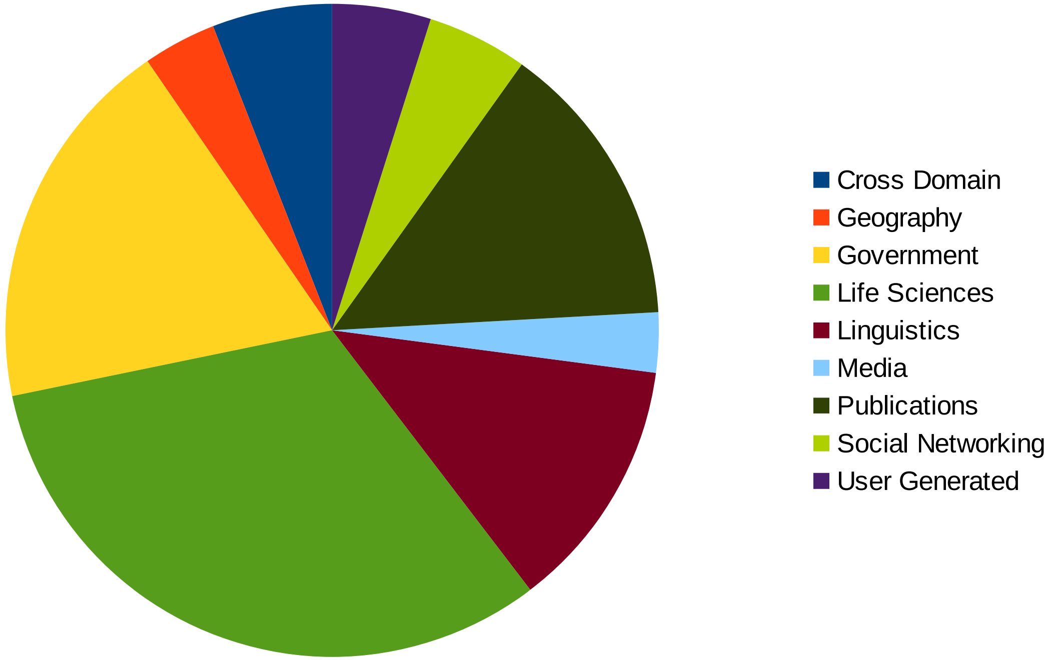
- In numbers:
  - >1,200 Data sets
  - Several billion triples
  - Several million interlinks

- Topical domains:
  - Government
  - Publications
  - Life sciences
  - User-generated content
  - Cross-domain
  - Media
  - Geographic
  - Social web

http://lod-cloud.net/

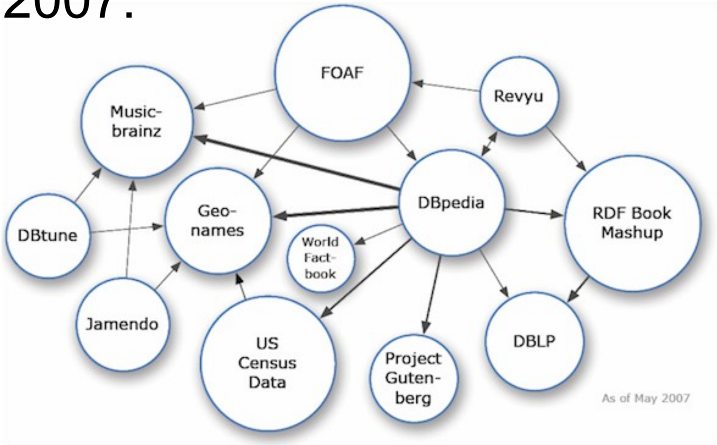
The Linked Open Data Cloud

- Domains by number of datasets in Linked Open Data
  - As of 2019
  - Classified based on data provider tags
  - More than half of the datasets are government and life sciences

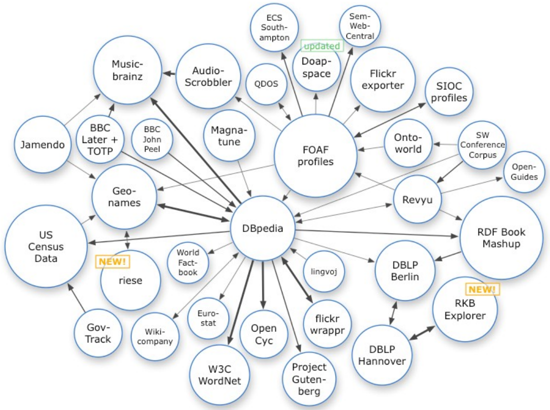


A Short History of Linked Open Data

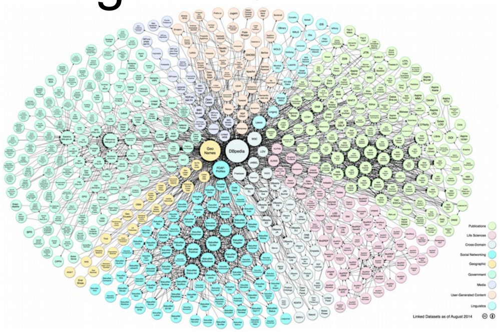
- May 2007:



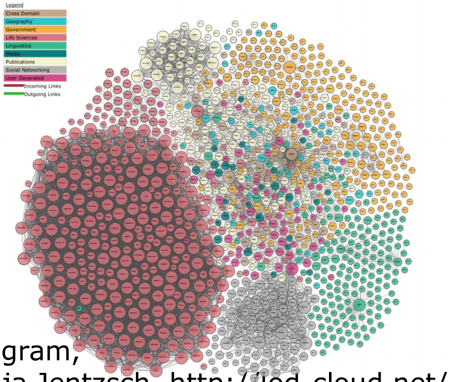
- March 2008:



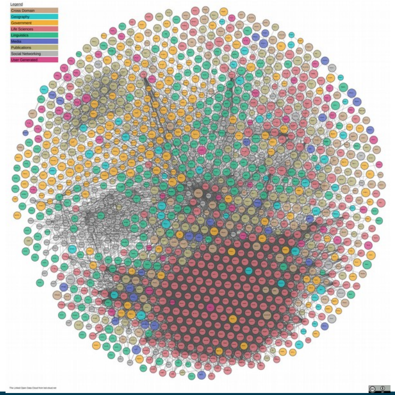
- August 2014



- August 2017

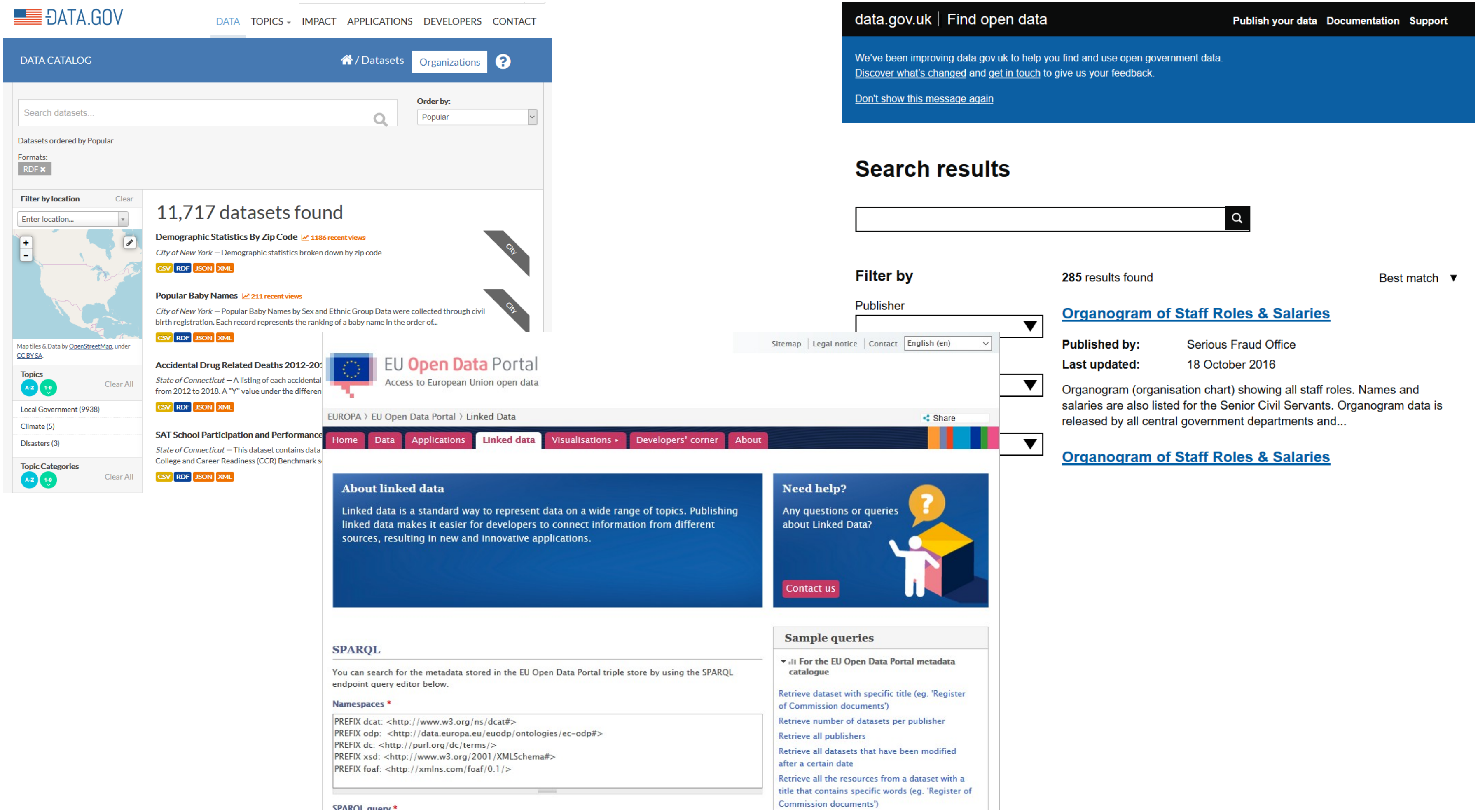


- March 2019



Linking Open Data cloud diagram,
by Richard Cyganiak and Anja Jentzsch. http://lod-cloud.net/

Examples: Government Data



Search datasets...

Order by: Popular

Datasets ordered by Popular

Formats: RDF ✖

Filter by location — Clear

Enter location...

Map tiles & Data by OpenStreetMap, under CC BY SA.

Topics — A-Z 1-9 — Clear All

- Local Government (9938)
- Climate (5)
- Disasters (3)

Topic Categories — A-Z 1-9 — Clear All

11,717 datasets found

Demographic Statistics By Zip Code 1186 recent views
City of New York — Demographic statistics broken down by zip code
CSV RDF JSON XML

Popular Baby Names 211 recent views
City of New York — Popular Baby Names by Sex and Ethnic Group Data were collected through civil birth registration. Each record represents the ranking of a baby name in the order of...
CSV RDF JSON XML

Accidental Drug Related Deaths 2012-201
State of Connecticut — A listing of each accidental from 2012 to 2018. A "Y" value under the differen
CSV RDF JSON XML

SAT School Participation and Performance
State of Connecticut — This dataset contains data College and Career Readiness (CCR) Benchmark s
CSV RDF JSON XML

We've been improving data.gov.uk to help you find and use open government data.
Discover what's changed and get in touch to give us your feedback.

Don't show this message again

Search results

Filter by

Publisher

285 results found — Best match ▼

Organogram of Staff Roles & Salaries

Published by: Serious Fraud Office
Last updated: 18 October 2016

Organogram (organisation chart) showing all staff roles. Names and salaries are also listed for the Senior Civil Servants. Organogram data is released by all central government departments and...

Organogram of Staff Roles & Salaries

EUROPA › EU Open Data Portal › Linked Data

About linked data

Linked data is a standard way to represent data on a wide range of topics. Publishing linked data makes it easier for developers to connect information from different sources, resulting in new and innovative applications.

Need help?

Any questions or queries about Linked Data?

SPARQL

You can search for the metadata stored in the EU Open Data Portal triple store by using the SPARQL endpoint query editor below.

