Chapter 3 Querying RDF stores with SPARQL

TL;DR

- We will want to query large RDF datasets, e.g. LOD
- SPARQL is the SQL of RDF
- SPARQL is a language to query and update triples in one or more triples stores
- It’s key to exploiting Linked Open Data

Three RDF use cases

- *Markup web documents* with semi-structured data for better understanding by search engines (Microdata)
- Use as a *data interchange language* that's more flexible and has a richer semantic schema than XML or SQL
- Assemble and link large datasets and publish as as knowledge bases to support a domain (e.g., genomics) or in general (DBpedia)

Three RDF use cases

- *Markup web documents* with semi-structured data for better understanding by search engines (Microdata)
- Use as a *data interchange language* that's more flexible and has a richer semantic schema than XML or SQL
- Assemble and link large datasets and publish as as knowledge bases to support a domain (e.g., genomics) or in general (DBpedia)
  - Such knowledge bases may be very large, e.g., Dbpedia has ~300M triples
  - Using such a large dataset requires a language to query and update it

Semantic Web

Use Semantic Web Technology to publish shared data & knowledge

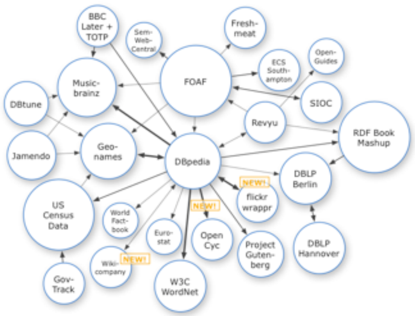
Semantic web technologies allow machines to share data and knowledge using common web language and protocols.

~ 1997

Semantic Web beginnin

Semantic Web => Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge



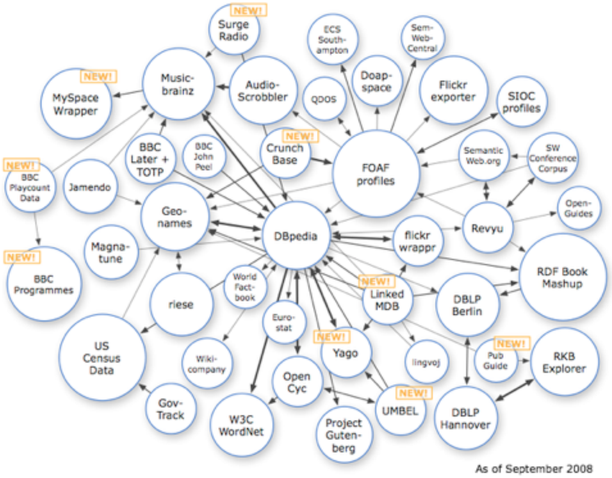
2007

Data is interlinked to support integration and fusion of knowledge

LOD beginnin

Semantic Web => Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge



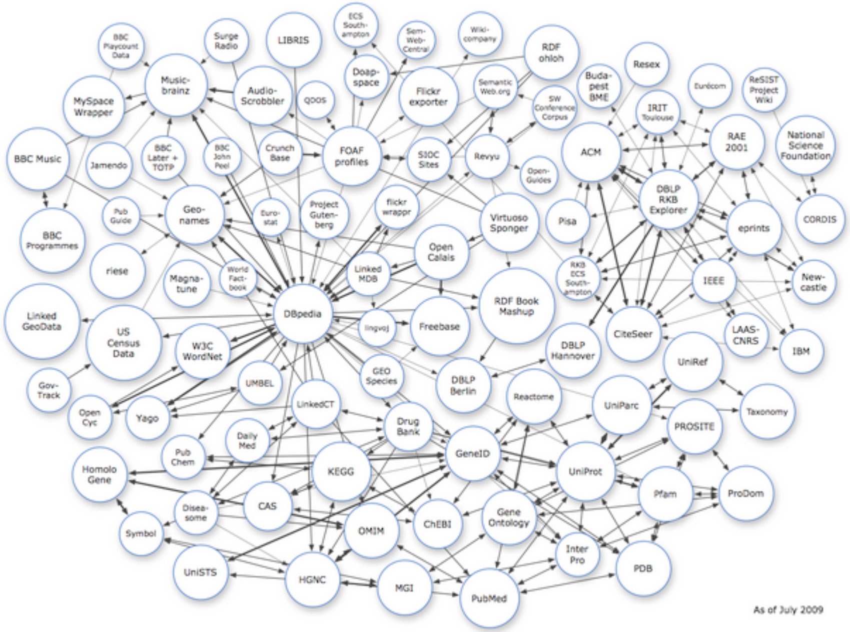
2008

Data is inter-linked to support inte-gration and fusion of knowledge

LOD growing

Semantic Web => Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge



2009

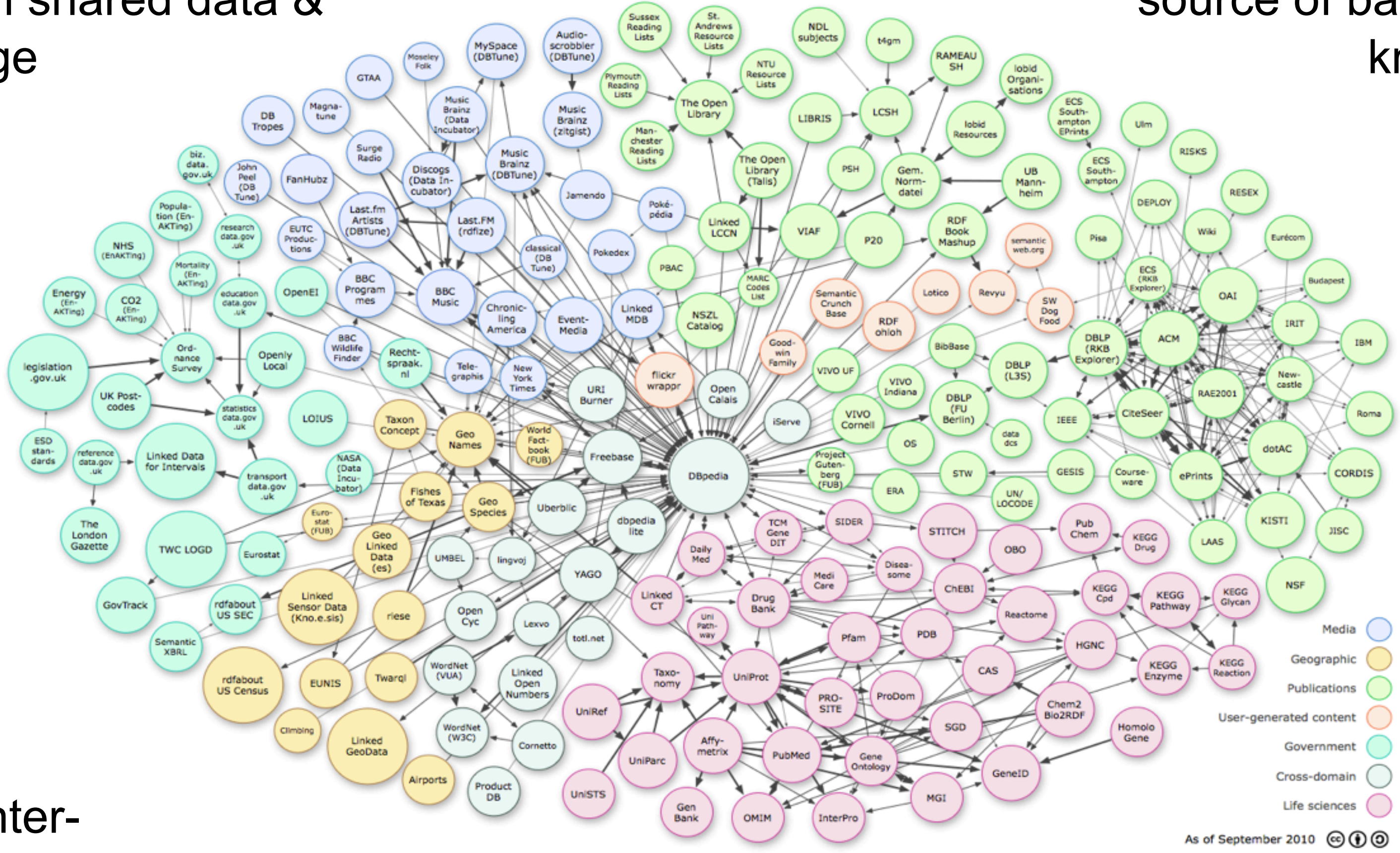
Data is interlinked to support integration and fusion of knowledge

