

Linked Open Data & Programming

IE650 Knowledge Graphs



Overview

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

Linked Open Data

- What we've got to know up to now
 - RDF as a universal language for encoding knowledge
 - RDF Schema for describing vocabularies (i.e., classes and properties)
- How can we publish such knowledge?
- Linked Open Data
 - Uses techniques like URIs, RDF, RDF schema for publishing knowledge on the Web

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
 - Publishing your own knowledge graph online just adds a scattered piece
 - “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:

:Uni_MA :locatedIn <<http://dbpedia.org/resource/Mannheim>> .

DBpedia  Browse using  Formats  Faceted Browser  Sparql Endpoint

About: [Mannheim](http://dbpedia.org/resource/Mannheim)

An Entity of Type: [Stadt](http://dbpedia.org/resource/Stadt), from Named Graph: <http://dbpedia.org>, within Data Space: dbpedia.org

Die Universitätsstadt Mannheim (kurpfälzisch Mannem [manəm], auch Monnem) ist ein Stadtkreis mit 311.831 Einwohnern (31. Dezember 2021) im Regierungsbezirk Karlsruhe in Baden-Württemberg. Sie ist nach der Landeshauptstadt Stuttgart und vor Karlsruhe die zweitbevölkerungsreichste Stadt des Landes. Die ehemalige Residenzstadt (1720–1778) der Kurpfalz mit ihrem stadtprägenden Barockschloss, einer der größten Schlossanlagen der Welt, bildet das wirtschaftliche und kulturelle Zentrum der Metropolregion Rhein-Neckar mit 2,4 Millionen Einwohnern.



Property	Value
dbpedia:areaCode	0621
dbpedia:areaTotal	14496000.000000 (xsd:double)
dbpedia:country	dbpedia:Germany
dbpedia:district	dbpedia:Urban_districts_of_Germany
dbpedia:division	dbpedia:Stadtbezirke
dbpedia:elevation	97.000000 (xsd:double)
dbpedia:federalState	dbpedia:Baden-Württemberg
dbpedia:foundingYear	1607-01-01 (xsd:year)
dbpedia:leaderName	dbpedia:Peter_Kurz
dbpedia:leaderTitle	Lord Mayor (en)
dbpedia:licenceNumber	MA
dbpedia:populationMetro	2362046 (xsd:nonNegativeInteger)
dbpedia:postalCode	68001–68309

<http://dbpedia.org/resource/Mannheim>

Why “Linked” Open Data?

- Example:

:Uni_MA :locatedIn <http://dbpedia.org/resource/Mannheim> .

```
@prefix dbo: <http://dbpedia.org/ontology/> .
@prefix dbr: <http://dbpedia.org/resource/> .
dbr:Helicopter dbo:wikiPageWikiLink dbr:Mannheim .
dbr:War_of_the_First_Coalition dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Decathlon dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/4_u0007_100_metres_relay> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Parkrun dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/Paul_Davidson_(producer)> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:DFL-Ligapokal dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/Belarus_men_u0027s_national_ice_hockey_team> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:DFL-Supercup dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Arthur_Schopenhauer dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Voltaire dbo:wikiPageWikiLink dbr:Mannheim .
dbr:List_of_twin_towns_and_sister_cities_in_China dbo:wikiPageWikiLink dbr:Mannheim .
dbr:List_of_twin_towns_and_sister_cities_in_Poland dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Jagdeschwader_52 dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/419_Tactical_Fighter_Training_Squadron> dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/2020_u201321_DFB-Pokal> dbo:wikiPageWikiLink dbr:Mannheim .
@prefix dbp: <http://dbpedia.org/property/> .
<http://dbpedia.org/resource/2020_u201321_DFB-Pokal> dbp:location dbr:Mannheim .
dbr:Oppenheim dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Street_name dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Bon_Jovi_Live dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Madly_in_Anger_with_the_World_Tour dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Stalking dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Sociology_of_knowledge dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Felix_Sturm dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/Battle_of_Berlin_(RAF_campaign)> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Die_PARTEI dbo:wikiPageWikiLink dbr:Mannheim .
dbr:PopMart_Tour dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/3_u00F0Crgen_Klinsmann> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Monsters_of_Rock dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/2011_Uefa_European_Under-19_Championship_qualification> dbo:wikiPageWikiLink dbr:Mannheim ;
dbp:stadium dbr:Mannheim .
<http://dbpedia.org/resource/Bruce_Springsteen_1992_u20131993_World_Tour> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Razors_Edge_World_Tour dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Break_Every_Rule_World_Tour dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Wacken_Open_Air dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Sade_discography dbo:wikiPageWikiLink dbr:Mannheim .
dbr:German_Chess_Championship dbo:wikiPageWikiLink dbr:Mannheim .
<http://dbpedia.org/resource/2016_Uefa_European_Under-19_Championship> dbo:wikiPageWikiLink dbr:Mannheim ;
dbp:stadium dbr:Mannheim .
<http://dbpedia.org/resource/Henry_J_Leir> dbo:wikiPageWikiLink dbr:Mannheim .
dbr:Allied_advance_from_Paris_to_the_Rhine dbo:wikiPageWikiLink dbr:Mannheim .
```

<https://dbpedia.org/data/Mannheim.ttl>

HTML Links vs. Links in Linked Open Data

- Compare

Uni MA located in `<a href="http://www.mannheim.de">Mannheim</a>.`

to

`:UniMA :locatedIn <http://dbpedia.org/resource/Mannheim> .`

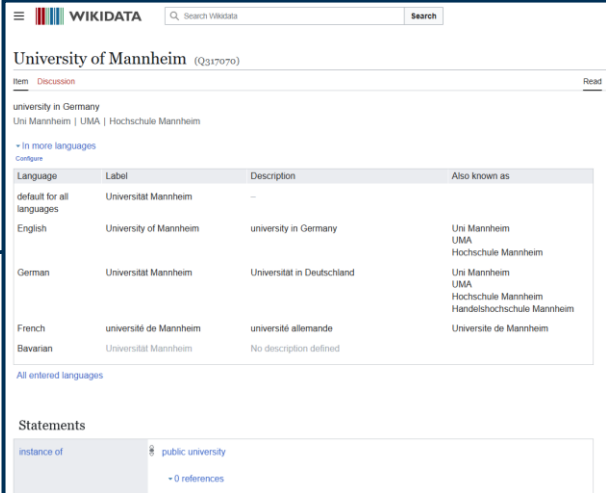
- Observation:

- 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*

:Uni_MA owl:sameAs <https://www.wikidata.org/wiki/Q317070> .



Language	Label	Description	Also known as
default for all languages	Universität Mannheim	—	
English	University of Mannheim	university in Germany	Uni Mannheim UMA Hochschule Mannheim
German	Universität Mannheim	Universität in Deutschland	Uni Mannheim UMA Hochschule Mannheim Handelshochschule Mannheim
French	université de Mannheim	université allemande	Université de Mannheim
Bavarian	Universität Mannheim	No description defined	

All entered languages

Statements

instance of public university

+ 0 references



* 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`

Linking to a Schema

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

:Uni MA
<http://xmlns.com/foaf/0.1/name>
 "University Of Mannheim" .



```
<rdf:domain rdf:resource="http://xmlns.com/foaf/0.1/Agent"/>
<rdf: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"/>
  <rdf:domain rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  <rdf:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
  <rdf:isDefinedBy rdf:resource="http://xmlns.com/foaf/0.1/">
  <rdf: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"/>
  <rdf:domain rdf:resource="http://xmlns.com/foaf/0.1/Person"/>
  <rdf:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
  <rdf: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"/>
  <rdf:domain rdf:resource="http://xmlns.com/foaf/0.1/Person"/>
  <rdf:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal"/>
  <rdf:isDefinedBy rdf:resource="http://xmlns.com/foaf/0.1/">
  </rdf:Property>
```

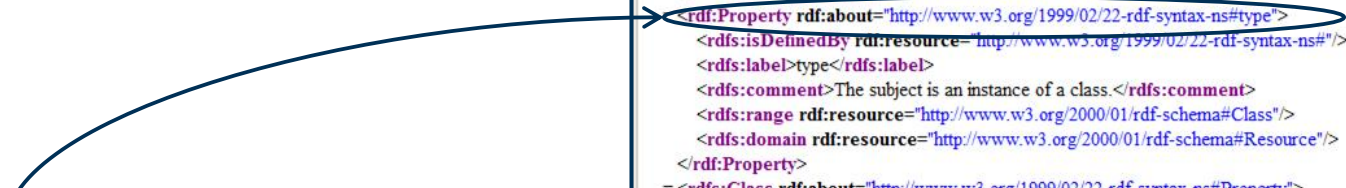
<http://xmlns.com/foaf/0.1/name>



Linking to a Schema

- This also works for “built in” schemas

:Uni_MA rdf:type:University.



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

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



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

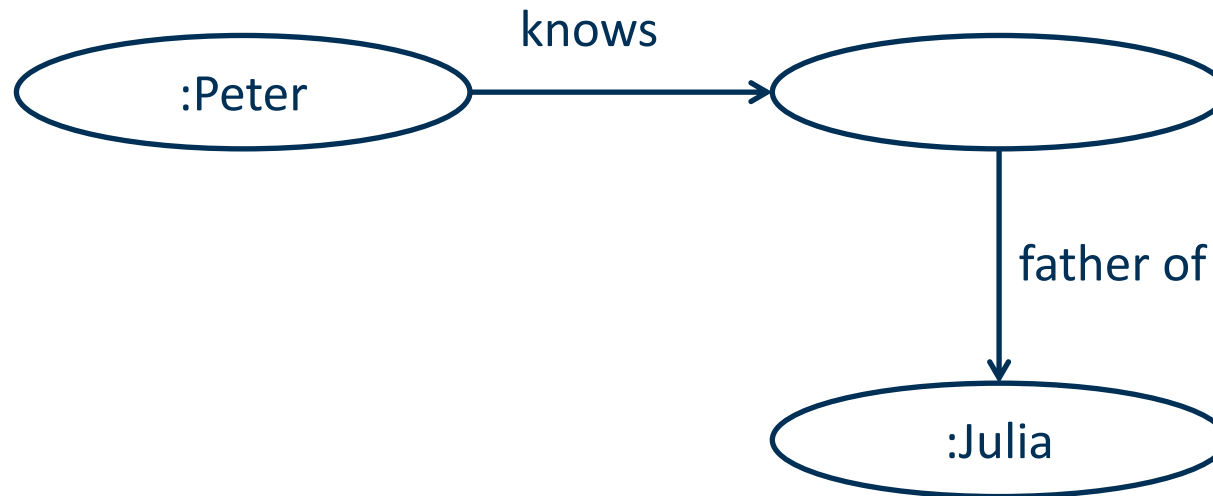


What Data to Serve at a URI?