Namespaces *

```
PREFIX dcat: <http://www.w3.org/ns/dcat#>
PREFIX odp:  <http://data.europa.eu/euodp/ontologies/ec-odp#>
PREFIX dc: <http://purl.org/dc/terms/>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
```

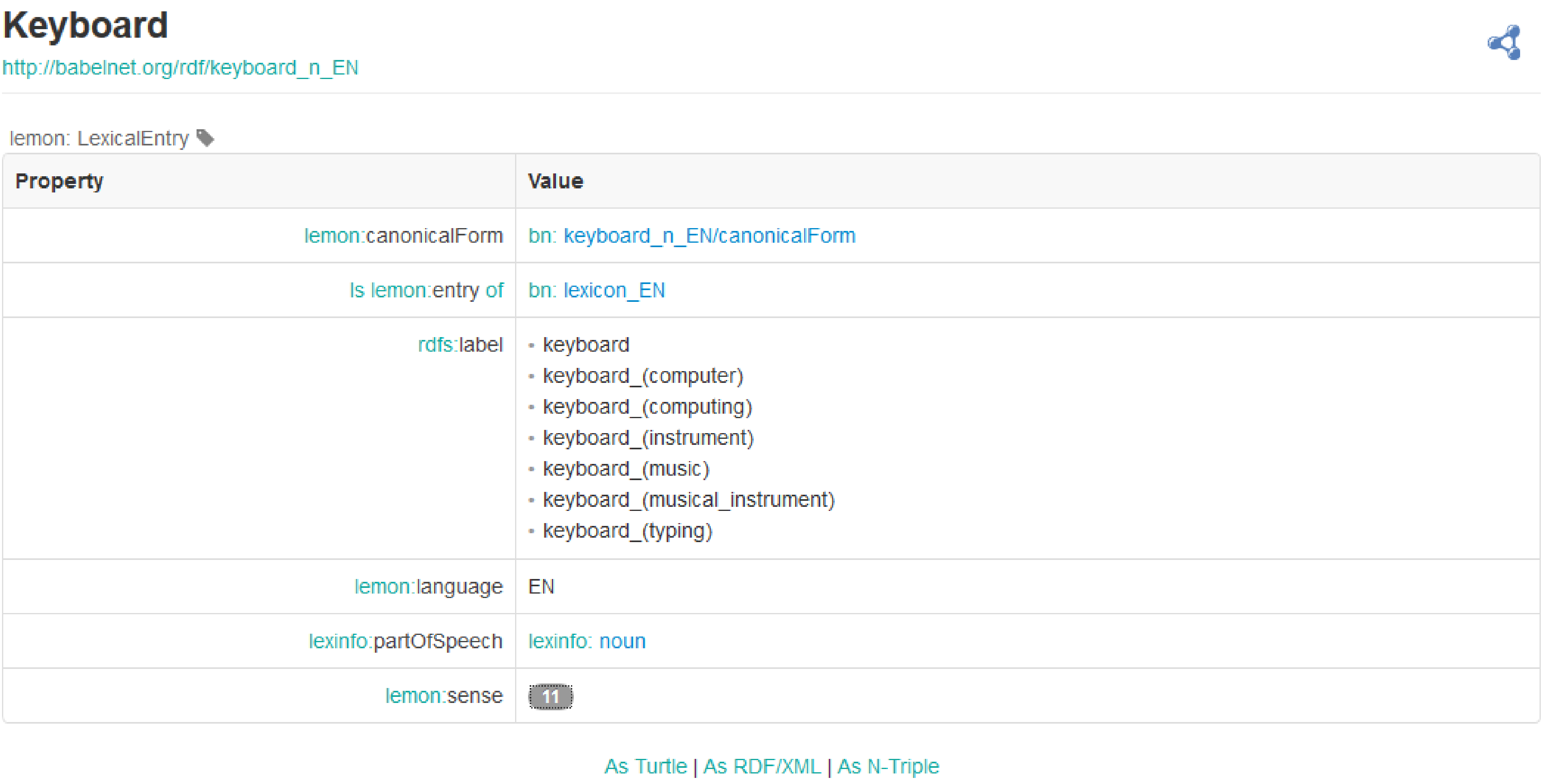
SPARQL query *

Sample queries

▾ For the EU Open Data Portal metadata catalogue

- Retrieve dataset with specific title (eg. 'Register of Commission documents')
- Retrieve number of datasets per publisher
- Retrieve all publishers
- Retrieve all datasets that have been modified after a certain date
- Retrieve all the resources from a dataset with a title that contains specific words (eg. 'Register of Commission documents')

Linguistics Example: BabelNet



Keyboard

http://babelnet.org/rdf/keyboard_n_EN

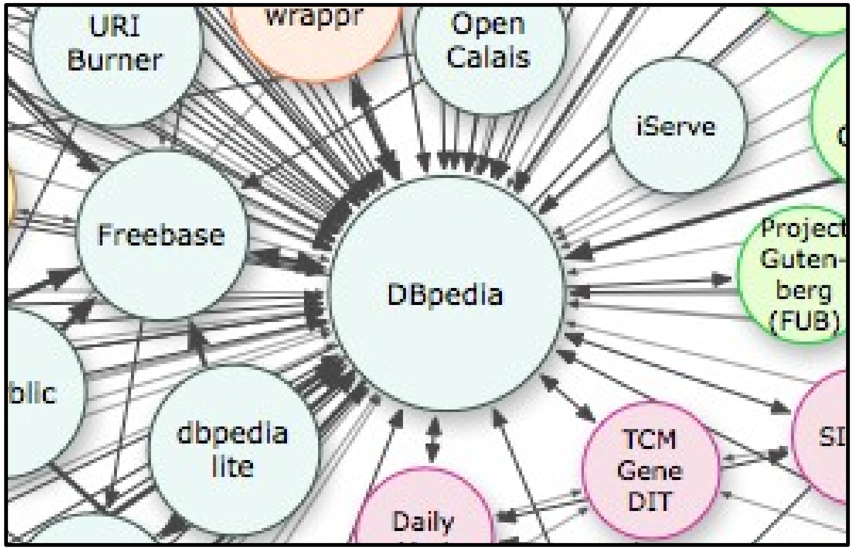
lemon: LexicalEntry

Property	Value
lemon:canonicalForm	bn: keyboard_n_EN/canonicalForm
Is lemon:entry of	bn: lexicon_EN
rdfs:label	• keyboard • keyboard_(computer) • keyboard_(computing) • keyboard_(instrument) • keyboard_(music) • keyboard_(musical_instrument) • keyboard_(typing)
lemon:language	EN
lexinfo:partOfSpeech	lexinfo: noun
lemon:sense	11

As Turtle | As RDF/XML | As N-Triple

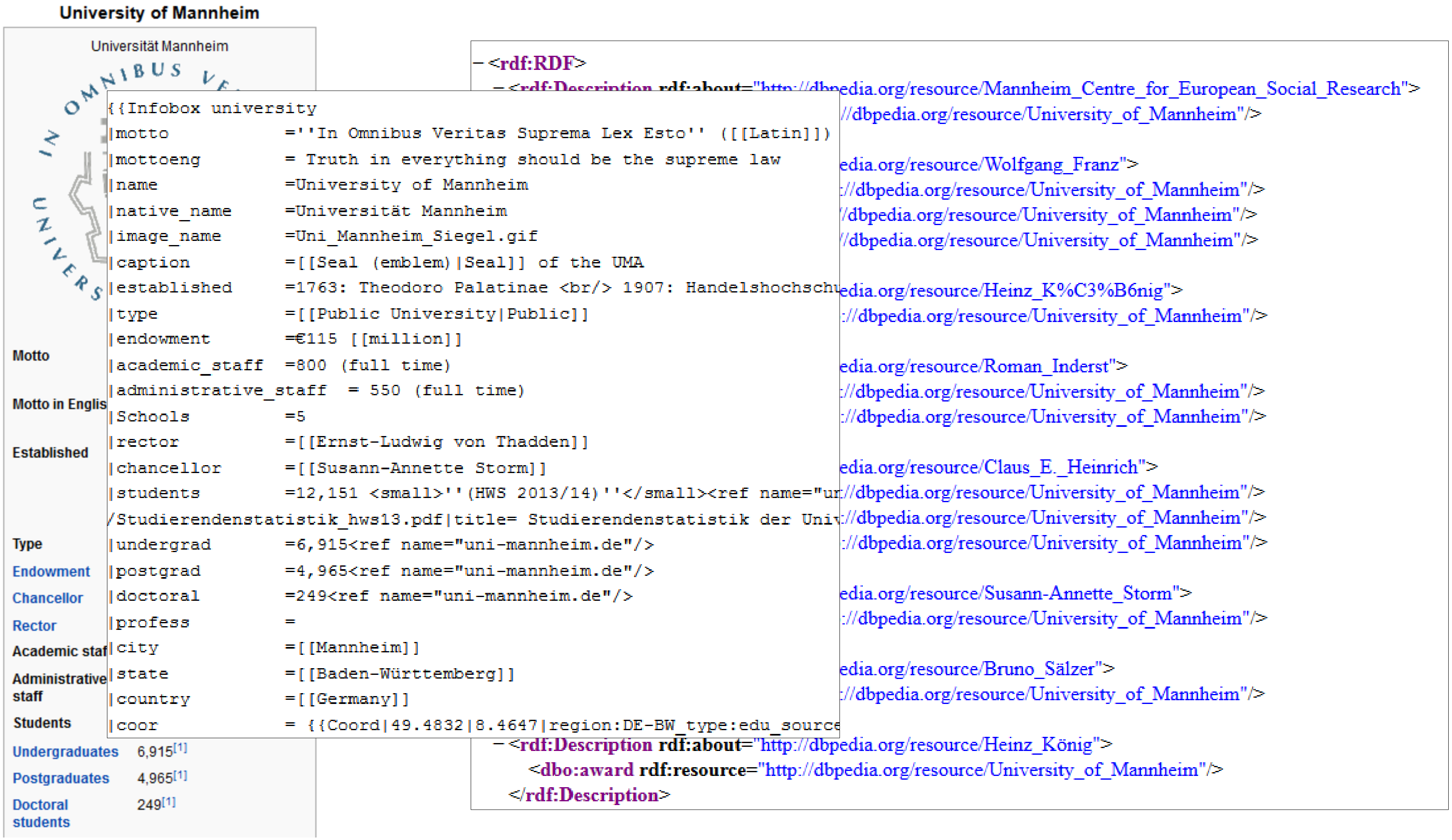
Cross-Domain Example: DBpedia

- General knowledge on almost five million entities
- Hundreds of millions of triples
- Linked to ~100 other datasets
  - the most interlinked dataset



http://lod-cloud.net/

DBpedia: How It Is built



University of Mannheim

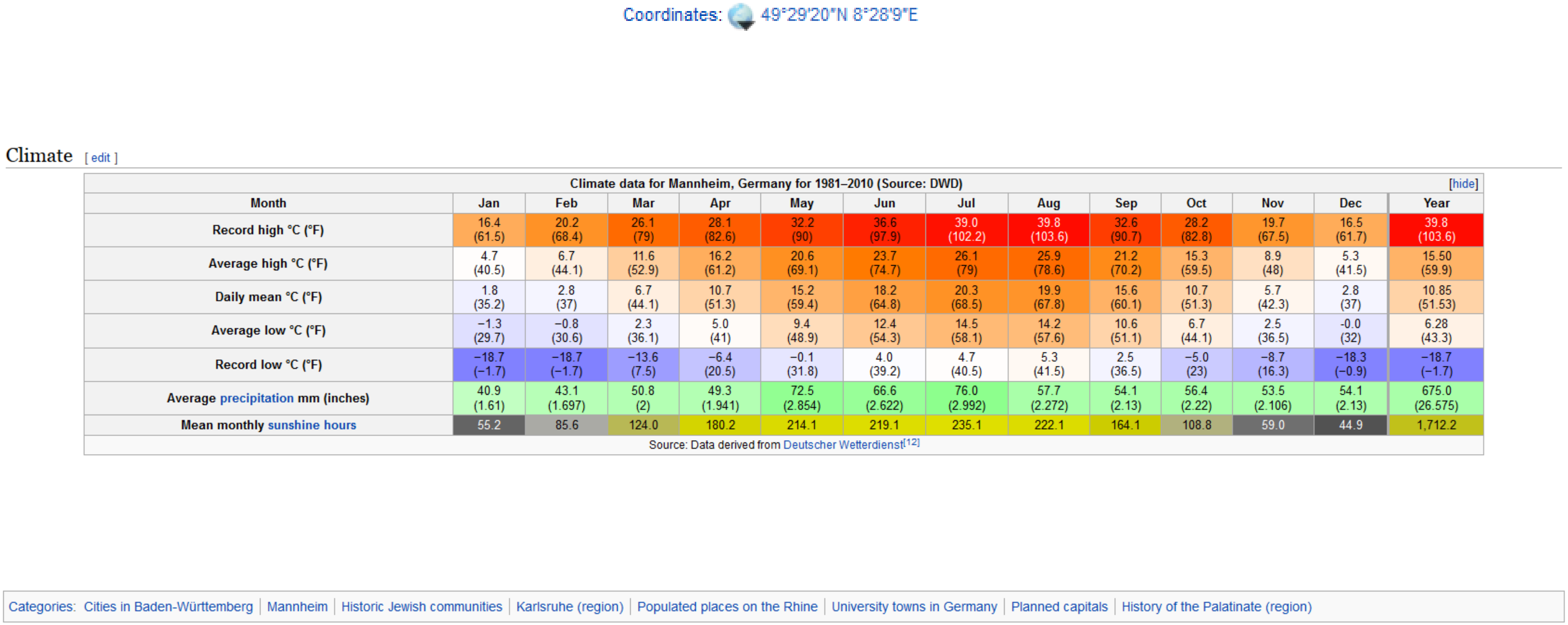
Universität Mannheim

Motto	
Motto in Englis	
Established	
Type	
Endowment	
Chancellor	
Rector	
Academic staf	
Administrative staff	
Students	
Undergraduates	6,915[1]
Postgraduates	4,965[1]
Doctoral students	249[1]

```
{{Infobox university
|motto              =''In Omnibus Veritas Suprema Lex Esto'' ([[Latin]])
|mottoeng           = Truth in everything should be the supreme law
|name               =University of Mannheim
|native_name        =Universität Mannheim
|image_name         =Uni_Mannheim_Siegel.gif
|caption            =[[Seal (emblem)|Seal]] of the UMA
|established        =1763: Theodoro Palatinae <br/> 1907: Handelshochschu
|type               =[[Public University|Public]]
|endowment          =€115 [[million]]
|academic_staff     =800 (full time)
|administrative_staff  = 550 (full time)
|Schools            =5
|rector             =[[Ernst-Ludwig von Thadden]]
|chancellor         =[[Susann-Annette Storm]]
|students           =12,151 <small>''(HWS 2013/14)''</small><ref name="ur
/Studierendenstatistik_hws13.pdf|title= Studierendenstatistik der Univ
|undergrad          =6,915<ref name="uni-mannheim.de"/>
|postgrad           =4,965<ref name="uni-mannheim.de"/>
|doctoral           =249<ref name="uni-mannheim.de"/>
|profess            =
|city               =[[Mannheim]]
|state              =[[Baden-Württemberg]]
|country            =[[Germany]]
|coor               = {{Coord|49.4832|8.4647|region:DE-BW_type:edu_source
```

```
- <rdf:RDF>
  - <rdf:Description rdf:about="http://dbpedia.org/resource/Mannheim_Centre_for_European_Social_Research">
                                   //dbpedia.org/resource/University_of_Mannheim"/>

                                   edia.org/resource/Wolfgang_Franz">
                                   ://dbpedia.org/resource/University_of_Mannheim"/>
                                   //dbpedia.org/resource/University_of_Mannheim"/>
                                   //dbpedia.org/resource/University_of_Mannheim"/>

                                   edia.org/resource/Heinz_K%C3%B6nig">
                                   ://dbpedia.org/resource/University_of_Mannheim"/>

                                   edia.org/resource/Roman_Inderst">
                                   ://dbpedia.org/resource/University_of_Mannheim"/>
                                   ://dbpedia.org/resource/University_of_Mannheim"/>

                                   edia.org/resource/Claus_E._Heinrich">
                                   ://dbpedia.org/resource/University_of_Mannheim"/>
                                   ://dbpedia.org/resource/University_of_Mannheim"/>
                                   ://dbpedia.org/resource/University_of_Mannheim"/>

                                   edia.org/resource/Susann-Annette_Storm">
                                   ://dbpedia.org/resource/University_of_Mannheim"/>

                                   edia.org/resource/Bruno_Sälzer">
                                   ://dbpedia.org/resource/University_of_Mannheim"/>
  - <rdf:Description rdf:about="http://dbpedia.org/resource/Heinz_König">
      <dbo:award rdf:resource="http://dbpedia.org/resource/University_of_Mannheim"/>
    </rdf:Description>
```