… and growin

Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge

LOD is the new Cyc: a common source of background knowledge



Data is inter-linked to support integration and fusion of knowledge

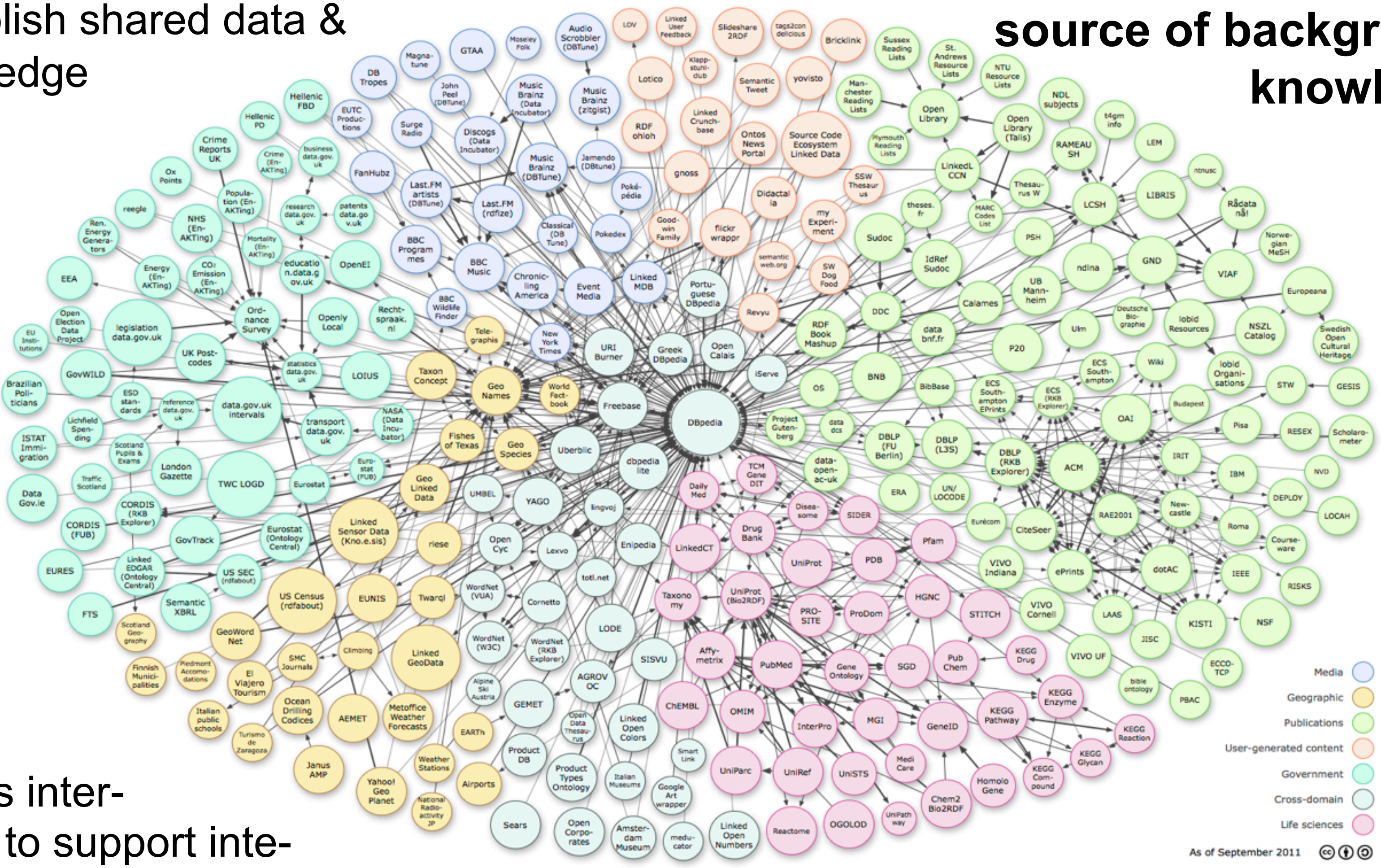
2010

…growing faste

Linked Open Data

Use Semantic Web Technology to publish shared data & knowledge

LOD is the new Cyc: a common source of background knowledge



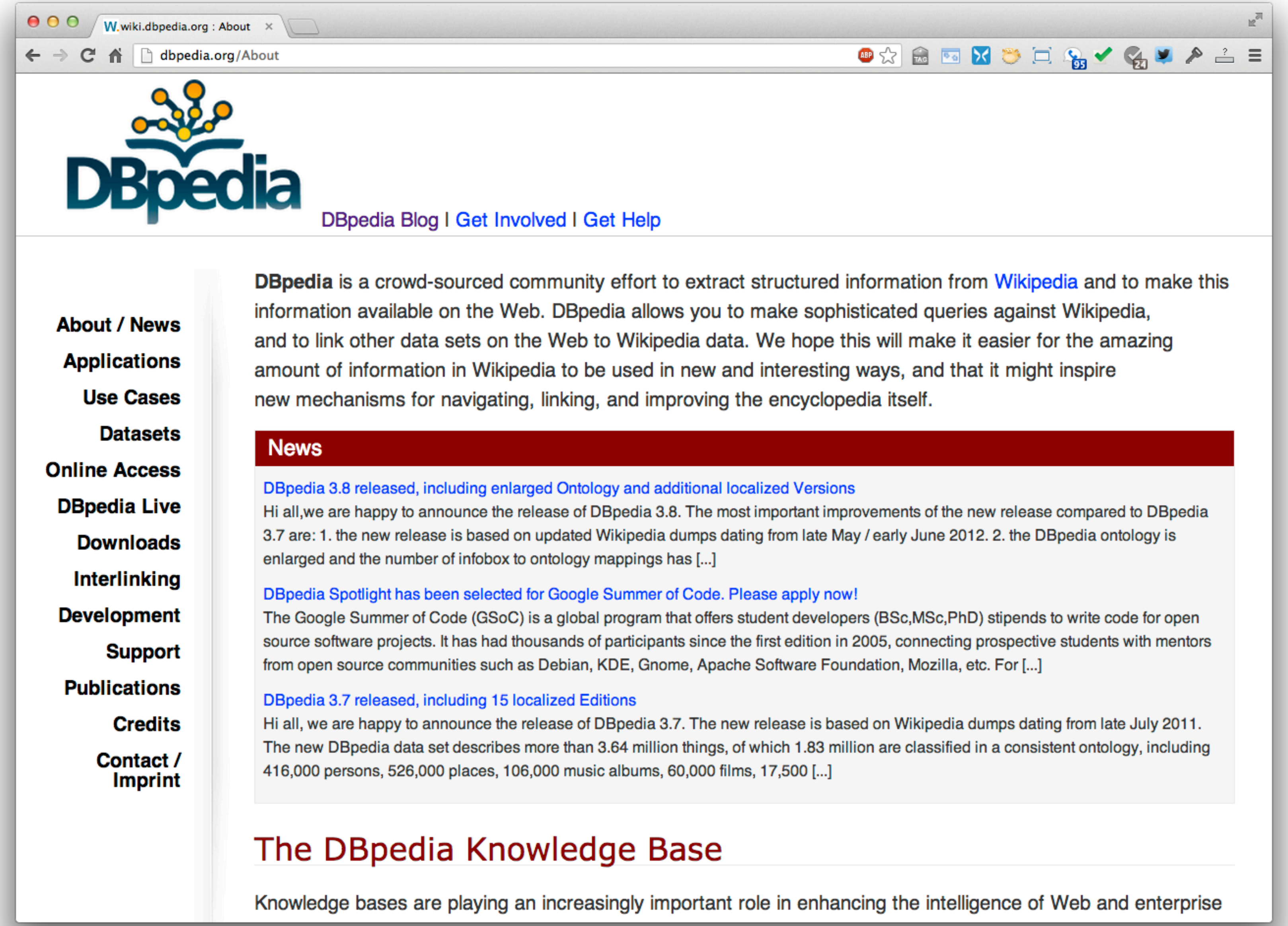
Data is inter-linked to support inte-gration and fusion of knowledge