- 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

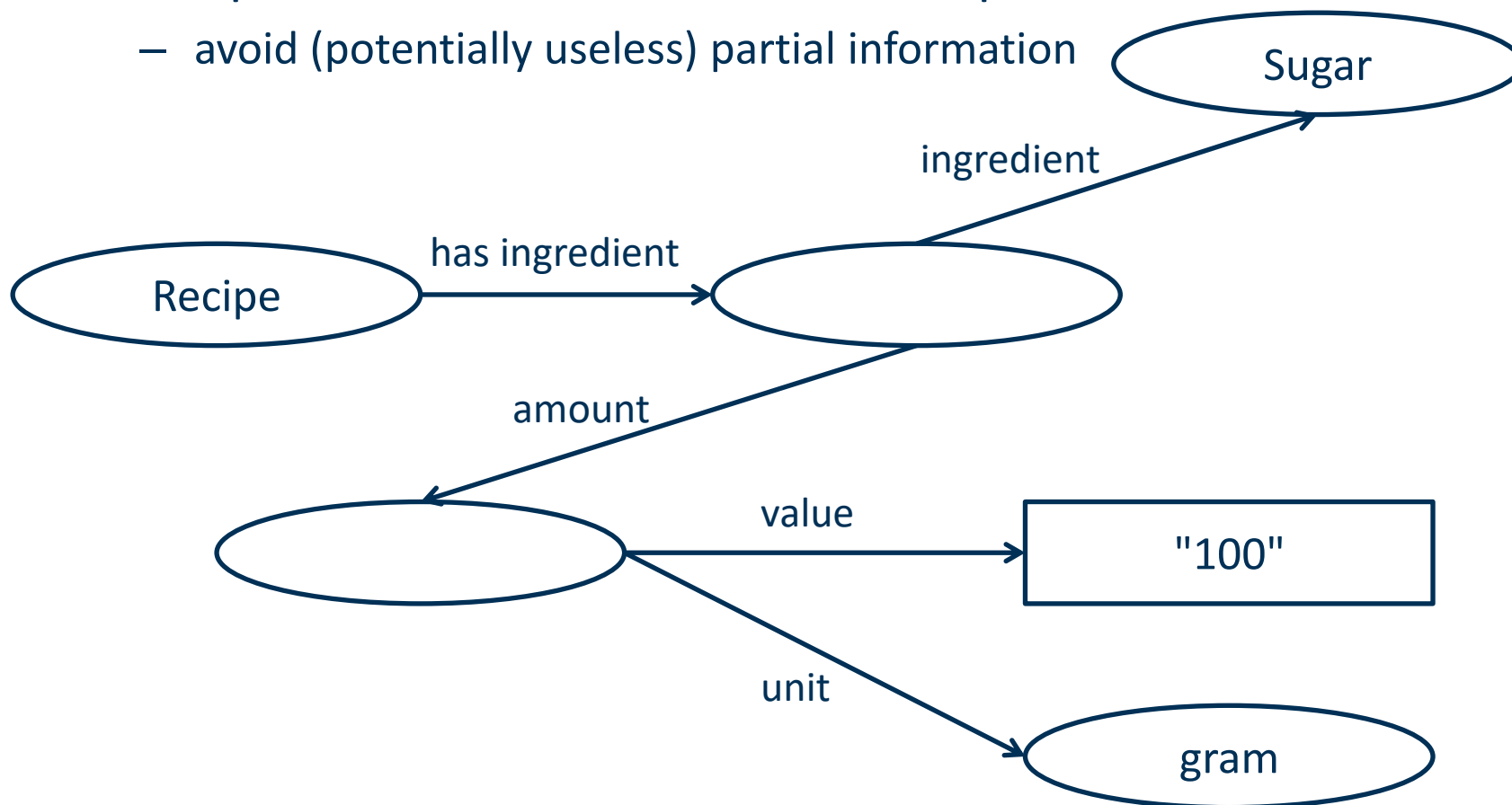
RDF Molecules

- Avoid dead ends in browsing



RDF Molecules

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

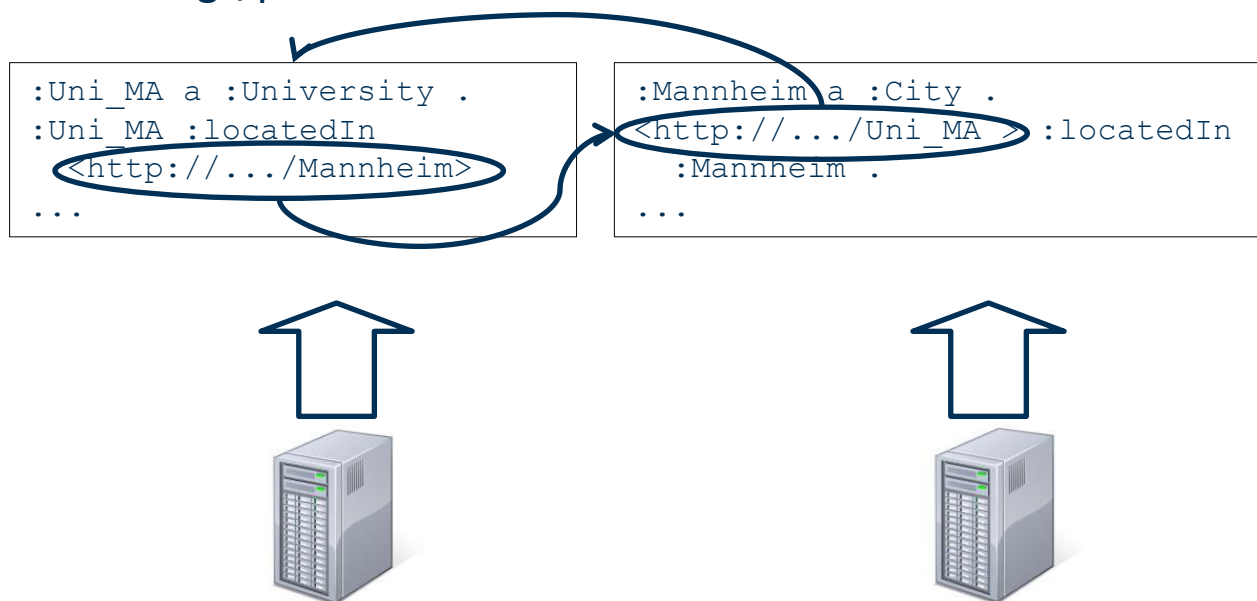


RDF Molecules: Theory and Practice

- 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

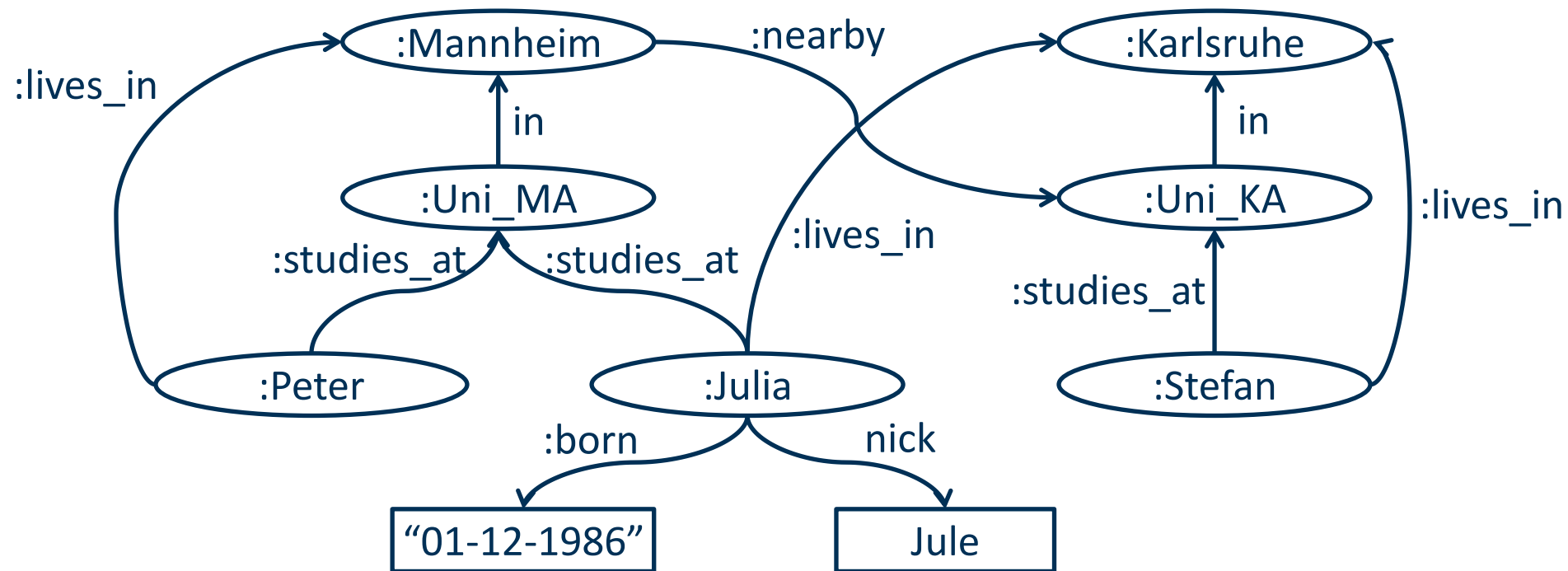
RDF Molecules: Theory and Practice

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



RDF Molecules: Theory and Practice

- Example Graph



The Five Star Schema

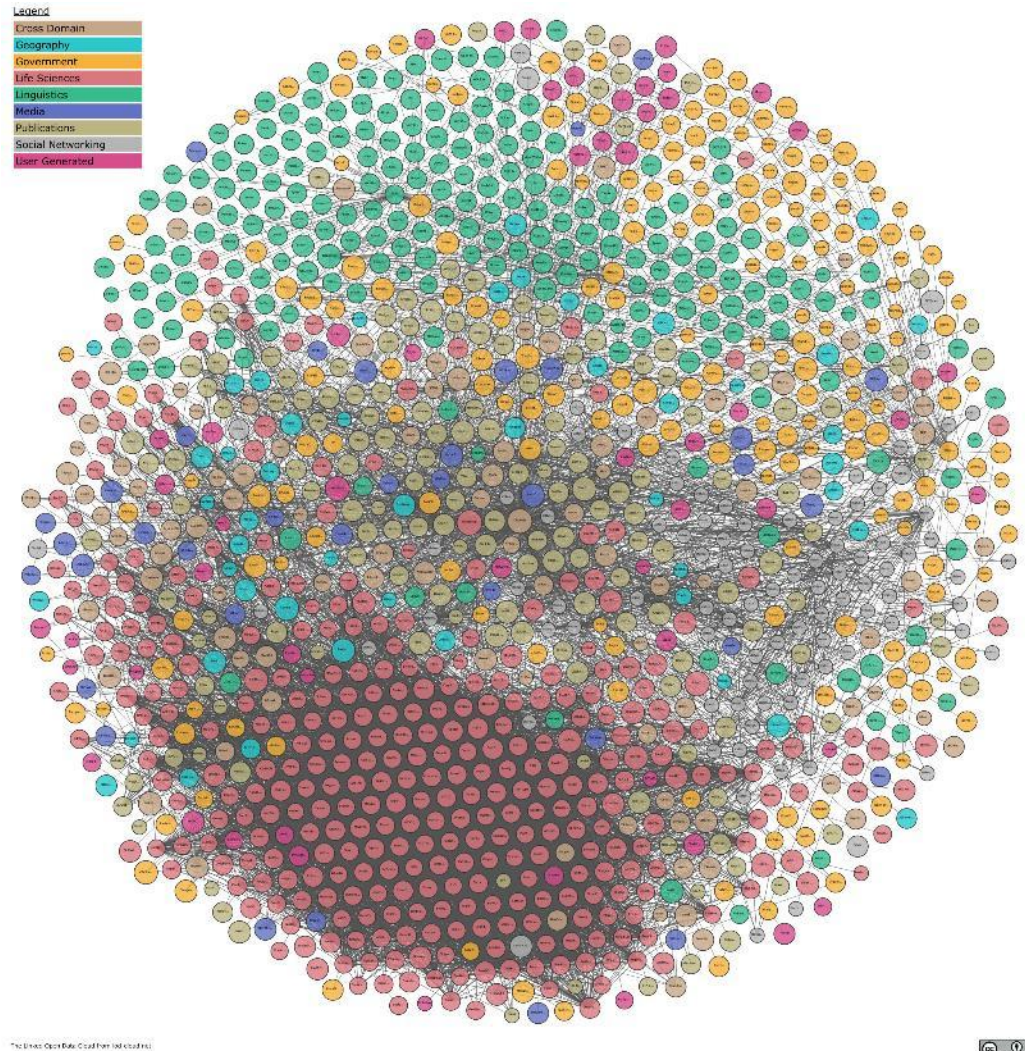
- Five Star Scheme (Tim Berners-Lee, 2010)
 - * Available on the web with an open license
 - ** Available as machine-readable, structured data
 - *** like ** plus using a non-proprietary format
 - **** like*** plus using open standards by the W3C
 - ***** like **** plus links to other datasets



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

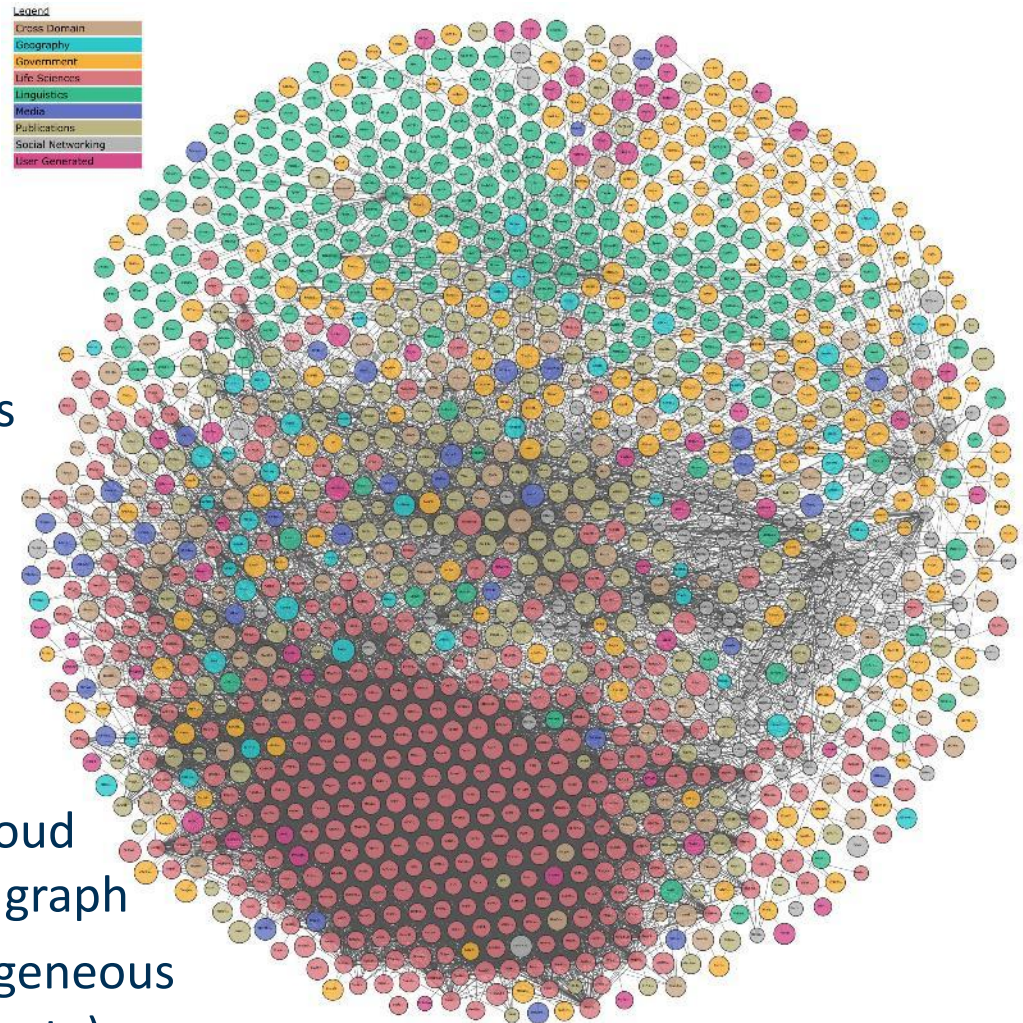


The Linked Open Data Cloud (lod-cloud.net)



What is the Linked Open Data Cloud?

