Introduction to the Semantic Web (tutorial)

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Towards a Semantic Web

- Tasks often require to combine data on the Web:
  - hotel and travel information may come from different sites
  - searches in different digital libraries
  - etc.
- Humans combine these information easily even if
  - different terminologies are used
  - the information is incomplete, or buried in images, videos, …

Example: automatic airline reservation

- Your automatic airline reservation
  - knows about your preferences
  - builds up knowledge base using your past
  - can combine the local knowledge with remote services:
    - airline preferences
    - dietary requirements
    - calendaring
    - etc
- It communicates with remote information (i.e., on the Web!)
  - (M. Dertouzos: The Unfinished Revolution)

Example: data(base) integration

- Databases are very different in structure, in content
- Lots of applications require managing several databases
  - after company mergers
  - combination of administrative data for e-Government
  - biochemical, genetic, pharmaceutical research
  - combination of online library data
  - etc.
- Most of these data are accessible from the Web (though not necessarily public yet)

This problem you know very well…

CoCoDat - Collation of Cortical Data - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.cocom

CoCoMac DATABASES ORT EXAMPLES

CoCoDat: Collation of Cortical [s
microcircuitry] Data

CoCoDat is a microcircuitry database that
published experimental reports. The data
and cellular compartment), as well as the

- Morphology
- Firing properties
- Ionic currents
- Ionic conductances
- Synaptic currents
- Connectivity

The database is available for download u
data tables but also a Search Board with
manual or automatic relaxation of the sea

- Brain region
- Layer
- Neuron type

http://www.cocomac.org/cocodat/catalyzer/inc

Cell Centered Database - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://ccdb.ucsd.edu/sand/main?event=gallery&action=show&dpl=y

red database

Cell Centered Database™
National Center for Microscopy and Imaging Research
Gallery

Data | Search | Gallery | Dictionary | Publications | MyCCDB | Data Download | Contact us | Help

2D image | Reconstruction | Segmentation | Animation

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D: P1188
ct Brain Maps
e:
ct Tom Deerinck
r:
nt BioRad RTS 2000MP
d: Multiphoton
n: montage of cerebellar cortex triple labeled for Hoescht stain (blue), IP3 receptor (green) and GFAP (red)

logged out

NeuronDB = Thalamic relay neuron - Overview (A) () - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://senselab.med.yale.edu

senselab

NeuronDB

Back

Thalamic relay neuron

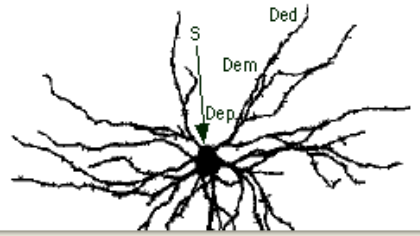
Mode: Overview | Data/Search | plus Connectivity | plus Classical References/Notes | Models

Region: Distal equivalent dendrite | Middle equivalent dendrite | Proximal equivalent dendrite | Soma | Axon hillock | Axon fiber | Axon terminal | All Compartments

Properties: Receptors | Channels | Transmitters | All Properties

Interoperation: Gene and Chromosome | Experimental Data (neurodatabase.org) | Microscopy Data (CCDB)

Neuron type: principal
Organism: Vertebrates



1. Equivalent dendrite — Show other
2. Distal equivalent dendrite — Show other
3. Middle equivalent dendrite — Show other
4. Proximal equivalent dendrite — Show other
5. Soma — Show other

Done

logged out

W3C Semantic Web

Example: social networks

- Social sites are everywhere these days (LinkedIn, Facebook, Dopplr, Digg, Plexo, Zyb, …)
- Data is not interchangeable: how many times did you have to add your contacts?
- Applications should be able to get to those data via standard means
  - there are, of course, privacy issues…

Example: digital libraries

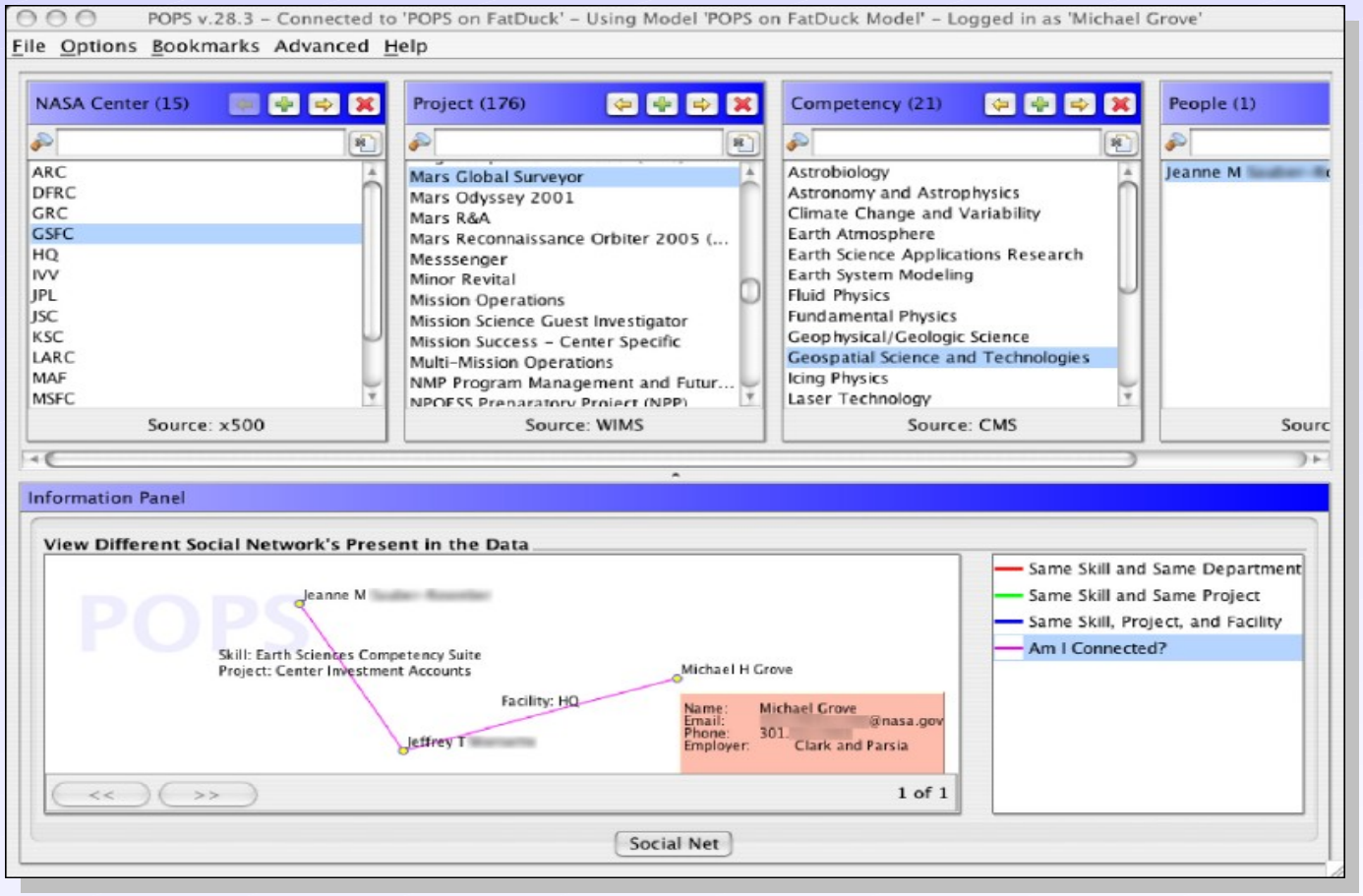
- Sort of catalogues on the Web
  - librarians have known how to do that for centuries
  - goal is to have this on the Web, World-wide
  - extend it to multimedia data, too
- But it is more: software agents should also be librarians!
  - e.g., help you in finding the right publications

What is needed?

- (Some) data should be available for machines for further processing
- Data should be possibly combined, merged on a Web scale
- Machines may also need to *reason* about that data
- Create a *Web of Data* (beyond the Web of Documents)

Find the right experts at NASA

- Expertise locater for nearly 70,000 NASA civil servants, integrating 6 or 7 geographically distributed databases, data sources, and web services…



So what is the Semantic Web?

