

Lecture 9

Artificial Intelligence: Knowledge Graphs

Part II: Vocabularies & Ontologies, RDFS, Linked Open Data

COMP 6721, Winter 2022

Outline

- ① RDF Schema
- ② Vocabularies
- ③ Example: schema.org
- ④ Knowledge Bases & Linked Open Data
- ⑤ Notes and Further Reading

Slides Credit

- Includes slides from Jay Pujara & Sameer Singh, *Mining Knowledge Graphs from Text*, <https://kgtutorial.github.io/>
- Includes slides by Ivan Herman, W3C [Her]
- Includes slides from Hoifung Poon, Chris Quirk & Scott Wen-Tau Yih, *Machine Reading for Precision Medicine*,
https://www.microsoft.com/en-us/research/uploads/prod/2018/01/1802_aaai-tutorial_precision-med.pdf

Outline

① RDF Schema

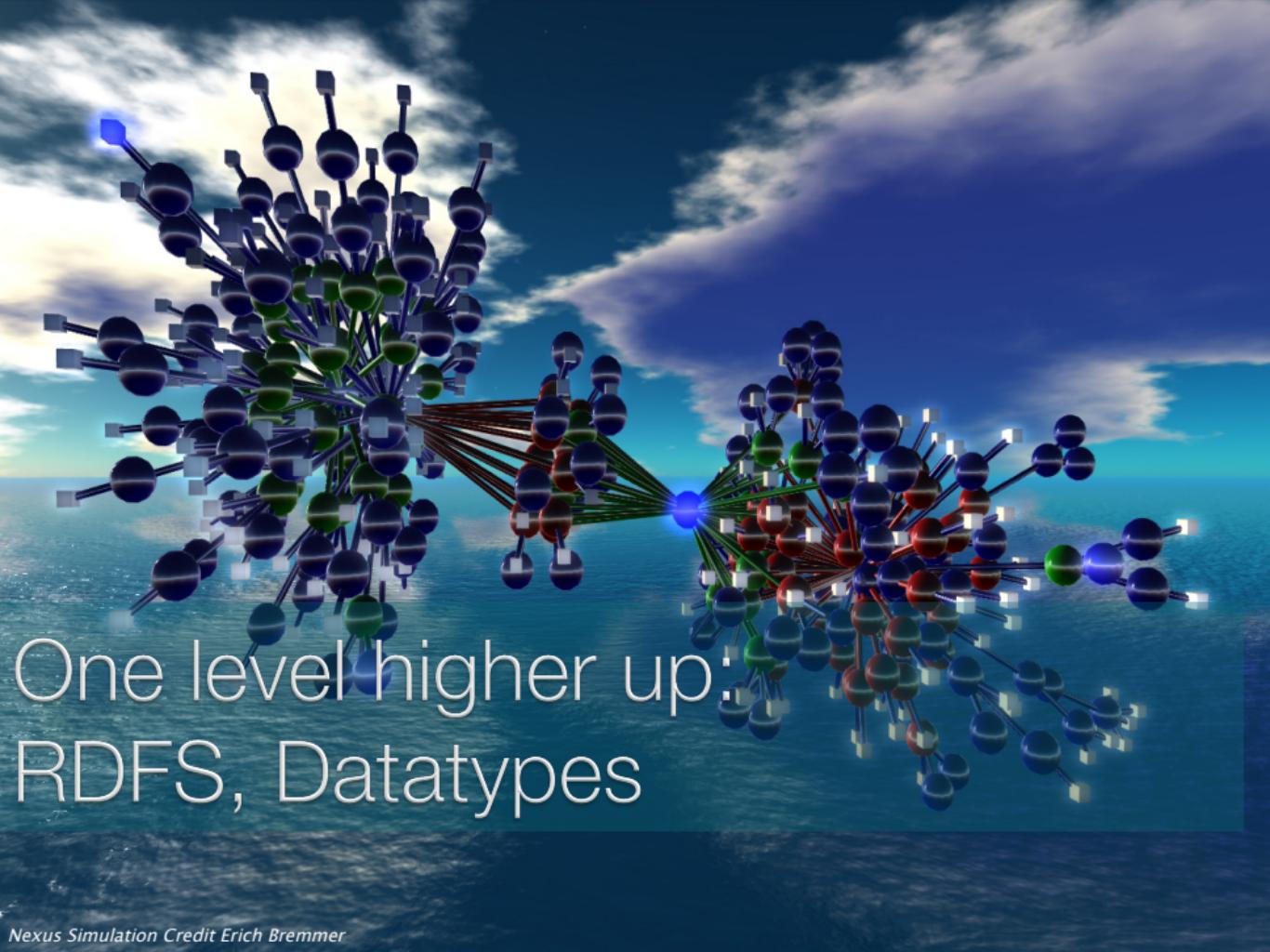
- Introduction
- Class and Instance
- Label & Comment
- Subclass
- Property
- RDFS Utility Vocabulary
- RDFS Summary

② Vocabularies

③ Example: schema.org

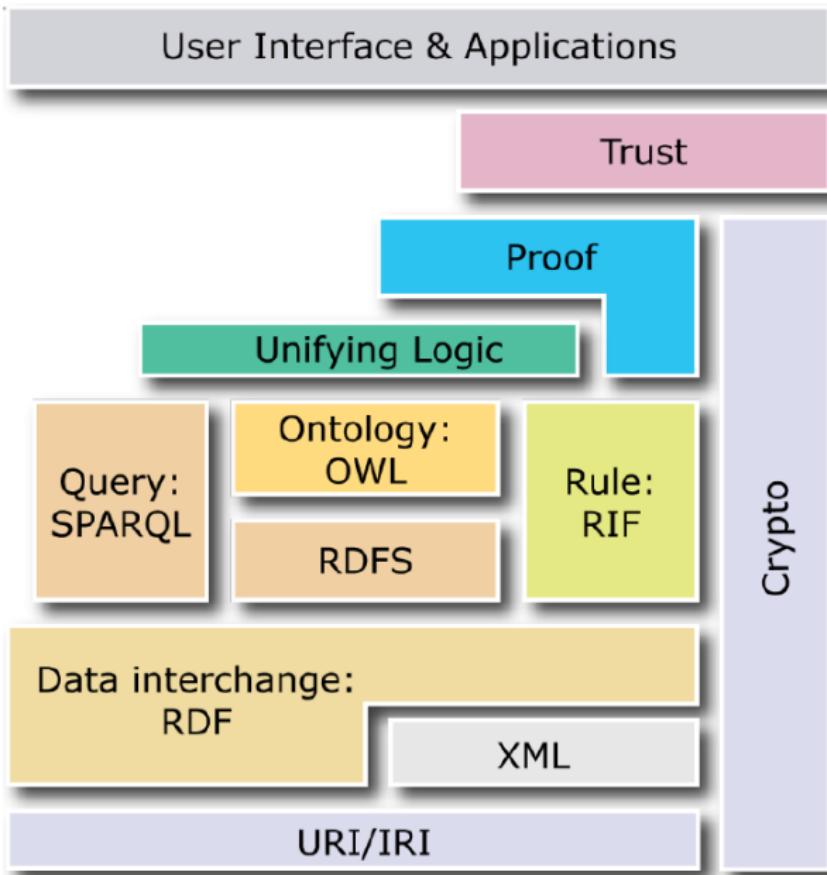
④ Knowledge Bases & Linked Open Data

⑤ Notes and Further Reading



One level higher up
RDFS, Datatypes

The W3C “Layer Cake”



RDF Schema (RDFS)

W3C Recommendation

- “RDF Vocabulary Description Language 1.0: RDF Schema” (RDFS 1.0)
- Current version (2014): “RDF Schema 1.1”

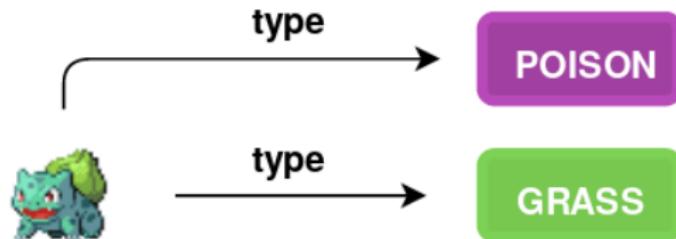
Used together with RDF

- RDF provides “a way to make statements about resources” (IRIs)
- RDFS provides *semantics* about what the IRIs stand for
(Schemas aka Vocabularies aka Ontologies aka...)

Classes and Instances

Classes

- Resources may be divided into groups called **classes**
- The members of a class are known as **instances** of the class
- An instance can be member of **more than one class**



What is a knowledge graph – Pokémon edition:
<https://pieterheyvaert.com/blog/2019/12/27/kg-pkmn/>

Defining Classes

We define that an IRI in a triple is a class using ... a triple!
(sounds weird the first time you hear it, but you get used to it)

Classes and Instances (contd.)

Defining Classes

To define that **C** (a resource) is an RDFS **class**, write:

C rdf:type rdfs:Class

with **rdfs** defined as <http://www.w3.org/2000/01/rdf-schema#>

Example

ex:Novel rdf:type rdfs:Class

Turtle

In Turtle, **rdf:type** can be abbreviated as **a**

→ Worksheet #8: “N-Triples” & “Your first Vocabulary”

Classes and Instances (contd.)

Instances

To define that **I** (a resource) is an instance of **C** (a class), write:

I `rdf:type C`

(or `a` instead of `rdf:type` in Turtle.)

Example

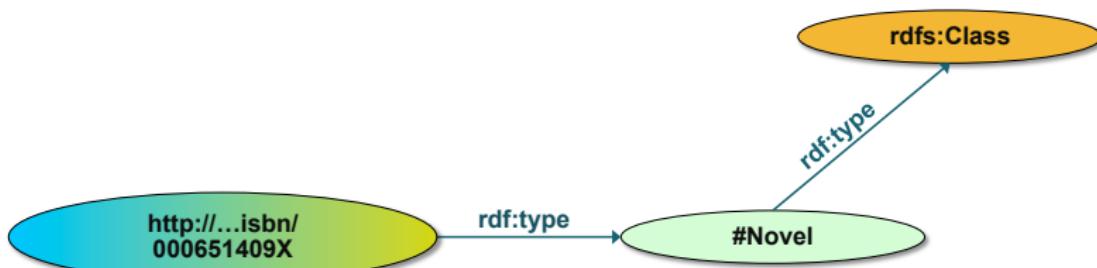
```
<http://...isbn/000651409X> rdf:type ex:Novel
```

Note

This is just another triple...

→ Worksheet #8: "Creating Instances"

Classes, resources in RDF(S)



- ▶ RDFS defines the meaning of these terms
 - (these are all special URI-s, we just use the namespace abbreviation)

Label & Comment

Human-Readable Content

By convention, always provide:

`rdflib:label` a human-readable label

`rdflib:comment` a short (one paragraph) description
using language tags for multiple languages.