2011: 31B facts in 295 datasets interlinked by 504M assertions on ckan.net

Linked Open Data (LOD)

- Linked **data** is just RDF data, typically just the instances (ABOX), not schema (TBOX)
- RDF data is a graph of triples
  - URI URI string
    dbr:Barack_Obama dbo:spouse “Michelle Obama”
  - URI URI URI
    dbr:Barack_Obama dbo:spouse dbpedia:Michelle_Obama
- Best **linked** data practice prefers the 2nd pattern, using nodes rather than strings for “entities”
- Liked **open** data is just linked data freely accessible on the Web along with any required ontologies

Dbpedia: Wikipedia data in RDF



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Online Access
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Development
Support
Publications
Credits
Contact / Imprint

DBpedia is a crowd-sourced community effort to extract structured information from Wikipedia and to make this information available on the Web. DBpedia allows you to make sophisticated queries against Wikipedia, and to link other data sets on the Web to Wikipedia data. We hope this will make it easier for the amazing amount of information in Wikipedia to be used in new and interesting ways, and that it might inspire new mechanisms for navigating, linking, and improving the encyclopedia itself.

News

DBpedia 3.8 released, including enlarged Ontology and additional localized Versions

Hi all,we are happy to announce the release of DBpedia 3.8. The most important improvements of the new release compared to DBpedia 3.7 are: 1. the new release is based on updated Wikipedia dumps dating from late May / early June 2012. 2. the DBpedia ontology is enlarged and the number of infobox to ontology mappings has [...]

DBpedia Spotlight has been selected for Google Summer of Code. Please apply now!

The Google Summer of Code (GSoC) is a global program that offers student developers (BSc,MSc,PhD) stipends to write code for open source software projects. It has had thousands of participants since the first edition in 2005, connecting prospective students with mentors from open source communities such as Debian, KDE, Gnome, Apache Software Foundation, Mozilla, etc. For [...]

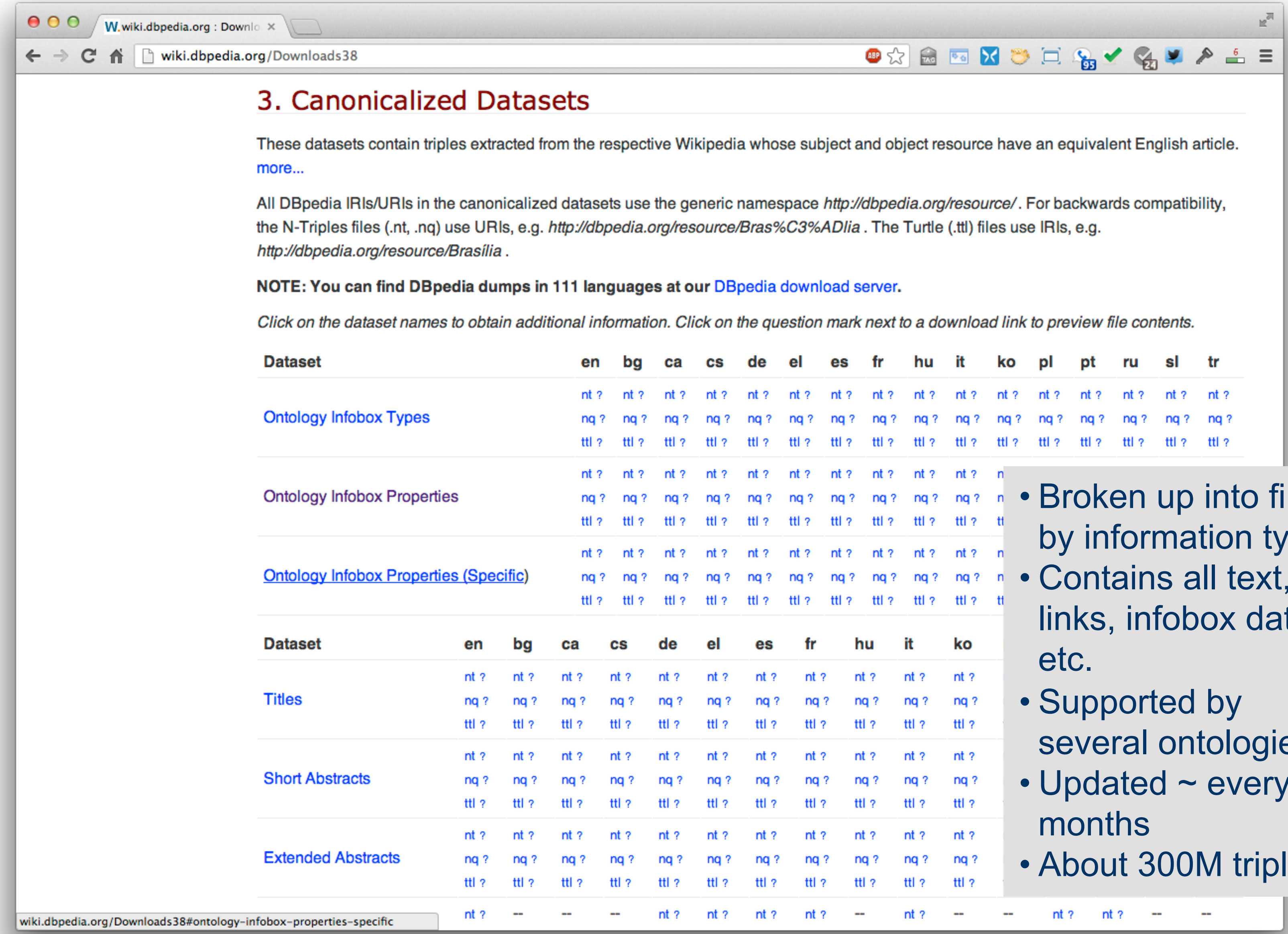
DBpedia 3.7 released, including 15 localized Editions

Hi all, we are happy to announce the release of DBpedia 3.7. The new release is based on Wikipedia dumps dating from late July 2011. The new DBpedia data set describes more than 3.64 million things, of which 1.83 million are classified in a consistent ontology, including 416,000 persons, 526,000 places, 106,000 music albums, 60,000 films, 17,500 [...]

The DBpedia Knowledge Base

Knowledge bases are playing an increasingly important role in enhancing the intelligence of Web and enterprise

Available for download



3. Canonicalized Datasets

These datasets contain triples extracted from the respective Wikipedia whose subject and object resource have an equivalent English article. more...

All DBpedia IRIs/URIs in the canonicalized datasets use the generic namespace *http://dbpedia.org/resource/* . For backwards compatibility, the N-Triples files (.nt, .nq) use URIs, e.g. *http://dbpedia.org/resource/Bras%C3%ADlia* . The Turtle (.ttl) files use IRIs, e.g. *http://dbpedia.org/resource/Brasília* .