It is, essentially, the Web of Data.

"Semantic Web Technologies" is a collection of standard technologies to realize a Web of Data

- It is that simple…
- Of course, the devil is in the details
  - a common model has to be provided for machines to describe, query, etc, the data and their connections
  - the “classification” of the terms can become *very* complex for specific knowledge areas: this is where ontologies, thesauri, etc, enter the game…

In what follows…

- We will use a simplistic example to introduce the main technical concepts
- The details will be for later during the course

The rough structure of data integration

1. Map the various data onto an abstract data representation
   - make the data independent of its internal representation…
2. Merge the resulting representations
3. Start making queries on the whole!
   - queries that could not have been done on the individual data sets

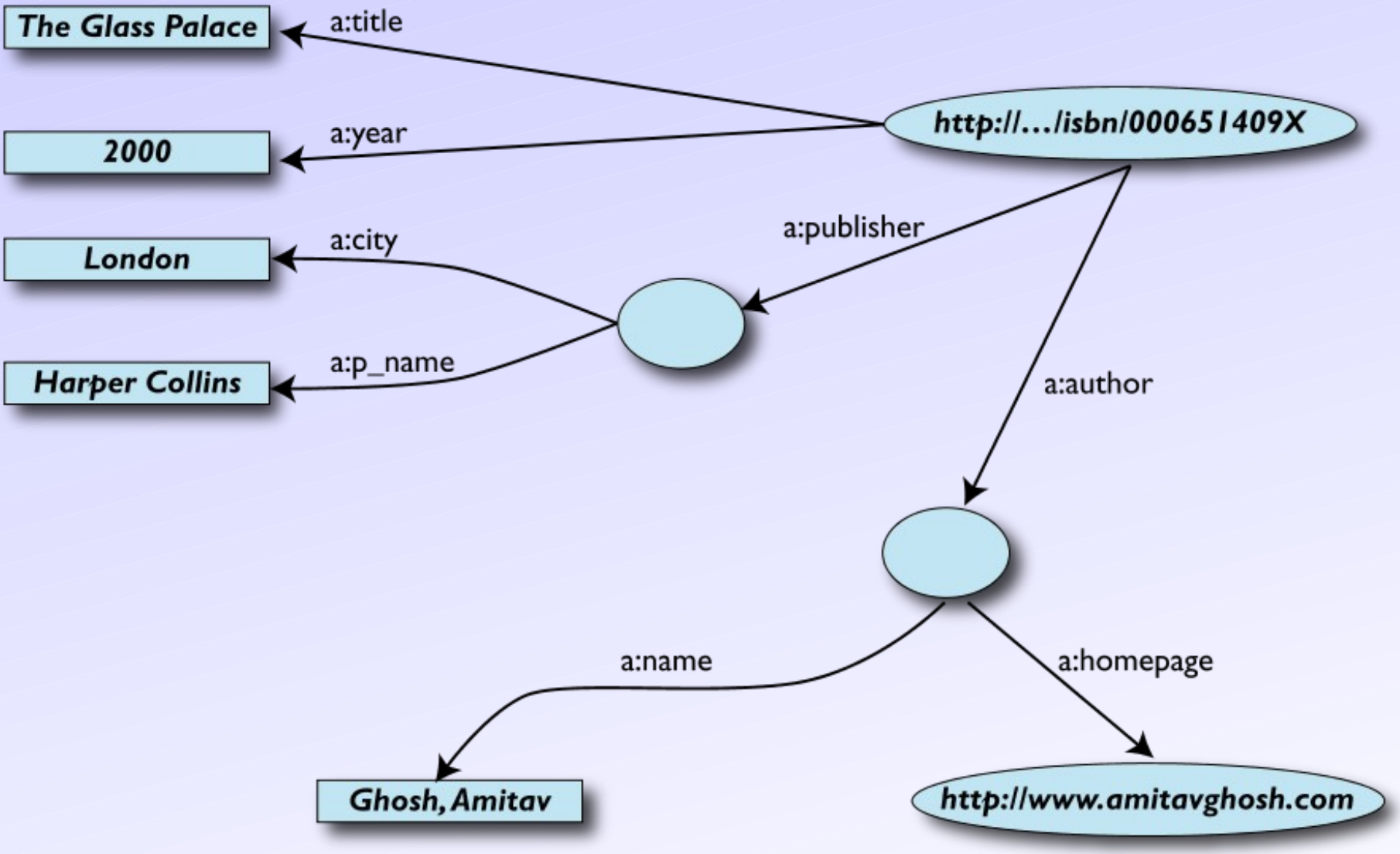
A *simplified* bookstore data (dataset "A")

ID	Author	Title	Publisher	Year
ISBN0-00-651409-X	id_xyz	The Glass Palace	id_qpr	2000

ID	Name	Home Page
id_xyz	Ghosh, Amitav	http://www.amitavghosh.com

ID	Publ. Name	City
id_qpr	Harper Collins	London

1st: export your data as a set of relations



Some notes on the exporting the data

- Relations form a graph
  - the nodes refer to the “real” data or contain some literal
  - how the graph is represented in machine is immaterial for now
- Data export does *not* necessarily mean physical conversion of the data
  - relations can be generated on-the-fly at query time
    - via SQL “bridges”
    - scraping HTML pages
    - extracting data from Excel sheets
    - etc.
- One can export *part* of the data