DBpedia: Further Sources



Coordinates: 49°29′20″N 8°28′9″E

Climate [edit]

Climate data for Mannheim, Germany for 1981–2010 (Source: DWD) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	16.4 (61.5)	20.2 (68.4)	26.1 (79)	28.1 (82.6)	32.2 (90)	36.6 (97.9)	39.0 (102.2)	39.8 (103.6)	32.6 (90.7)	28.2 (82.8)	19.7 (67.5)	16.5 (61.7)	39.8 (103.6)
Average high °C (°F)	4.7 (40.5)	6.7 (44.1)	11.6 (52.9)	16.2 (61.2)	20.6 (69.1)	23.7 (74.7)	26.1 (79)	25.9 (78.6)	21.2 (70.2)	15.3 (59.5)	8.9 (48)	5.3 (41.5)	15.50 (59.9)
Daily mean °C (°F)	1.8 (35.2)	2.8 (37)	6.7 (44.1)	10.7 (51.3)	15.2 (59.4)	18.2 (64.8)	20.3 (68.5)	19.9 (67.8)	15.6 (60.1)	10.7 (51.3)	5.7 (42.3)	2.8 (37)	10.85 (51.53)
Average low °C (°F)	−1.3 (29.7)	−0.8 (30.6)	2.3 (36.1)	5.0 (41)	9.4 (48.9)	12.4 (54.3)	14.5 (58.1)	14.2 (57.6)	10.6 (51.1)	6.7 (44.1)	2.5 (36.5)	-0.0 (32)	6.28 (43.3)
Record low °C (°F)	−18.7 (−1.7)	−18.7 (−1.7)	−13.6 (7.5)	−6.4 (20.5)	−0.1 (31.8)	4.0 (39.2)	4.7 (40.5)	5.3 (41.5)	2.5 (36.5)	−5.0 (23)	−8.7 (16.3)	−18.3 (−0.9)	−18.7 (−1.7)
Average precipitation mm (inches)	40.9 (1.61)	43.1 (1.697)	50.8 (2)	49.3 (1.941)	72.5 (2.854)	66.6 (2.622)	76.0 (2.992)	57.7 (2.272)	54.1 (2.13)	56.4 (2.22)	53.5 (2.106)	54.1 (2.13)	675.0 (26.575)
Mean monthly sunshine hours	55.2	85.6	124.0	180.2	214.1	219.1	235.1	222.1	164.1	108.8	59.0	44.9	1,712.2

Source: Data derived from Deutscher Wetterdienst[12]

Categories: Cities in Baden-Württemberg | Mannheim | Historic Jewish communities | Karlsruhe (region) | Populated places on the Rhine | University towns in Germany | Planned capitals | History of the Palatinate (region)

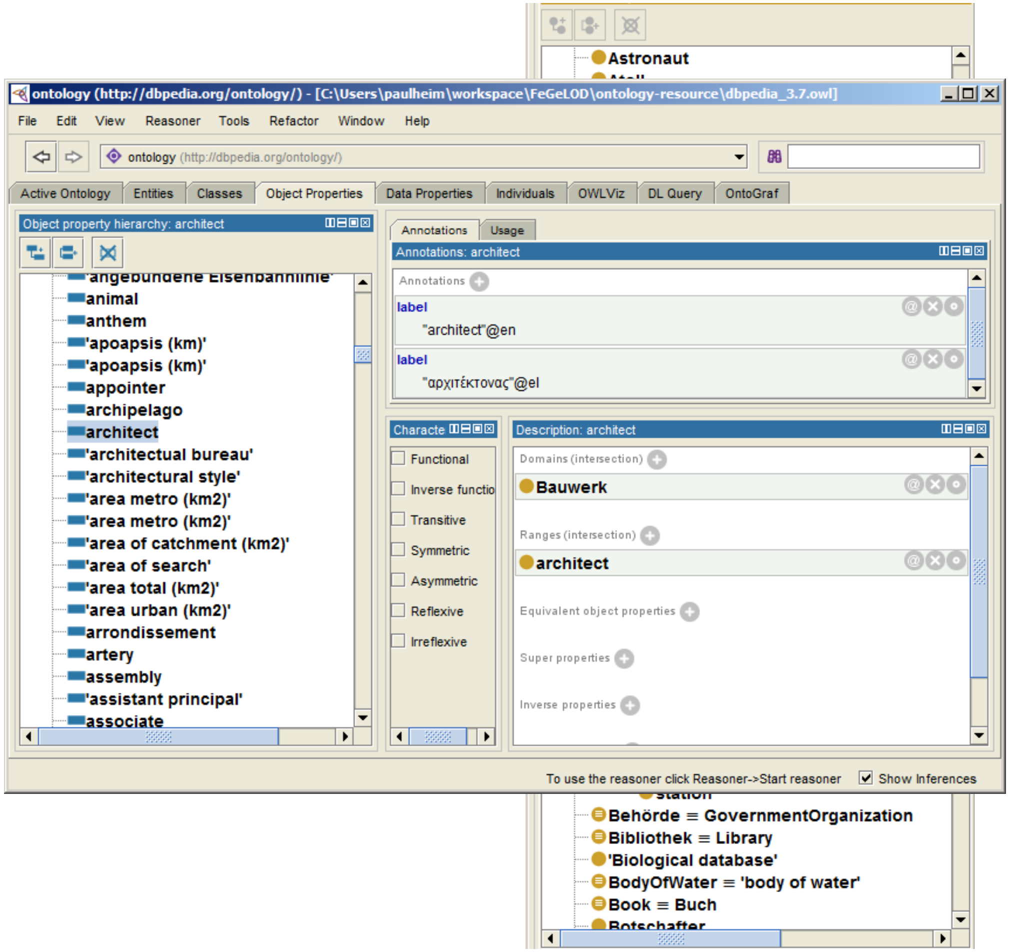
DBpedia: Contents

- Data from different infoboxes (extracted from multiple languages)
- Redirects and disambiguations
- External web links
- Abstracts in multiple languages
- Instance type information
  - DBpedia Ontology
  - YAGO*
  - schema.org*
  - DOLCE**
  - ...and others

* later today
** in a few weeks

The DBpedia Ontology

- Classes:
  - 739 classes
  - partial hierarchy
- Properties:
  - ~1,100 relations
    - some with domain/range
  - ~1,700 data properties
    - i.e., literal-valued
  - a bit of hierarchy



'angebundene Eisenbahnlinie'
animal
anthem
'apoapsis (km)'
'apoapsis (km)'
appointer
archipelago
architect
'architectual bureau'
'architectural style'
'area metro (km2)'
'area metro (km2)'
'area of catchment (km2)'
'area of search'
'area total (km2)'
'area urban (km2)'
arrondissement
artery
assembly
'assistant principal'
associate

Annotations

label

"architect"@en

label

"αρχιτέκτονας"@el

□ Functional
□ Inverse functio
□ Transitive
□ Symmetric
□ Asymmetric
□ Reflexive
□ Irreflexive

Domains (intersection)

Bauwerk

Ranges (intersection)

architect

Equivalent object properties

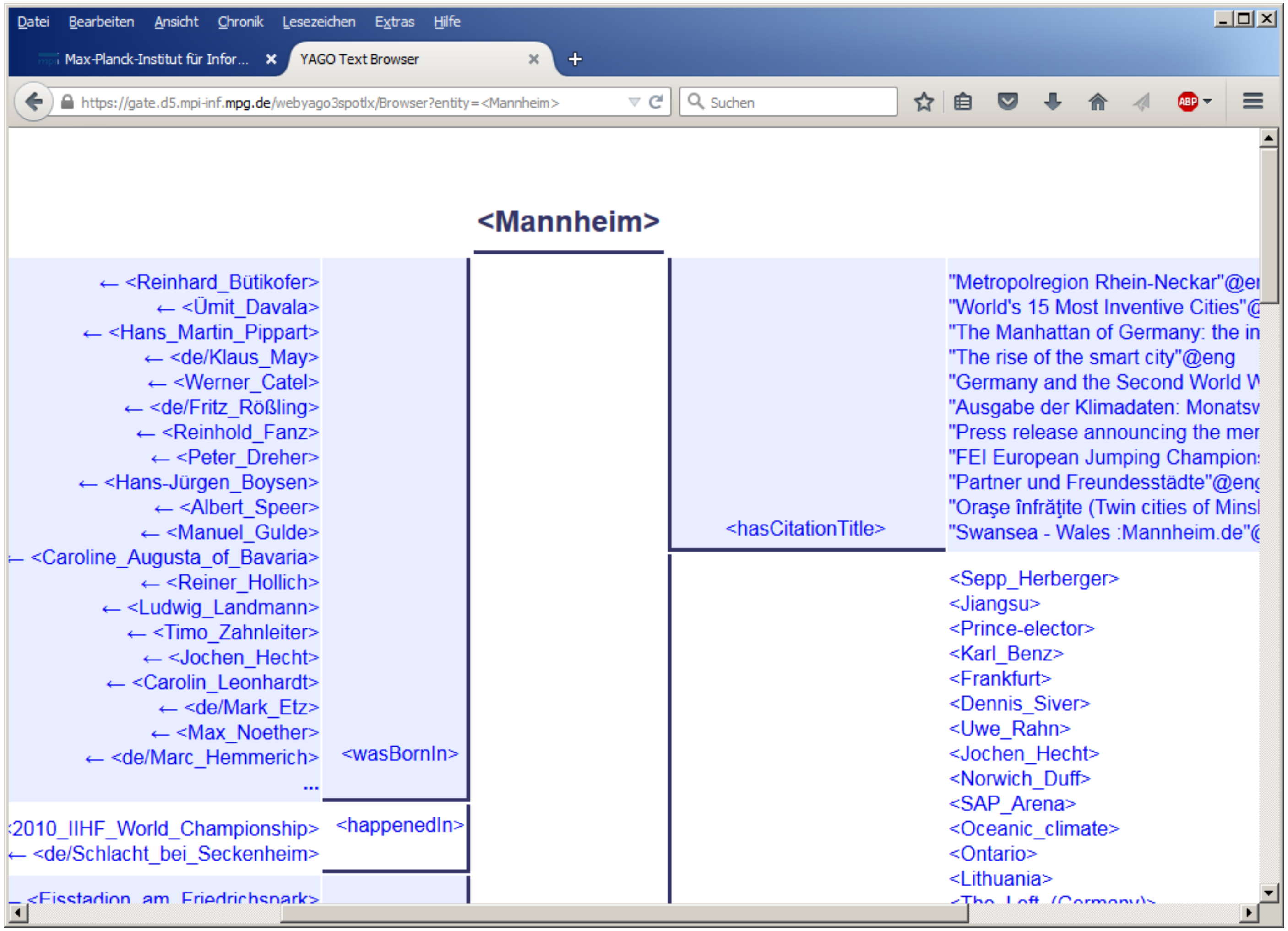
Super properties

Inverse properties

To use the reasoner click Reasoner->Start reasoner ☑ Show Inferences

Astronaut
Atoll
station
Behörde ≡ GovernmentOrganization
Bibliothek ≡ Library
'Biological database'
BodyOfWater ≡ 'body of water'
Book ≡ Buch
Botschafter

YAGO


Datei Bearbeiten Ansicht Chronik Lesezeichen Extras Hilfe
Max-Planck-Institut für Infor...
YAGO Text Browser
https://gate.d5.mpi-inf.mpg.de/webyago3spotlx/Browser?entity=<Mannheim>
Suchen

<Mannheim>

← <Reinhard_Bütikofer>
← <Ümit_Davala>
← <Hans_Martin_Pippart>
← <de/Klaus_May>
← <Werner_Catel>
← <de/Fritz_Rößling>
← <Reinhold_Fanz>
← <Peter_Dreher>
← <Hans-Jürgen_Boysen>
← <Albert_Speer>
← <Manuel_Gulde>
← <Caroline_Augusta_of_Bavaria>
← <Reiner_Hollich>
← <Ludwig_Landmann>
← <Timo_Zahnleiter>
← <Jochen_Hecht>
← <Carolin_Leonhardt>
← <de/Mark_Etz>
← <Max_Noether>
← <de/Marc_Hemmerich>
...