NOTE: You can find DBpedia dumps in 111 languages at our DBpedia download server.

Click on the dataset names to obtain additional information. Click on the question mark next to a download link to preview file contents.

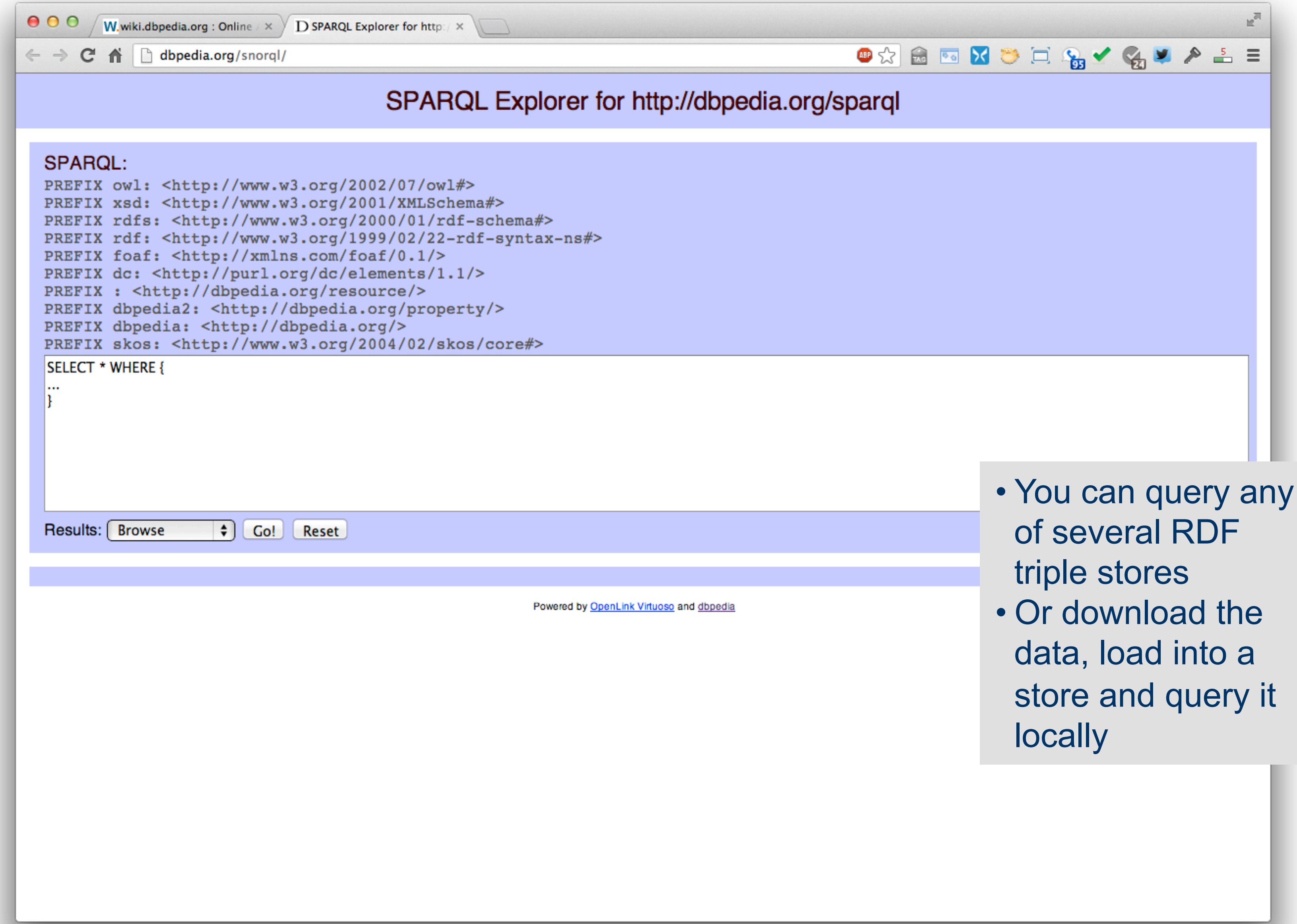
Dataset	en	bg	ca	cs	de	el	es	fr	hu	it	ko	pl	pt	ru	sl	tr
Ontology Infobox Types	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?
Ontology Infobox Properties	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	n n tt					
Ontology Infobox Properties (Specific)	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	n n tt					

Dataset	en	bg	ca	cs	de	el	es	fr	hu	it	ko					
Titles	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?					
Short Abstracts	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?					
Extended Abstracts	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?	nt ? nq ? ttl ?					
	nt ?	--	--	--	nt ?	nt ?	nt ?	nt ?	--	nt ?	--	--	nt ?	nt ?	--	--

wiki.dbpedia.org/Downloads38#ontology-infobox-properties-specific

- Broken up into files by information type
- Contains all text, links, infobox data, etc.
- Supported by several ontologies
- Updated ~ every 3 months
- About 300M triples!

Queryable



SPARQL Explorer for http://dbpedia.org/sparql

SPARQL:

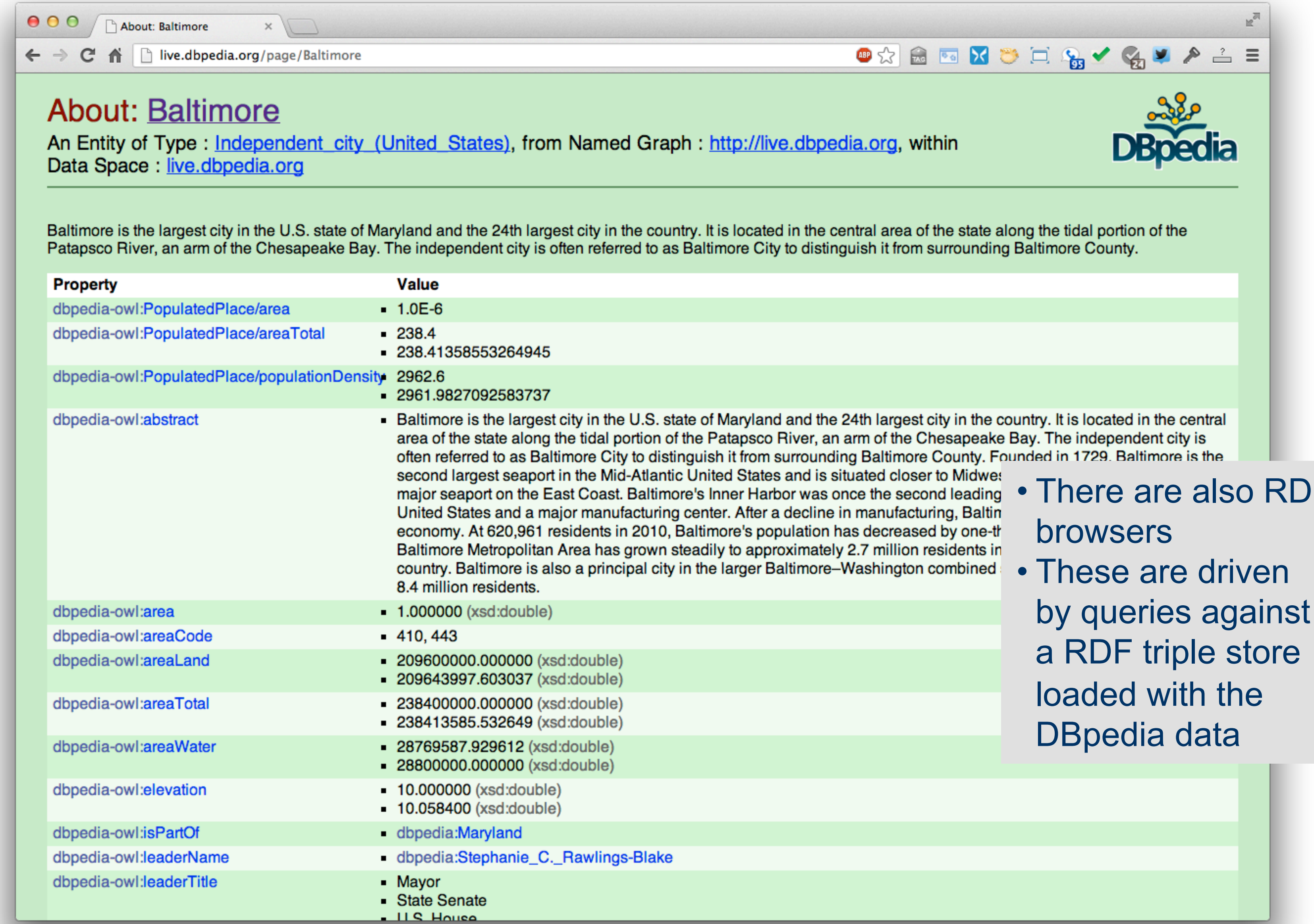
```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbpedia2: <http://dbpedia.org/property/>
PREFIX dbpedia: <http://dbpedia.org/>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
SELECT * WHERE {
...
}
```