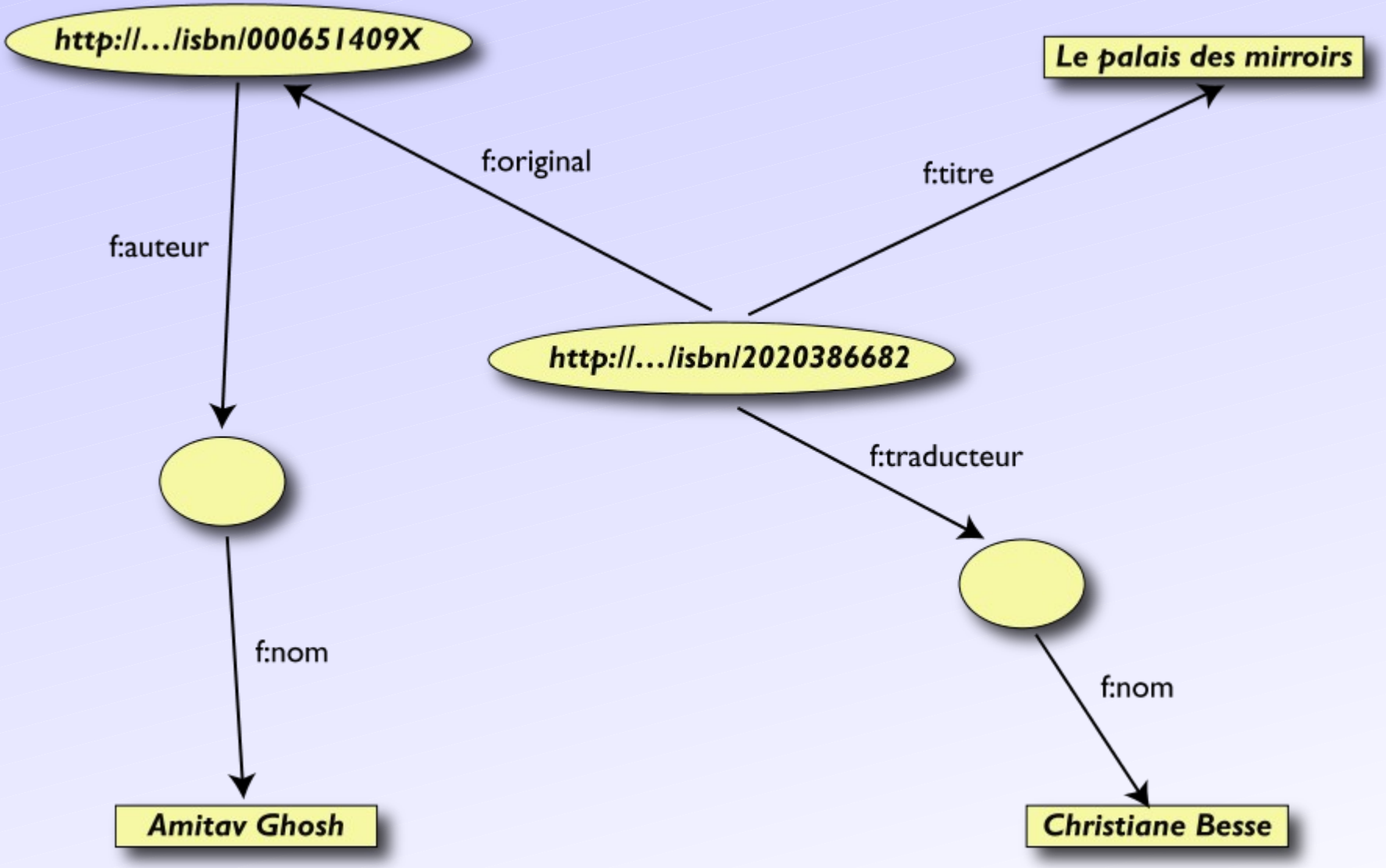
Another *bookstore data (dataset "F")*

	A	B	D	E
1	**ID**	**Titre**	**Traducteur**	**Original**
2	ISBN0 2020386682	Le Palais des miroirs	A13	ISBN-0-00-651409-X
3				

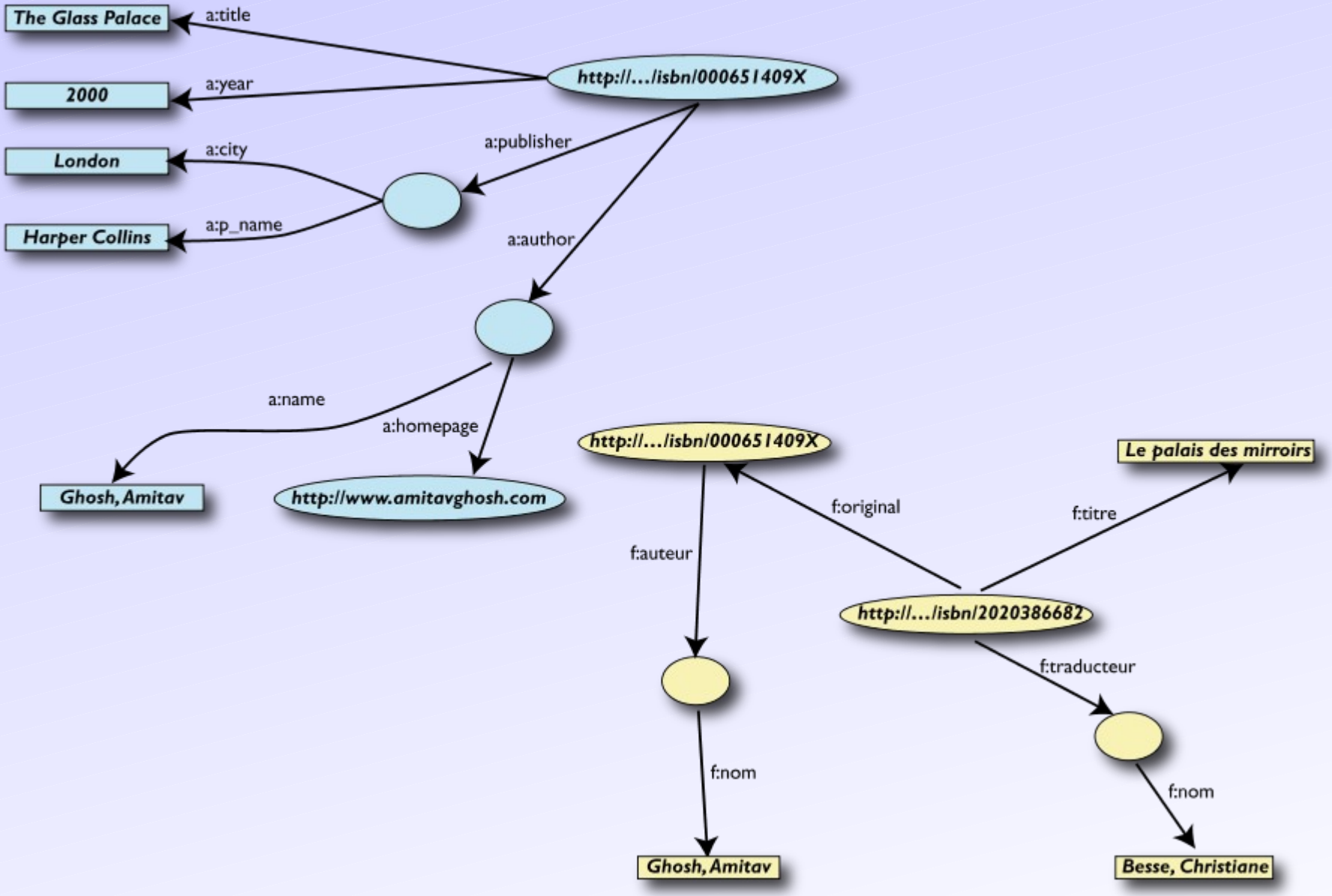
6	**ID**	**Auteur**
7	ISBN-0-00-651409-X	A12