<wasBornIn>

<2010_IIHF_World_Championship>
← <de/Schlacht_bei_Seckenheim>

<happenedIn>

← <Eisstadion_am_Friedrichspark>

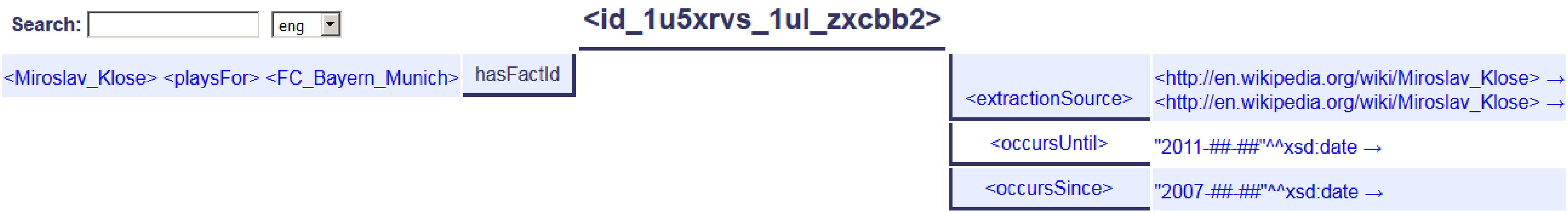
<hasCitationTitle>

"Metropolregion Rhein-Neckar"@en
"World's 15 Most Inventive Cities"@
"The Manhattan of Germany: the in
"The rise of the smart city"@eng
"Germany and the Second World W
"Ausgabe der Klimadaten: Monatsv
"Press release announcing the mer
"FEI European Jumping Champion
"Partner und Freundesstädte"@eng
"Orașe înfrățite (Twin cities of Mins
"Swansea - Wales :Mannheim.de"@

<Sepp_Herberger>
<Jiangsu>
<Prince-elector>
<Karl_Benz>
<Frankfurt>
<Dennis_Siver>
<Uwe_Rahn>
<Jochen_Hecht>
<Norwich_Duff>
<SAP_Arena>
<Oceanic_climate>
<Ontario>
<Lithuania>
<The_Loft_(Germany)>

YAGO

- Also derived from Wikipedia
  - ~4.6M entities
  - ~26M statements
- Uses Wikipedia categories for typing
  - a class hierarchy of ~500,000 types
- Tries to capture time
  - i.e., statements that held true for a period of time
  - e.g., soccer players playing for teams
  - uses reification



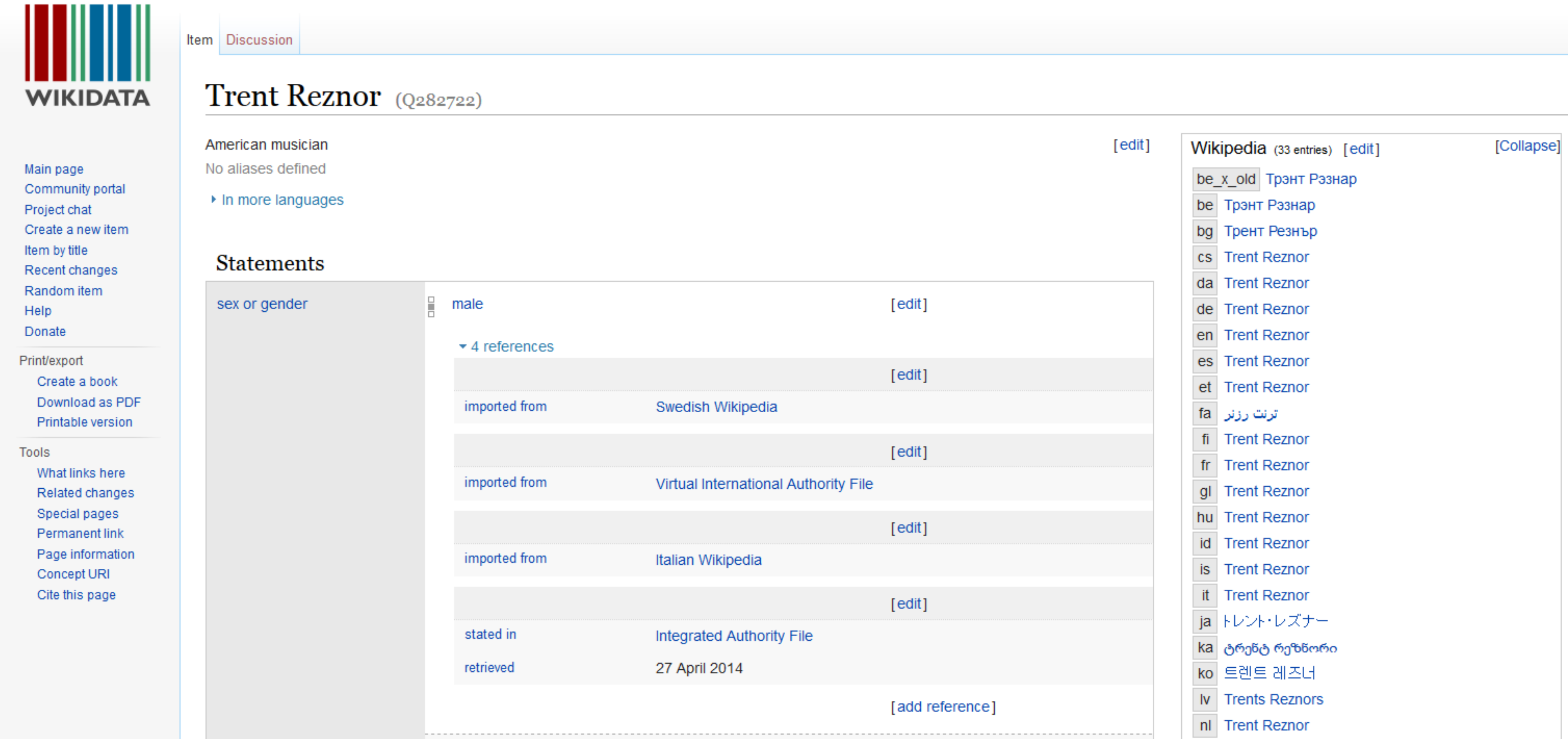
<id_1u5xrvs_1ul_zxcbb2>

<Miroslav_Klose> <playsFor> <FC_Bayern_Munich>	hasFactId	<extractionSource>	<http://en.wikipedia.org/wiki/Miroslav_Klose> → <http://en.wikipedia.org/wiki/Miroslav_Klose> →
		<occursUntil>	"2011-##-##"^^xsd:date →
		<occursSince>	"2007-##-##"^^xsd:date →

Wikidata

- Collaboratively edited knowledge base
- Size
  - ~15M instances
  - ~66M statements
- Ontology
  - ~23k classes
  - ~1.6k properties
- Special
  - provenance information
  - i.e., evidence: where did that statement come from?

Wikidata



WIKIDATA

- Main page
- Community portal
- Project chat
- Create a new item
- Item by title
- Recent changes
- Random item
- Help
- Donate

Print/export

- Create a book
- Download as PDF
- Printable version

Tools

- What links here
- Related changes
- Special pages
- Permanent link
- Page information
- Concept URI
- Cite this page

Item | Discussion

Trent Reznor (Q282722)

American musician [edit]

No aliases defined

‣ In more languages

Statements

sex or gender

male [edit]

▾ 4 references

[edit]

imported from — Swedish Wikipedia

[edit]

imported from — Virtual International Authority File

[edit]

imported from — Italian Wikipedia

[edit]

stated in — Integrated Authority File

retrieved — 27 April 2014

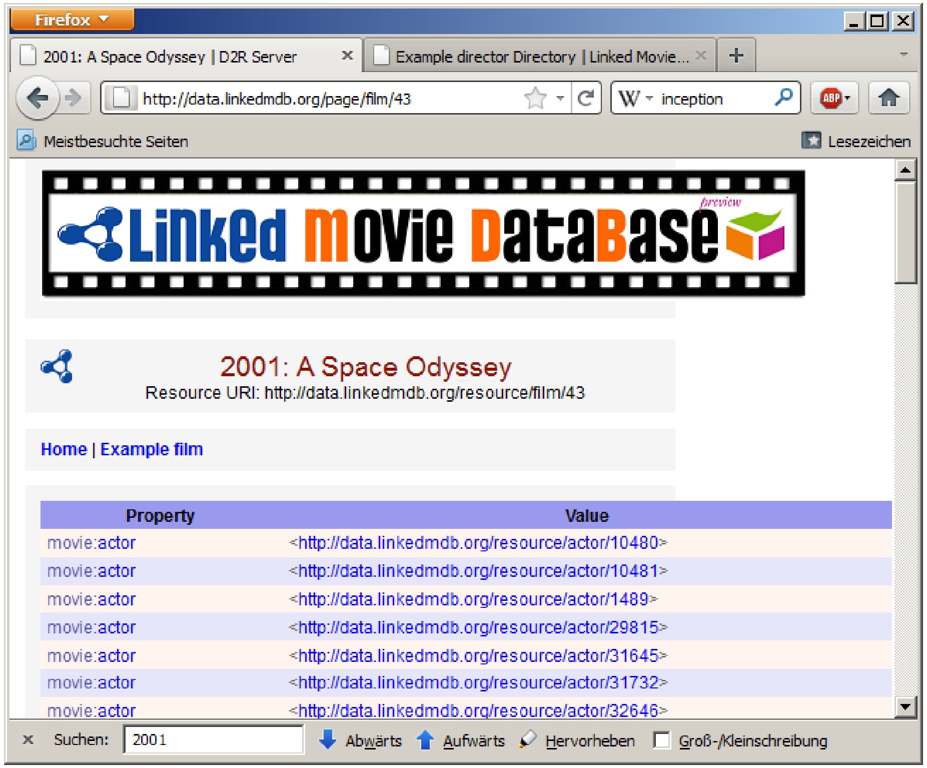
[add reference]

Wikipedia (33 entries) [edit] [Collapse]

be_x_old	Трэнт Рэзнар
be	Трэнт Рэзнар
bg	Трент Резнър
cs	Trent Reznor
da	Trent Reznor
de	Trent Reznor
en	Trent Reznor
es	Trent Reznor
et	Trent Reznor
fa	ترنت رزنر
fi	Trent Reznor
fr	Trent Reznor
gl	Trent Reznor
hu	Trent Reznor
id	Trent Reznor
is	Trent Reznor
it	Trent Reznor
ja	トレント・レズナー
ka	ტრენტ რეზნორი
ko	트렌트 레즈너
lv	Trents Reznors
nl	Trent Reznor

Further Example Datasets

- Linked Movie Database
  - Movies, actors, directors...
- MusicBrainz
  - Artists, albums, ...
- Open Library
  - books, authors, publishers
- DBLP
  - computer science publications


Firefox
2001: A Space Odyssey | D2R Server
Example director Directory | Linked Movie...
http://data.linkedmdb.org/page/film/43
inception
Meistbesuchte Seiten
Lesezeichen
Linked Movie DataBase
preview

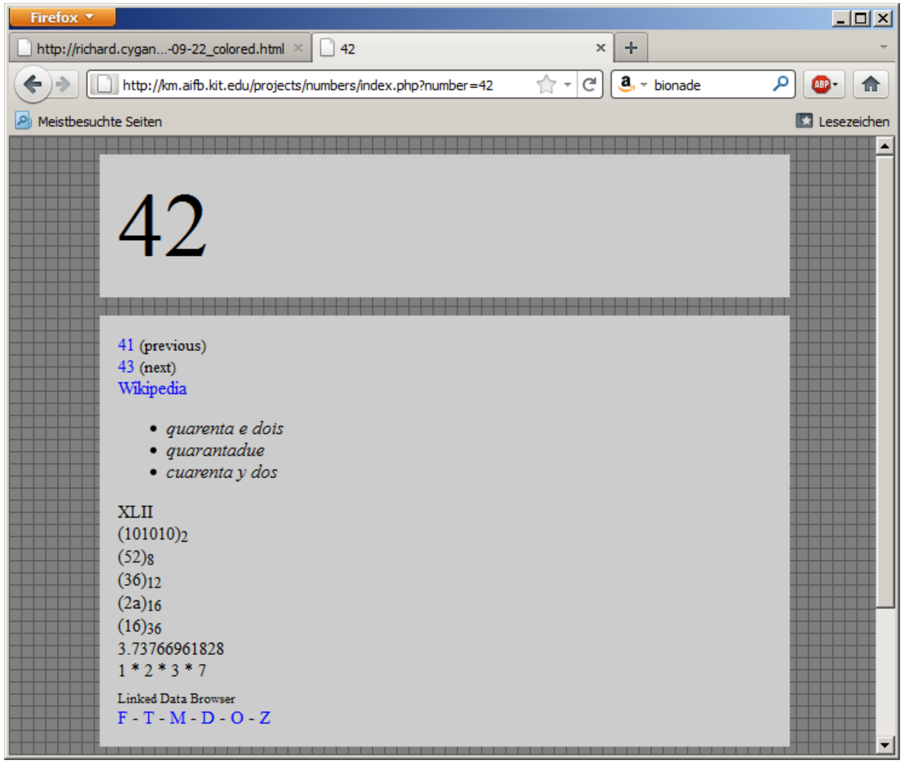
2001: A Space Odyssey
Resource URI: http://data.linkedmdb.org/resource/film/43

Home | Example film

Property	Value
movie:actor	<http://data.linkedmdb.org/resource/actor/10480>
movie:actor	<http://data.linkedmdb.org/resource/actor/10481>
movie:actor	<http://data.linkedmdb.org/resource/actor/1489>
movie:actor	<http://data.linkedmdb.org/resource/actor/29815>
movie:actor	<http://data.linkedmdb.org/resource/actor/31645>
movie:actor	<http://data.linkedmdb.org/resource/actor/31732>
movie:actor	<http://data.linkedmdb.org/resource/actor/32646>

Further Example Datasets

- Linked Open Numbers
  - Numbers and their names in different languages
  - roman and arabic notations, binary, hex etc.