Examples (`dbpedia:The_Glass_Palace`)

```
<http://dbpedia.org/resource/The_Glass_Palace>
    rdflib:label      "The Glass Palace"@en ,
                      "Le Palais des miroirs"@fr ;
```

```
    rdflib:comment   "The Glass Palace is a 2000 historical novel..."@en ,
                      "Le Palais des miroirs est un roman..."@fr ;
```

Subclasses

Defining a subclass

To define that **C1** (a class) is a **subclass** of **C2** (a class), write:

C1 rdfs:subClassOf C2

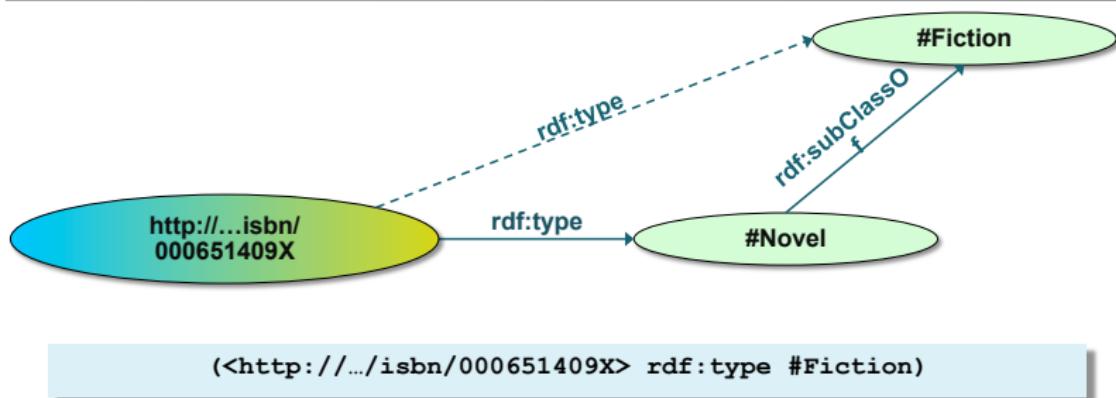
Semantics

This states that all the instances of C1 are also instances of C2.

The **rdfs:subClassOf** property is **transitive**.

→ Worksheet #8: “Subclasses”

Inferred properties



- ▶ is not in the original RDF data...
- ▶ ...but can be inferred from the RDFS rules
- ▶ RDFS environments return that triple, too

Inference: let us be formal...

- ▶ The RDF Semantics document has a list of (33) entailment rules:
 - “if such and such triples are in the graph, add this and this”
 - do that recursively until the graph does not change
- ▶ The relevant rule for our example:

```
If:  
  uuu rdfs:subClassOf xxx .  
  vvv rdf:type uuu .  
Then add:  
  vvv rdf:type xxx .
```

Properties

Defining a Property

To define that P (a resource) is a **property**, write:

$P \text{ rdf:type } \text{Property}$

Properties are used to define **relations** between subject resources and object resources.

Example

<is a friend of> <type> <Property>

→ Worksheet #8: "Properties"

Domain and Range

Domain

To define a class **C** as the **domain** of a property **P**, write:

P rdfs:domain C

This states that values of a property are instances of one (or more) class(es).

Range

To define a class **C** as the **range** of a property **P**, write:

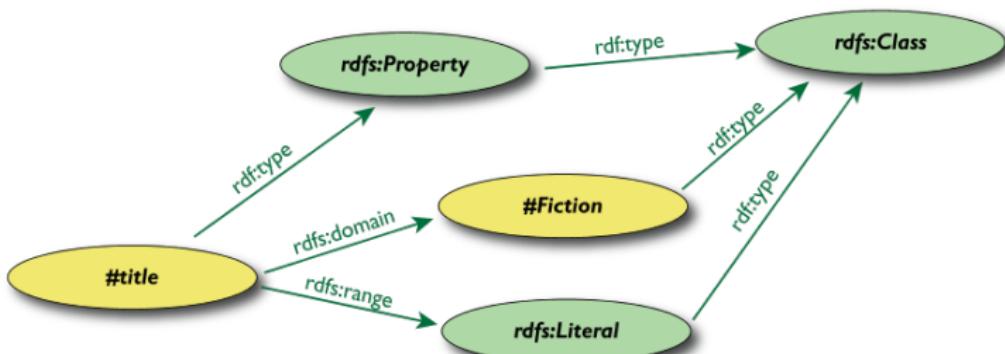
P rdfs:range C

This states that any resource that has a given property is an instance of one (or more) class(es).

Note

- Properties are also resources (named with URIs)
- So we define properties of properties using... RDF properties!
- Again, you'll get used to it...

Property specification example



Property specification serialized

- ▶ In RDF/XML:

```
<rdf:Property rdf:ID="title">
  <rdfs:domain rdf:resource="#Fiction"/>
  <rdfs:range rdf:resource="http://...#Literal"/>
</rdf:Property>
```

- ▶ In Turtle:

```
:title
  rdf:type    rdf:Property;
  rdfs:domain :Fiction;
  rdfs:range   rdfs:Literal.
```

Subproperties

Defining a Subproperty

To define that **P1** (a property) is a **subproperty** of **P2** (a property), write:

P1 rdfs:subPropertyOf P2

With a subproperty, we can state that all resources related by one property are also related by another.

Example

Like inheritance for classes, we can have inheritance for properties:

<is father of> <subPropertyOf> <is parent of>

RDFS Utility Vocabulary

Some "helper" constructs

`rdfs:seeAlso` a property that links a resource to another for more information (can be in any format)

`rdfs:isDefinedBy` a property typically used to refer to a vocabulary (RDF Schema) defining the subject IRI

There are also some datastructures (bag, list etc.) – read more before using!



RDF Schema Constructs: Summary

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

Outline

1 RDF Schema

2 Vocabularies

Introduction

FOAF

Dublin Core

Summary

3 Example: schema.org

4 Knowledge Bases & Linked Open Data

5 Notes and Further Reading

Vocabularies

Goal: Knowledge Integration

Two major principles:

- ① Reuse of vocabularies

E.g., always use FOAF to describe names, emails, etc., instead of making up your own schema

- ② Make your data self-describing

Self-Describing Datasets

Provide useful information about new terms

For example, if we create our own proprietary term, like [SmallMediumEnterprise](#), we could describe it as [HB11]:

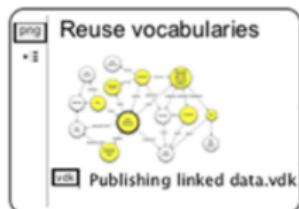
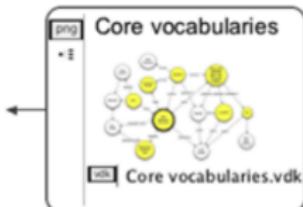
```
1 @prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .  
2 @prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .  
3 @prefix owl: <http://www.w3.org/2002/07/owl#> .  
4 @prefix co: <http://biglynx.co.uk/vocab/sme#> .  
5  
6 <http://biglynx.co.uk/vocab/sme#SmallMediumEnterprise>  
7   rdfs:type rdfs:Class ;  
8     rdfs:label "Small or Medium-sized Enterprise" ;  
9     rdfs:subClassOf <http://dbpedia.org/ontology/Company> .  
10    rdfs:subClassOf <http://umbel.org/umbel/sc/Business> ;  
11    rdfs:subClassOf <http://sw.opencyc.org/concept/Mx4rvVjQNpwpEbGdrcN5Y29ycA> ;  
12    rdfs:subClassOf <http://rdf.freebase.com/ns/m/0qb7t> .
```

Reuse vocabularies whenever possible

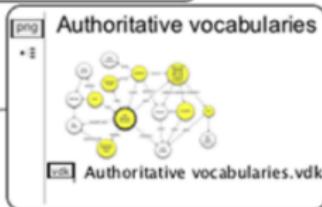
Use well-known and authoritative vocabularies to describe things whenever possible.



Describe common types of data by using terms from core vocabularies.



Use authoritative vocabularies for terms not defined by the core vocabularies.



Create your own vocabulary if necessary.



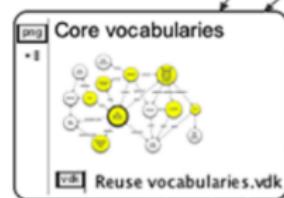
Use RDFS and OWL.



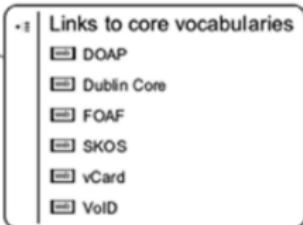
Be prepared to maintain it.

Core Vocabularies

Use terms from these core vocabularies to describe commonly understood data.



- ? Naming things? ← Use rdfs:label, foaf:name, skos:prefLabel.
- ? Describing people? ← Use FOAF, vCard.
- ? Describing addresses? ← Use vCard.
- ? Describing projects? ← Use Description of a Project (DOAP).
- ? Describing web pages and other publications? ← Use dc:creator and dc:description.
- ? Describing an RDF vocabulary? ← Use a VoID description.
- ? Describing existing taxonomies? ← Use SKOS.