11	**Nom**
12	Ghosh, Amitav
13	Besse, Christianne

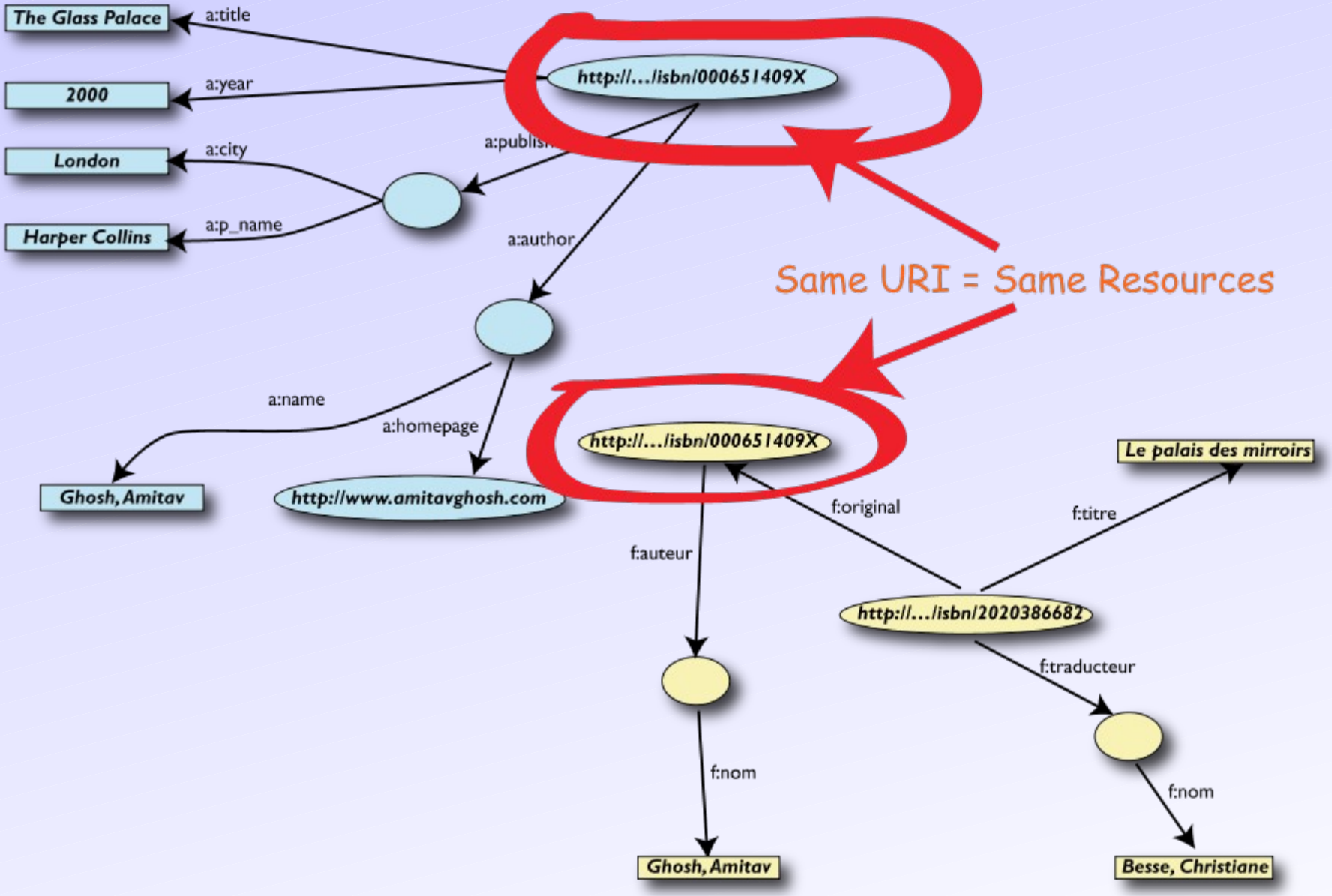
2nd: export your second set of data



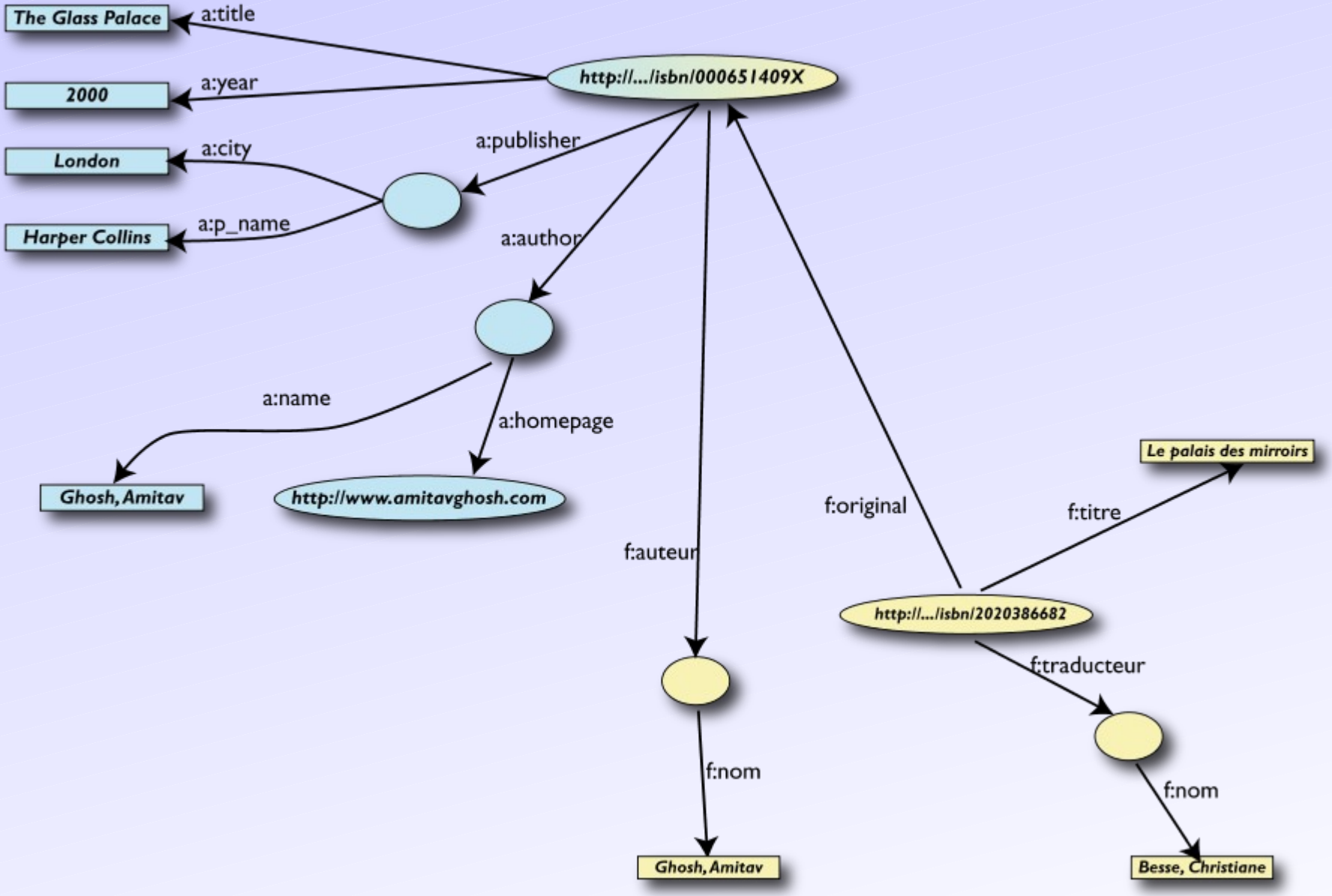
3rd: start merging your data



3rd: start merging your data (cont.)