Results: Browse

Powered by OpenLink Virtuoso and dbpedia

- You can query any of several RDF triple stores
- Or download the data, load into a store and query it locally

Browseable



About: Baltimore

live.dbpedia.org/page/Baltimore

About: Baltimore

An Entity of Type : Independent city (United States), from Named Graph : http://live.dbpedia.org, within Data Space : live.dbpedia.org

Baltimore is the largest city in the U.S. state of Maryland and the 24th largest city in the country. It is located in the central area of the state along the tidal portion of the Patapsco River, an arm of the Chesapeake Bay. The independent city is often referred to as Baltimore City to distinguish it from surrounding Baltimore County.

Property	Value
dbpedia-owl:PopulatedPlace/area	▪ 1.0E-6
dbpedia-owl:PopulatedPlace/areaTotal	▪ 238.4 ▪ 238.41358553264945
dbpedia-owl:PopulatedPlace/populationDensity	▪ 2962.6 ▪ 2961.9827092583737
dbpedia-owl:abstract	▪ Baltimore is the largest city in the U.S. state of Maryland and the 24th largest city in the country. It is located in the central area of the state along the tidal portion of the Patapsco River, an arm of the Chesapeake Bay. The independent city is often referred to as Baltimore City to distinguish it from surrounding Baltimore County. Founded in 1729, Baltimore is the second largest seaport in the Mid-Atlantic United States and is situated closer to Midwes major seaport on the East Coast. Baltimore's Inner Harbor was once the second leading United States and a major manufacturing center. After a decline in manufacturing, Baltin economy. At 620,961 residents in 2010, Baltimore's population has decreased by one-th Baltimore Metropolitan Area has grown steadily to approximately 2.7 million residents in country. Baltimore is also a principal city in the larger Baltimore–Washington combined 8.4 million residents.
dbpedia-owl:area	▪ 1.000000 (xsd:double)
dbpedia-owl:areaCode	▪ 410, 443
dbpedia-owl:areaLand	▪ 209600000.000000 (xsd:double) ▪ 209643997.603037 (xsd:double)
dbpedia-owl:areaTotal	▪ 238400000.000000 (xsd:double) ▪ 238413585.532649 (xsd:double)
dbpedia-owl:areaWater	▪ 28769587.929612 (xsd:double) ▪ 28800000.000000 (xsd:double)
dbpedia-owl:elevation	▪ 10.000000 (xsd:double) ▪ 10.058400 (xsd:double)
dbpedia-owl:isPartOf	▪ dbpedia:Maryland
dbpedia-owl:leaderName	▪ dbpedia:Stephanie_C._Rawlings-Blake
dbpedia-owl:leaderTitle	▪ Mayor ▪ State Senate ▪ U.S. House

- There are also RDF browsers
- These are driven by queries against a RDF triple store loaded with the DBpedia data

Why an RDF Query Language?

- Why not use an XML query language?
- XML at a lower level of abstraction than RDF
- There are various ways of syntactically representing an RDF statement in XML
- Thus we would require several XPath queries, e.g.
  - **//uni:lecturer/uni:title** if **uni:title** element
  - **//uni:lecturer/@uni:title** if **uni:title** attribute
  - Both XML representations equivalent!

SPARQL

- A key to exploiting such large RDF data sets is the SPARQL query language
- Sparql Protocol And Rdf Query Language
- W3C began developing a spec for a query language in 2004
- There were/are other RDF query languages, and extensions, e.g., RQL and Jena's ARQ
- SPARQL a W3C recommendation in 2008
- SPARQL 1.1 is a proposed recommendation with update, aggregation functions, federation & more
- Most triple stores support SPARQL 1.1

SPARQL Example

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?age
WHERE {
  ?person a foaf:Person.
  ?person foaf:name ?name.
  ?person foaf:age ?age
}
ORDER BY ?age DESC
LIMIT 10
```

SPARQL Protocol, Endpoints, APIs

- SPARQL query language
- SPROT = SPARQL Protocol for RDF
  - Among other things specifies how results can be encoded as RDF, XML or JSON
- SPARQL endpoint
  - A service that accepts queries and returns results via HTTP
  - Either generic (fetching data as needed) or specific (querying an associated triple store)
  - May be a service for federated queries

SPARQL Basic Queries

- SPARQL is based on matching graph patterns
- The simplest graph pattern is the triple pattern
  - *?person foaf:name ?name*
  - Like an RDF triple, but variables can be in any position
  - Variables begin with a question mark
- Combining triple patterns gives a graph pattern; an exact match to a graph is needed
- Like SQL, a set of results is returned with a result for each way the graph pattern can be instantiated

Turtle Like Syntax

As in Turtle and N3, we can omit a common subject in a graph pattern.

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?age
WHERE {
  ?person a foaf:Person;
                foaf:name ?name;
                foaf:age ?age
}
```

Optional Data

- The query fails unless the entire pattern matches
- We often want to collect some information that might not always be available
- Note difference with relational model