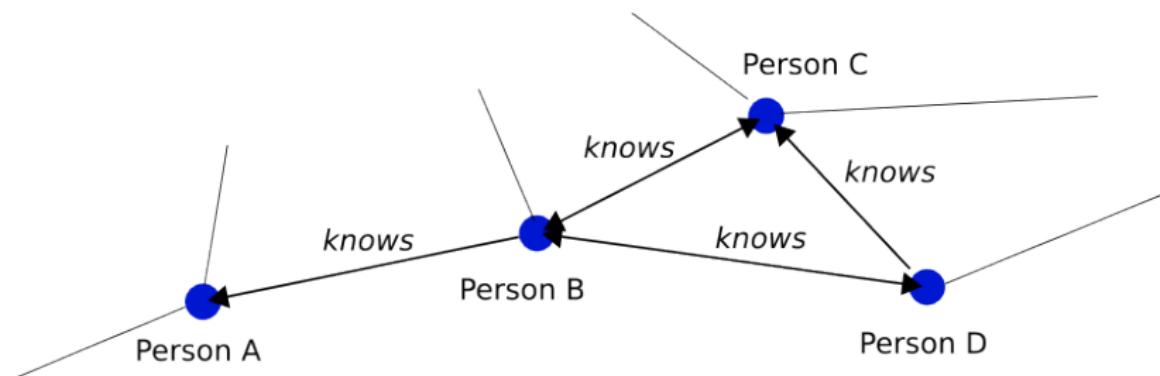
FOAF (Friend-of-a-Friend) Vocabulary

FOAF

Model people and their connections in a social network.



```
<#RW>
  a foaf:Person ;
  foaf:name "Rene Witte" ;
  foaf:mbox_sha1sum "5d5705ff1b2142d62a38061f804f766ffaf806ef" .
```



→ Worksheet #8: “FOAF”

Dublin Core



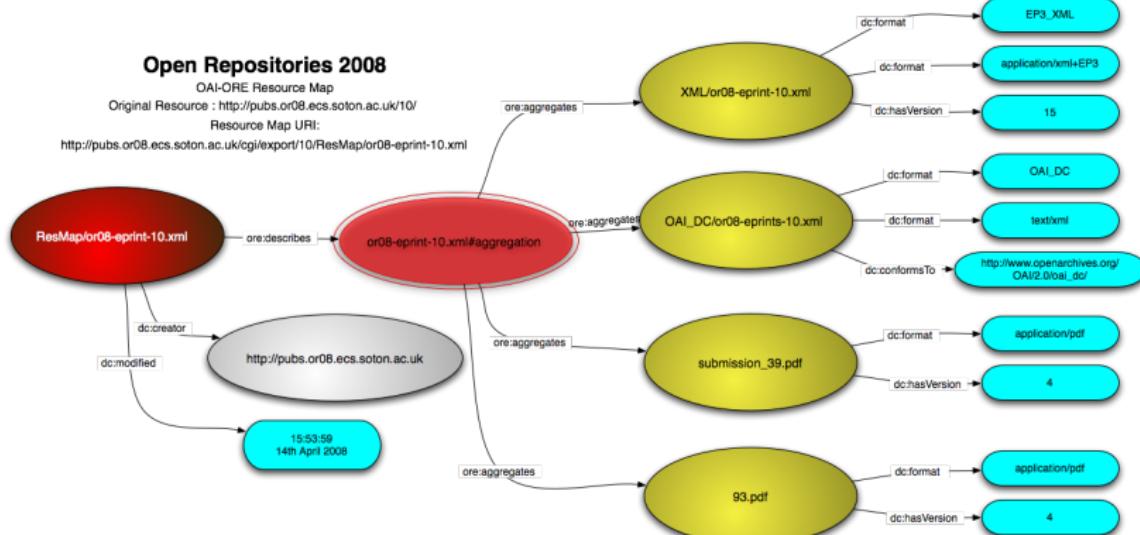
Open Repositories 2008

OAI-ORE Resource Map

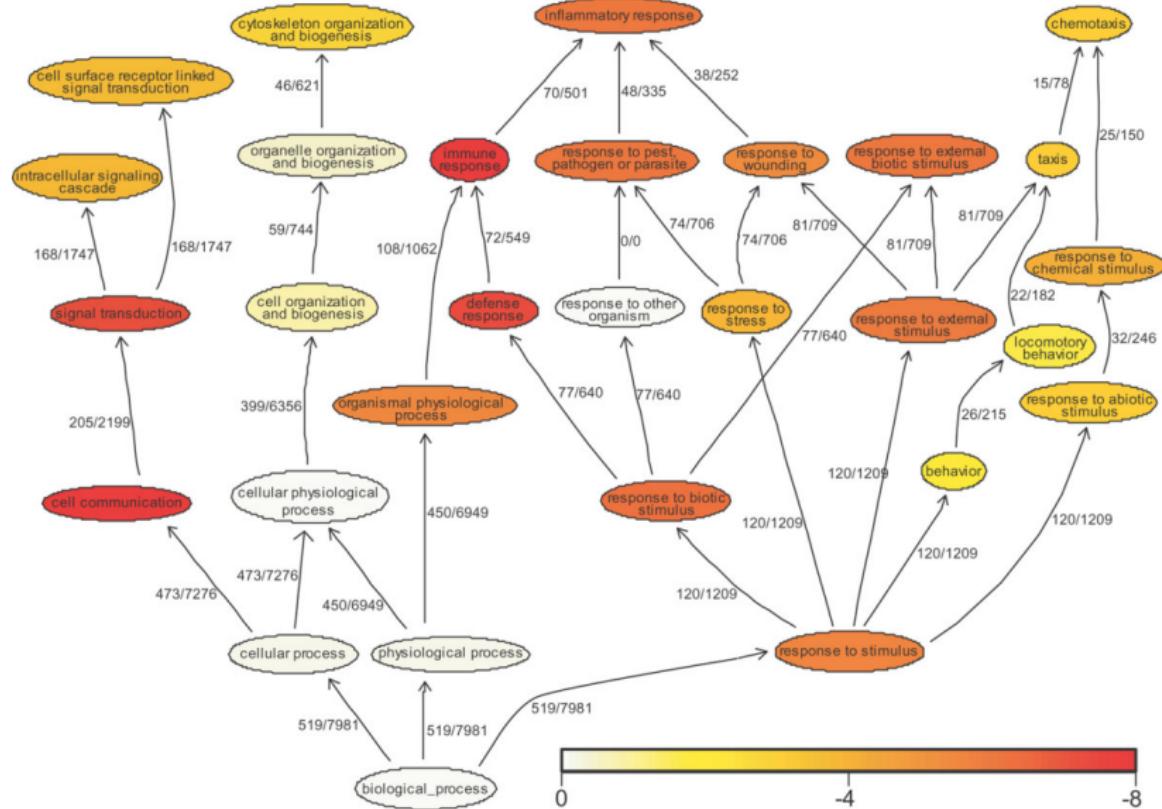
Original Resource : <http://pubs.or08.ecs.soton.ac.uk/10/>

Resource Map URI:

<http://pubs.or08.ecs.soton.ac.uk/cgi/export/10/ResMap/or08-eprint-10.xml>

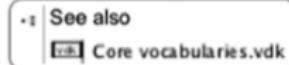


Gene Ontology (GO)

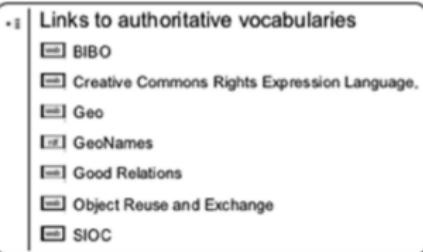


More authoritative vocabularies

Use these authoritative vocabularies to describe data you couldn't describe with the core vocabularies.



- FAQ icon: Specifying the geographical location of something? ← Use Geo.
- FAQ icon: Describing citations and bibliographic references? ← Use BIBO.
- FAQ icon: Describing copyright licenses? ← Use the Creative Commons Rights Expression Language
- FAQ icon: Describing a place? ← Use GeoNames.
- FAQ icon: Describing product, price, or company data? ← Use Good Relations.
- FAQ icon: Describing web resources that are compound digital objects? ← Use Object Reuse and Exchange.
- FAQ icon: Describing information about an online community? ← Use SIOC.



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- 1 RDF Schema
- 2 Vocabularies
- 3 Example: schema.org
- 4 Knowledge Bases & Linked Open Data
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Typical usage of structured data

the artist movie – Google Search

https://www.google.nl/#hl=en&sugexp=frgbld&gs_nf=1&cp=11&gs_id=5p&xhr=t&q=the+artist+movie+database

Delicious LocalData TR 2012 My Mercurial Private Mailing lists Social SW Python RDFa It! Bookmarks To... Web Data Inspector

Everything **The Artist** showtimes for Amsterdam

Pathé Tuschinski - Reguliersbreestraat 26-34, Amsterdam - [Map](#)
11:50 - 14:05 - 19:10

Filmtheater "De Uitkijk" - Prinsengracht 452, Amsterdam - [Map](#)
12:15 - 19:00 - 21:15

Filmtheater Ratio - Ceintuurbaan 338, Amsterdam - [Map](#)
12:45

+ Show more theaters

The Artist (2011) - IMDb
www.imdb.com/title/tt1655442/
Silent movie star George Valentin bemoans the coming era of talking ... Still of Jean Dujardin and Miss Pyle in **The Artist** Still of Bérénice Bejo in **The Artist** Reem ...
→ Full cast and crew - **The Artist** Trailer (Official) ... - Bérénice Bejo - Jean Dujardin

The Artist (film) - Wikipedia, the free encyclopedia
[en.wikipedia.org/wiki/The_Artist_\(film\)](http://en.wikipedia.org/wiki/The_Artist_(film))
The Artist is a 2011 French romantic comedy drama in the style of a black-and-white silent film written and directed by Michel Hazanavicius, starring Jean ...
→ Jean Dujardin - Bérénice Bejo - Uggie - Diegese

The Artist Trailer 2011 HD - YouTube
www.youtube.com/watch?v=0BKMZcSQJE
25 Aug 2011 - 3 min - Uploaded by TrailersApplecom
I love how George Clooney, and Brad Pitt, lost the Best actor category to this film. It just shows that there is ...
2:32

More videos for the artist movie »

Oscars 2012: The Artist review - Telegraph
www.telegraph.co.uk/Culture/Film/Film_Reviews

★★★★★ Review by Robbie Collin
14 Feb 2012 - **The Artist**, the final film to be released in 2011 and also the most heart-wrenchingly joyous film, is a silent movie, screened in black and white and ...

The Artist is the perfect film about Hollywood | Hartley Freeman

Oscars 2012: The Artist, review – Telegraph

<http://www.telegraph.co.uk/culture/film/filmreviews/8982558/Oscars-2012-The-Artist.html>

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The Telegraph

Search - enhanced by Google

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Dating Offers Jobs

CULTURE

HOME NEWS SPORT FINANCE COMMENT BLOGS TRAVEL LIFESTYLE FASHION TECH

Film Music Art Books TV and Radio Theatre Hay Festival Dance Opera Photography Comedy Video In the Know

Oscars Film Reviews Cinema Trailers Coming Soon Talking Movies Interviews DVDs Film Life Film Video

HOME > CULTURE > FILM > FILM REVIEWS

Oscars 2012: The Artist, review

The Artist, an utterly beguiling silent, black-and-white celebration of early Hollywood won Best Picture at the Oscars 2012.