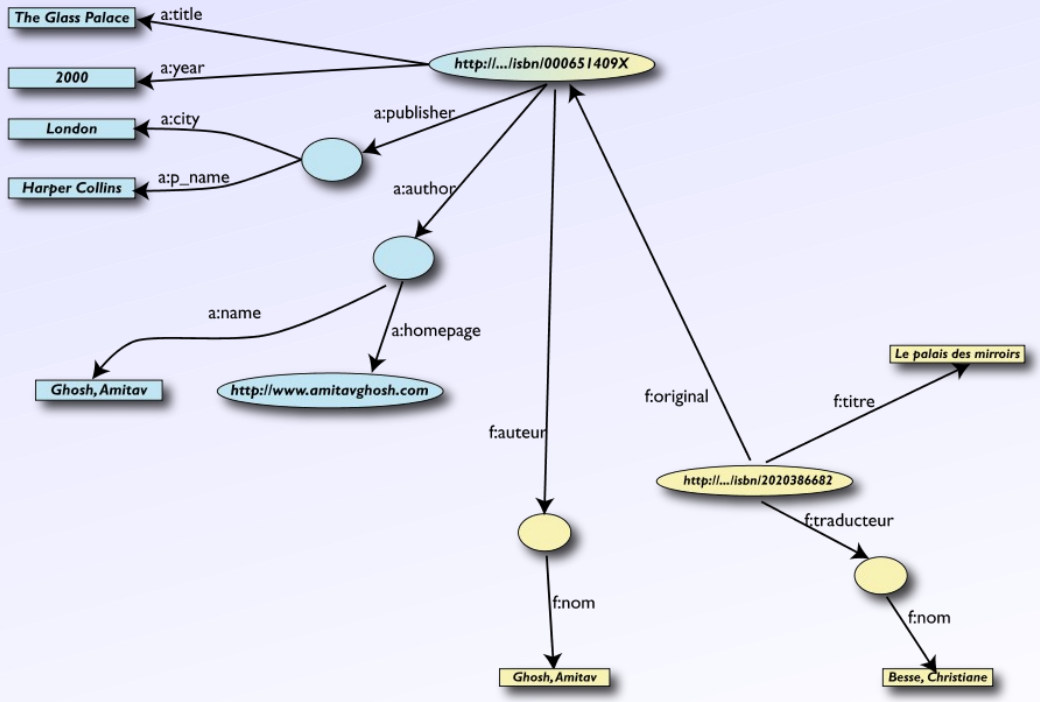


3rd: merge identical resources



Start making queries…

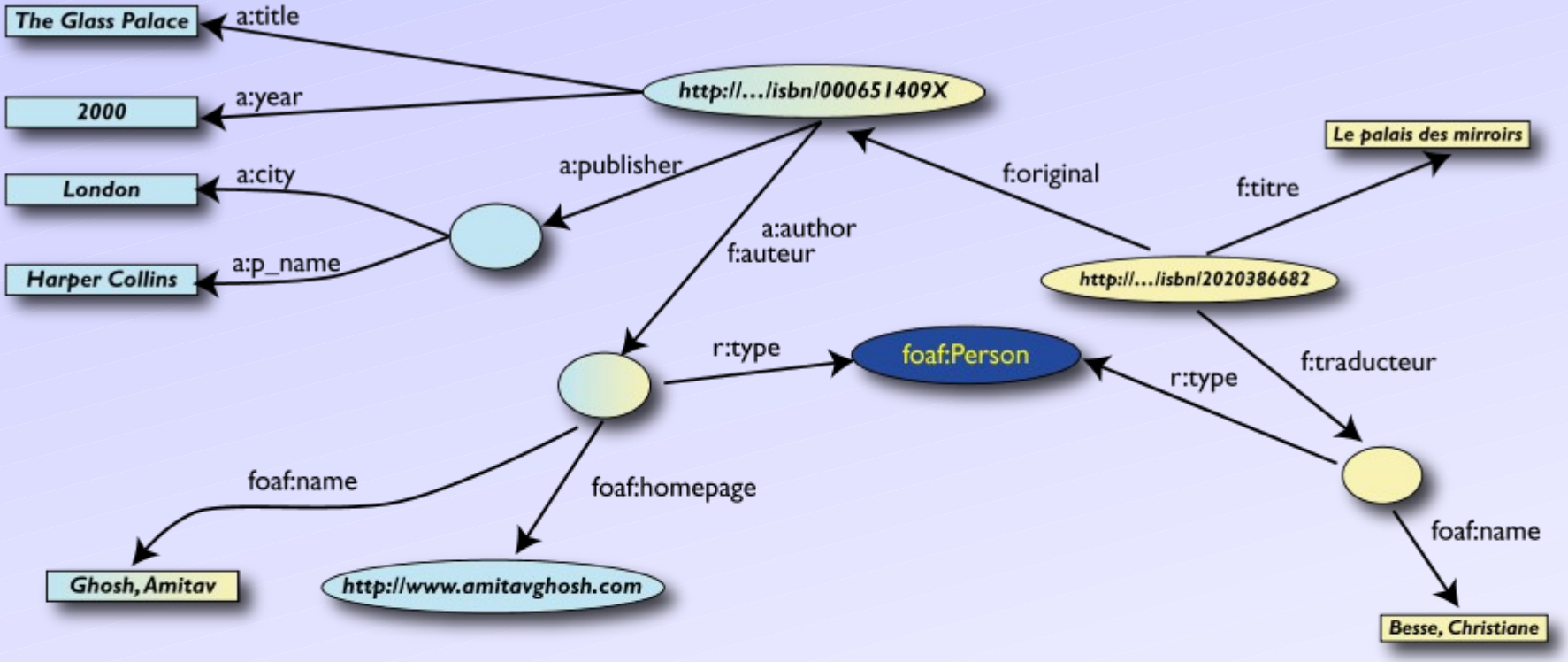
- User of data “F” can now ask queries like:
  - “give me the title of the original”
    - well, … « donnes-moi le titre de l’original »
- This information is not in the dataset “F”…
- …but can be retrieved by merging with dataset “A”!

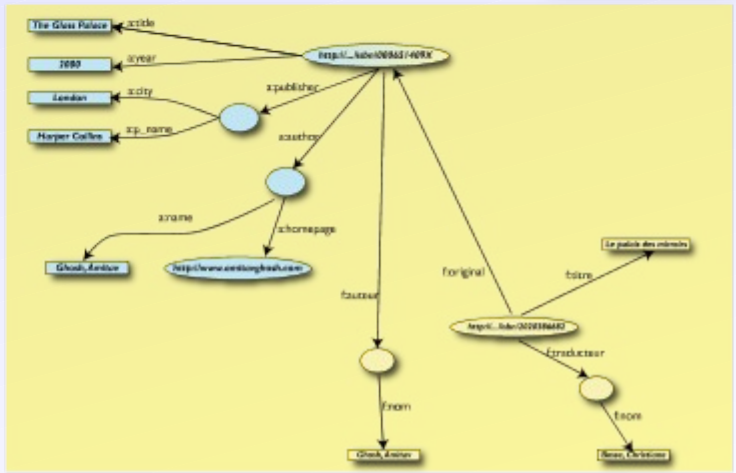


However, more can be achieved…

- We "feel" that **`a:author`** and **`f:auteur`** should be the same
- But an automatic merge doest not know that!
- Let us add some extra information to the merged data:
  - **`a:author`** same as **`f:auteur`**
  - both identify a "Person"
  - a term that a community may have already defined:
    - a "Person" is uniquely identified by his/her name and, say, homepage
    - it can be used as a "category" for certain type of resources

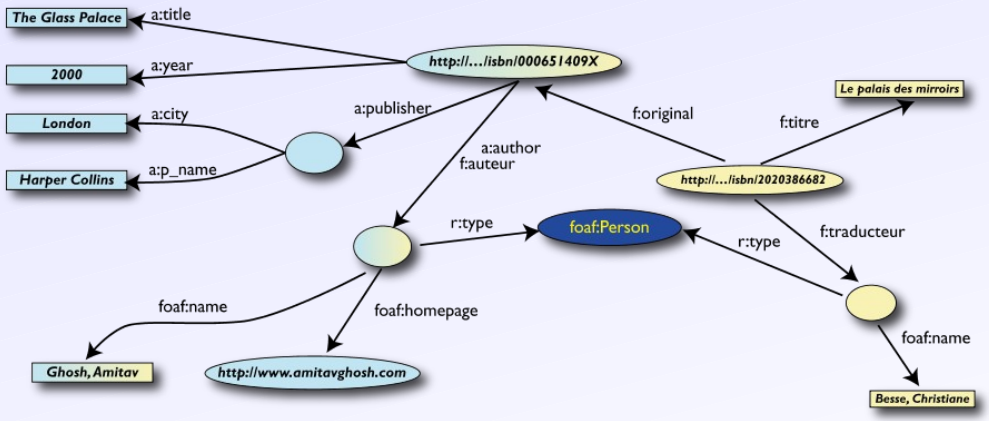
3rd revisited: use the extra knowledge





Start making richer queries!

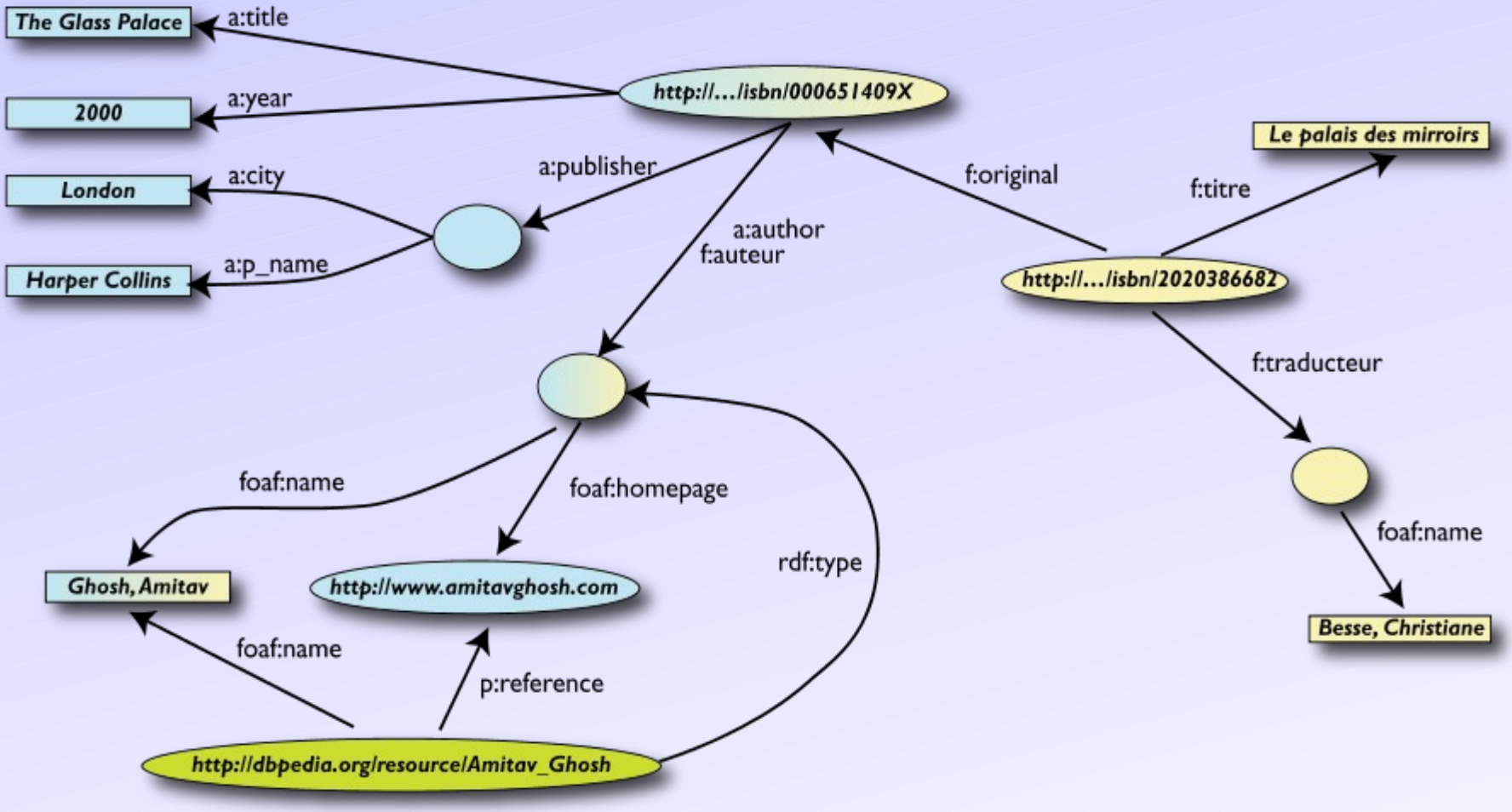
- User of dataset “F” can now query:
  - “donnes-moi la page d’accueil de l’auteur de l’originale”
    - well… “give me the home page of the original’s ‘auteur’”
- The information is not in datasets “F” or “A”…
- …but was made available by:
  - merging datasets “A” and datasets “F”
  - adding three simple extra statements as an extra “glue”