- Viewpoint 1: a set of interconnected knowledge graphs
 - People have published ~1,000 knowledge graphs
 - They are linked to one another
- Viewpoint 2: one huge knowledge graph
 - In its entirety, the LOD cloud forms a large knowledge graph
 - This graph is very heterogeneous (i.e., uses different schemata)

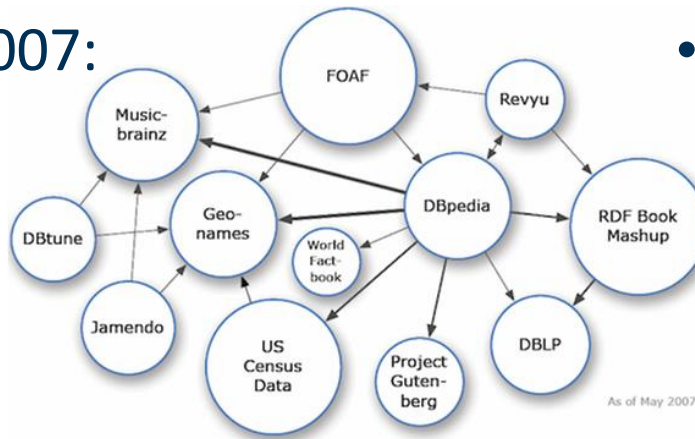


The Linked Open Data Cloud

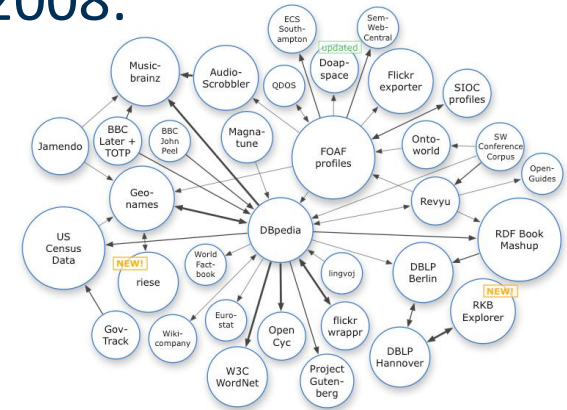
- In numbers:
 - >1,300 Data sets
 - Several billion triples
 - Several million interlinks
- Topical domains:
 - Government
 - Publications
 - Life sciences
 - User-generated content
 - Cross-domain
 - Media
 - Geographic
 - Social web

A Short History of Linked Open Data

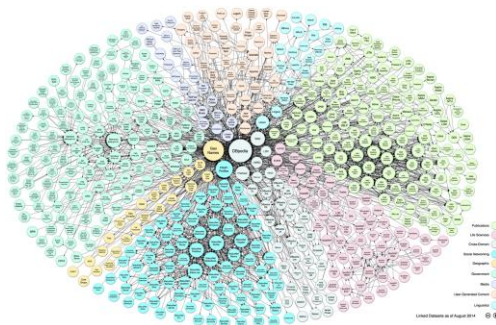
- May 2007:



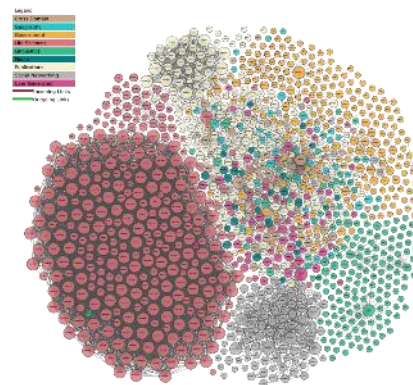
- March 2008:



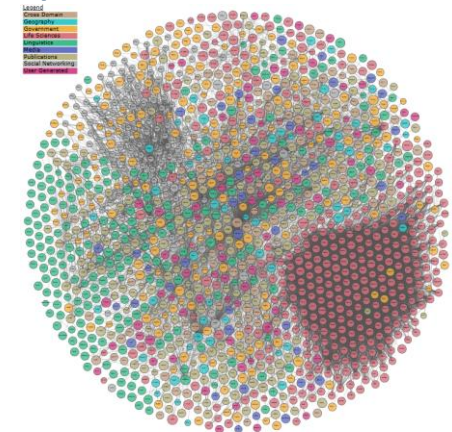
- August 2014



- August 2017



- September 2025



Examples: Government Data

 DATA.GOV

DATA TOPICS - IMPACT APPLICATIONS DEVELOPERS CONTACT

DATA CATALOG [/ Datasets](#) [Organizations](#) [?](#)

Search datasets...

Order by: Popular

Datasets ordered by Popular

Formats: RDF

Filter by location: Enter location...

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 [213 recent views](#)

City of New York — Popular Baby Names by Sex and Ethnic Group Data were collected through civil birth registration. Each record represents a baby born in New York City.

[CSV](#) [RDF](#) [JSON](#) [XML](#)

Accidental Drug Related Deaths

State of Connecticut — A listing of deaths from 2012 to 2018. A "Y" value under the "Cause of Death" column indicates a death from an accidental drug-related cause.

[CSV](#) [RDF](#) [JSON](#) [XML](#)

SAT School Participation and Performance

State of Connecticut — This dataset contains data on SAT School Participation and Performance for the Class of 2016.

[CSV](#) [RDF](#) [JSON](#) [XML](#)

Map tiles & Data by [OpenStreetMap](#), under [CC BY-SA](#).

Topics: [Local Government \(9938\)](#) [Climate \(5\)](#) [Disasters \(3\)](#)

Topic Categories: [Local Government \(9938\)](#) [Climate \(5\)](#) [Disasters \(3\)](#)

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Filter by 285 results found Best match ▼

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[Roles & Salaries](#)

us Fraud Office
October 2016
(part) showing all staff roles. Names and
Senior Civil Servants. Organogram data is
ment departments and...

[Roles & Salaries](#)

EU Open Data Portal

Access to European Union open data

EUROPA > EU Open Data Portal > Linked Data

[Home](#) [Data](#) [Applications](#) [Linked data](#) [Visualisations](#) [Developers' corner](#) [About](#)

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?

[Contact us](#)

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 dc: <http://www.w3.org/ns/dc/ >
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/ >

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



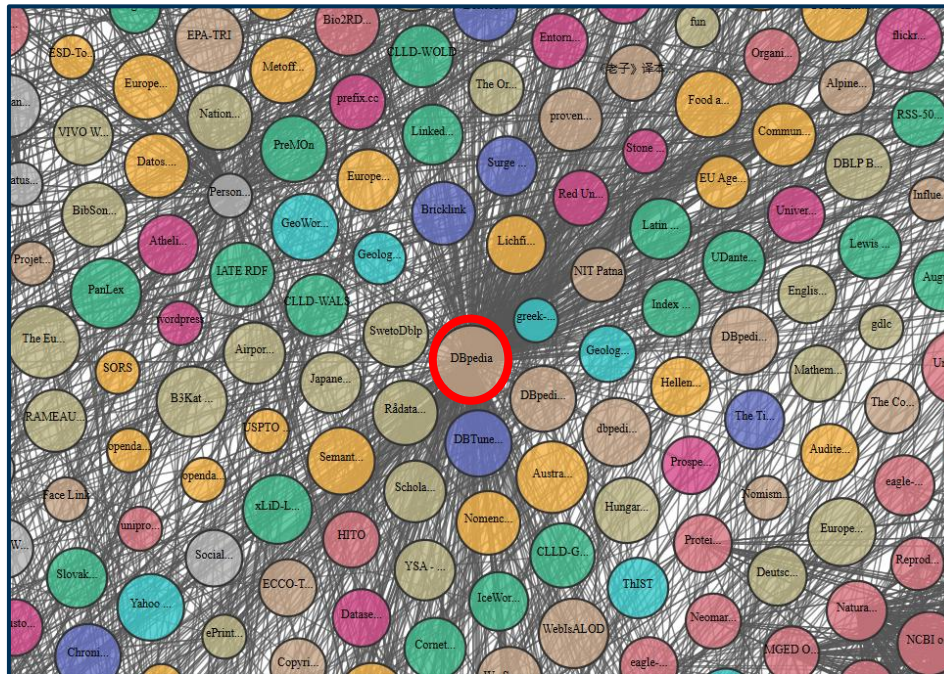
lemon: LexicalEntry 

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

[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

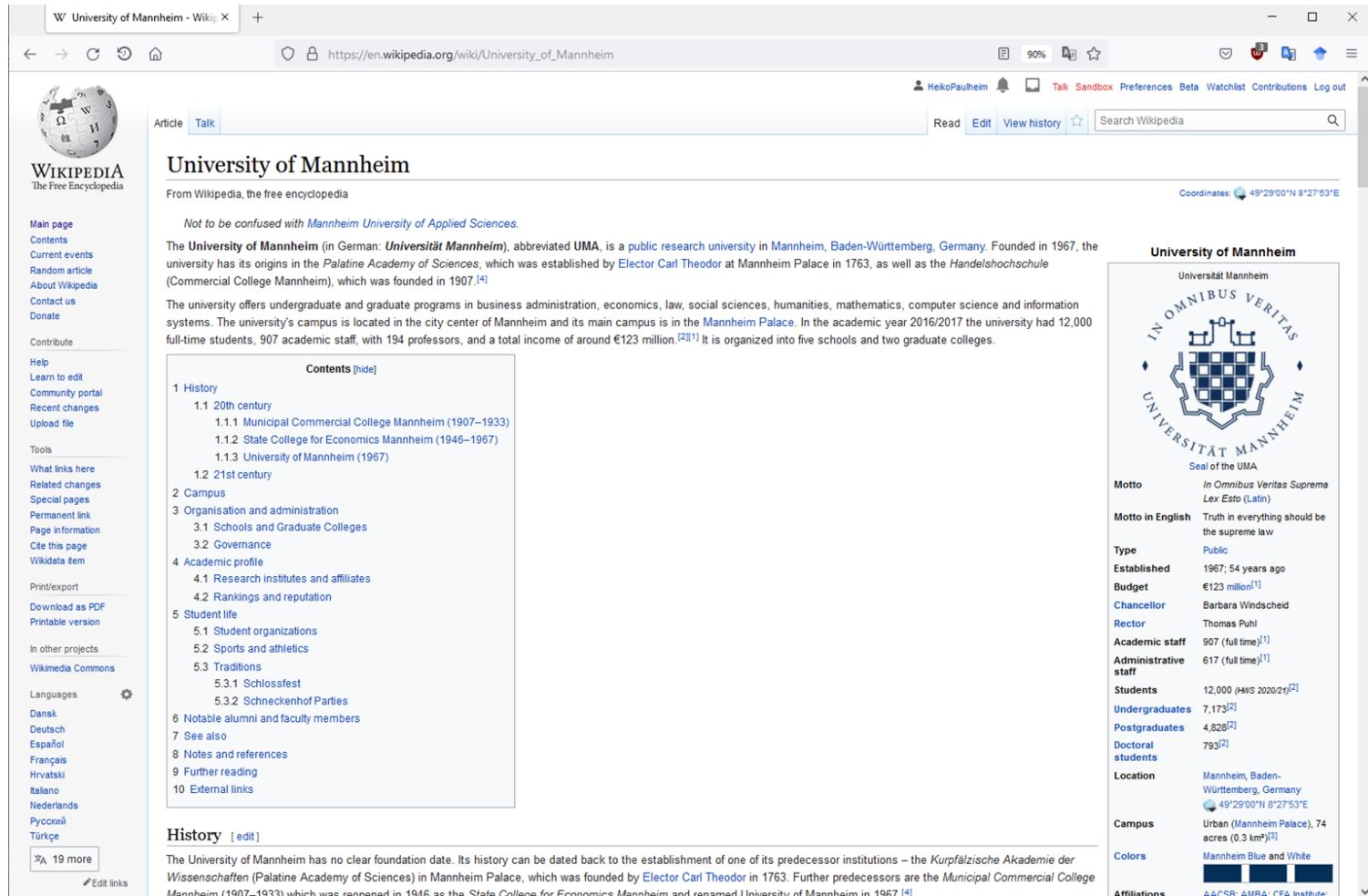


Knowledge Graph Creation: DBpedia & YAGO

- The 2010s
 - DBpedia: launched 2007
 - YAGO: launched 2008
 - Extraction from Wikipedia using mappings & heuristics
- Present
 - Two of the most used knowledge graphs
 - Next to Wikidata



Wikipedia as a Knowledge Graph



The screenshot shows the Wikipedia page for the University of Mannheim. The page is in English and provides a comprehensive overview of the institution. The main content area includes a summary paragraph, a detailed history section, and a list of contents. The right sidebar contains a table with key facts about the university, such as its motto, type, established date, budget, and location. The left sidebar offers navigation options like 'Main page', 'Contents', and 'Tools'.