Firefox
http://richard.cygan...-09-22_colored.html
42
http://km.aifb.kit.edu/projects/numbers/index.php?number=42
bionade
Meistbesuchte Seiten
Lesezeichen

42

41 (previous)
43 (next)
Wikipedia

- *quarenta e dois*
- *quarantadue*
- *cuarenta y dos*

XLII
$(101010)_2$
$(52)_8$
$(36)_{12}$
$(2a)_{16}$
$(16)_{36}$
3.73766961828
1 * 2 * 3 * 7

Linked Data Browser
F - T - M - D - O - Z

Vocabularies

- Recap: LOD Best Practices, Principle 3:
  - Use terms from widely deployed vocabularies

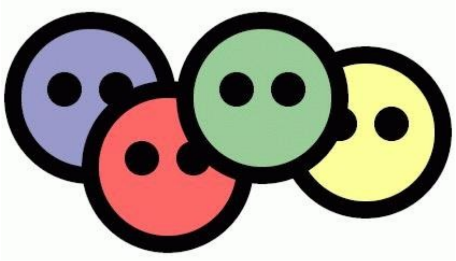
- So, what are common widely deployed vocabularies?

Dublin Core

- We have already encountered this
- Usage: Metadata for resources and documents
- Namespace `http://purl.org/dc/elements/1.1/`
- Common prefix: `dc`
- defines properties, e.g.,
  - creator
  - subject
  - date
- Resources: DCMI Type Vocabulary:
  - Text
  - Image
  - Software
  - ...

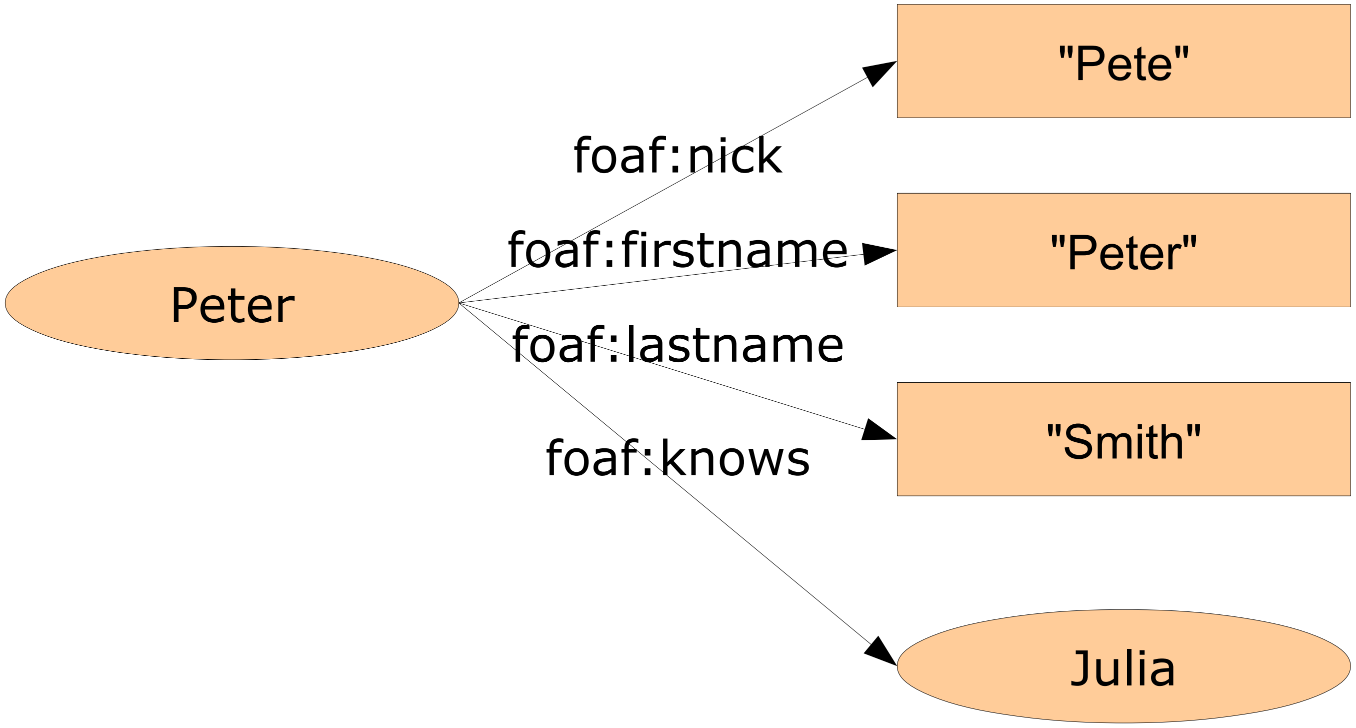
FOAF (Friend of a Friend)

- Persons and their relations
- Created for personal home pages
  - but used widely beyond that
- Namespace `http://xmlns.com/foaf/0.1/`
- Common prefix: `foaf:`

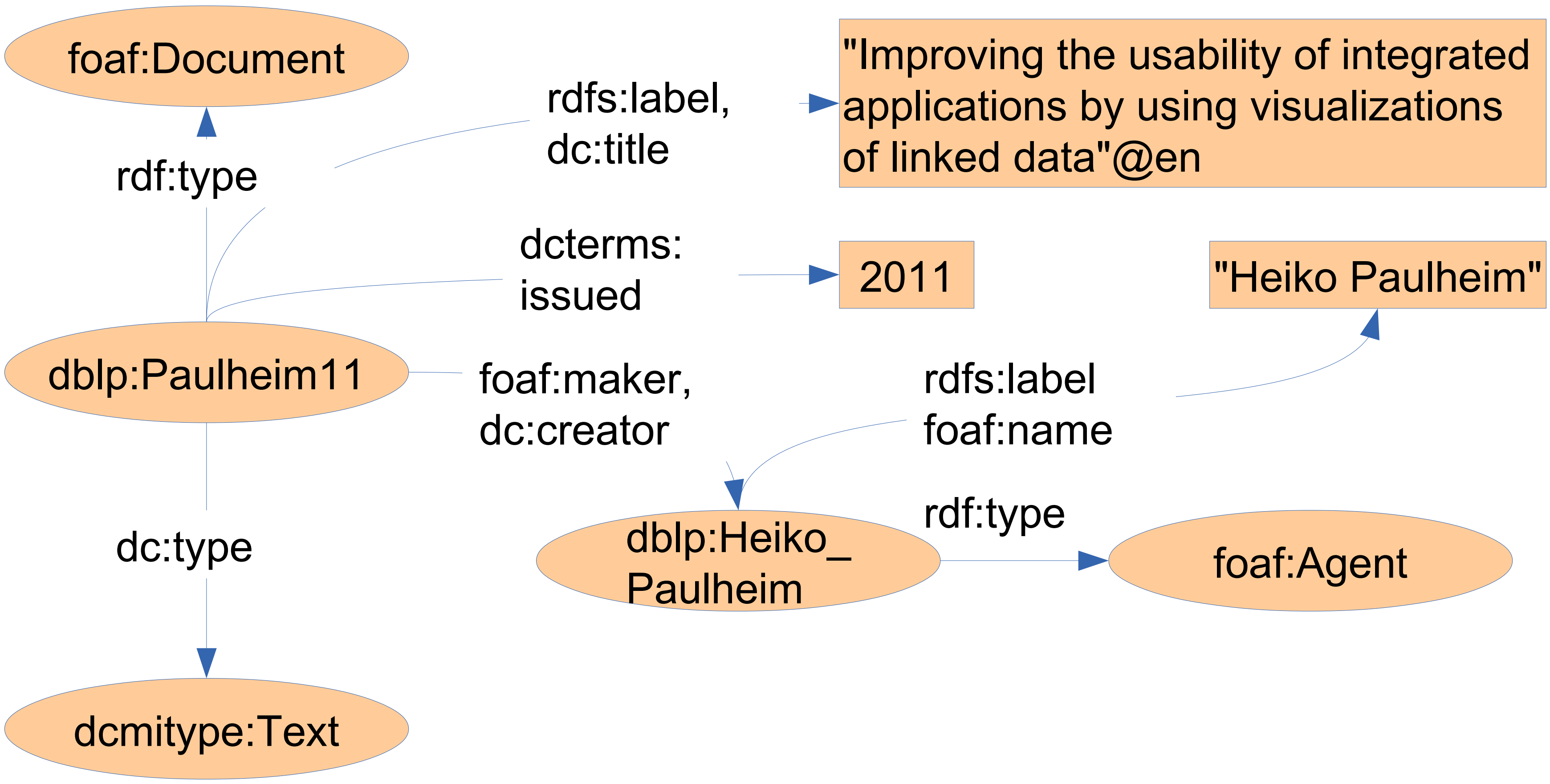


- Important classes
  - Person
  - Group
  - Organization
  - Project
  - ...
- Important properties
  - name, firstName, lastName
  - phone, mbox, homepage
  - knows
  - currentProject, pastProject
  - ...

FOAF (Friend of a Friend)



DBLP: Combining FOAF and DC



WGS 84

- Encodes geographic data
- World Geodetic System 1984
- 3D reference model
- Namespace `http://www.w3.org/2003/01/geo/wgs84_pos#`
- Common prefix: `geo:`

- Classes:
  - SpatialThing
  - Point

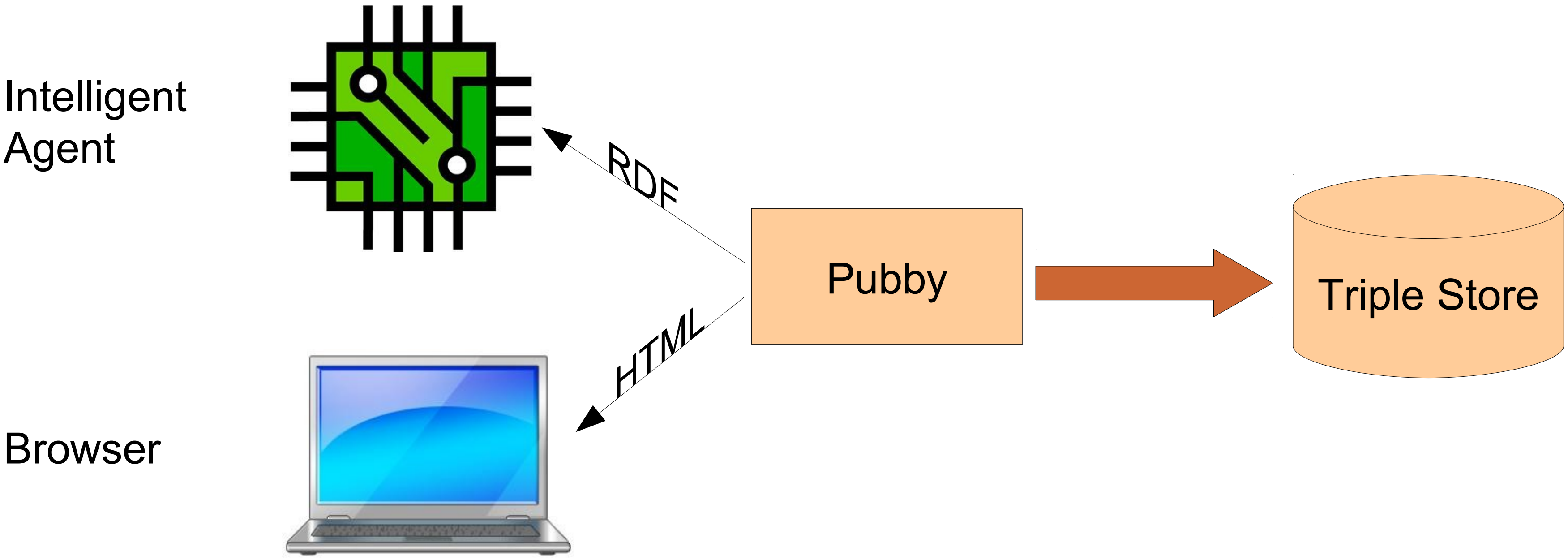
- Properties:
  - latitude
  - longitude
  - altitude
  - location

Publishing Linked Open Data

- Possible variants
  - hand coded
  - from triple stores
  - from relational databases