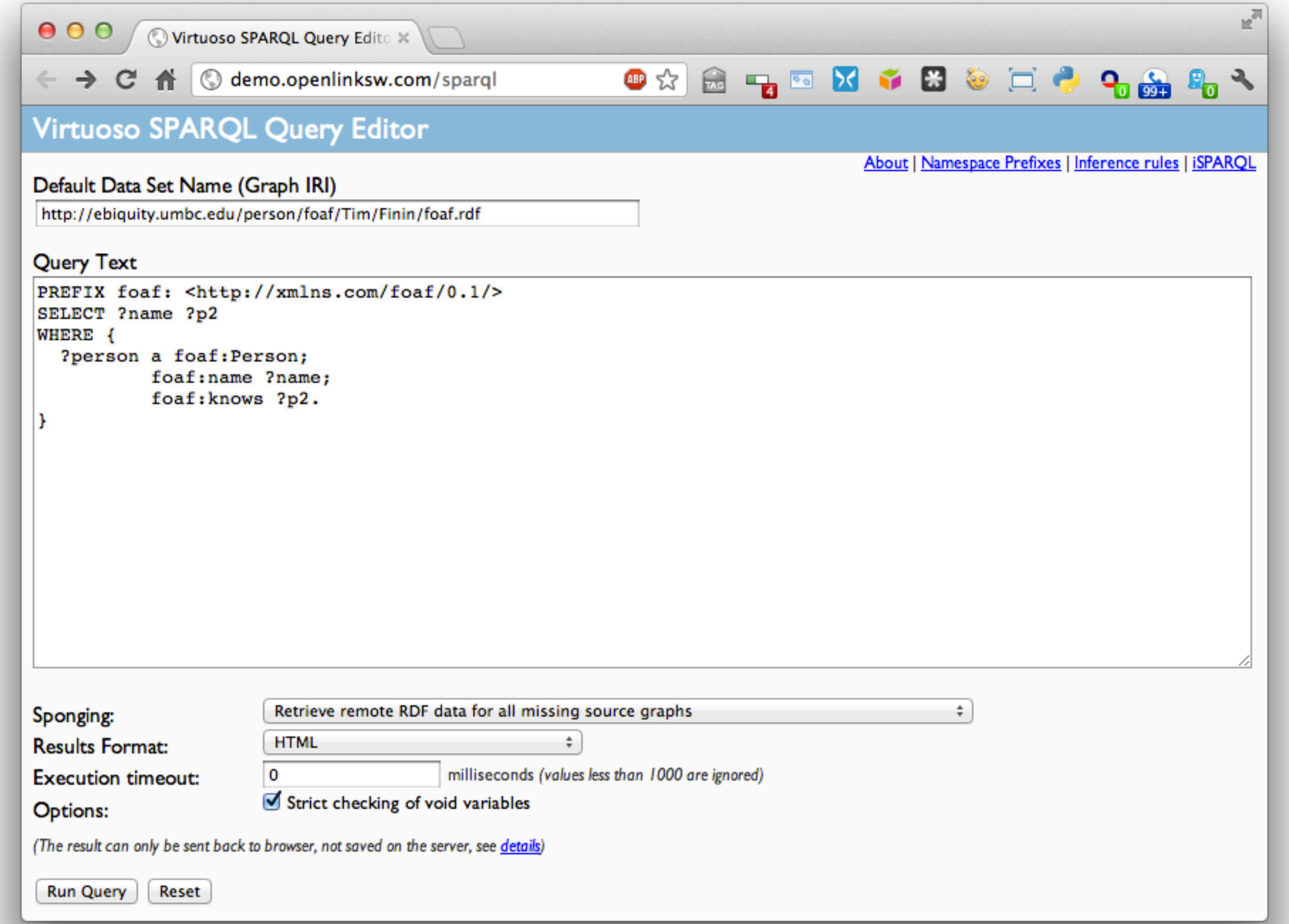
```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?age
WHERE {
  ?person a foaf:Person;
                 foaf:name ?name.
OPTIONAL {?person foaf:age ?age}
}
```

Example of a Generic Endpoint

- Use the sparql endpoint at
  - http://demo.openlinksw.com/sparql
- To query graph at
  - http://ebiq.org/person/foaf/Tim/Finin/foaf.rdf
- For foaf knows relations

```
SELECT ?name ?p2
WHERE { ?person a foaf:Person;
                  foaf:name ?name;
                  foaf:knows ?p2.  }
```

Example



Virtuoso SPARQL Query Edito
demo.openlinksw.com/sparql
Virtuoso SPARQL Query Editor
About | Namespace Prefixes | Inference rules | iSPARQL

Default Data Set Name (Graph IRI)