★★★★★



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Oscars 2012: The Artist, review – Telegraph

<http://www.telegraph.co.uk/culture/film/filmreviews/8982558/Oscars-2012-The-Artist.html>

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The Telegraph

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```
Source of http://www.telegraph.co.uk/culture/film/filmreviews/8982558/Oscars-2012-The-Artist-review.html
    <li class="first"><a href="/">Home</a><span>&raquo;</span></li>
    <li><a href="http://www.telegraph.co.uk/culture/">Culture</a><span>&raquo;</span></li>
        <li><a href="http://www.telegraph.co.uk/culture/film/">Film</a><span>&raquo;</span></li>
    <li class="styleSix"><a href="http://www.telegraph.co.uk/culture/film/filmreviews/">Film reviews</a></li>
</div>
</div>

<!-- googleon: all -->
<div id="tmglBody" >
    <div class="access"><a name="article"></a></div>

    <div class="twoThirdsThird2 gutterUnder" >
        <div class="twoThirds gutter" itemscope itemtype="http://schema.org/Review">
            <div class="storyHead">

                <h1 itemprop="name">Oscars 2012: The Artist, review</h1>
                <h2 itemprop="description">
                    The Artist, an utterly beguiling silent, black-and-white celebration of early Hollywood won Best Picture at the Oscars 2012.
                </h2>
                <div class="rating" itemprop="reviewRating" itemscope itemtype="http://schema.org/Rating">
                    <meta itemprop="worstRating" content = "0.5">
                    <meta itemprop="bestRating" content = "5">
                    <span itemprop="ratingValue" class="hidden">5</span>
                    
                </div>
                <div class="artIntro">
                    <div id="storyEmbSlide">
                        <div class="slideshow ssIntro">
                            <div class="nextPrevLayer">
                                <div class="ssImg">
                                    
                                <div class="artImageExtras" >
                                    <div class="ingCaptionCredit">
                                        <span class="caption">Bérénice Bejo as Rita in The Artist</span>
                                    </div>
                                </div>
                            </div>
                        </div>
                    </div>
                </div>
            </div>
        </div class="oneHalf gutter" >
            <div class="story">
                <div class="cl" ></div>
            </div>
        <!-- remove the whitespace added by escenic before end of </a> tag -->
    </div>
</div>
```

In a slightly more readable format...

```
<div itemscope itemtype="http://schema.org/Review">
  ...
  <h1 itemprop="name">Oscars 2012: The Artist, review</h1>
  <h2 itemprop="description">The Artist, an utterly beguiling..</h2>
  ...
  <span itemprop="ratingValue" class="hidden">5</span>
  ...
```

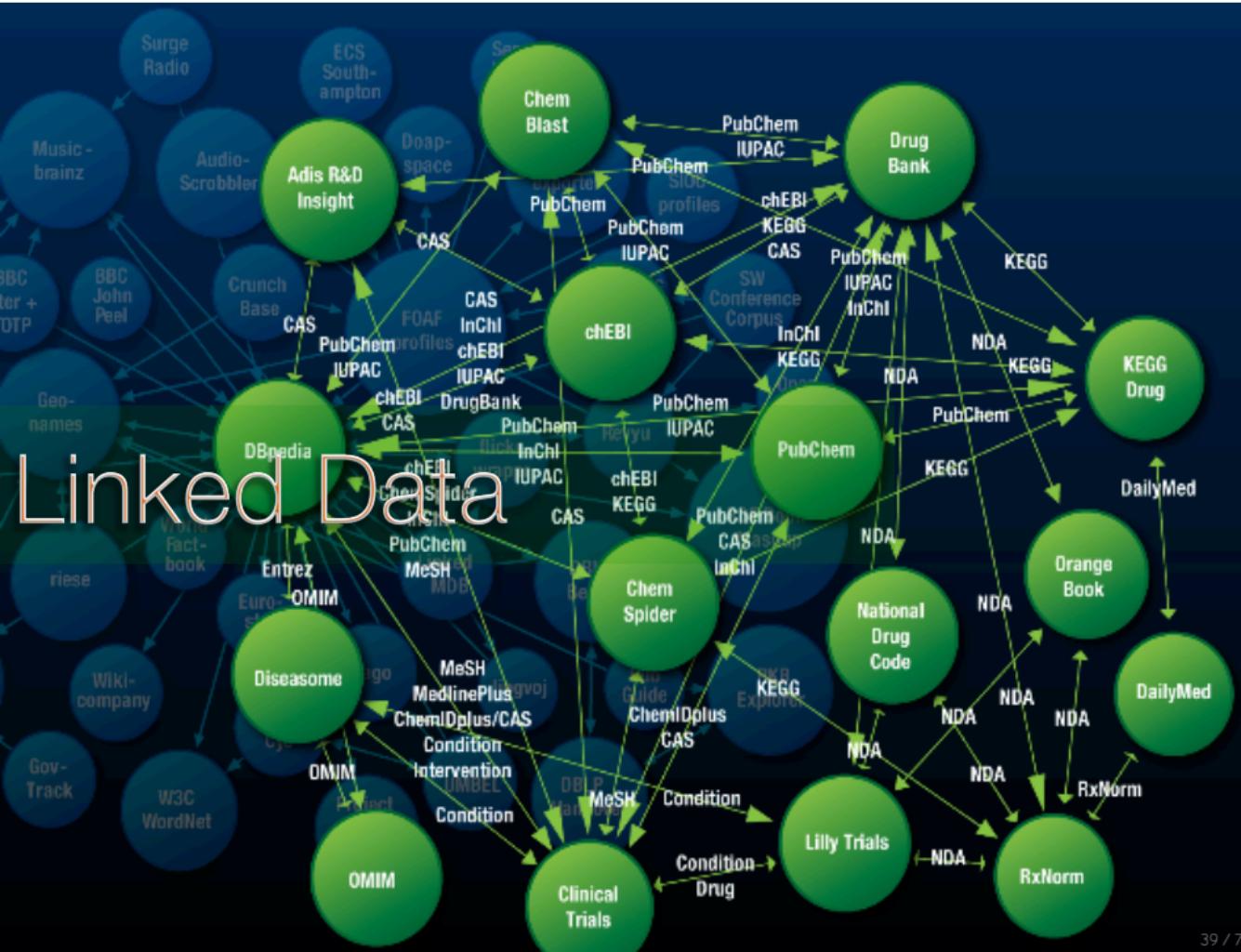
Yielding...

```
[ rdf:type schema:Review ,  
  schema:name "Oscars 2012: The Artist, review" ;  
  schema:description "The Artist, an utterly beguiling..." ;  
  schema:ratingValue "5" ;  
  ...  
 ]
```

Outline

- 1 RDF Schema
- 2 Vocabularies
- 3 Example: schema.org
- 4 Knowledge Bases & Linked Open Data
 - Introduction
 - DBpedia
 - Google's Knowledge Graph
 - SPARQL Queries
 - Application Architecture
- 5 Notes and Further Reading

Linked Data



Linked Data “Project”

- ▶ Goal: “expose” datasets on the Web
 - remember the importance of data!
- ▶ Set links among the data items from different datasets
 - we want to avoid the silo effects

Is your data 5 Star?



- ★ Available on the web (whatever format), but with an open license
- ★★ Available as machine-readable structured data (e.g., excel instead of an image scan)
- ★★★ As before, but using a non-proprietary format (e.g., CSV instead of excel)
- ★★★★ All the above, plus use open standards (RDF & Co.) to identify things, so that people could point at your stuff
- ★★★★★ All the above, plus link your data to other people's data to provide context

Example data source: DBpedia

- ▶ DBpedia is a community effort to
 - extract structured (“infobox”) information from Wikipedia
 - provide a query endpoint to the dataset
 - interlink the DBpedia dataset with other datasets on the Web



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Extracting structured data from Wikipedia

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

dbpedia:**Amsterdam**

```
dbterm:officialName "Amsterdam" ;  
dbterm:longd "4" ;  
dbterm:longm "53" ;  
dbterm:longs "32" ;  
dbterm:website <http://www.amsterdam.nl> ;  
dbterm:populationUrban "1364422" ;  
dbterm:areaTotalKm "219" ;  
...
```

dbpedia:**ABN_AMRO**

```
dbterm:location dbpedia:Amsterdam ;  
...
```

Amsterdam	
— Municipality / City —	
	Coordinates: 52°22'23"N 4°53'32"E
Country	Netherlands
Province	North Holland
COROP	Amsterdam
Boroughs	Boroughs
Government	Eberhard van der Laan (PvdA)
- Mayor	Carolin Gijssels
- Aldermen	Hans Gerven Maarten Poelgeest Preek Ooster Marjole Vos Henk de Jong
Area[1][2]	
- Municipality / City	219 km ² (84.6 sq mi)
- Land	166 km ² (64.1 sq mi)
- Water	53 km ² (20.5 sq mi)
- Urban	1,003 km ² (387.3 sq mi)
- Metro	1,815 km ² (700.8 sq mi)
Elevation[3]	2 m (7 ft)
Population (June 2009)[4][5]	
- Municipality / City	762,057
- Density	4,459 km ² (11,548.8/sq mi)
- Urban	1,364,422
- Metro	2,158,372
- Demonym	Amsterdammer
Time zone	CET (UTC+01)
- Summer (DST)	CEST (UTC+02) (UTC)
Postal codes	1011–1109
Area code(s)	020
Website	www.amsterdam.nl

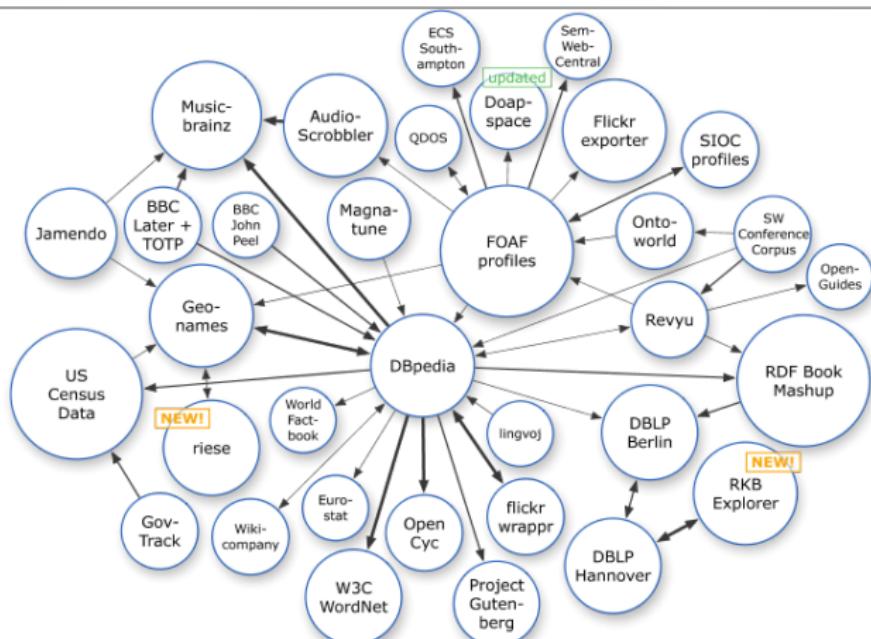
Automatic links among open datasets

```
<http://dbpedia.org/resource/Amsterdam> ←  
owl:sameAs <http://rdf.freebase.com/ns/...> ;  
owl:sameAs <http://sws.geonames.org/2759793> ;  
...
```