University of Mannheim

From Wikipedia, the free encyclopedia

Not to be confused with Mannheim University of Applied Sciences.

The **University of Mannheim** (in German: *Universität Mannheim*), abbreviated **UMA**, is a public research university in Mannheim, Baden-Württemberg, Germany. Founded in 1967, the university has its origins in the *Palatine Academy of Sciences*, which was established by *Elector Carl Theodor* at Mannheim Palace in 1763, as well as the *Handelshochschule* (Commercial College Mannheim), which was founded in 1907.^[4]

The university offers undergraduate and graduate programs in business administration, economics, law, social sciences, humanities, mathematics, computer science and information systems. The university's campus is located in the city center of Mannheim and its main campus is in the *Mannheim Palace*. In the academic year 2016/2017 the university had 12,000 full-time students, 907 academic staff, with 194 professors, and a total income of around €123 million.^{[2][1]} It is organized into five schools and two graduate colleges.

Contents [hide]

- History
 - 20th century
 - Municipal Commercial College Mannheim (1907–1933)
 - State College for Economics Mannheim (1946–1967)
 - University of Mannheim (1967)
 - 21st century
- Campus
- Organisation and administration
 - Schools and Graduate Colleges
 - Governance
- Academic profile
 - Research institutes and affiliates
 - Rankings and reputation
- Student life
 - Student organizations
 - Sports and athletics
 - Traditions
 - Schlossfest
 - Schneckenhof Parties
- Notable alumni and faculty members
- See also
- Notes and references
- Further reading
- External links

History [edit]

The University of Mannheim has no clear foundation date. Its history can be dated back to the establishment of one of its predecessor institutions – the *Kurfürstliche Akademie der Wissenschaften* (Palatine Academy of Sciences) in Mannheim Palace, which was founded by *Elector Carl Theodor* in 1763. Further predecessors are the *Municipal Commercial College Mannheim* (1907–1933) which was reopened in 1946 as the *State College for Economics Mannheim* and renamed University of Mannheim in 1967.^[4]

University of Mannheim

Universität Mannheim

IN OMNIBUS VERITAS

UNIVERSITÄT MANNHEIM

Seal of the UMA

Motto *In Omnibus Veritas Suprema Lex Esto* (Latin)

Motto in English Truth in everything should be the supreme law

Type Public

Established 1967; 54 years ago

Budget €123 million^[1]

Chancellor Barbara Windscheid

Rector Thomas Puhl

Academic staff 907 (full time)^[1]

Administrative staff 617 (full time)^[1]

Students 12,000 (HWS 2020/21)^[2]

Undergraduates 7,173^[2]

Postgraduates 4,828^[2]

Doctoral students 793^[2]

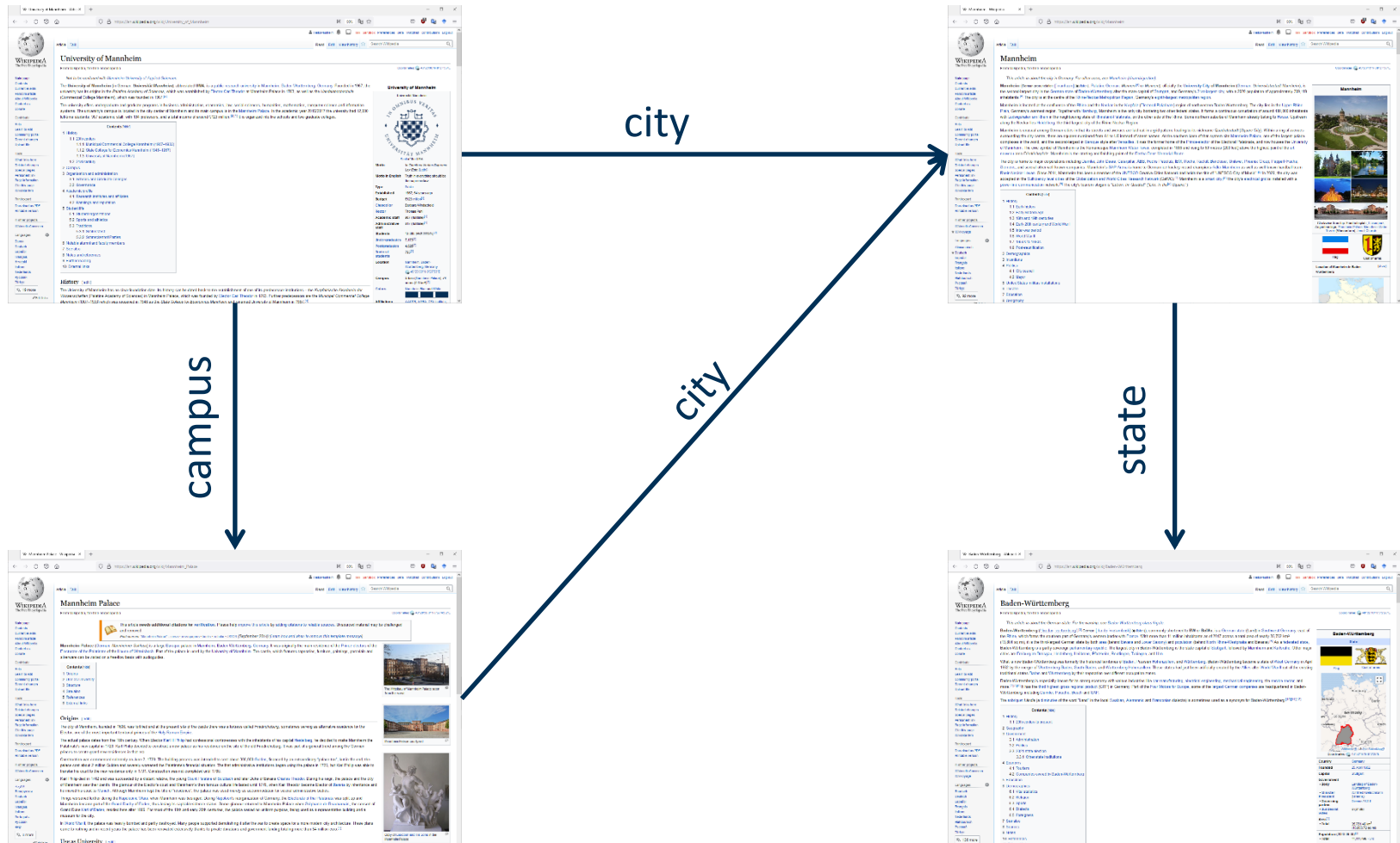
Location Mannheim, Baden-Württemberg, Germany

Campus Urban (Mannheim Palace), 74 acres (0.3 km²)^[3]

Colors Mannheim Blue and White

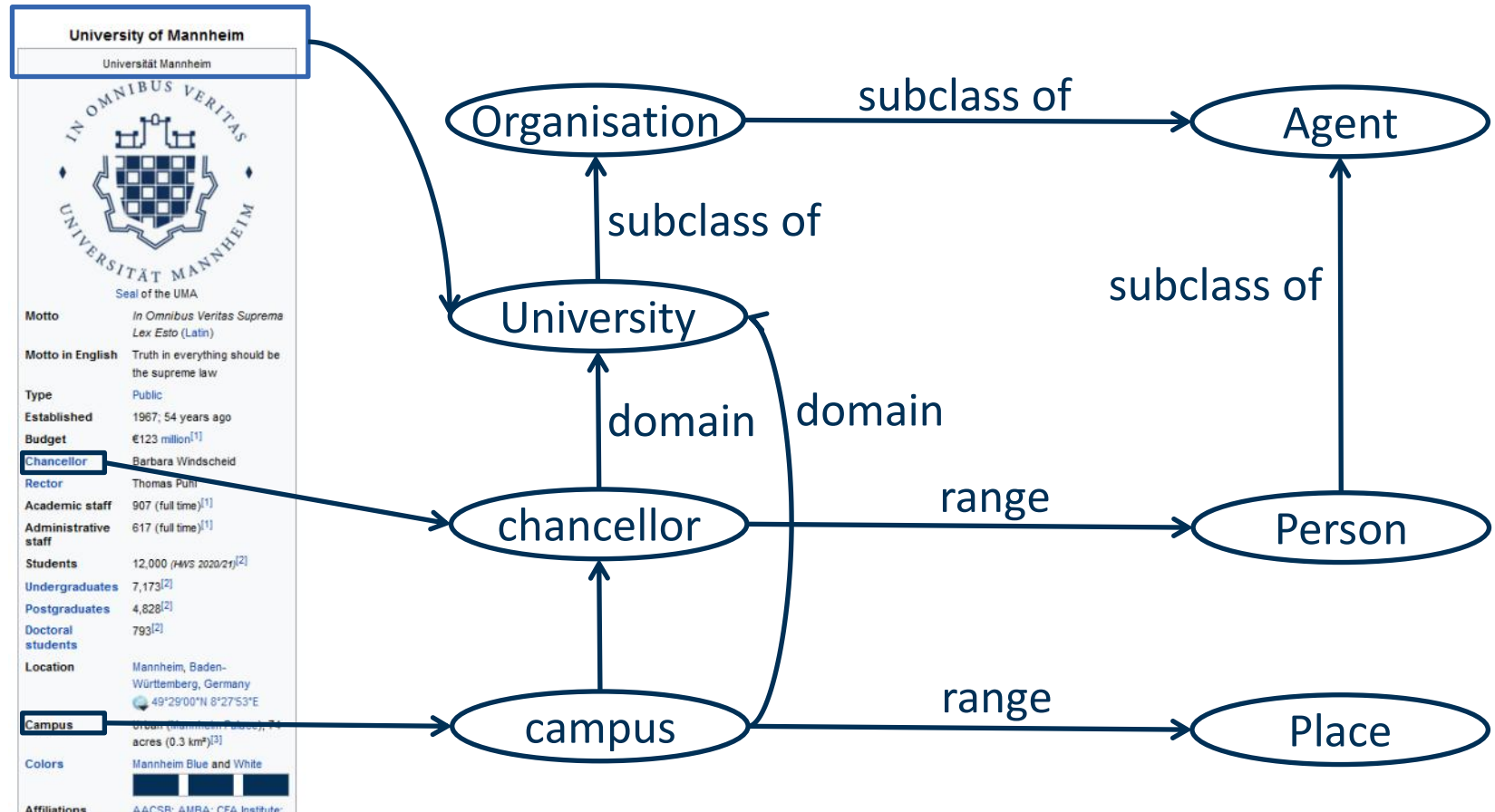
Affiliations AACSB; AMBA; CFA Institute;