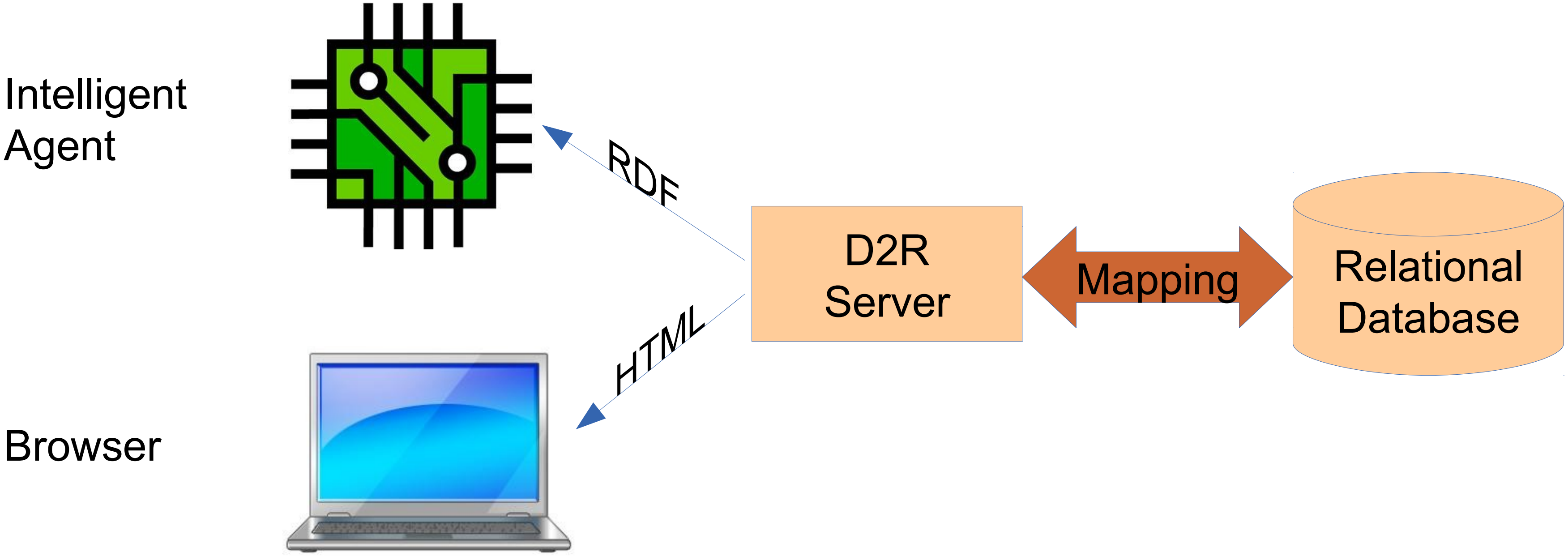
Linked Data from Triple Stores

- Triple Store: RDF storage engine
  - e.g., Virtuoso
- Pubby: Front end for triple stores
- Supports content negotiation etc.



Linked Open Data from RDBMS

- D2R: Linked Open Data interface on relational databases
  - e.g., MySQL



Linked Open Data from RDBMS

ID (int)	name (text)	location (int)
1327890123	"Heiko"	"Mannheim"
		...

```
map:Person a d2rq:ClassMap;
    d2rq:dataStorage map:Database1.
    d2rq:class foaf:Person;
    d2rq:uriPattern "http://foo.bar/p@@Person.ID@@";
    .
map:personName a d2rq:PropertyBridge;
    d2rq:belongsToClassMap map:Person;
    d2rq:property foaf:name;
    d2rq:column "Person.name";
    d2rq:datatype xsd:string;
    .
map:location a d2rq:PropertyBridge;
    d2rq:belongsToClassMap map:Person;
    d2rq:property foaf:basedNear;
    d2rq:column "Person.location";
    d2rq:datatype xsd:string;
    .
```

```
<http://foo.bar/p1327890123> a foaf:Person .
<http://foo.bar/p1327890123> foaf:name "Heiko" .
<http://foo.bar/p1327890123> foaf:basedNear "Mannheim" .
```

Microdata and schema.org

- We have already seen that in the first lecture

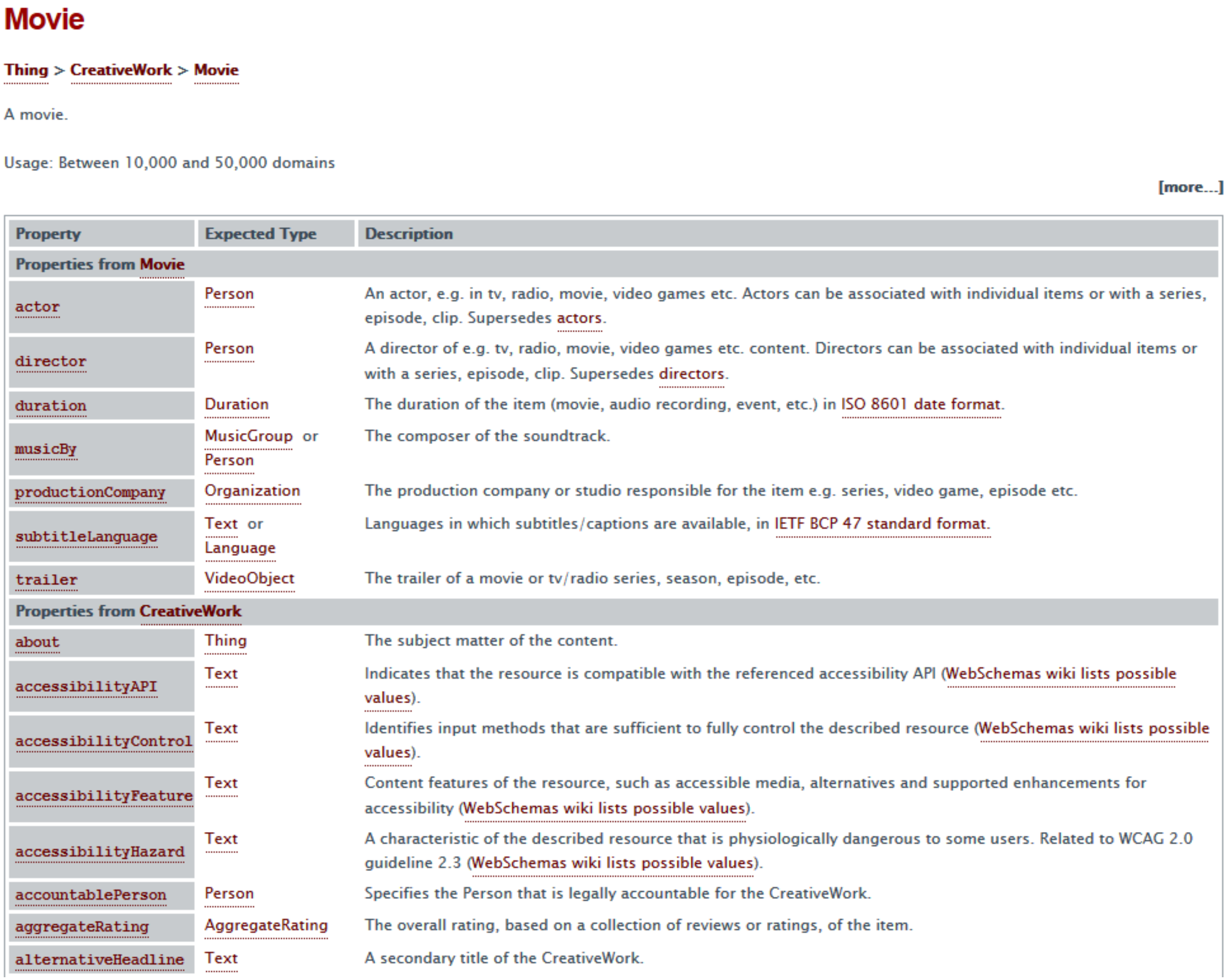
```
<div itemscope
itemtype="http://schema.org/PostalAddress">
 <span itemprop="name">Data and Web Science Group</
```

```
_:1 a <http://schema.org/PostalAddress> .
_:1 <http://schema.org/name> "Data and Web Science Group" .
_:1 <http://schema.org/addressLocality> "Mannheim" .
_:1 <http://schema.org/postalCode> "68131" .
_:1 <http://schema.org/adressCounty> "Germany" .
```

Microdata and schema.org

- schema.org defines (among others)
  - products
  - product offers
  - businesses and local businesses (stores, cafés, …)
  - books, movies, records
  - events
  - recipes
  - persons
  - ...

schema.org



Movie

Thing > CreativeWork > Movie

A movie.

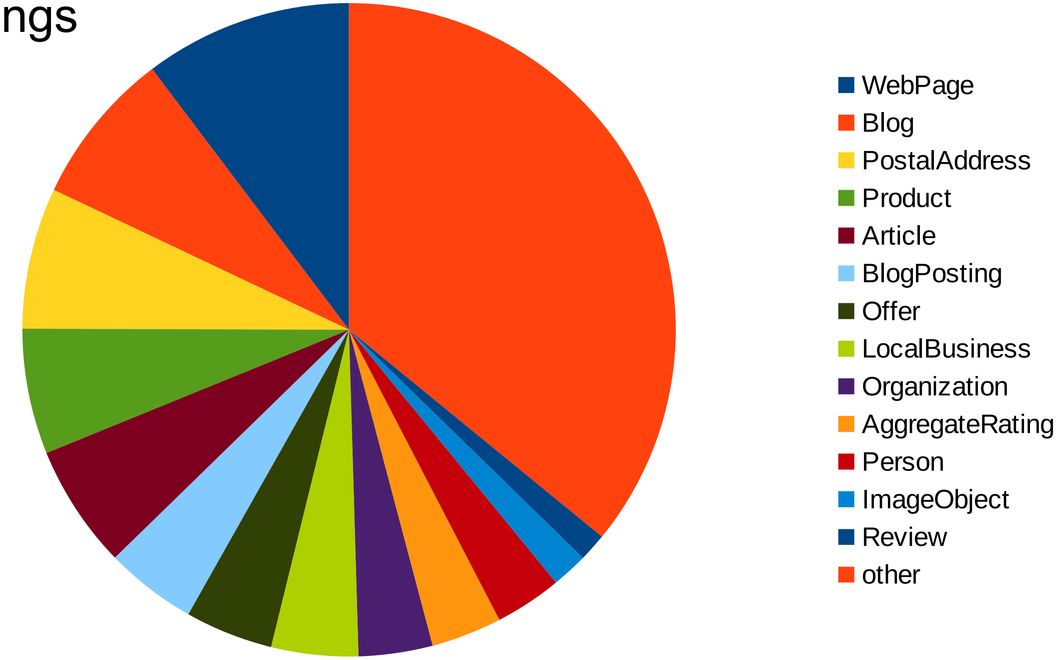
Usage: Between 10,000 and 50,000 domains

[more...]

Property	Expected Type	Description
Properties from Movie		
actor	Person	An actor, e.g. in tv, radio, movie, video games etc. Actors can be associated with individual items or with a series, episode, clip. Supersedes actors.
director	Person	A director of e.g. tv, radio, movie, video games etc. content. Directors can be associated with individual items or with a series, episode, clip. Supersedes directors.
duration	Duration	The duration of the item (movie, audio recording, event, etc.) in ISO 8601 date format.
musicBy	MusicGroup or Person	The composer of the soundtrack.
productionCompany	Organization	The production company or studio responsible for the item e.g. series, video game, episode etc.
subtitleLanguage	Text or Language	Languages in which subtitles/captions are available, in IETF BCP 47 standard format.
trailer	VideoObject	The trailer of a movie or tv/radio series, season, episode, etc.
Properties from CreativeWork		
about	Thing	The subject matter of the content.
accessibilityAPI	Text	Indicates that the resource is compatible with the referenced accessibility API (WebSchemas wiki lists possible values).
accessibilityControl	Text	Identifies input methods that are sufficient to fully control the described resource (WebSchemas wiki lists possible values).
accessibilityFeature	Text	Content features of the resource, such as accessible media, alternatives and supported enhancements for accessibility (WebSchemas wiki lists possible values).
accessibilityHazard	Text	A characteristic of the described resource that is physiologically dangerous to some users. Related to WCAG 2.0 guideline 2.3 (WebSchemas wiki lists possible values).
accountablePerson	Person	Specifies the Person that is legally accountable for the CreativeWork.
aggregateRating	AggregateRating	The overall rating, based on a collection of reviews or ratings, of the item.
alternativeHeadline	Text	A secondary title of the CreativeWork.