http://ebiquity.umbc.edu/person/foaf/Tim/Finin/foaf.rdf

Query Text

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?p2
WHERE {
  ?person a foaf:Person;
          foaf:name ?name;
          foaf:knows ?p2.
}
```

Sponging: Retrieve remote RDF data for all missing source graphs

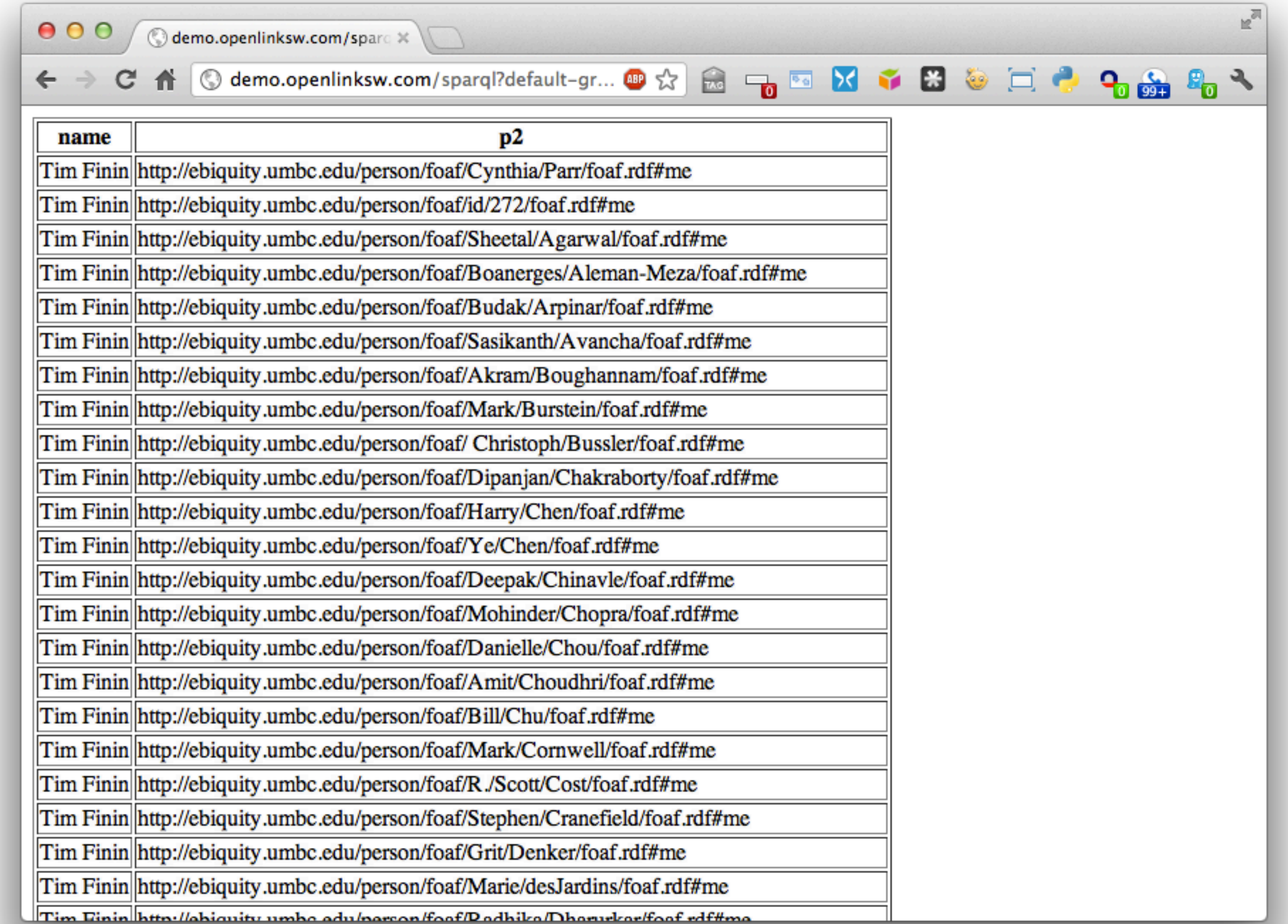
Results Format: HTML

Execution timeout: 0 milliseconds *(values less than 1000 are ignored)*

Options: ☑ Strict checking of void variables

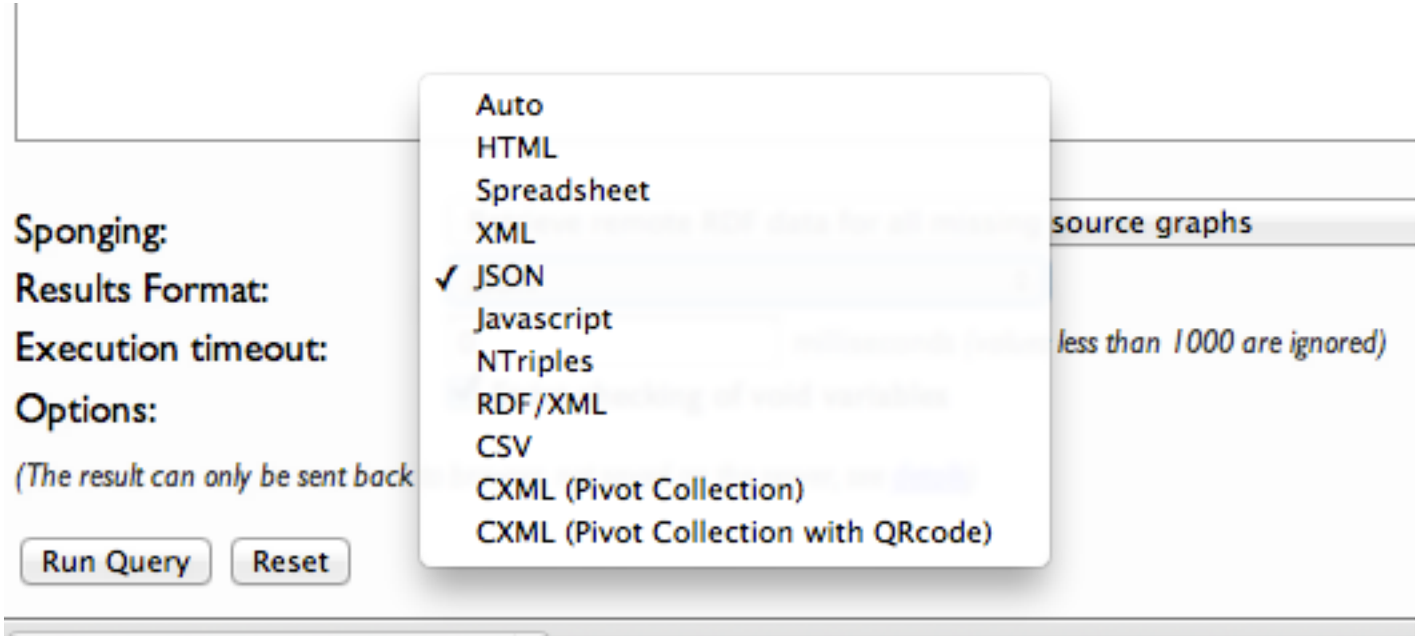
(The result can only be sent back to browser, not saved on the server, see details)

Query results as HTML


demo.openlinksw.com/sparc
demo.openlinksw.com/sparql?default-gr...

name	p2
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Cynthia/Parr/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/id/272/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Sheetal/Agarwal/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Boanerges/Aleman-Meza/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Budak/Arpinar/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Sasikanth/Avancha/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Akram/Boughannam/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Mark/Burstein/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/ Christoph/Bussler/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Dipanjan/Chakraborty/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Harry/Chen/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Ye/Chen/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Deepak/Chinavle/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Mohinder/Chopra/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Danielle/Chou/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Amit/Choudhri/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Bill/Chu/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Mark/Cornwell/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/R./Scott/Cost/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Stephen/Cranefield/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Grit/Denker/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Marie/desJardins/foaf.rdf#me
Tim Finin	http://ebiquity.umbc.edu/person/foaf/Radhika/Dharurkar/foaf.rdf#me

Other result format options



Sponging: source graphs

Results Format: ✓ JSON

Execution timeout: less than 1000 are ignored)

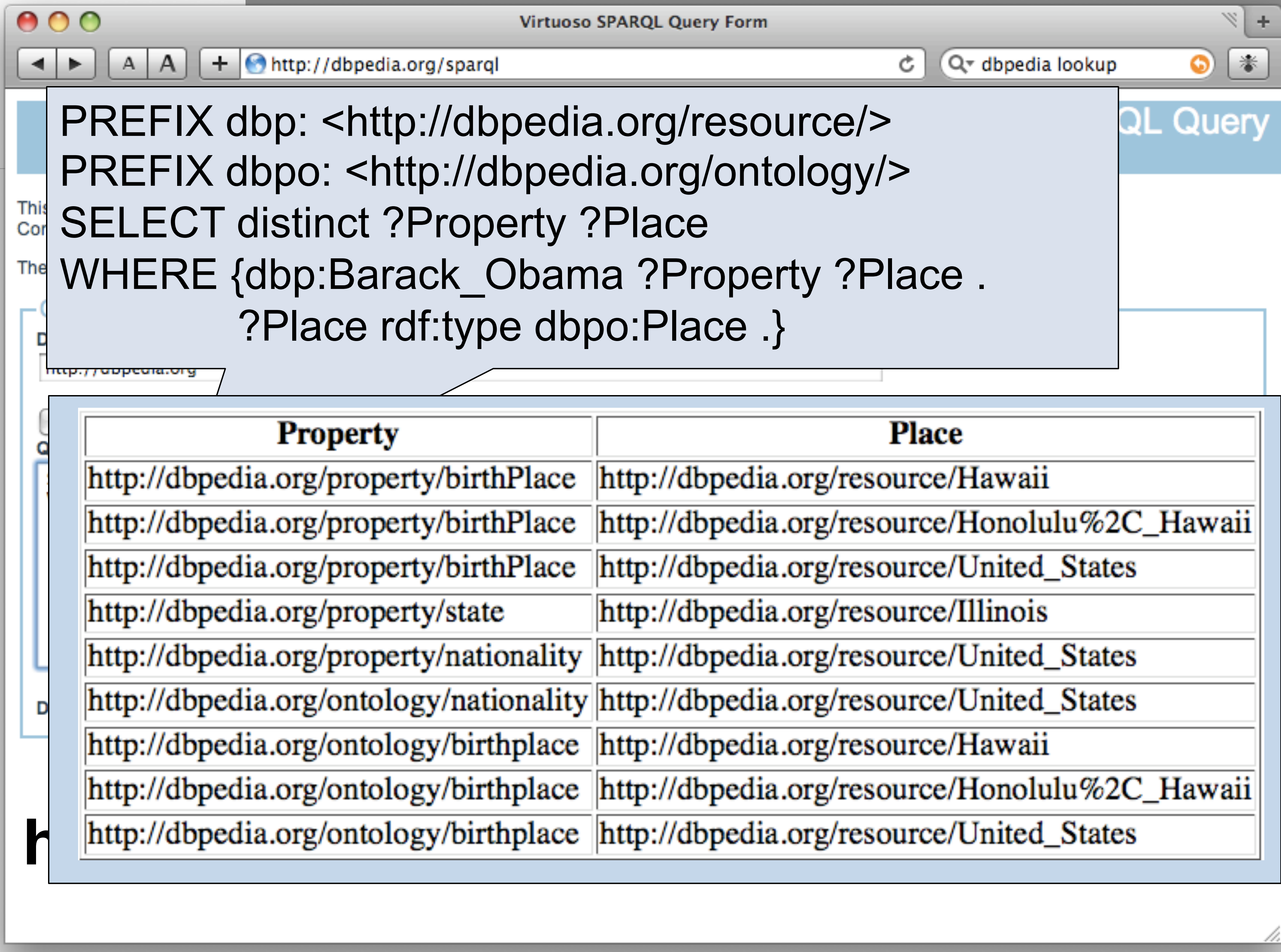
Options:

(The result can only be sent back

Example of a dedicated Endpoint

- Use the sparql endpoint at
  - http://dbpedia.org/sparql
- To query DBpedia
- To discover places associated with President Obama

```
PREFIX dbp: <http://dbpedia.org/resource/>
PREFIX dbpo: <http://dbpedia.org/ontology/>
SELECT distinct ?Property ?Place
WHERE {dbp:Barack_Obama ?Property ?Place .
              ?Place rdf:type dbpo:Place .}
```