Wikipedia as a Knowledge Graph



Wikipedia as a Knowledge Graph

- Mapping to a central schema/ontology



DBpedia

University of Mannheim



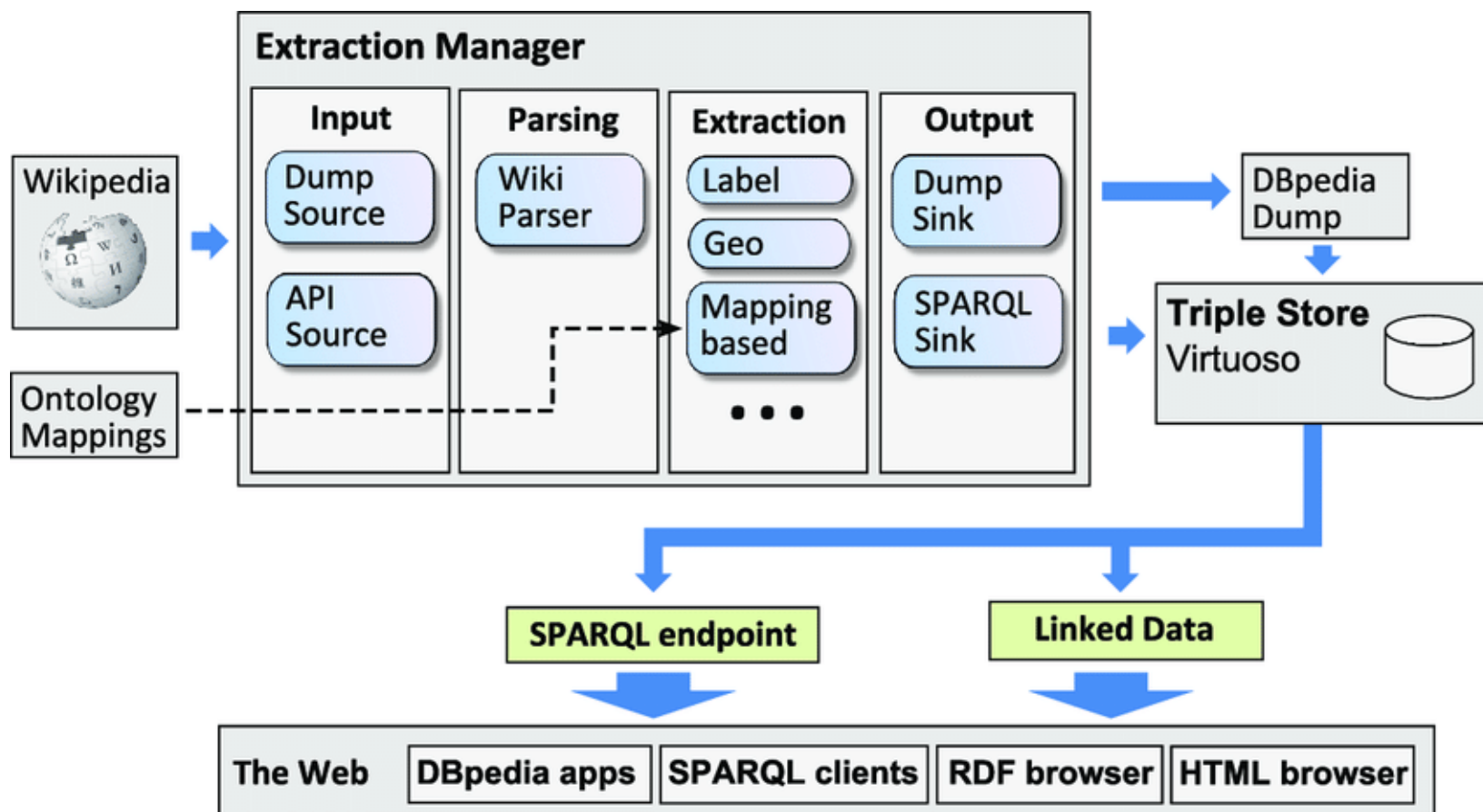
Motto	<i>In Omnibus Veritas</i> <i>Suprema Lex Esto</i> (Latin)
Motto in English	Truth in everything should be the supreme law
Established	1763: Theodoro Palatinae 1907: Handelshochschule 1967: Universität Mannheim
Type	Public
Endowment	€115 million
Chancellor	Susann-Annette Storm
Rector	Ernst-Ludwig von Thadden
Academic staff	800 (full time)
Administrative staff	550 (full time)
Students	12,151 (HWS 2013/14) ^[1]
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: Handelshochschule
|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="un
/Studierendenstatistik_hws13.pdf|title= Studierendestatistik 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]]
|coord              = {{Coord
<?xml version="1.0" encoding="utf-8" ?>
<rdf:RDF
  <rdf:Description rdf:about="http://dbpedia.org/resource/University_of_Mannheim">
    <dbp:mottoeng xml:lang="en">Truth in everything should be the supreme law</dbp:mottoeng>
    <dbp:chancellor xml:lang="en">Susann-Annette Storm</dbp:chancellor>
    <dbp:budget rdf:datatype="http://dbpedia.org/datatype/euro">1.23E8</dbp:budget>
    <dbp:campus xml:lang="en">Urban , 74 acres</dbp:campus>
    <dbp:caption xml:lang="en">Seal of the UMA</dbp:caption>
    <dbp:city rdf:resource="http://dbpedia.org/resource/Mannheim" />
    <dbp:colors xml:lang="en">Mannheim Blue and White</dbp:colors>
    <dbp:country rdf:resource="http://dbpedia.org/resource/Germany" />
    <dbp:imageName xml:lang="en">Uni_Mannheim_Seal.png</dbp:imageName>
    <dbp:logo xml:lang="en">University of Mannheim.svg</dbp:logo>
    <dbp:logoSize rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">280</dbp:logoSize>
    <dbp:nativeName xml:lang="en">Universität Mannheim</dbp:nativeName>
    <dbp:rector xml:lang="en">Thomas Puhl</dbp:rector>
    <dbp:state rdf:resource="http://dbpedia.org/resource/Baden-Württemberg" />
    <dbp:type rdf:resource="http://dbpedia.org/resource/Public_University" />
    <dbp:website rdf:resource="https://www.uni-mannheim.de/en/%7C2=www.uni-mannheim.de" />
    <georss:point>49.4832 8.4647</georss:point>
  </rdf:Description>
</rdf:RDF>

```

DBpedia



Mapping en:Infobox film

This is the mapping for the Wikipedia template [Infobox film](#). Find usages of this Wikipedia template [Test this mapping](#) (or in namespace [File](#) or [Creator](#)) with some example Wikipedia pages. [Read more](#) about mapping Wikipedia templates.

Template Mapping (help)	
map to class	Film

Mappings

Property Mapping (help)	
template property	director
ontology property	director

Property Mapping (help)	
template property	producer
ontology property	producer

OntologyClass:Film

This is the definition of an ontology class.

Show all [properties](#) available for this class.

Show class in [class hierarchy](#).

[Read more](#) about editing the ontology schema.

You can see the result of your edit on [DBpedia Live](#) (

Ontology class (help)	
rdfs:label (en)	film
rdfs:label (en)	movie
rdfs:label (nl)	film
rdfs:label (da)	film
rdfs:label (de)	Film
rdfs:label (el)	ταινία
rdfs:label (fr)	film
rdfs:label (ko)	영화
rdfs:label (ja)	映画
rdfs:label (ar)	فيلم
rdfs:label (pl)	film
rdfs:label (ga)	scannán
rdfs:label (es)	película
rdfs:subClassOf	Work
owl:equivalentClass	schema:Movie , wikidata:Q11424
owl:disjointWith	

OntologyProperty:director

This is the definition of an ontology property.

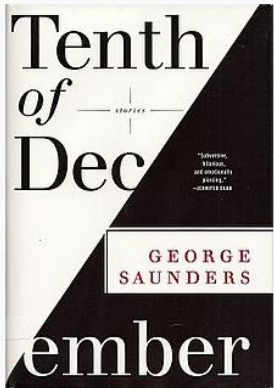
[Read more](#) about editing the ontology schema.

You can see the result of your edit on [DBpedia Live](#) (this is BETA!).

Ontology object property (help)	
rdfs:label (en)	director
rdfs:label (en)	film director
rdfs:label (nl)	regisseur
rdfs:label (da)	instruktør
rdfs:label (de)	regisseur
rdfs:label (ru)	директор
rdfs:label (el)	σκηνοθέτης
rdfs:label (es)	director de cine
rdfs:label (fr)	réalisateur
rdfs:comment (en)	A film director is a person who directs the making of a film. ^[1]
rdfs:comment (fr)	Un réalisateur (au féminin, réalisatrice) est une personne qui dirige la fabrication d'une œuvre audiovisuelle, généralement pour le cinéma ou la télévision. ^[2]
rdfs:domain	Film
rdfs:range	Person
rdf:type	
rdfs:subPropertyOf	dul:coparticipatesWith
owl:equivalentProperty	schema:director , wikidata:P57
owl:propertyDisjointWith	

DBpedia

Tenth of December



US release cover

Author	George Saunders
Language	English
Genre	Short story collection
Publisher	Random House
Publication date	January 8, 2013
Publication place	United States
Media type	Print (hardcover)
Pages	208
ISBN	0812993802
OCLC	785558855