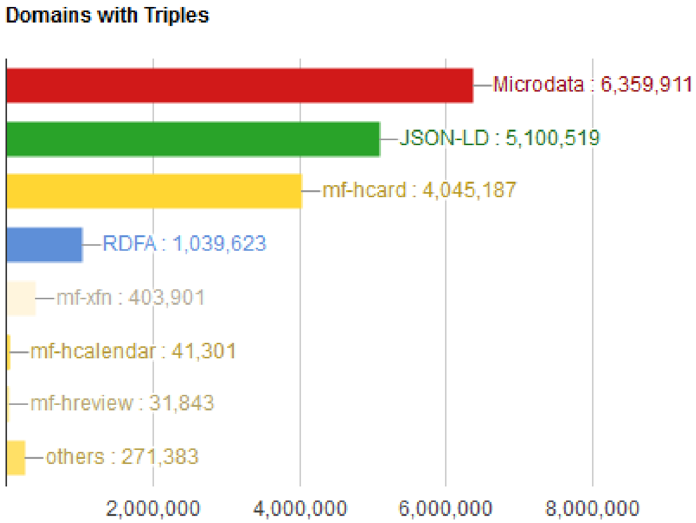
Deployment of schema.org

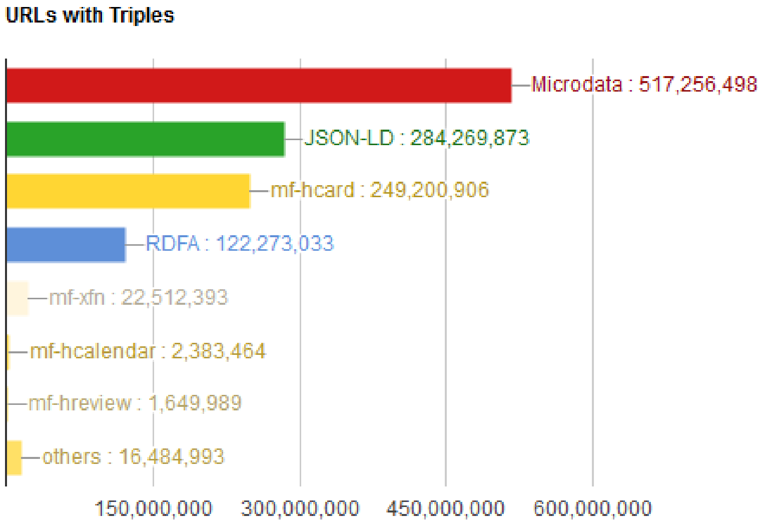
- Main topics of schema.org:
  - Meta information on web page content (web page, blog...)
  - Business data (products, offers, …)
  - Contact data (businesses, persons, ...)
  - (Product) reviews and ratings
- ...and a massive long tail



Growth of schema.org

- Note: schema.org is mainly used with Microdata
  - ...and Microdata is mainly used with schema.org





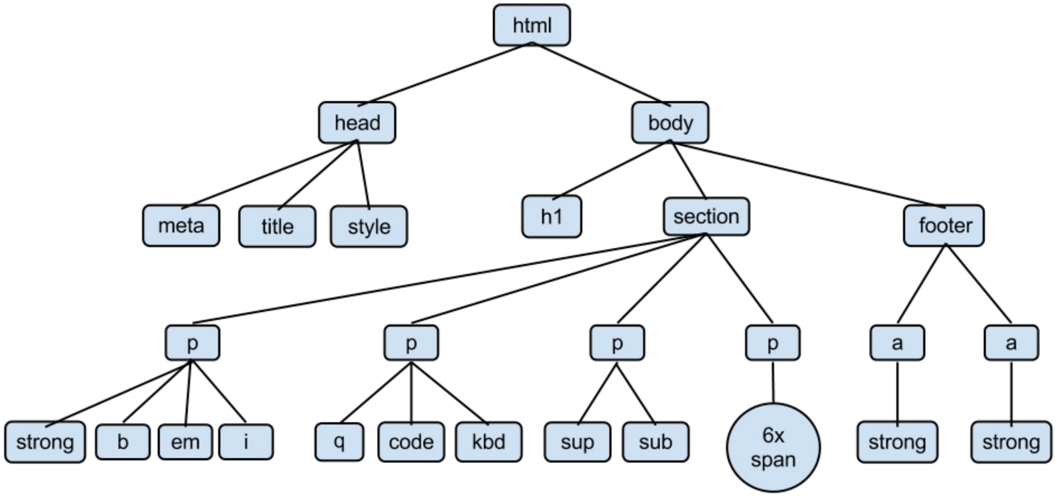
http://webdatacommons.org/structureddata/

Microdata/schema.org vs. Linked Open Data

- Commonalities
  - Both encode machine-interpretable knowledge
  - Schema.org uses a standard vocabulary
  - Both can be encoded as RDF

Microdata/schema.org vs. Linked Open Data

- Differences
  - Microdata is embedded in the DOM tree
    - i.e., the resulting RDF is always a set of trees
    - not a general directed graph
    - no cycles, no reification
  - Microdata uses only blank nodes and literals



Microdata/schema.org vs. Linked Open Data

- Linked Data Principles (Tim Berners-Lee 2006)
  - Use URIs as names for things
  - Use HTTP URIs that can be looked up
  - When someone looks up a HTTP URI, provide useful information using a standard

MD2RDF creates blank nodes

Blank nodes cannot be looked up

HTML5+MD is a standard

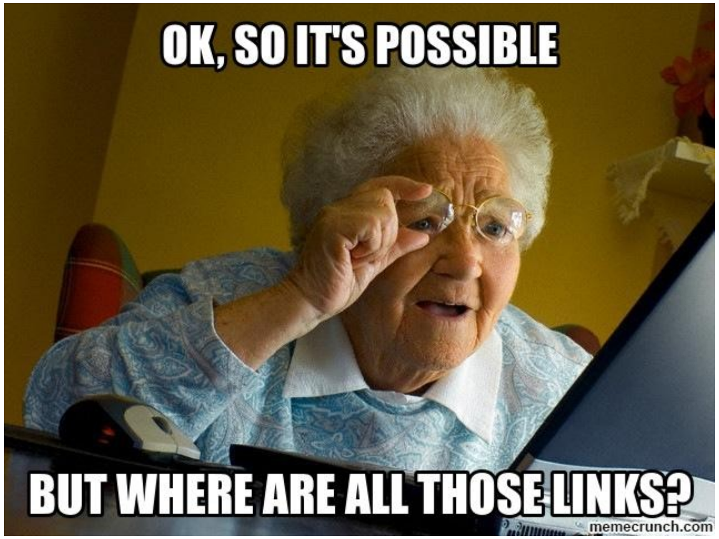
```
<div itemscope
itemtype="http://schema.org/PostalAddress">
 <span itemprop="name">Data and Web Science Group</span>
```

```
<http://foo.bar/#1> a <http://schema.org/PostalAddress> .
<http://foo.bar/#1> <http://schema.org/name> "Data and Web
Science Group" .
<http://foo.bar/#1> <http://schema.org/addressLocality>
"Mannheim" .
<http://foo.bar/#1> <http://schema.org/postalCode> "68131" .
<http://foo.bar/#1> <http://schema.org/adressCounty> "Germany" .
```

Microdata/schema.org vs. Linked Open Data

- Linked Data Principles (TimBL 2006)
  - Use URIs as names for things
  - Use HTTP URIs that can be looked up
  - When someone looks up a HTTP URI, provide useful information using a standard
  - Include links to other URIs

This is possible with schema.org/sameas



- Linkage within schema.org Microdata:
  - Only 0.02% of all data providers use schema.org/sameas

Microdata/schema.org vs. LOD

- Five Star Scheme (TimBL 2010)

  * Available on the web with an open license

  ** Available as machine-readable, structured data

  *** as (**), using a non-proprietary format

  **** plus: using open standards by the W3C

  ***** plus: links to other datasets

- What's the license of web data?

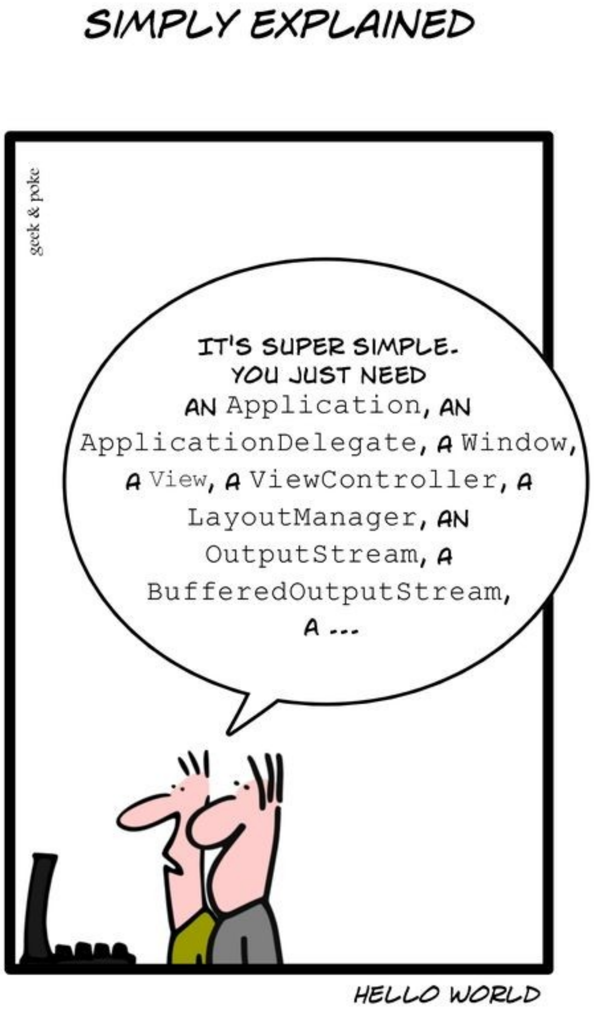
Intermediate Summary

- Until today, we have dealt with the Semantic Web as a *vision*
- Today, we have seen two incarnations of that vision
  - Linked Open Data
  - schema.org/Microdata
- Both have a lot in common

And Now for Something Completely Different

Programming for the Semantic Web

- Let's start with a simple application
  - a Hello World application for the Semantic Web

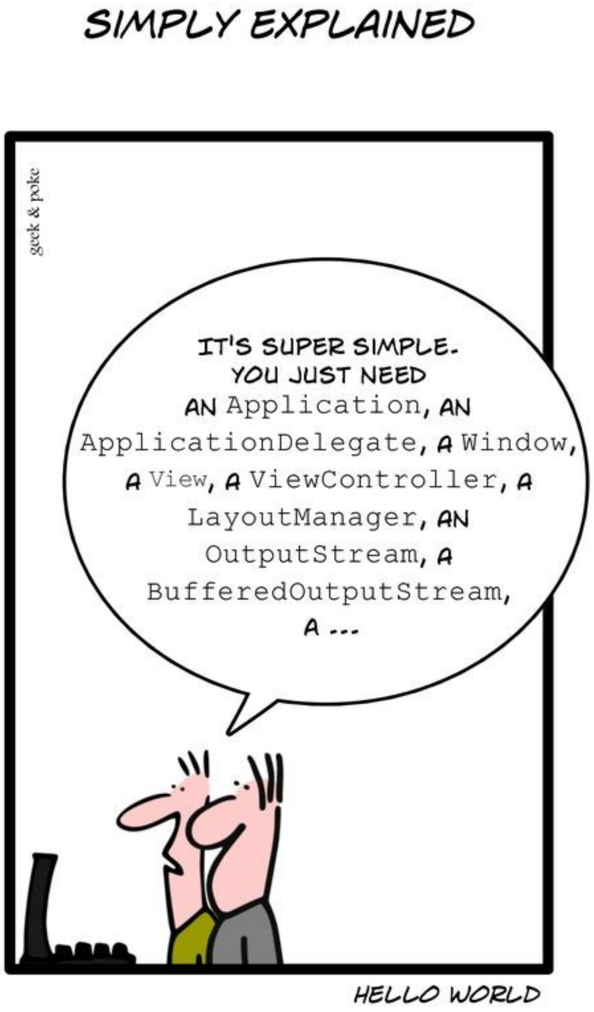

SIMPLY EXPLAINED
geek & poke
IT'S SUPER SIMPLE. YOU JUST NEED AN Application, AN ApplicationDelegate, A Window, A View, A ViewController, A LayoutManager, AN OutputStream, A BufferedOutputStream, A ...
HELLO WORLD

Using only Plain Java

```
URL url = new URL("http://dbpedia.org/resource/Mannheim");
URLConnection conn = url.openConnection();
conn.addRequestProperty("Accept", "text/rdf+n3");
BufferedReader BR = new BufferedReader(
                      new InputStreamReader(conn.getInputStream())
                    );

while(BR.ready()) {
  String triple = BR.readLine();
  StringTokenizer tokenizer = new StringTokenizer(triple, " ");
  String subject = tokenizer.nextToken();
  String predicate = tokenizer.nextToken();
  String object = tokenizer.nextToken();
  ...
}
```

Using only Plain Java

- Let's start with a simple application
  - a Hello World application for the Semantic Web
- Using plain Java is possible
  - but not very comfortable
  - there are more sophisticated frameworks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IT'S SUPER SIMPLE. YOU JUST NEED AN Application, AN ApplicationDelegate, A Window, A View, A ViewController, A LayoutManager, AN OutputStream, A BufferedOutputStream, A ...
HELLO WORLD

Programming with Jena

- Jena is a well-known Semantic Web programming framework
- started in 2000 at HP Labs
- Apache open source project since 2010

- Central concepts
  - Models (`class Model`) are RDF graphs
  - Resources (`class Resource`) are resources in RDF graphs
- Special features
  - Database connectors for persistence
  - Support for reasoning
  - Rule engines
  - Support for SPARQL (see next lecture)

Programming with Jena

- Reading a model from a derefencable URI

```
model.read("http://dbpedia.org/resource/Mannheim");
```

- Navigating within a model

```
Resource mannheim =
  model.getResource("http://dbpedia.org/resource/
                                   Mannheim");

Resource countryOfMannheim =
  model.getProperty(
    "http://dbpedia.org/ontology/country").
  getResource();
```

Programming with Jena

- Working with literals

```
Literal lit = mannheim.getProperty(
        "http://www.w3.org/2000/01/rdf-schema#label").
        getLiteral();

lit.getString();

lit.getLanguage();

lit.getDatatype();
```

Programming with Jena

- Working with multi-valued relations

  -
    ```
    StmtIterator iter = mannheim.getProperty(
    "http://www.w3.org/2000/01/rdf-schema#label");
    ```

  -
    ```
    while(iter.hasNext()) {
       Statement s = iter.next();
       RDFNode node = s.getObject();
       if(node.isLiteral())
          System.out.println(node.asLiteral().getString());
       }
    ```

creates an iterator over all triples
with the subject node
and the given predicate