```
PREFIX dbp: <http://dbpedia.org/resource/>
PREFIX dbpo: <http://dbpedia.org/ontology/>
SELECT distinct ?Property ?Place
WHERE {dbp:Barack_Obama ?Property ?Place .
               ?Place rdf:type dbpo:Place .}
```

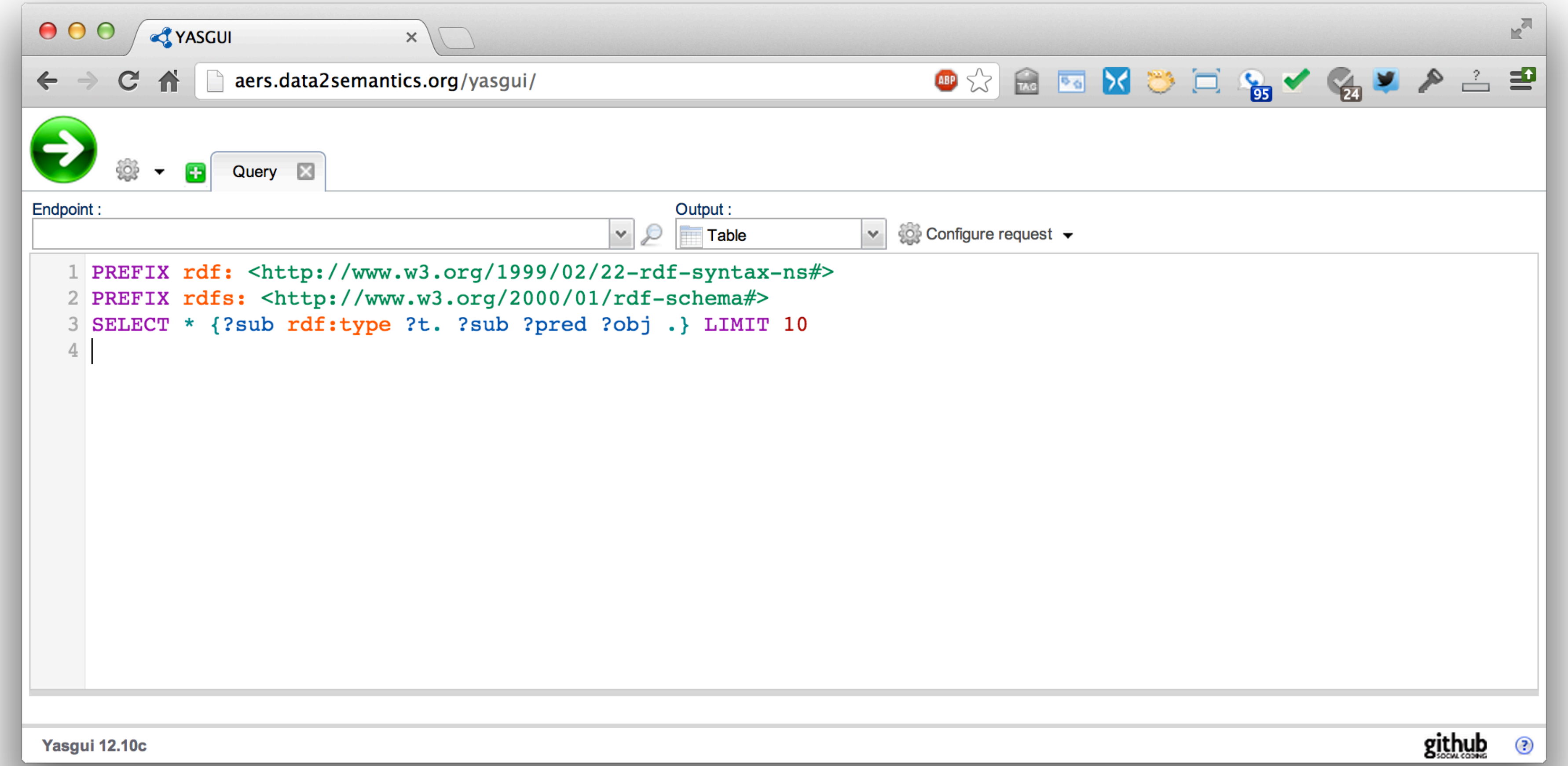
Property	Place
http://dbpedia.org/property/birthPlace	http://dbpedia.org/resource/Hawaii
http://dbpedia.org/property/birthPlace	http://dbpedia.org/resource/Honolulu%2C_Hawaii
http://dbpedia.org/property/birthPlace	http://dbpedia.org/resource/United_States
http://dbpedia.org/property/state	http://dbpedia.org/resource/Illinois
http://dbpedia.org/property/nationality	http://dbpedia.org/resource/United_States
http://dbpedia.org/ontology/nationality	http://dbpedia.org/resource/United_States
http://dbpedia.org/ontology/birthplace	http://dbpedia.org/resource/Hawaii
http://dbpedia.org/ontology/birthplace	http://dbpedia.org/resource/Honolulu%2C_Hawaii
http://dbpedia.org/ontology/birthplace	http://dbpedia.org/resource/United_States

SELECT FROM

- The FROM clause lets us specify the target graph in the query
- SELECT * returns all

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT *
FROM <http://ebiq.org/person/foaf/Tim/Finin/foaf.rdf>
WHERE {
  ?P1 foaf:knows ?p2
}
```

A generic web client



```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT * {?sub rdf:type ?t. ?sub ?pred ?obj .} LIMIT 10
```

Try it: http://aers.data2semantics.org/yasgui/

Source: https://github.com/LaurensRietveld/yasgui

FILTER

Find landlocked countries with a population >15 million

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX type: <http://dbpedia.org/class/yago/>
PREFIX prop: <http://dbpedia.org/property/>
SELECT ?country_name ?population
WHERE {
    ?country a type:LandlockedCountries ;
             rdfs:label ?country_name ;
             prop:populationEstimate ?population .
    FILTER (?population > 15000000) .
}
```

FILTER Functions

- Logical: !, &&, ||
- Math: +, -, *, /
- Comparison: =, !=, >, <, ...
- SPARQL tests: isURI, isBlank, isLiteral, bound
- SPARQL accessors: str, lang, datatype
- Other: sameTerm, langMatches, regex
- Conditionals (SPARQL 1.1): IF, COALESCE
- Constructors (SPARQL 1.1): URI, BNODE, STRDT, STRLANG
- Strings (SPARQL 1.1): STRLEN, SUBSTR, UCASE, …
- More math (SPARQL 1.1): abs, round, ceil, floor, RAND
- Date/time (SPARQL 1.1): now, year, month, day, hours, …
- Hashing (SPARQL 1.1): MD5, SHA1, SHA224, SHA256, …

Union

- The UNION keyword forms a disjunction of two graph patterns
- Both subquery results are included

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX vCard: <http://www.w3.org/2001/vcard-rdf/3.0#>
SELECT ?name
WHERE
{
  { [ ] foaf:name ?name } UNION { [ ] vCard:FN ?name }
}
```

Query forms

Each form takes a WHERE block to restrict the query

- SELECT: Extract raw values from a SPARQL endpoint, the results are returned in a table format
- CONSTRUCT: Extract information from the SPARQL endpoint and transform the results into valid RDF
- ASK: Returns a simple True/False result for a query on a SPARQL endpoint
- DESCRIBE Extract an RDF graph from the SPARQL endpoint, the contents of which is left to the endpoint to decide based on what the maintainer deems as useful information

SPARQL 1.1

SPARQL 1.1 includes

- Updated 1.1 versions of SPARQL Query and SPARQL Protocol
- SPARQL 1.1 Update
- SPARQL 1.1 Graph Store HTTP Protocol
- SPARQL 1.1 Service Descriptions
- SPARQL 1.1 Entailments
- SPARQL 1.1 Basic Federated Query

Summary

- An important usecase for RDF is exploiting large collections of semi-structured data, e.g., the linked open data cloud
- We need a good query language for this
- SPARQL is the SQL of RDF
- SPARQL is a language to query and update triples in one or more triples stores
- It’s key to exploiting Linked Open Data