```
{{Infobox book
| name = Tenth of December
| author = [[George Saunders]]
| language = English
| country = United States
| genre = [[Short story collection]]
| publisher = [[Random House]]
| isbn = 0812993802
| image = Tenth of December.jpg
| caption = US release cover
| release_date = January 8, 2013
| media type = Print (hardcover)
| pages = 208
| oclc = 785558855
```

Mapping en:Infobox book

This is the mapping for the Wikipedia template [Infobox book](#). Find usages of this Wikipedia template [Test this mapping](#) (or in namespace [File](#) or [Creator](#)) with some example Wikipedia pages. [Read more](#) about mapping Wikipedia templates.

Template Mapping (help)

map to class	Book
--------------	------

Mappings

Property Mapping (help)

template property	name
ontology property	foaf:name

Property Mapping (help)

template property	genre
ontology property	literaryGenre

Property Mapping (help)

template property	pages
ontology property	numberOfPages

About: [Tenth of December: Stories](#)

An Entity of Type: [Buch](#), from Named Graph: <http://dbpedia.org>, within Data Space: [dbpedia.org](#)

Tenth of December is a collection of short stories by American author George Saunders, published in *The New Yorker* and *Granta* magazines between 1995 and 2012. The book was published on January 8, 2013, by Random House. It was a 2011 Bram Stoker Award finalist. Tenth of December was selected as one of the 10 Best Books of 2013 by the New York Times Book Review. The collection also won the 2013 Story Prize for short-story collections and the inaugural Folio Prize.

Property	Value
dbo:abstract	Tenth of December is a collection of short stories by American author George Saunders, published in <i>The New Yorker</i> and <i>Granta</i> magazines between 1995 and 2012. The book was published on January 8, 2013, by Random House. It was a 2011 Bram Stoker Award finalist. Tenth of December was selected as one of the 10 Best Books of 2013 by the New York Times Book Review. The collection also won the 2013 Story Prize for short-story collections and the inaugural Folio Prize.
dbo:author	dbr:George_Saunders
dbo:isbn	0812993802
dbo:literaryGenre	dbr:Short_story_collection
dbo:numberOfPages	208 (xsd:positiveInteger)
dbo:oclc	785558855
dbo:publisher	dbr:Random_House
dbo:releaseDate	2013-01-08 (xsd:date)

DBpedia: Further Sources

- Coordinate templates

Coordinates:  49°29'20"N 8°28'9"E

- Climate tables

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

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

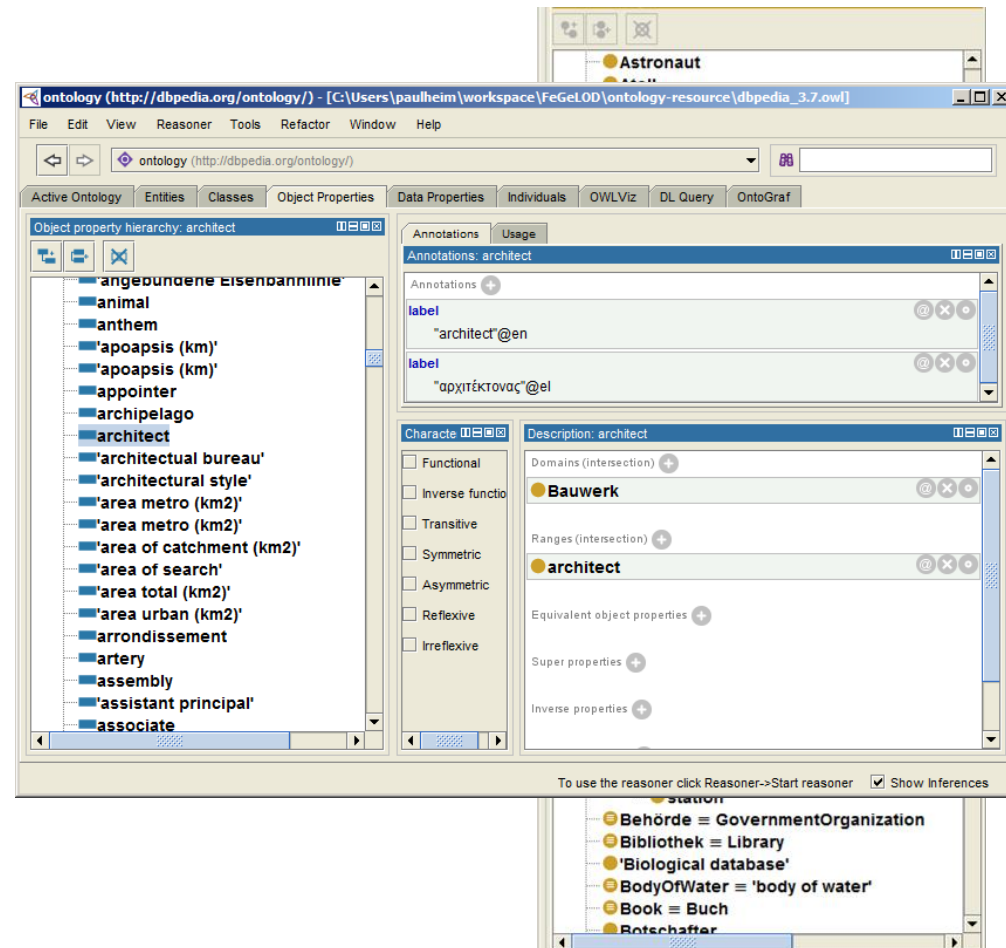
- Data from different infoboxes
(extracted from multiple languages)
- Redirects and disambiguations
- External web links
- Abstracts in multiple languages
- Instance type information
 - DBpedia Ontology
 - YAGO*
 - schema.org*
 - DOLCE**
 - ...and others

* later today

** in a few weeks

The DBpedia Ontology

- Classes:
 - ~1,800 classes
 - partial hierarchy
- Properties:
 - ~1,200 relations
 - many with domain/range
 - ~1,700 data properties
 - i.e., literal-valued
 - a bit of hierarchy




[Home](#)
[Getting Started](#)
[Downloads](#)
[Browse/Query](#)
[Publications](#)
[Contributors](#)

Search (use correct uppercase for named entities)

SEARCH

University of Mannheim

university in Germany

Shapes:

URI:

http://yago-knowledge.org/resource/University_of_Mannheim

[http://yago-](http://yago-knowledge.org/resource/University_of_Mannheim)



[GRAPH VISUALIZATION](#)

[WIKIDATA](#)

[OFFICIAL WEBSITE](#)

Properties

Predicate

Object

[schema:alternateName](#)

"Universitæt Mannheim"@da
 "Uni Mannheim"@de
 "Uni Mannheim"@en
 "Uni Mannheim"@eo
 "Universität Mannheim"@fi
 "Universite de Mannheim"@fr
 "Mannheim Business School"@pl
 "Uniwersytet Mannheim"@pl
 "Uniwersytet w Mannheim"@pl

- Also derived from Wikipedia
 - ~6.3M entities
 - ~479M statements
- Used Wikipedia categories for typing (~820,000 types)
- Now uses schema.org ontology
- Tries to capture time
 - i.e., statements that held true for a period of time
 - e.g., soccer players playing for teams
 - uses reification

Search: eng 

<id_1u5xrvs_1ul_zxcbb2>

<Miroslav_Klose>	<playsFor>	<FC_Bayern_Munich>	hasFactId	
				<extractionSource>
				<occursUntil>
				<occursSince>

http://en.wikipedia.org/wiki/Miroslav_Klose →
http://en.wikipedia.org/wiki/Miroslav_Klose →
 "2011-##-##"^^xsd:date →
 "2007-##-##"^^xsd:date →

Knowledge Graph Creation: Wikidata

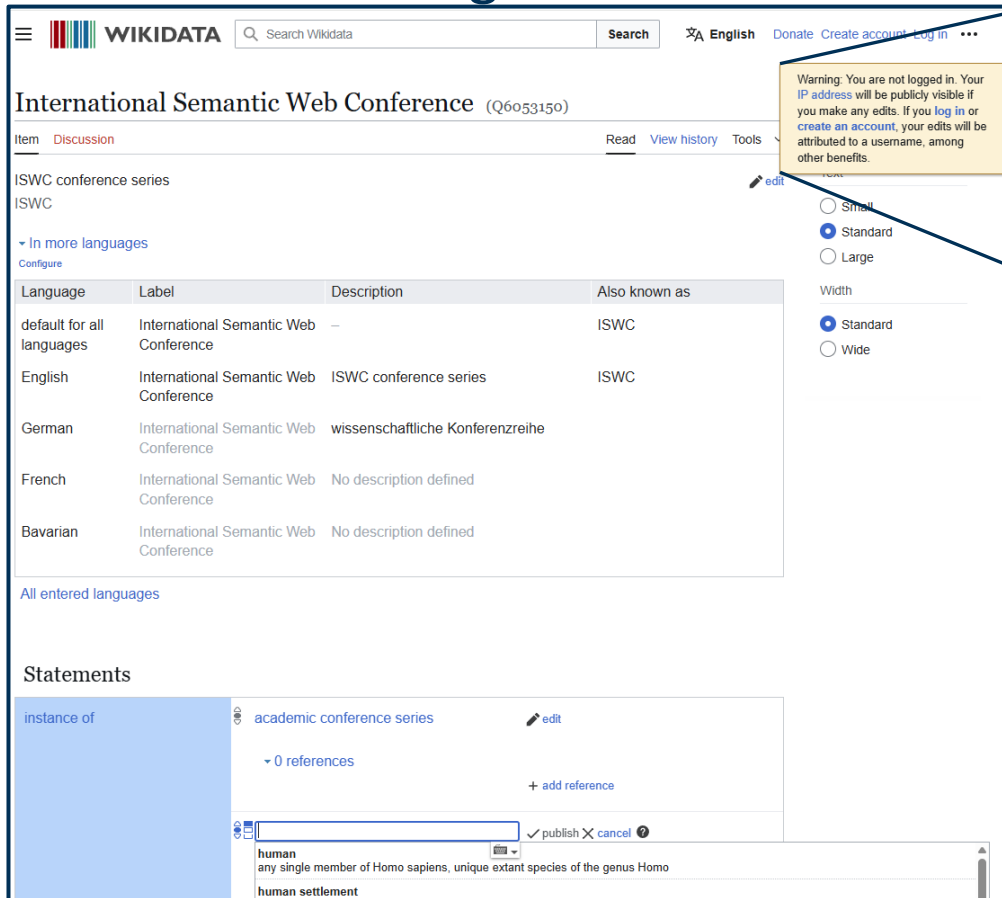
- The 2010s
 - Wikidata: launched 2012
 - Goal: centralize data from Wikipedia languages
 - Collaborative
 - Imports other datasets
- Present
 - One of the largest public knowledge graphs (see later)
 - Includes rich provenance



Knowledge Graph Creation: Wikidata

Even without login

- Collaborative editing



Warning: You are not logged in. Your IP address will be publicly visible if you make any edits. If you [log in](#) or [create an account](#), your edits will be attributed to a username, among other benefits.

Language	Label	Description	Also known as
default for all languages	International Semantic Web Conference	—	ISWC
English	International Semantic Web Conference	ISWC conference series	ISWC
German	International Semantic Web Conference	wissenschaftliche Konferenzreihe	
French	International Semantic Web Conference	No description defined	
Bavarian	International Semantic Web Conference	No description defined	