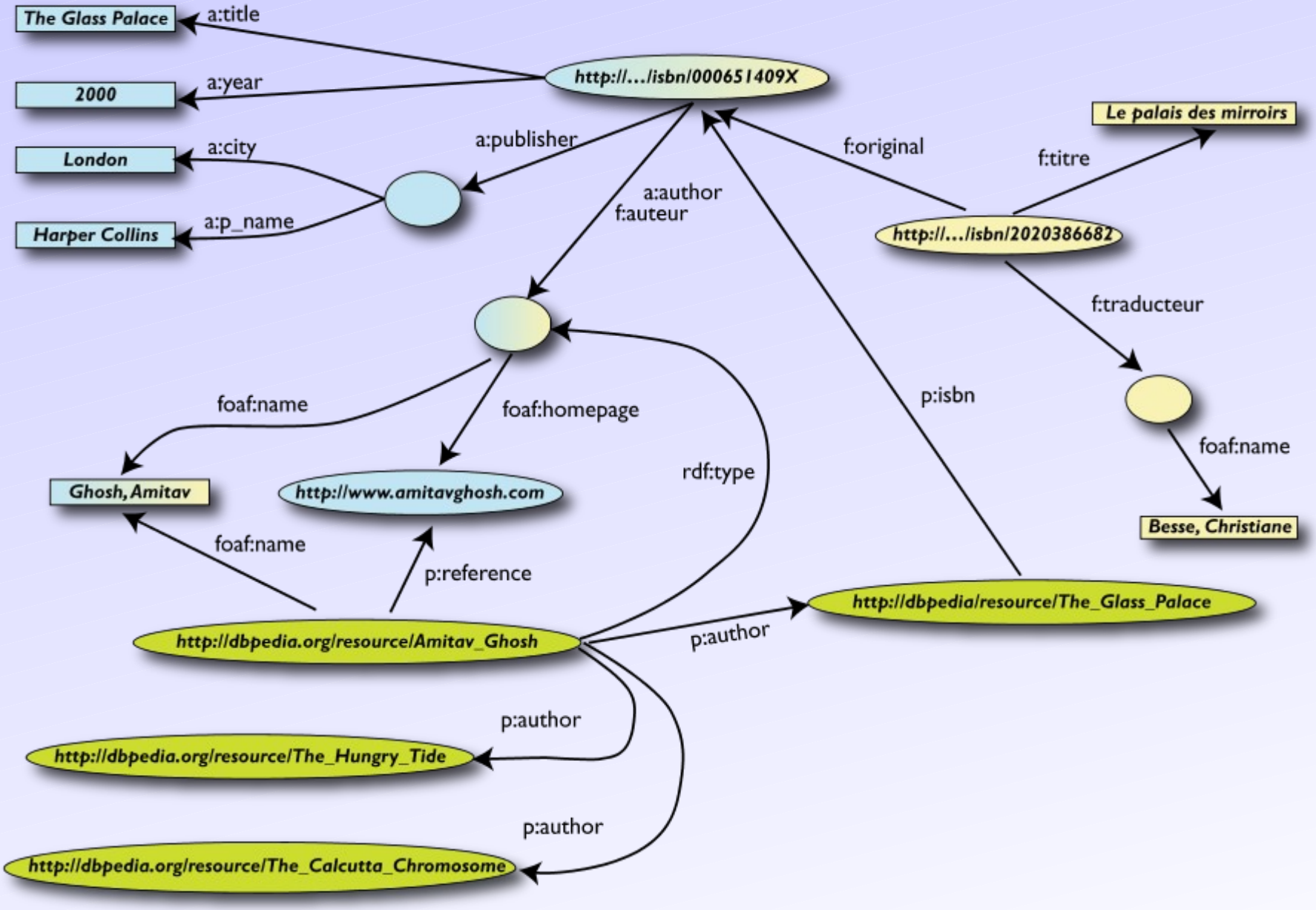
Combine with different datasets

- Using, e.g., the “Person”, the dataset can be combined with other sources
- For example, data in Wikipedia can be extracted using dedicated tools
  - e.g., the “dbpedia” project can extract the “infobox” information from Wikipedia already…