```
<http://sws.geonames.org/2759793>  
owl:sameAs <http://dbpedia.org/resource/Amsterdam>  
wgs84_pos:lat "52.3666667" ;  
wgs84_pos:long "4.8833333" ;  
geo:inCountry <http://www.geonames.org/countries/#NL> ;  
...
```

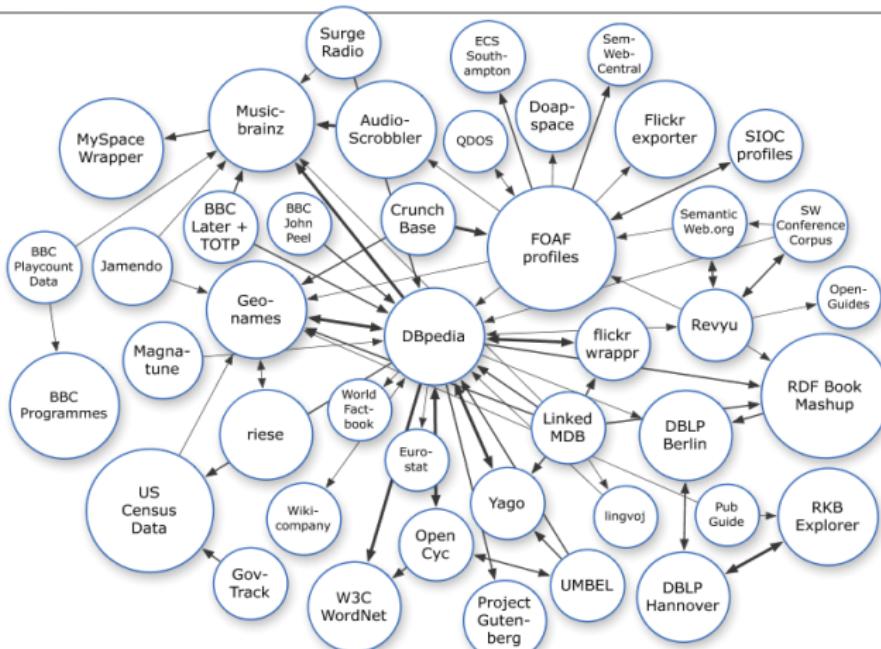
Processors can switch automatically from one to the other...

The LOD “cloud”, March 2008



Courtesy of Richard Cyganiak and Anja Jentzsch

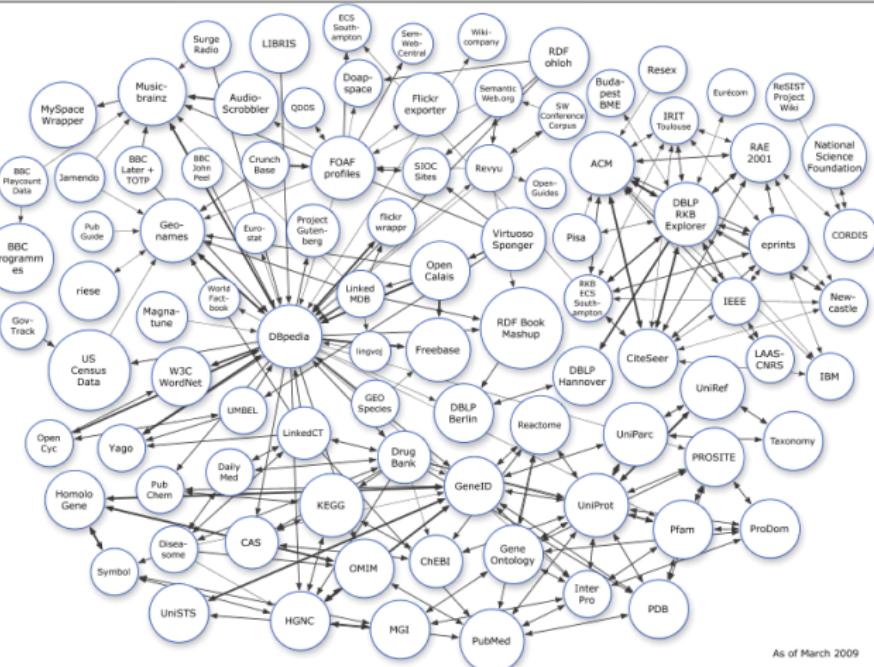
The LOD “cloud”, September 2008



As of September 2008

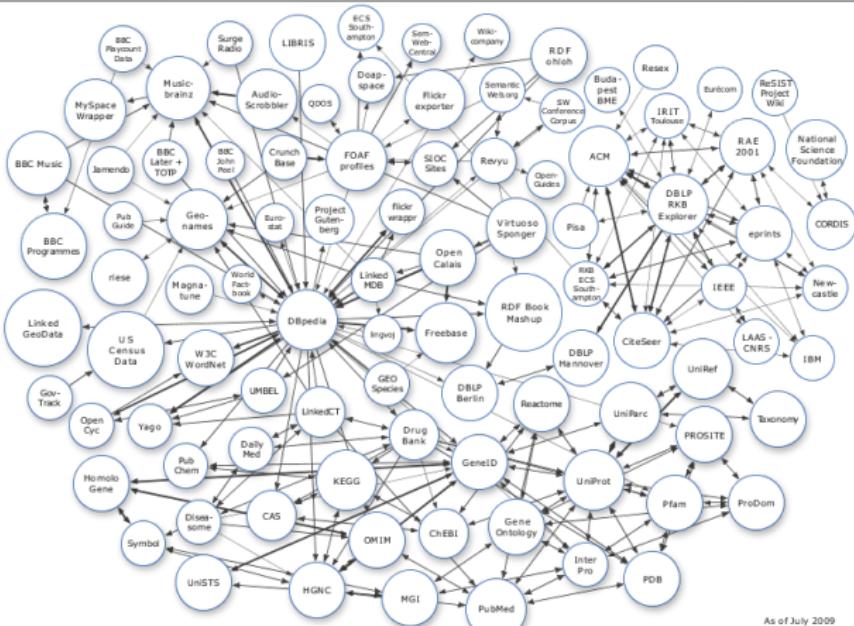
Courtesy of Richard Cyganiak and Anja Jentzsch

The LOD “cloud”, March 2009



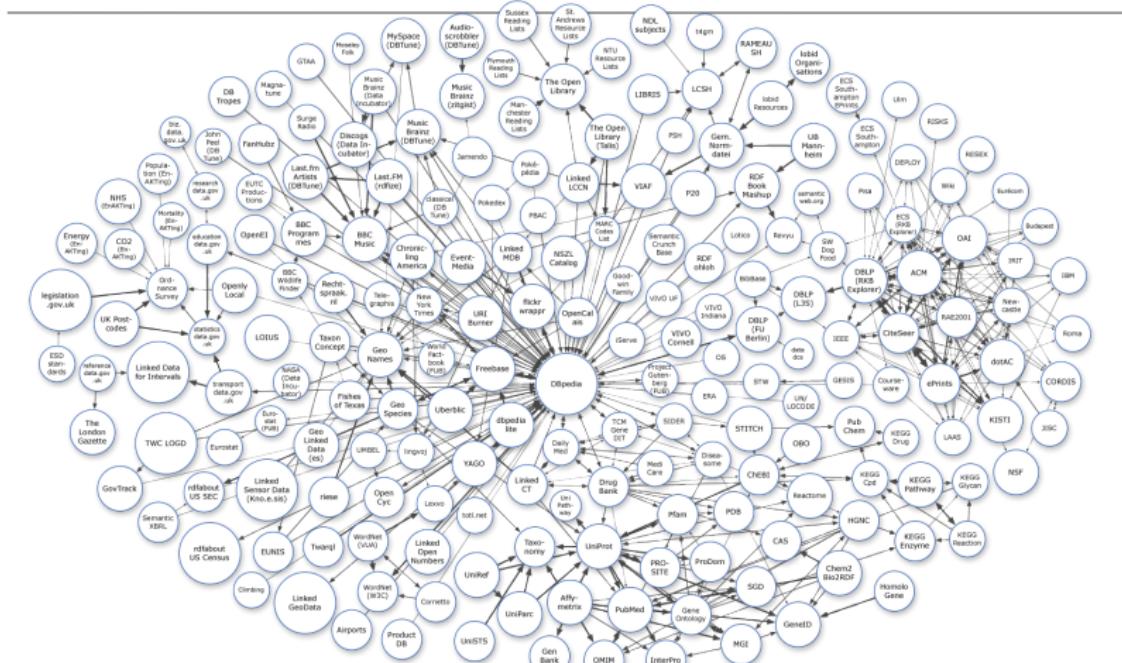
Courtesy of Richard Cyganiak and Anja Jentzsch

The LOD “cloud”, June 2009



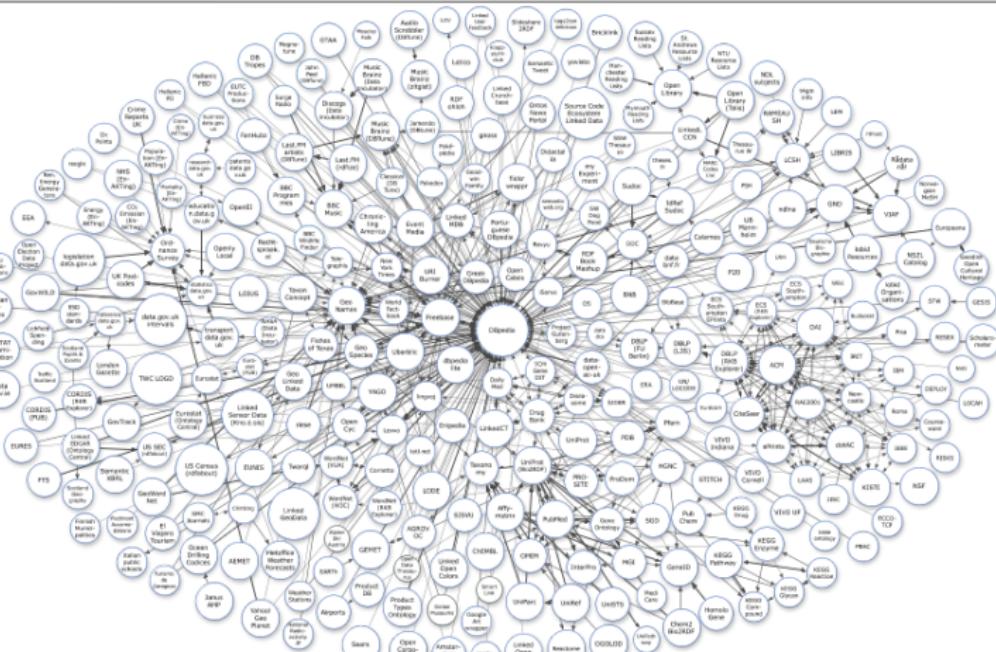
Courtesy of Richard Cyganiak and Anja Jentzsch

The LOD “cloud”, September 2010



Courtesy of Richard Guganick and Anis Jantzaeck

The LOD “cloud”, September 2011



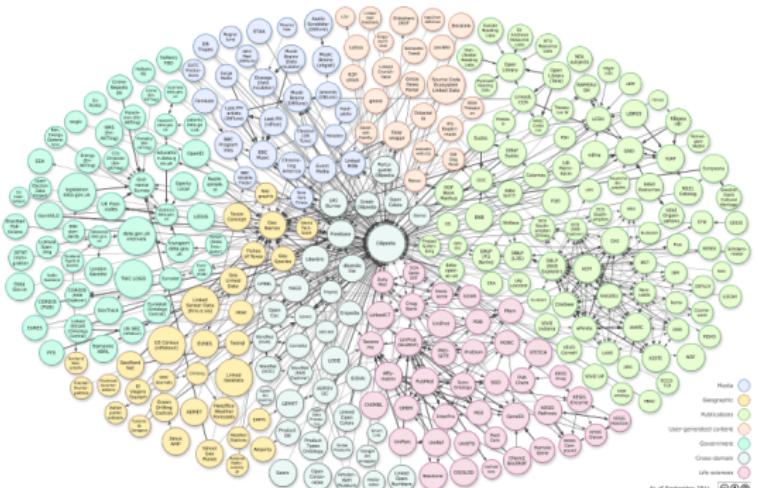
As of September 2011



Application specific portions of the cloud

► Eg, “bio” related datasets

- done, partially, by the “Linking Open Drug Data” task force of the HCLS IG at W3C

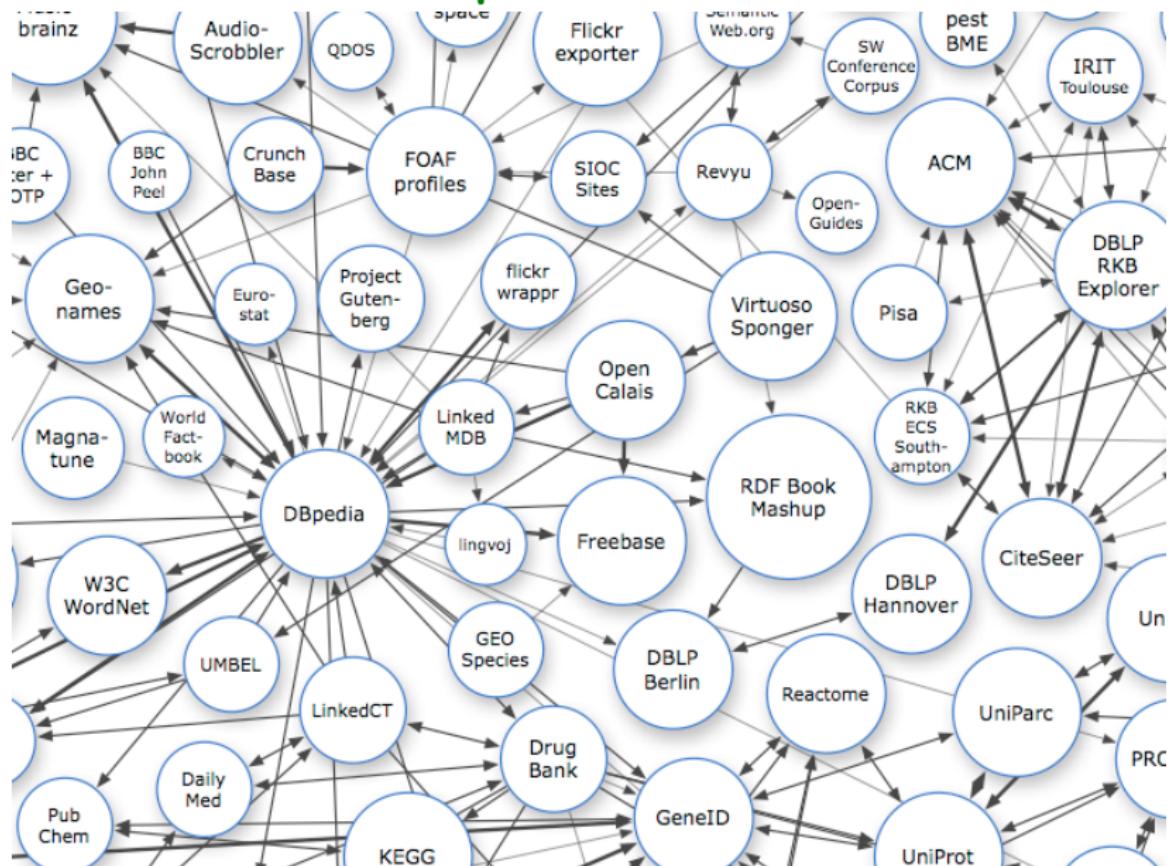


Courtesy of Richard Cyganiak and Anja Jentzsch

As of September 2011



LOD Datasets: <https://lod-cloud.net/>



Google's Knowledge Graph



Introducing the Knowledge Graph

<https://www.youtube.com/watch?v=mmQl6VGvX-c>

All Images Videos News Shopping Books Maps

About 125,000,000 results

Any country

Country: Canada

Any time

Past hour

Past 24 hours

Past week

Past month

Past year

All results

Verbatim

Entrepreneur,
Film producer,
Business magnate,
Inventor,
Businessperson,
Designer
Steve Jobs, Professions

[Steve Jobs - Inventor - Biography.com](#)

www.biography.com/people/steve-jobs-9354805 - Cached - Similar

24 Sep 2015 ... **Steven Paul Jobs** was born on February 24, 1955, in San Francisco, California, to Joanne Schieble (later Joanne Simpson) and Abdulfattah "John" Jandali, two University of Wisconsin graduate students who gave their unnamed son up for adoption.

[Steve Jobs - Wikipedia](#)

https://en.wikipedia.org/wiki/Steve_Jobs - Cached - Similar

—**Steve Jobs**, 1995. From the documentary, **Steve Jobs**: The Lost Interview. Schieble became pregnant in 1954 when she and Jandali spent the summer with his family in Homs, Syria.

[Biography | all about Steve Jobs .com](#)

allaboutstevejobs.com/bio/bio.php - Cached - Similar

Timeline, short biography and detailed biography of Apple CEO **Steve Jobs**, complete with key people in his life.

[all about Steve Jobs .com](#)

allaboutstevejobs.com/ - Cached - Similar

all about **Steve Jobs**.com: biography, pictures, movies, life and work of Apple CEO **Steve Jobs**.

Steve Jobs

Entrepreneur



Steven Paul "Steve" Jobs was an American information technology entrepreneur and inventor. He was the co-founder, chairman, and chief executive officer of Apple Inc.; CEO and majority shareholder of ... [Wikipedia](#)

Born: February 24, 1955, San Francisco, California, United States

Died: October 5, 2011, Palo Alto, California, United States

Spouse: Laurene Powell (m. 1991–2011)

Education: Reed College (1972–1974), more

Children: Lisa Brennan-Jobs, Eve Jobs, Erin Siena Jobs, Reed Jobs

Siblings: Mona Simpson, Patricia Ann Jobs

People also search for



Bill Gates



Laurene Powell Spouse



Lisa Brennan-Jobs Daughter

About: Steve Jobs

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

Steven Paul "Steve" Jobs (/dʒɒpbz/; February 24, 1955 – October 5, 2011) was an American information technology entrepreneur and inventor. He was the co-founder, chairman, and chief executive officer (CEO) of Apple Inc.; CEO and majority shareholder of Pixar Animation Studios; a member of The Walt Disney Company's board of directors following its acquisition of Pixar; and founder, chairman, and CEO of NeXT Inc. Jobs is widely recognized as a pioneer of the microcomputer revolution of the 1970s and 1980s, along with Apple co-founder Steve Wozniak. Shortly after his death, Jobs's official biographer, Walter Isaacson, described him as a "creative entrepreneur whose passion for perfection and ferocious drive revolutionized six industries: personal computers, animated movies, music, phones, tab

Property	Value
dbo:abstract	■ Steven Paul "Steve" Jobs (/dʒɒpbz/; February 24, 1955 – October 5, 2011) was an American information technology entrepreneur and inventor. He was the co-founder, chairman, and chief executive officer (CEO) of Apple Inc.; CEO and majority shareholder of Pixar Animation Studios; a member of The Walt Disney Company's board of directors following its acquisition of Pixar; and founder, chairman, and CEO of NeXT Inc. Jobs is widely recognized as a pioneer of the microcomputer revolution of the 1970s and

http://dbpedia.org/resource/Steve_Jobs

Querying RDF graphs

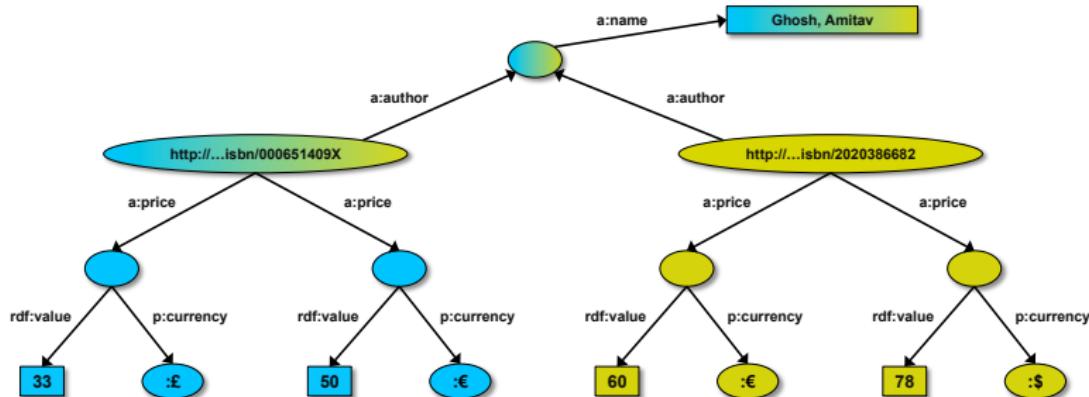
- ▶ In practice, more complex queries into the RDF data are necessary
 - something like: “give me the (a,b) pair of resources, for which there is an x such that (x parent a) and (b brother x) holds” (ie, return the uncles)
 - these rules may become quite complex
- ▶ The goal of SPARQL (Query Language for RDF)

General: graph patterns

- ▶ The fundamental idea: use graph patterns
 - the pattern contains unbound symbols
 - by binding the symbols, subgraphs of the RDF graph are selected
 - if there is such a selection, the query returns the bound resources

Simple SPARQL example

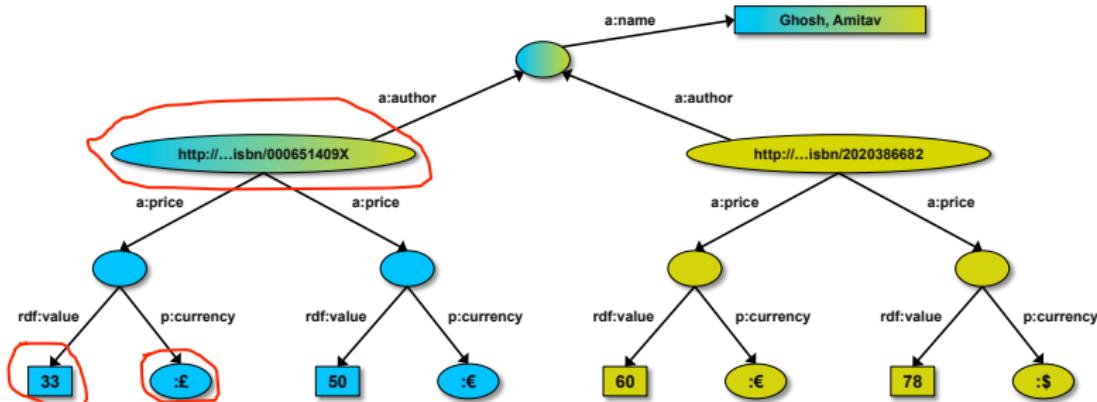
```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```