All entered languages

Statements

instance of  academic conference series 

▼ 0 references

+ add reference

 publish  cancel

human
any single member of Homo sapiens, unique extant species of the genus Homo

human settlement

Warning: You are not logged in. Your IP address will be publicly visible if you make any edits. If you [log in](#) or [create an account](#), your edits will be attributed to a username, among other benefits.

Knowledge Graph Creation: Wikidata

- Some pages are (semi-) protected

WIKIDATA

University of Mannheim (Q317070)

Item Discussion Read View history Tools

university in Germany
Uni Mannheim | UMA | Hochschule Mannheim

In more languages
Configure

Language	Label
default for all languages	Universität Mannheim
English	University of Mannheim
German	Universität Mannheim
French	université de Mannheim
Bavarian	Universität Mannheim

All entered languages

Statements

instance of public university

0 references

Protection types

There are three kinds of protection that can be applied to existing pages.

- Semi-protection** (symbolized by ) allows only [autoconfirmed users/confirmed users](#) to edit the page.
- Full protection** (symbolized by  or ) only allows [administrators](#) to edit the page.
- Move protection** (symbolized by ) does not affect who can edit pages, but does prevent anyone except for administrators from moving affected pages to new locations. Most high traffic pages are move protected. Move protection cannot be applied to items or properties.
- Create-protection** (symbolized by , for both full and semi-create protection) can be applied to deleted or nonexistent pages. Like move protection, however, it cannot be applied to deleted items or properties.
 - Full create protection** prevents the page from being created except by [administrators](#).
 - Semi-create protection** also allows [autoconfirmed](#) and [confirmed users](#) to create.

Semi-protected



Knowledge Graph Creation: Wikidata

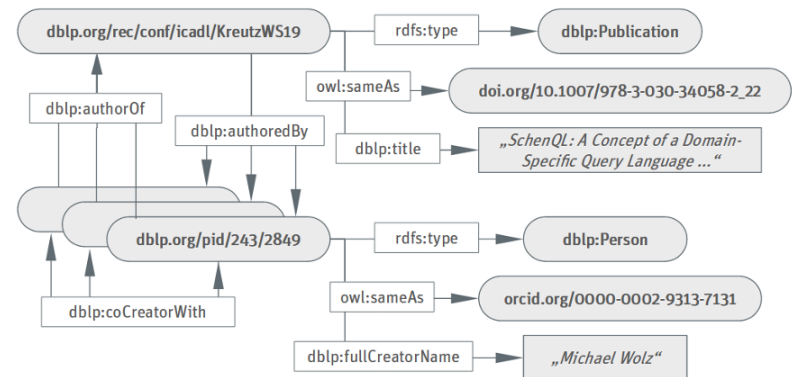
- Provenance

inception	2002 1 reference + add value
short name	ISWC (English) 0 references + add reference + add value
title	International Semantic Web Conference (English) 1 reference stated in dblp computer science bibliography reference URL https://dblp.org/db/conf/semweb/ retrieved 13 February 2021 + add reference + add value

- Size
 - ~52M instances
 - ~730M statements
- Ontology
 - ~2.3M classes
 - ~6k properties
- Special
 - provenance information
 - i.e., evidence: where did that statement come from?

Further Example Datasets

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



Further Example Datasets

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

42

... [39](#) - [40](#) - [41](#) - **42** - [43](#) - [44](#) - [45](#) ...

URI: <http://km.aifb.kit.edu/projects/numbers/n42> [\[URI4URI\]](#)

External links

Wikipedia: [42_\(number\)](#)
Wikidata: [Q812996](#)

Names

Estonian: *nelikümmend kaks*
Czech: *čtyřicet dva*
Portuguese: *quarenta e dois*
Lithuanian: *keturiasdešimt du*
French: *quarante-deux*
Italian: *quarantadue*
Spanish: *cuarenta y dos*
German: *zweiundvierzig*
English: *forty-two*

Other systems

Roman: XLII
Binary: 101010
Octal: 52
Duodecimal: 36
Hexadecimal: 2a
Hexatridecimal: 16

Properties

Natural logarithm: 3.7376696182834
Binary logarithm: 5.3923174227788
Common logarithm: 1.6232492903979
Prime factors: [1](#) * [2](#) * [3](#) * [7](#)
Digit sum: [6](#)

<https://km.aifb.kit.edu/projects/numbers/web/n1>

Vocabularies

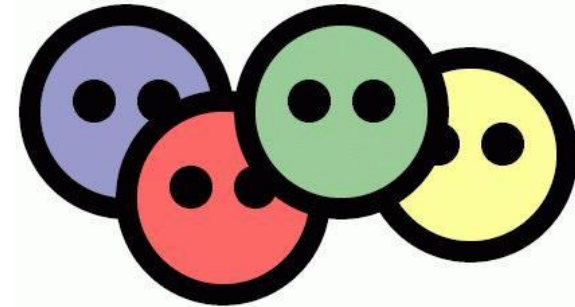
- Recap: LOD Best Practices, Principle 3:
 - Use terms from widely deployed vocabularies
- So, what are common widely deployed vocabularies?

Dublin Core



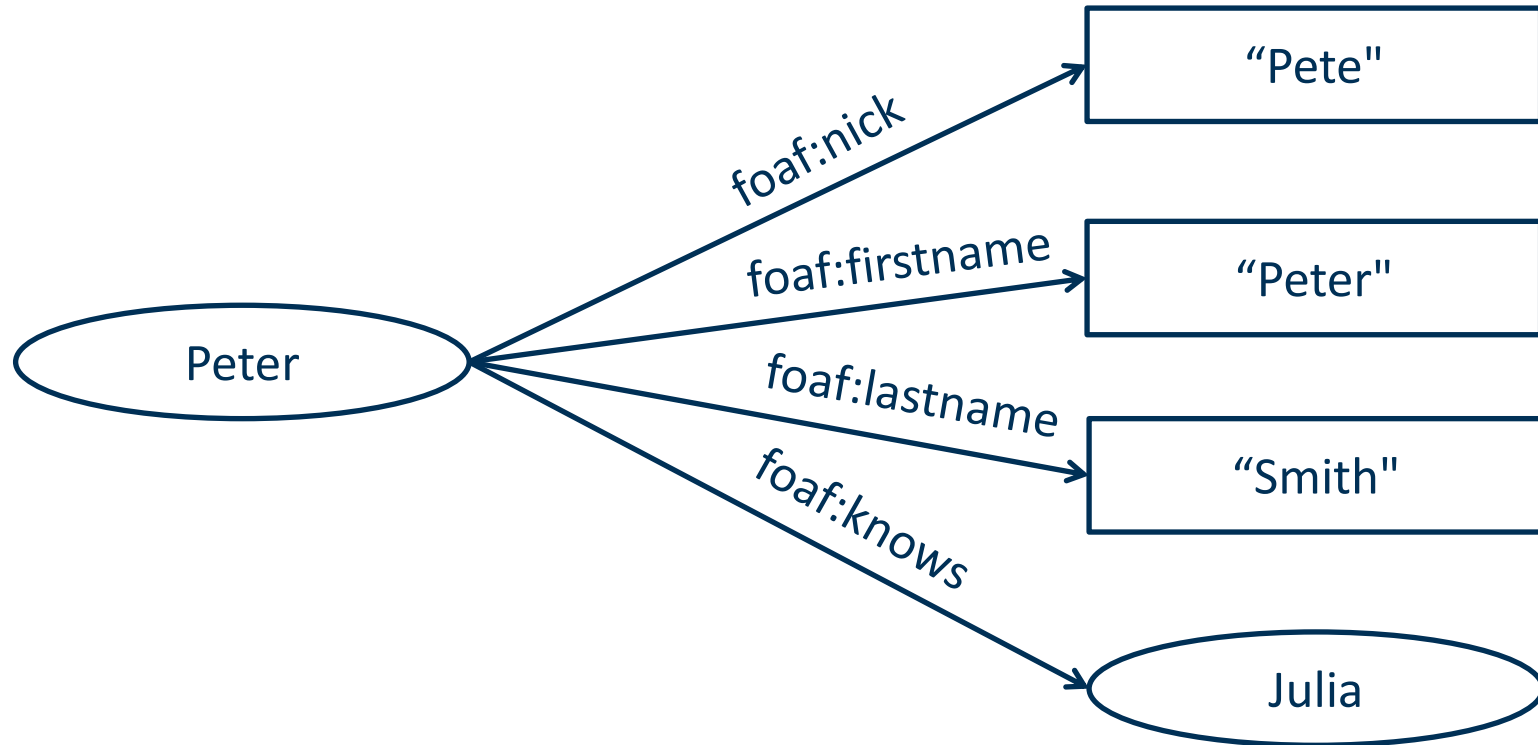
- We have already encountered this
- Usage: Metadata for resources and documents
- Namespace `http://purl.org/dc/elements/1.1/`
- Common prefix: `dc`
- Defines properties, e.g.,
 - creator
 - subject
 - date
- Resources: DCMI Type Vocabulary:
 - Text
 - Image
 - Software
 - ...

FOAF (Friend of a Friend)

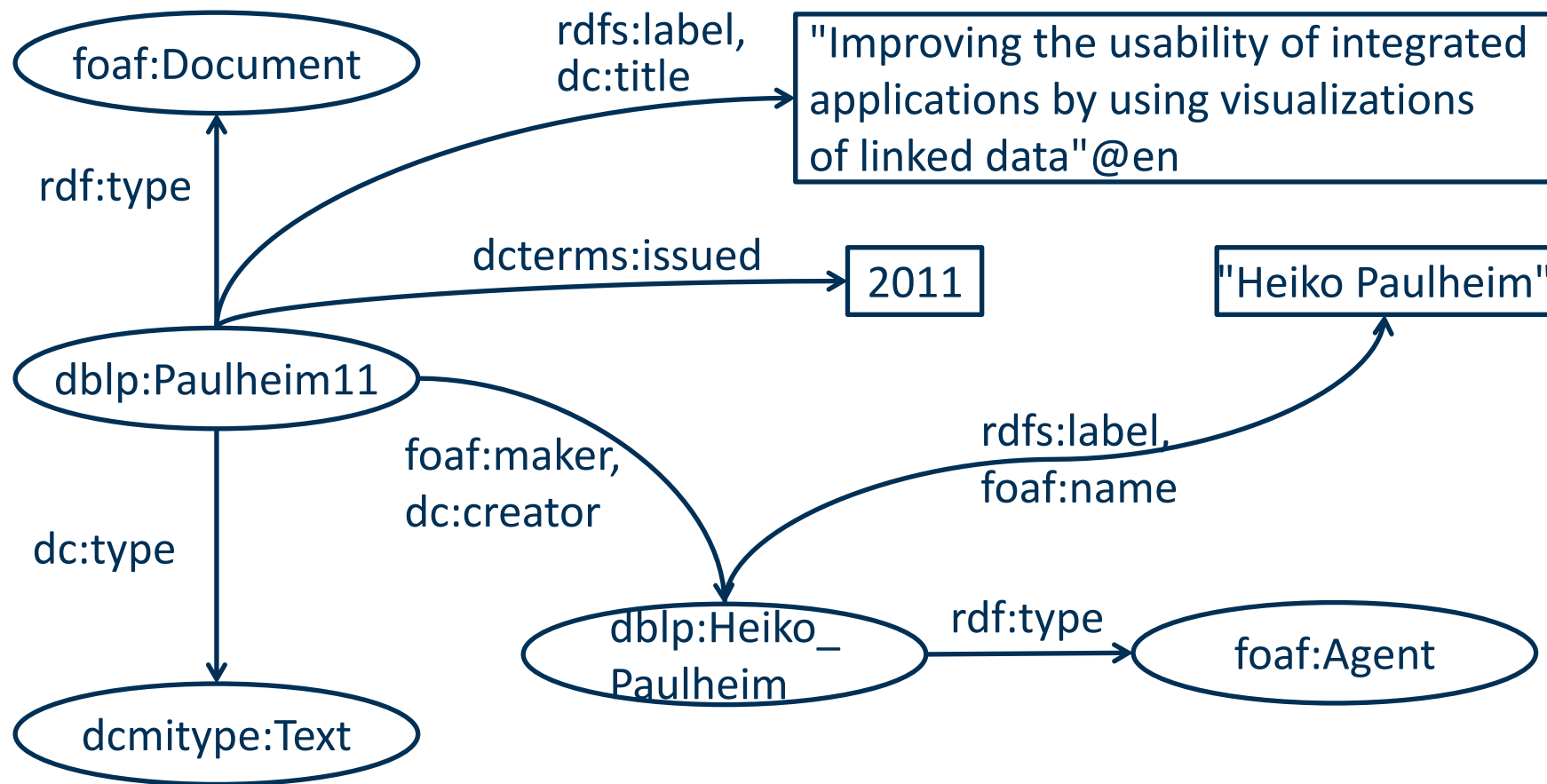


- Persons and their relations
- Created for personal home pages
 - but used widely beyond that
- Namespace `http://xmlns.com/foaf/0.1/`
- Common prefix: `foaf:`
- Important classes
 - Person
 - Group
 - Organization
 - Project
 - ...
- Important properties
 - name, firstName, lastName
 - phone, mbox, 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`



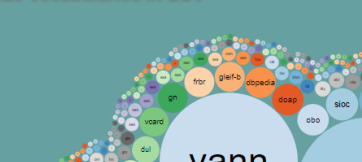
UNIVERSITY
OF MANNHEIM
Data and Web Science Group

- 
VOCABS TERMS AGENTS SPARQL/DUMP

Linked Open Vocabularies (LOV)

+ Suggest
  Documentation
  Follow
 
 

823 Vocabularies in LOV



Latest insertion	
kgc - KGRC Ontology	2023-09-25
rml - RML: Generic Mapping Language for RDF	2023-09-20
rml-io - RML-IO: Source and Target	2023-09-20
authn_provider - Authentication Provider	2023-09-20
rml-cc - RML-Containers	2023-09-20

Latest Updates	
kgc - KGRC Ontology	2023-09-25
rml-star - RML-star	2023-09-20
rml-fnml - RML-FNML	2023-09-20
rml-cc - RML-Containers	2023-09-20
rml-io - RML-IO: Source and Target	2023-09-20

Vocabularies

- Where to search for prefix definitions?
 - One possibility: <http://prefix.cc/>



rdfs

<http://www.w3.org/2000/01/rdf-schema#> ➡ +1
-1
Add alternative URI

ttr xml rdfs sparql txt json jsonld vann | lov | prefix.cc