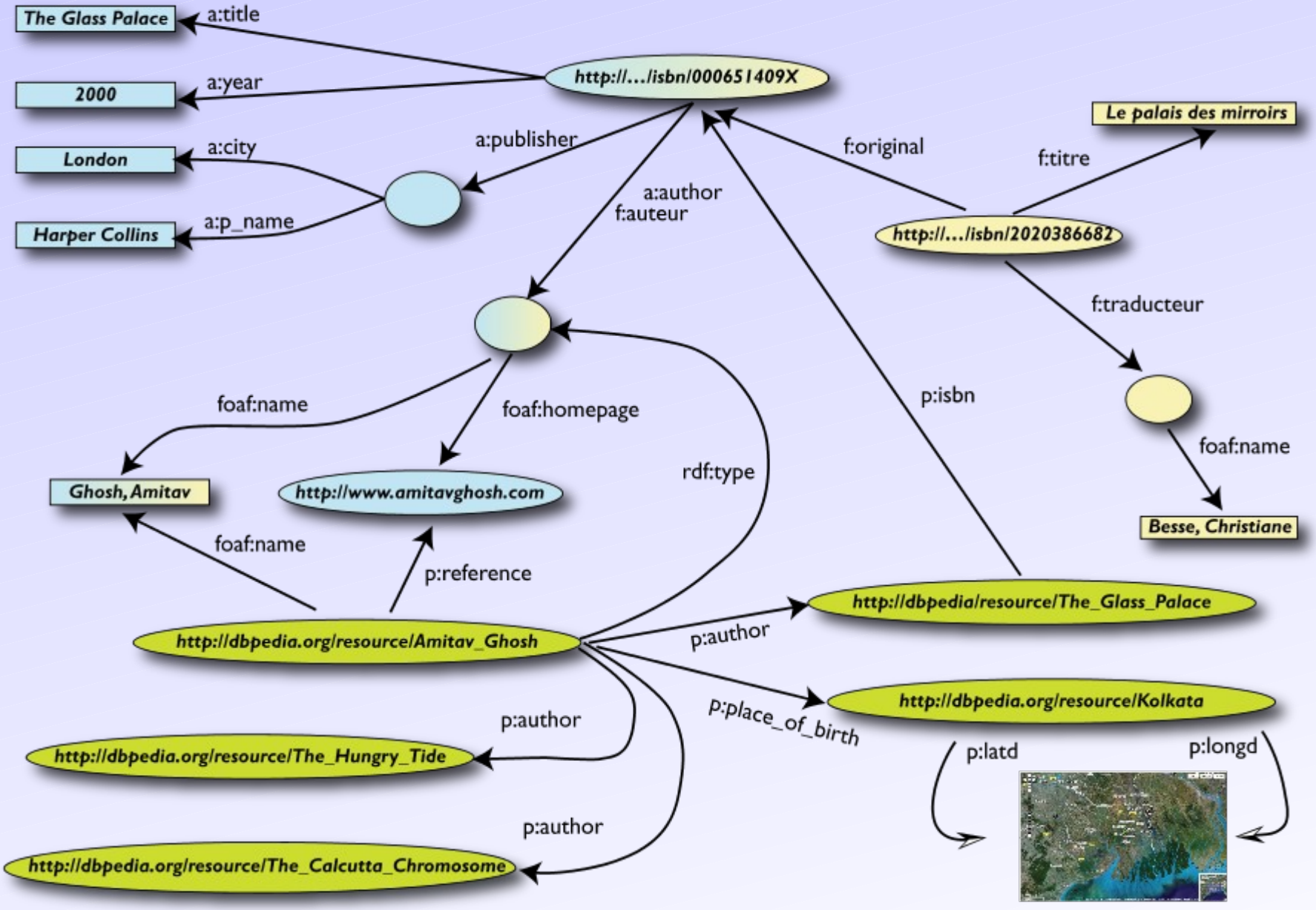
Merge with Wikipedia data



Merge with Wikipedia data



Merge with Wikipedia data



Is that surprising?

- It may look like it but, in fact, it should not be…
- What happened via automatic means is done every day by Web users!
- The difference: a bit of extra rigour so that machines could do this, too

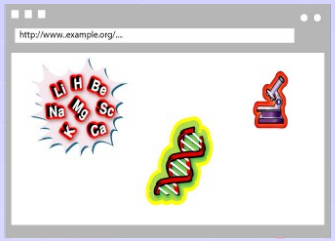
What did we do?

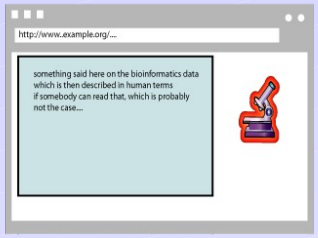
- We combined different datasets that
  - are somewhere on the web
  - are of different formats (mysql, excel sheet, XHTML, etc)
  - have different names for relations
- We could combine the data because some URI-s were identical (the ISBN-s in this case)
- We could add some simple additional information (the “glue”), possibly using common terminologies that a community has produced
- As a result, new relations could be found and retrieved

It could become even more powerful

- We could add extra knowledge to the merged datasets
  - e.g., a full classification of various types of library data
  - geographical information
  - etc.
- This is where *ontologies*, extra *rules*, etc, come in
  - ontologies/rule sets can be relatively simple and small, or huge, or anything in between…
- Even more powerful queries can be asked as a result

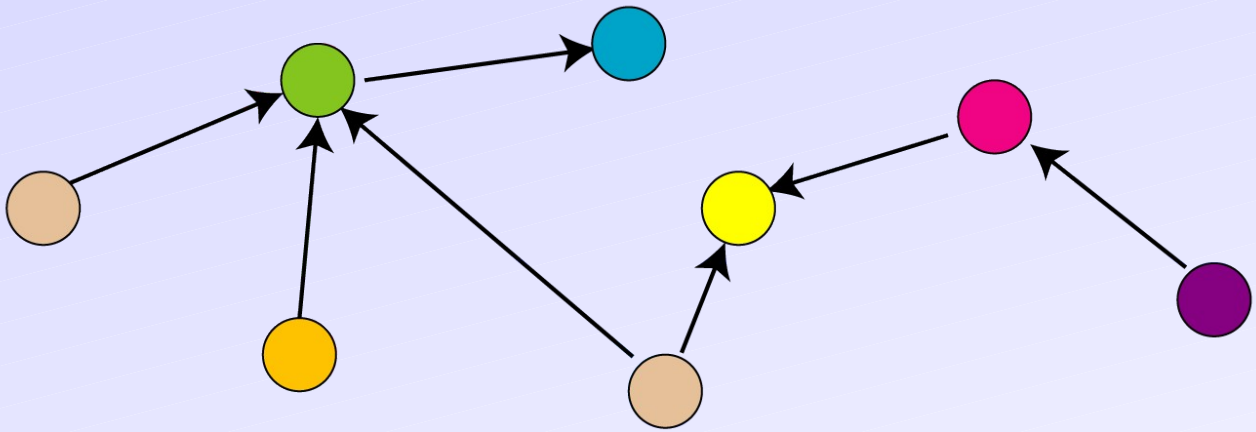
What did we do? (cont)





Applications

Query,
Manipulate,
etc.



Data represented in abstract format

Map,
Expose,
etc.

Data in various formats

The Basis: RDF

RDF triples

- Let us begin to formalize what we did!
  - we “connected” the data…
  - but a simple connection is not enough… data should be named somehow
  - hence the RDF Triples: *a labelled connection between two resources*

RDF triples (cont.)

- An RDF Triple **(s,p,o)** is such that:
  - "**s**", "**p**" are URI-s, ie, resources on the Web; "**o**" is a URI or a literal
    - "**s**", "**p**", and "**o**" stand for "subject", "property", and "object"
  - here is the complete triple:

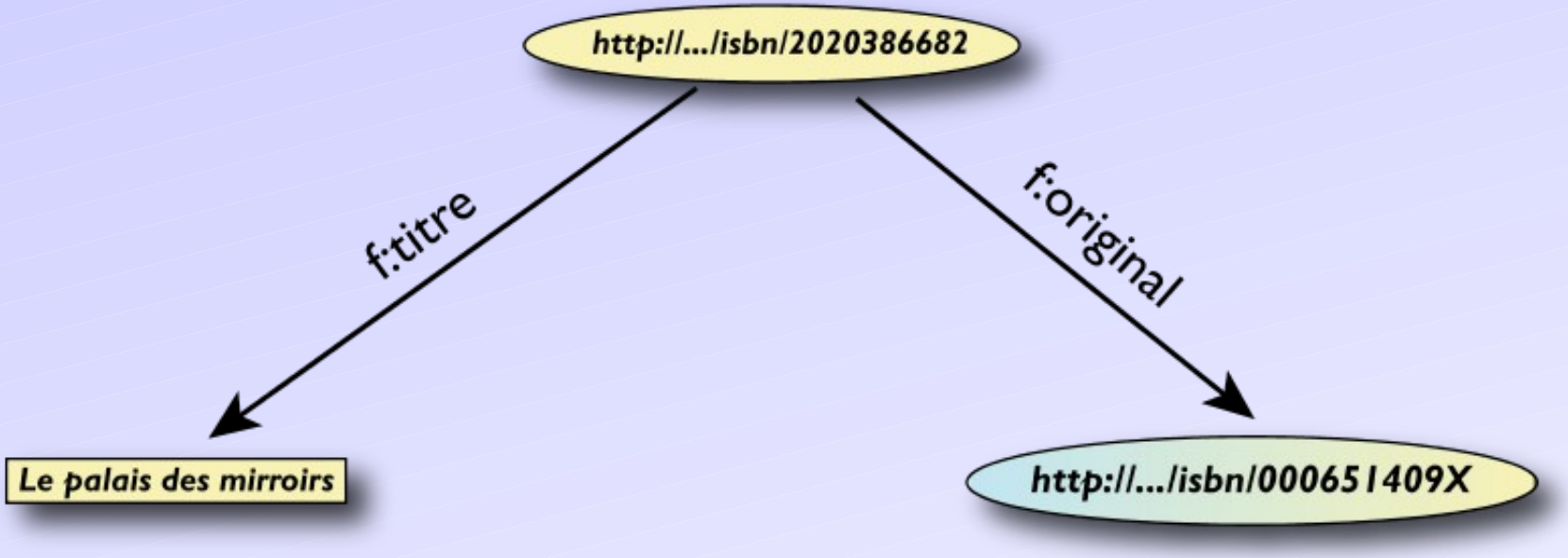
```
(<http://…isbn…6682>, <http://…/original>, <http://…isbn…409X>)
```

- *RDF* is a general model for such triples (with machine readable formats like RDF/XML, Turtle, N3, RXR, …)

RDF triples (cont.)