Simple SPARQL example

```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

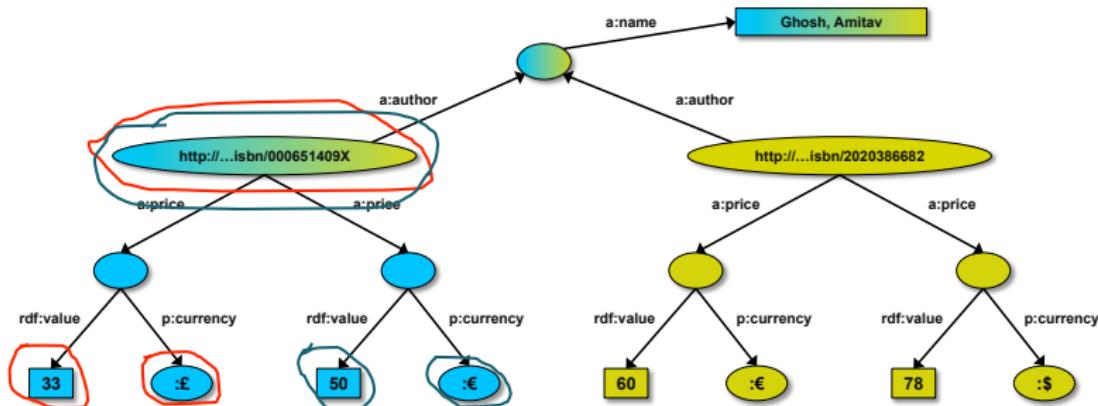
Returns: [<...409X>,33,:£]



Simple SPARQL example