```
< > ↺ w3.org/2000/01/rdf-schema#

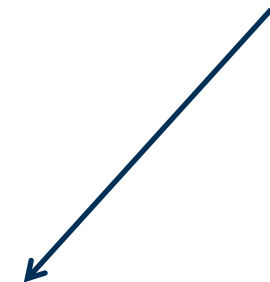
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .

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

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

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

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



Microdata and schema.org

HTML



- We have already seen that in the last lecture

```
<div itemscope itemtype="http://schema.org/PostalAddress">  
  <span itemprop="name">Data and Web Science Group</span>  
  <span itemprop="addressLocality">Mannheim</span>  
  <span itemprop="postalCode">68131</span>  
  <span itemprop="addressCountry">Germany</span>  
</div>
```

```
_: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
 - ...

Movie

Thing > CreativeWork > Movie

A movie.

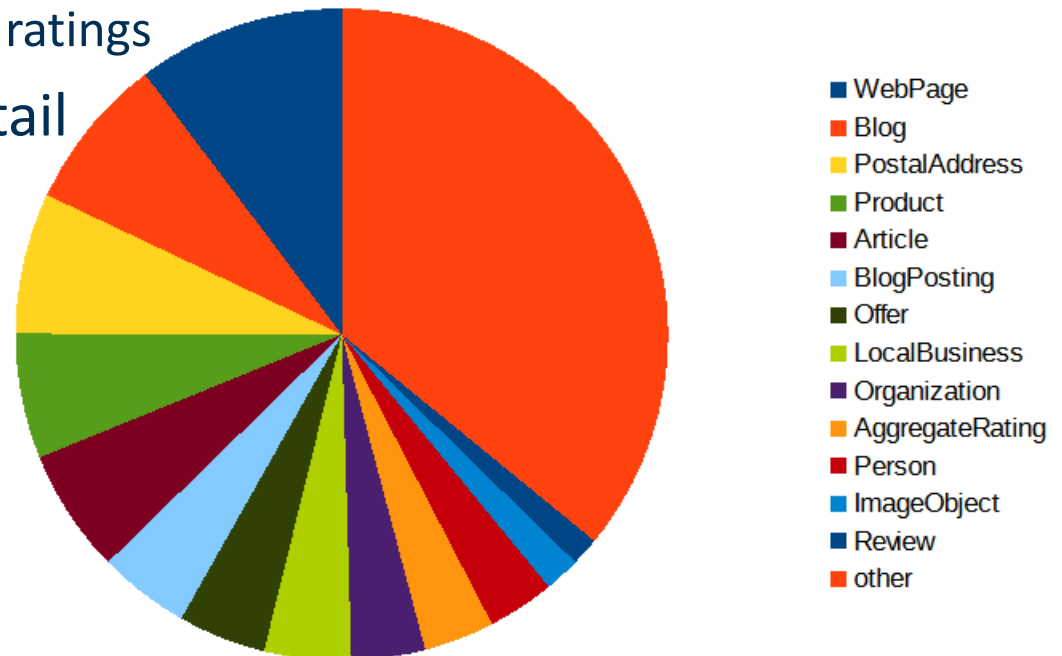
Usage: Between 10,000 and 50,000 domains

[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

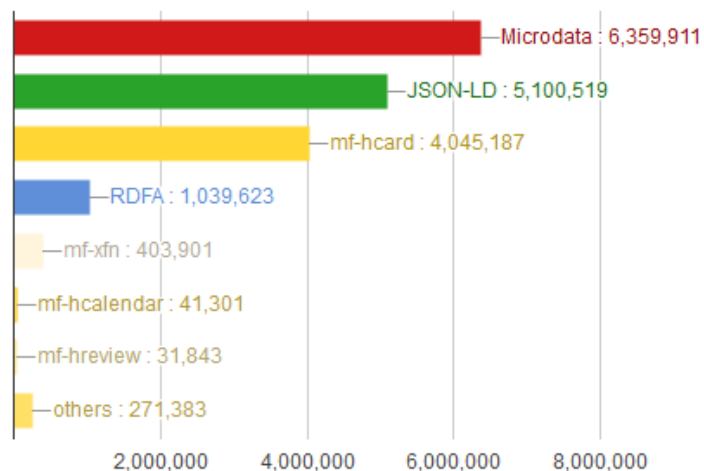
- Main topics of schema.org:
 - Meta information on web page content (web page, blog...)
 - Business data (products, offers, ...)
 - Contact data (businesses, persons, ...)
 - (Product) reviews and ratings
- ...and a massive long tail



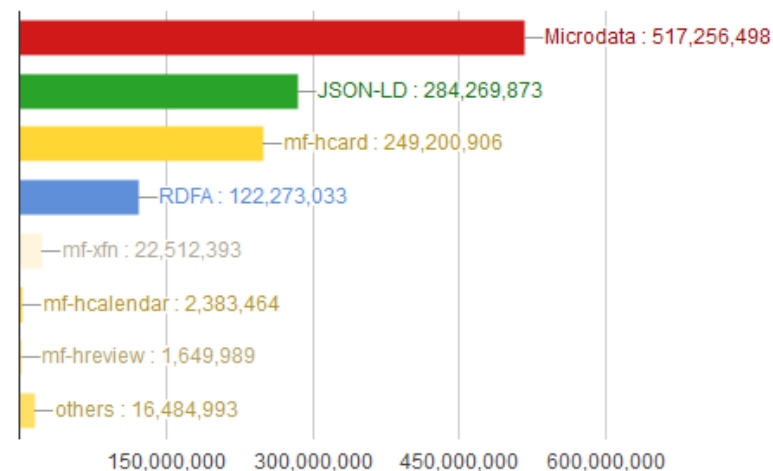
Growth of schema.org

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

Domains with Triples



URLs with Triples



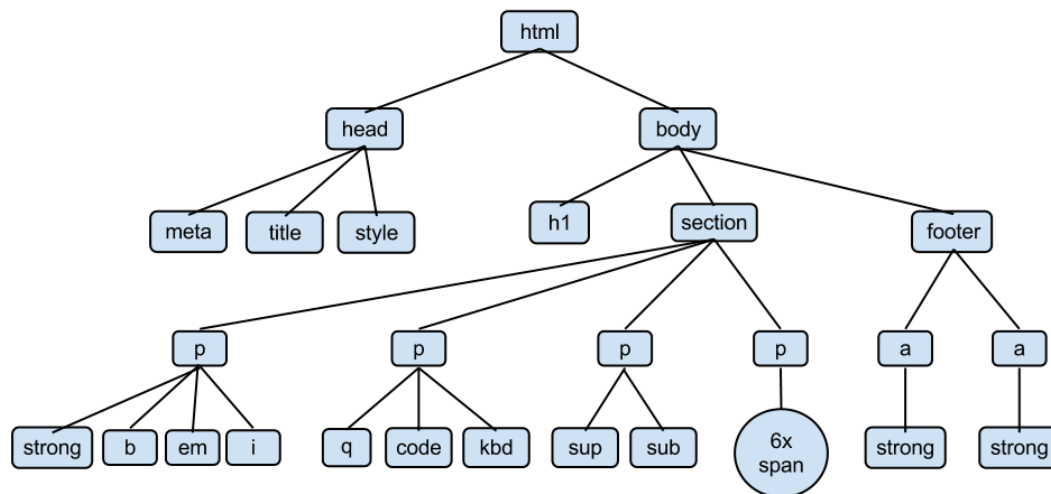
Microdata/schema.org vs. Linked Open Data

- 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 MD2RDF creates blank nodes
 - Use HTTP URIs that can be looked up Blank nodes cannot be looked up
 - When someone looks up a HTTP URI, provide useful information using a standard HTML5+MD is a standard

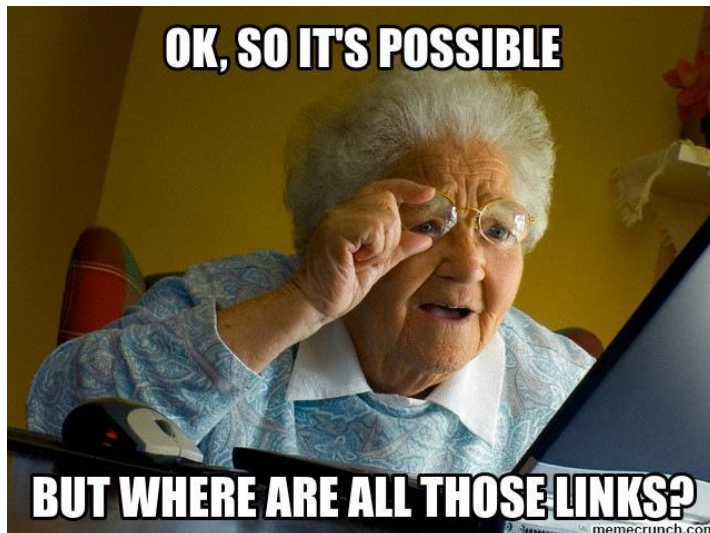
```
<div itemscope itemtype="http://schema.org/PostalAddress">  
  <span itemprop="name">Data and Web Science Group</span>  
  <span itemprop="addressLocality">Mannheim</span>,  
  <span itemprop="postalCode">68131</span>  
  <span itemprop="addressCountry">Germany</span>  
</div>
```

```
<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. Linked Open Data

- 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
- Linked Open Data:
 - A set of interconnected knowledge graphs, or a large knowledge graph
- schema.org/Microdata
 - A very large set of small knowledge graphs

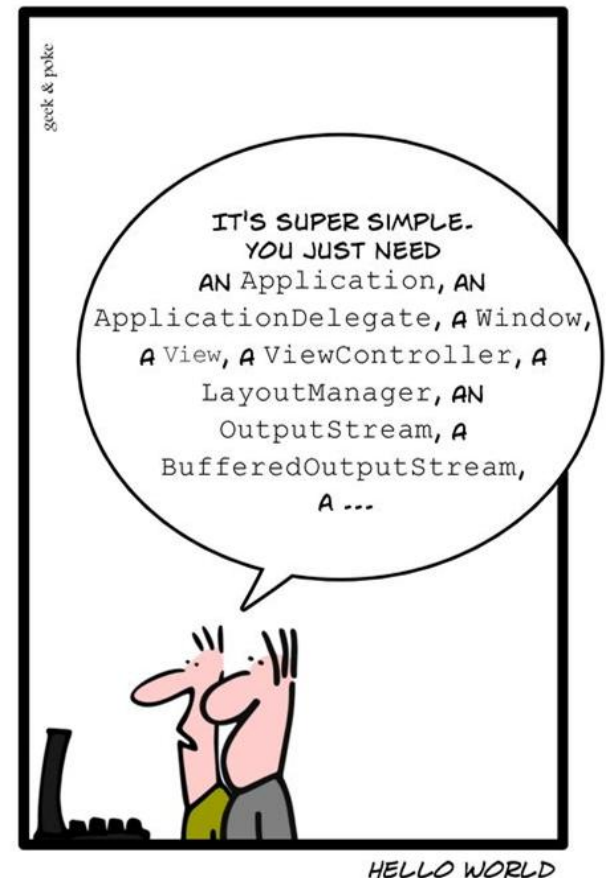
And Now for Something Completely Different



Programming with Knowledge Graphs

- Let's start with a simple application
 - a Hello World application for reading data from a knowledge graph

SIMPLY EXPLAINED



Using only Plain Java

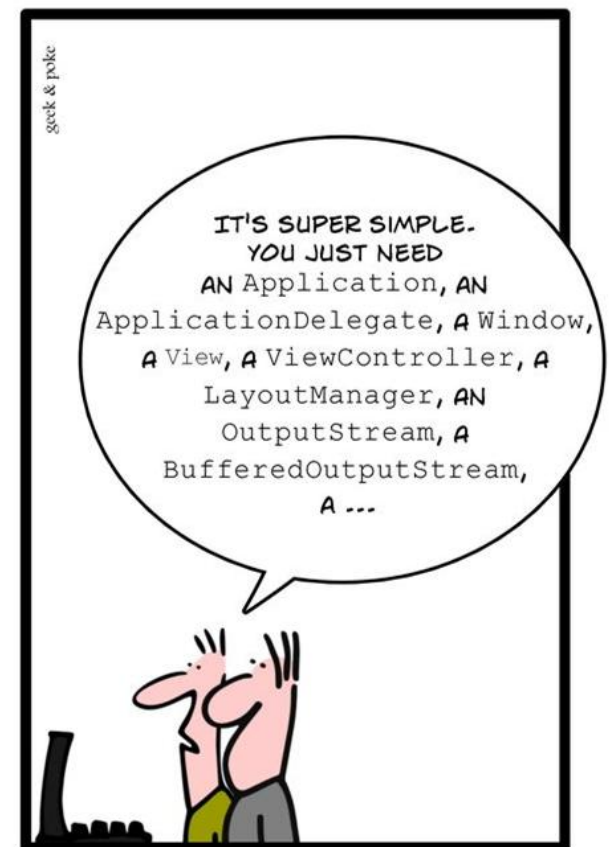
```
URL url = new URL("http://dbpedia.org/resource/Mannheim");
URLConnection conn = url.openConnection();
conn.addRequestProperty("Accept", "text/rdf+n3");
BufferedReader BR = new BufferedReader(
    new
    InputStreamReader(conn.getInputStream())
);

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 reading data from a knowledge graph
- Using plain Java is possible
 - but not very comfortable
 - there are more sophisticated frameworks

SIMPLY EXPLAINED



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 =  
    mannheim.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

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

```
- 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());  
}
```

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");
```

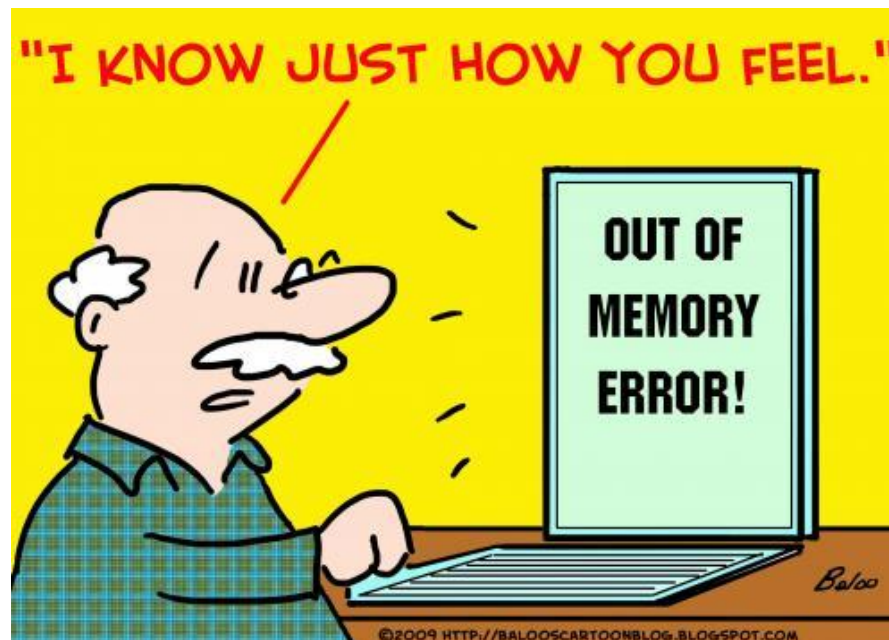
- But there is no such thing as

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

- Why?

Iterators in Jena

- Knowledge graphs can be very large
- E.g., reading all triples from DBpedia
 - Stored in List<Statement> would kill the main memory
 - Iterators allow a more efficient memory use



Programming with Jena

- Manipulating models

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

- Watching model changes

```
class MyListener implements ModelChangeListener...
```

```
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

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

- ```
[http://www.w3.org/2000/01/rdf-schema#subClassOf, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/2000/01/rdf-schema#domain, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/2000/01/rdf-schema#subPropertyOf, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/2000/01/rdf-schema#range, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/2000/01/rdf-schema#comment, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/2000/01/rdf-schema#label, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.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://www.w3.org/1999/02/22-rdf-syntax-ns#first, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/1999/02/22-rdf-syntax-ns#object, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://
```

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 as a set of 3-item triples
- ```
[
 (subject1, predicate1, object1),
 (subject2, predicate2, object2),
 ...
 (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)`

# 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")))
```

- Serialize graph

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

# Wrap-Up

- Today, we have seen
  - Two incarnations of knowledge graphs as publicly available data
    - i.e., Linked Open Data
    - and Microdata/schema.org
- ...and we have learned how to write programs consuming data in knowledge graphs
  - Jena & RDFlib programming frameworks
  - Loading RDF from files and from URLs
  - Performing reasoning

# Questions?