Iterators in Jena

- Jena uses the iterator pattern quite frequently
- e.g.:

```
StmtIterator iter = mannheim.getProperty(
"http://www.w3.org/2000/01/rdf-schema#label");
```

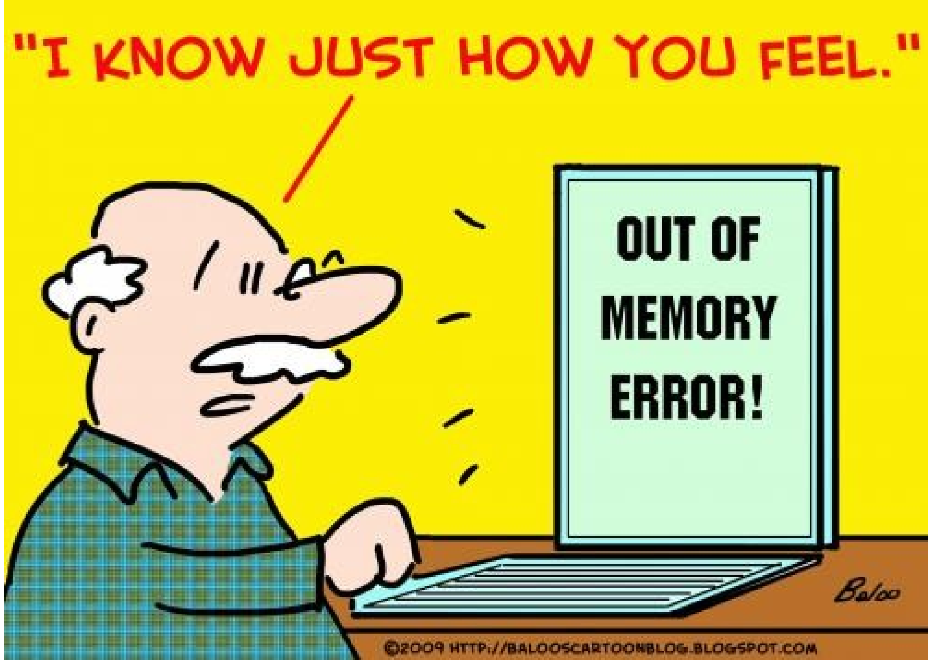
- But there is no such thing as

```
Collection<Statement> triples =
mannheim.getProperty(
"http://www.w3.org/2000/01/rdf-schema#label");
```

- Why?

Iterators in Jena

- Data volumes in the Semantic Web can be big
- e.g., reading all triples from DBpedia
  - stored in List<Statement> would kill the main memory
  - iterators allow a more efficient memory use


"I KNOW JUST HOW YOU FEEL."
OUT OF MEMORY ERROR!
Baloo
©2009 HTTP://BALOOSCARTOONBLOG.BLOGSPOT.COM

Programming with Jena

- Manipulating models

```
p1.addProperty("http://xmlns.com/foaf/0.1/knows",p2);
```

- Watching model changes

```
class MyListener implements ModelChangedListener...
MyListener listener = new MyListener();
model.add(listener);
```

Reasoning with Jena

- Recap: we can derive information from a schema (T-Box) and data (A-box)

```
:knows rdfs:domain :Person .
:knows rdfs:range :Person .
:Peter :knows :Tom .

→ :Peter a :Person .
→ :Tom a :Person .
```

- Jena also supports reasoning

Reasoning with Jena

- Given: a schema and some data

```
Model schemaModel = ModelFactory.createDefaultModel();
InputStream IS = new
FileInputStream("data/example_schema.rdf");
schemaModel.read(IS);

Model dataModel = ModelFactory.createDefaultModel();
IS = new FileInputStream("data/example_data.rdf");
dataModel.read(IS);

Model reasoningModel =
  ModelFactory.createRDFSModel(schemaModel, dataModel);
```

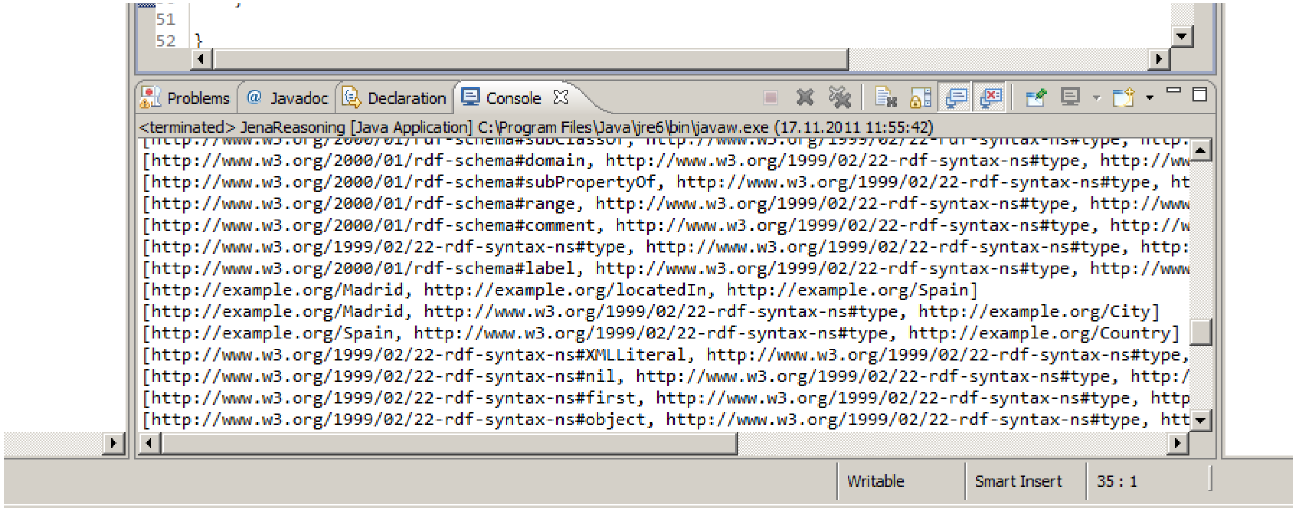
- Now, `reasoningModel` contains all derived facts

Reasoning with Jena

- Now, `reasoningModel` contains all derived facts

```
StmtIterator it =
  reasoningModel.listStatements();
while(it.hasNext()) {
  Statement s = it.next();
  System.out.println(s);
}
```

- Output:



```
}
```

```
<terminated> JenaReasoning [Java Application] C:\Program Files\Java\jre6\bin\javaw.exe (17.11.2011 11:55:42)
[http://www.w3.org/2000/01/rdf-schema#subClassOf, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http:
[http://www.w3.org/2000/01/rdf-schema#domain, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://ww
[http://www.w3.org/2000/01/rdf-schema#subPropertyOf, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, ht
[http://www.w3.org/2000/01/rdf-schema#range, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www
[http://www.w3.org/2000/01/rdf-schema#comment, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://w
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[http://www.w3.org/2000/01/rdf-schema#label, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www
[http://example.org/Madrid, http://example.org/locatedIn, http://example.org/Spain]
[http://example.org/Madrid, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://example.org/City]
[http://example.org/Spain, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://example.org/Country]
[http://www.w3.org/1999/02/22-rdf-syntax-ns#XMLLiteral, http://www.w3.org/1999/02/22-rdf-syntax-ns#type,
[http://www.w3.org/1999/02/22-rdf-syntax-ns#nil, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http:/
[http://www.w3.org/1999/02/22-rdf-syntax-ns#first, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http
[http://www.w3.org/1999/02/22-rdf-syntax-ns#object, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, htt
```

Programming with RDFLib (Python)

- RDFLib is a Python library for working with RDF
- initial release 4 June, 2002 by Daniel Krech
  - Now being developed by the community at github: https://github.com/RDFLib/rdflib/
- it contains parsers and serializers for
  - RDF/XML, N3, NTriples, N-Quads, Turtle, TriX, RDFa and Microdata
- graph interface which can be backed by store implementations
  - memory storage
  - persistent storage on top of the Berkeley DB
- reasoning possible (https://github.com/RDFLib/OWL-RL)
- SPARQL 1.1 implementation (see next lecture)

Programming with RDFLib (Python)

- primary interface is a Graph
  - represented a s a set of 3-item triples

```
[
    (subject,  predicate,  object),
    (subject1, predicate1, object1),
    ...
    (subjectN, predicateN, objectN)
]
```

Programming with RDFLib (Python)

- Reading a model from a derefencable URI

```
import rdflib
g=rdflib.Graph()
g.load('http://dbpedia.org/resource/Mannheim')
```

- Print out all RDF triples

```
for s,p,o in g:
    print(s,p,o)
```

- Navigating within a graph

```
print(g.value(
    URIRef("http://dbpedia.org/resource/Mannheim"),
    URIRef("http://dbpedia.org/ontology/country")
))
```

Programming with RDFLib (Python)

- Most often reduced to basic triple matching
- Graph.triples(subject, predicate, object)
  - each of them can be None (similar to null in Java)

```
for s,p,o in g.triples( (None, RDF.type, FOAF.Person) ):
   print("%s is a person"%s)
```

- Special functions for returning only specific parts
  - Graph.subjects(predicate, object) – returns only subjects
  - Graph.predicate(subject, object)
  - Graph.objects(subject, predicate)
  - Graph.subject_objects(predicate)
  - Graph.subject_predicates(object)
  - Graph.predicate_objects(subject)
  - Graph.value(subject, predicate)
    - For just one value and not a generator/iterator

Programming with RDFLib (Python)

- create URIs

```
mannheim = URIRef('http://example.com/Mannheim')
```

- create literals

```
mannheim_literal = Literal("Mannheim")
```

- Add triples to graph

```
   g.add( (mannheim, RDFS.label, mannheim_literal) )
   g.add( (mannheim, RDFS.label, Literal("Mannheim", lang="de")) )
```

- Serialize graph

```
print( g.serialize(format='n3') )
```

Wrap-Up

- Today, we have seen
  - two incarnations of the Semantic Web
  - i.e., Linked Open Data
  - and Microdata/schema.org

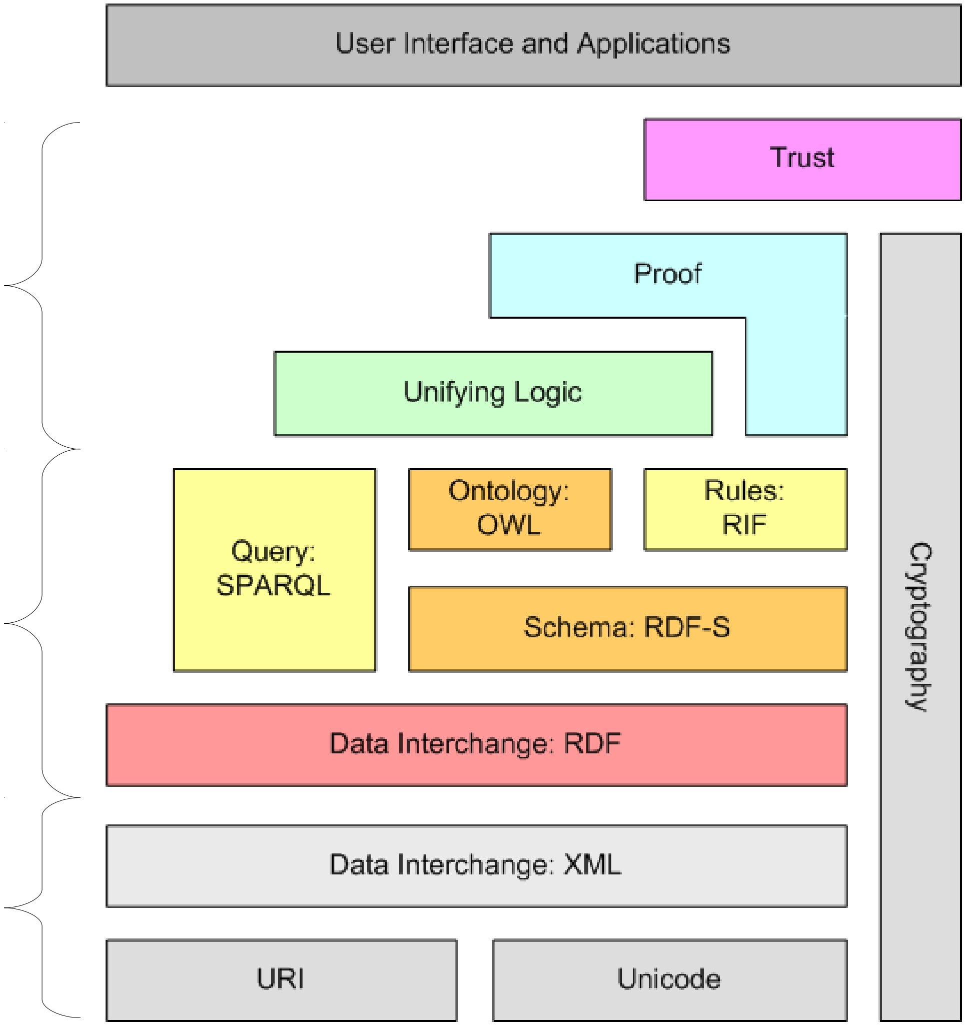
- ...and we have learned how to write programs consuming Semantic Web data
  - Jena & RDFlib programming frameworks
  - loading RDF from files and from URLs
  - performing reasoning

Semantic Web – Architecture

here be dragons...

Semantic Web Technologies (This lecture)

Technical Foundations



Berners-Lee (2009): *Semantic Web and Linked Data*
http://www.w3.org/2009/Talks/0120-campus-party-tbl/

Questions?