```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

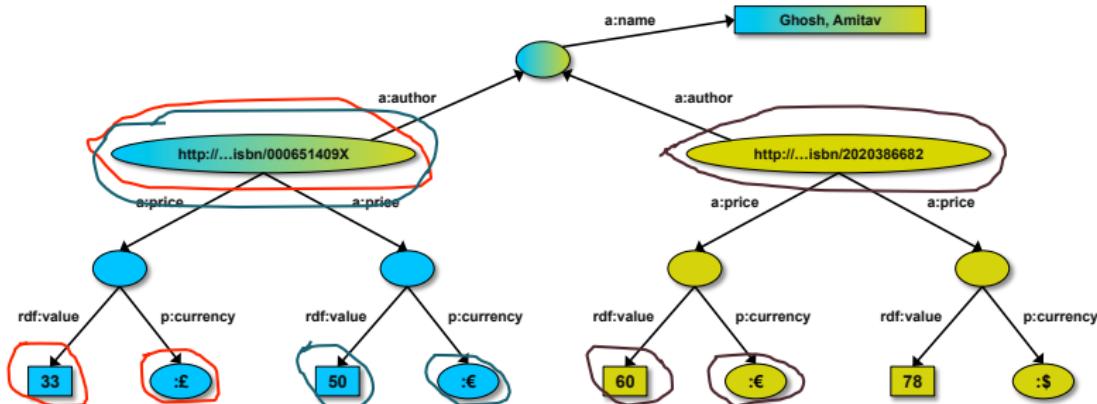
Returns: [<...409X>,33,:£], [<...409X>,50,:€]



Simple SPARQL example

```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

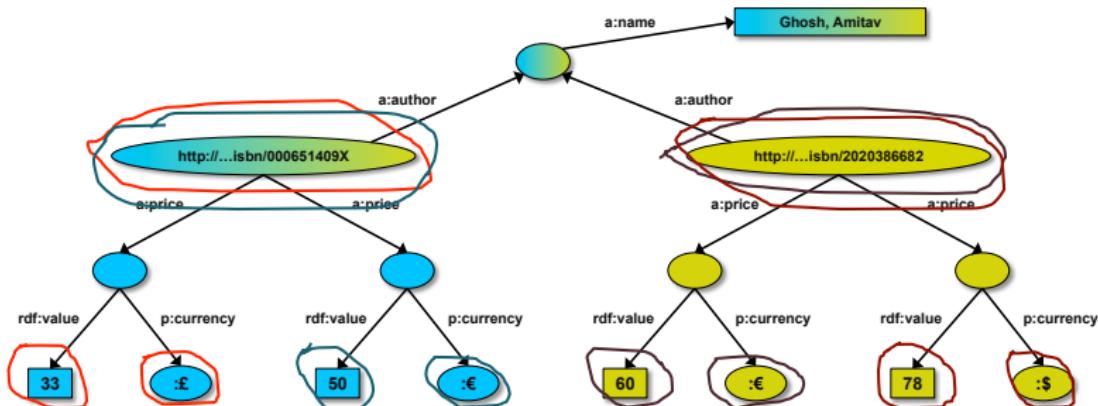
Returns: [⟨...409X>,33,:£], [⟨...409X>,50,:€],
[⟨...6682>,60,:€]



Simple SPARQL example

```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

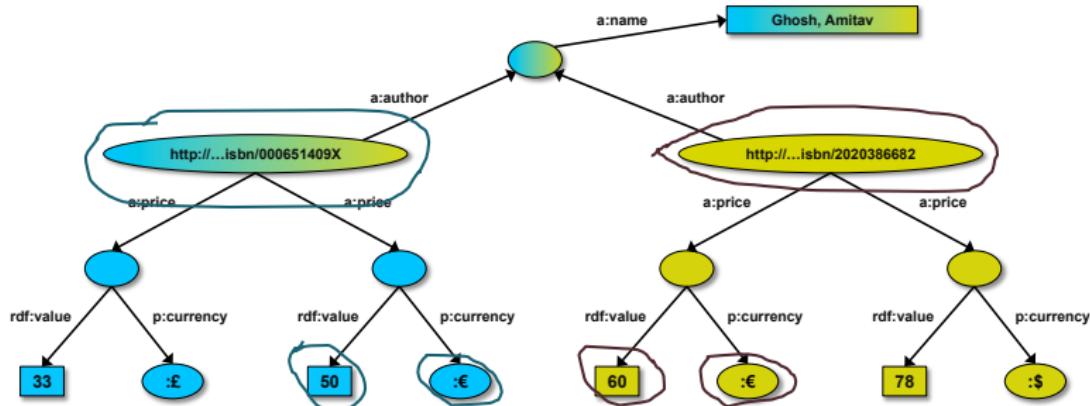
Returns: [⟨...409X>,33,:£], [⟨...409X>,50,:€],
[⟨...6682>,60,:€], [⟨...6682>,78,:\$]



Pattern constraints

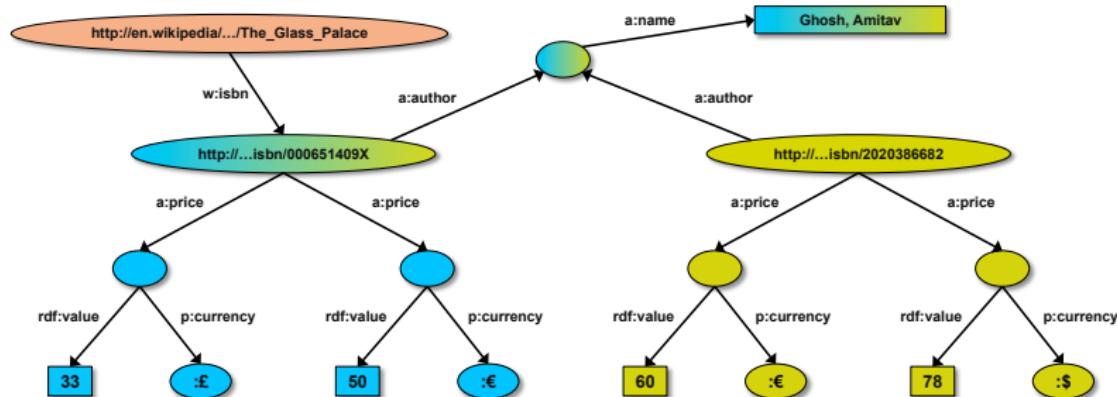
```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.
        FILTER(?currency == :€) }
```

Returns: [<...409X>,50,:€], [<...6682>,60,:€]



Optional pattern

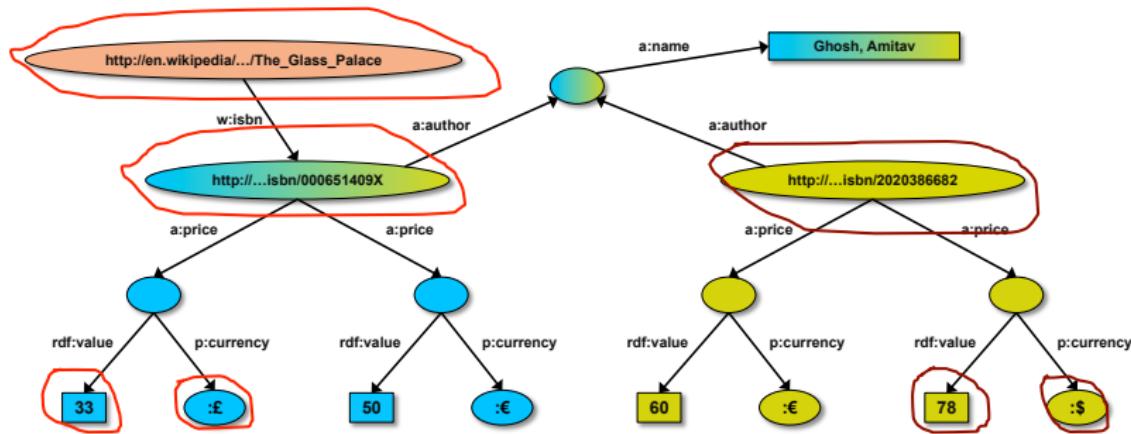
```
SELECT ?isbn ?price ?currency ?wiki
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.
        OPTIONAL ?wiki w:isbn ?isbn. }
```



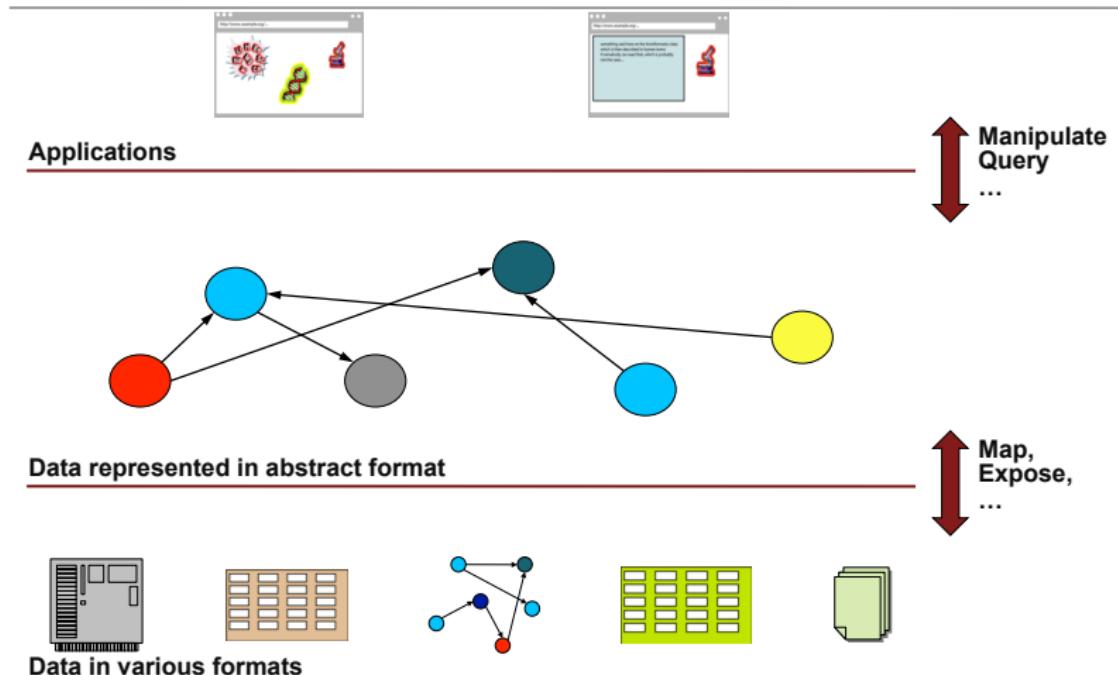
Optional pattern

```
SELECT ?isbn ?price ?currency ?wiki
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.
        OPTIONAL ?wiki w:isbn ?isbn. }
```

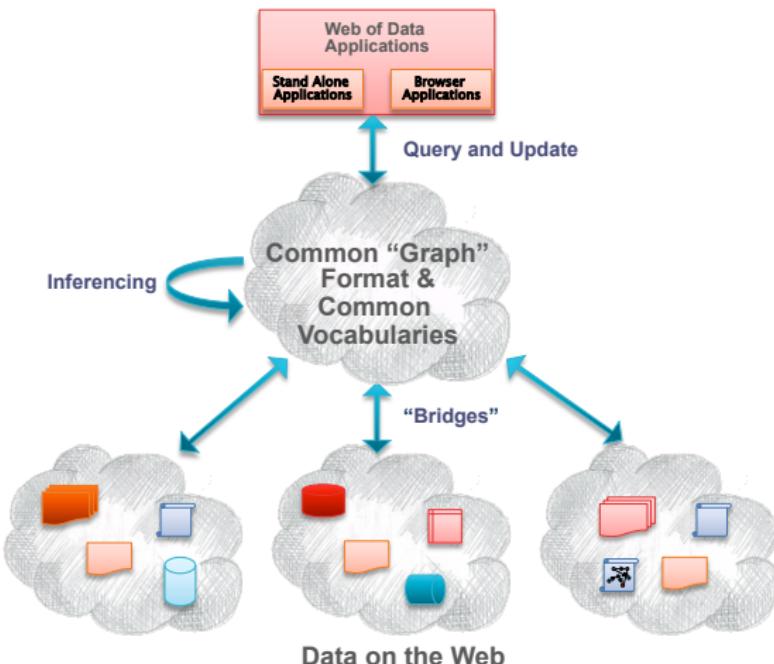
Returns: [[<..09X>,33,:£,<...Palace>], ... , [<..6682>,78,:\$,]]



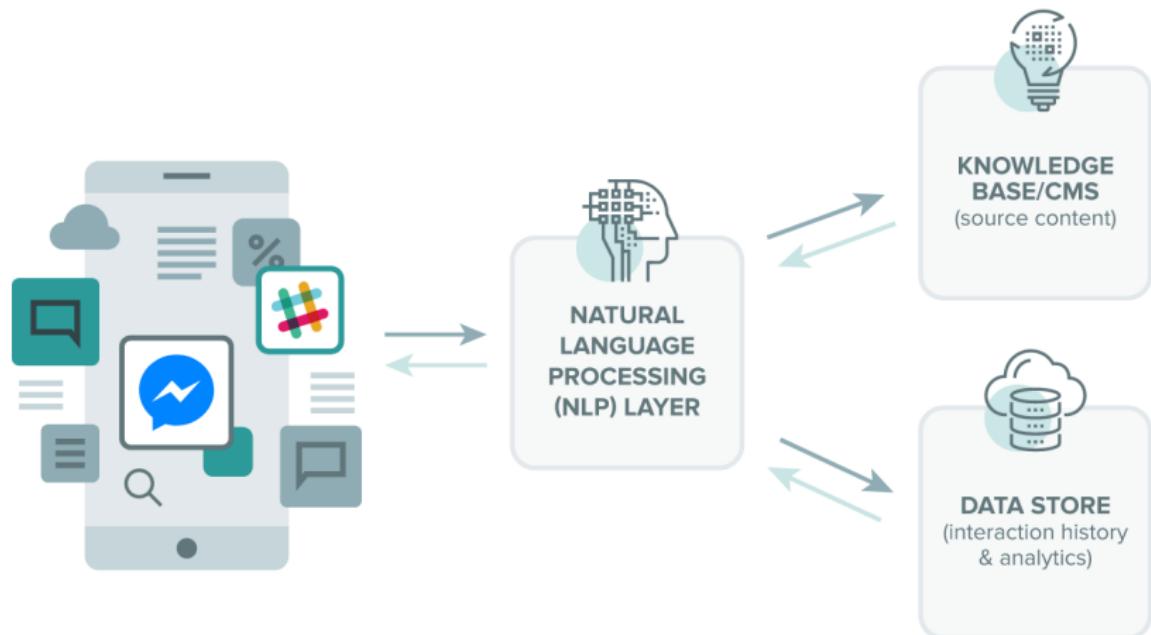
What did we do?



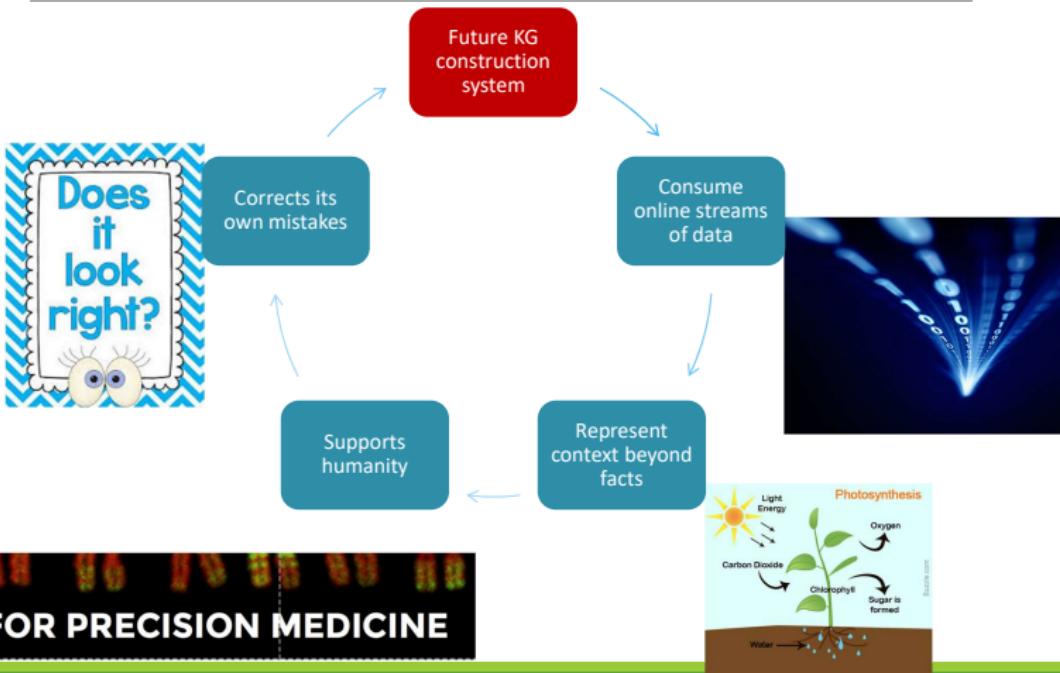
What did we do? (alternate view)



Generic Assistant Architecture



Future.....



Outline

- 1 RDF Schema
- 2 Vocabularies
- 3 Example: schema.org
- 4 Knowledge Bases & Linked Open Data
- 5 Notes and Further Reading

Reading Material

Required

- [Wor14, Sections 4–7] (RDF Primer)

Supplemental

- [Yu14, Chapter 4] (RDFS)
- [WZRH14, Chapters 1, 2] (Linked Data, RDF(S), Vocabularies)

References I

- [HB11] Tom Heath and Christian Bizer.
Linked Data: Evolving the Web into a Global Data Space.
Morgan & Claypool, 2011.
<https://www.worldcat.org/oclc/704257552>.
- [Her] Ivan Herman.
Tutorial on Semantic Web Technologies.
<http://www.w3.org/People/Ivan/CorePresentations/RDFTutorial/>.
- [Wor14] World Wide Web Consortium (W3C).
RDF 1.1 Primer.
<http://www.w3.org/TR/rdf11-primer/>, 24 June 2014.

References II

- [WZRH14] David Wood, Marsha Zaidman, Luke Ruth, and Michael Hausenblas.
Linked Data: Structured Data on the Web.
Manning, 2014.
<https://www.worldcat.org/oclc/871683907>.
- [Yu14] Liyang Yu.
A Developer's Guide to the Semantic Web.
Springer-Verlag Berlin Heidelberg, 2nd edition, 2014.
<https://www.worldcat.org/oclc/897466408>.