- Resources can use *any* URI, e.g.:
  - `http://www.example.org/file.xml#element(home)`
  - `http://www.example.org/file.html#home`
  - `http://www.example.org/file2.xml#xpath1(//q[@a=b])`
- URI-s can also denote non Web entities:
  - `http://www.ivan-herman.net/me` is me
  - not my home page, not my publication list, but *me*
- RDF triples form a directed, labelled graph

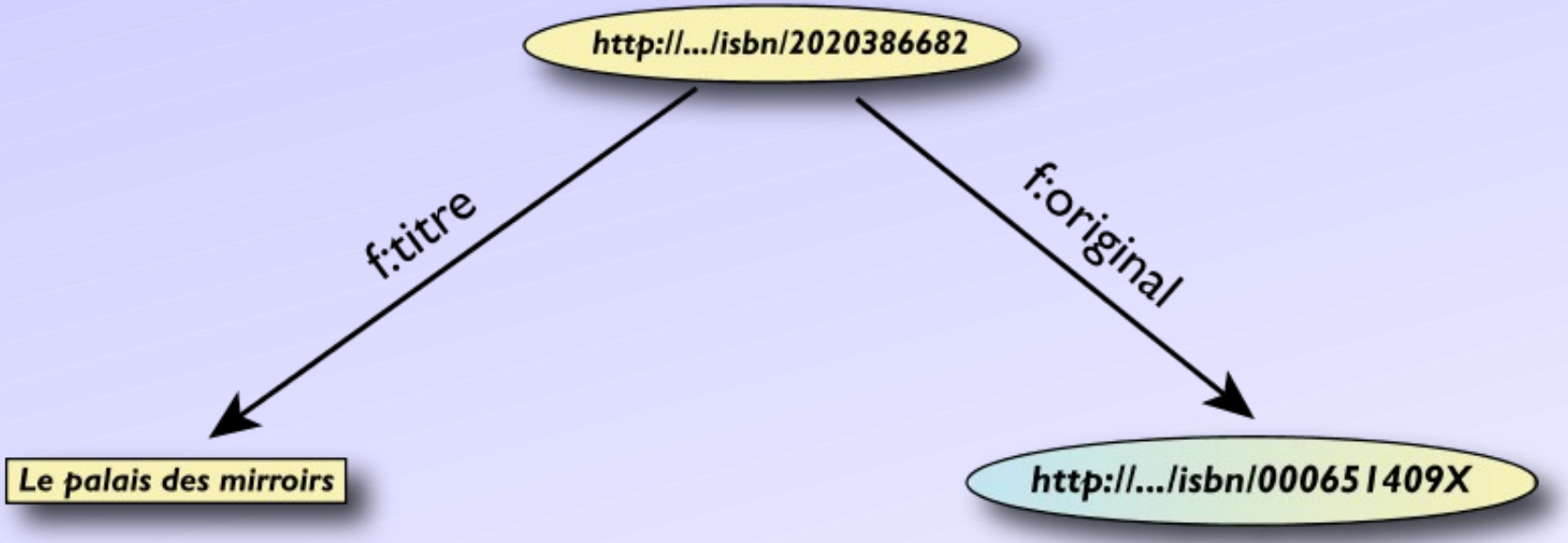
A simple RDF example (in RDF/XML)




```
<rdf:Description rdf:about="http://…/isbn/2020386682">
    <f:titre xml:lang="fr">Le palais des mirroirs</f:titre>
    <f:original rdf:resource="http://…/isbn/000651409X"/>
</rdf:Description>
```

(Note: namespaces are used to simplify the URI-s)

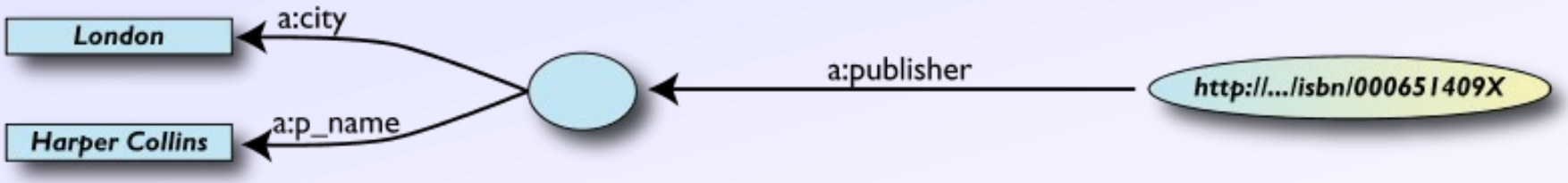
A simple RDF example (in Turtle)




```
<http://…/isbn/2020386682>
    f:titre "Le palais des mirroirs"@fr ;
    f:original <http://…/isbn/000651409X> .
```

"Internal" nodes

- Consider the following statement:
  - "the publisher is a «thing» that has a name and an address"
- Until now, nodes were identified with a URI. But…
- …what is the URI of «thing»?



Internal identifier ("blank nodes")

```
<rdf:Description rdf:about="http://…/isbn/000651409X">
   <a:publisher rdf:nodeID="A234"/>
</rdf:Description>
<rdf:Description rdf:nodeID="A234">
   <a:p_name>HarpersCollins</a:p_name>
   <a:city>HarpersCollins</a:city>
</rdf:Description>
```

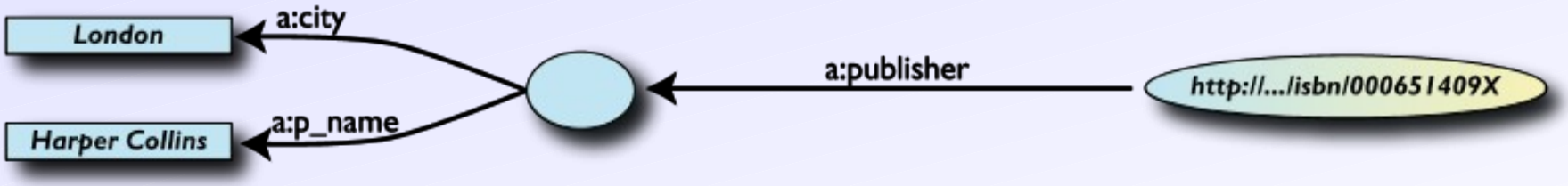
```
<http://…/isbn/2020386682> a:publisher _:A234.
_:A234 a:p_name "HarpersCollins".
```

- Syntax is serialization dependent
- A234 is invisible from outside (it is not a "real" URI!); it is an internal identifier for a resource

Blank nodes: the system can also do it

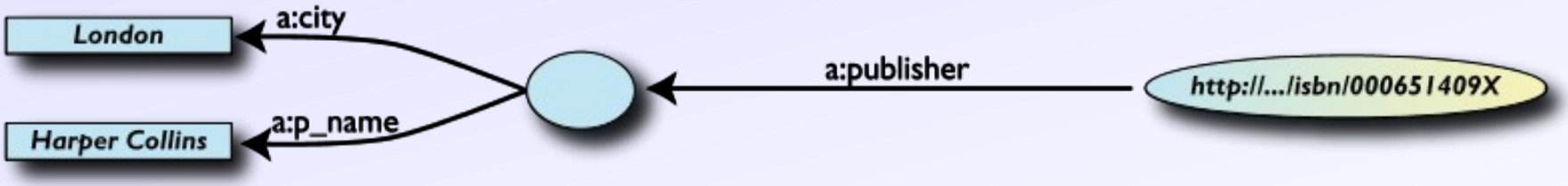
- Let the system create a “nodeID” internally (you do not really care about the name…)

```
<rdf:Description rdf:about="http://…/isbn/000651409X">
  <a:publisher>
      <rdf:Description>
          <a:p_name>HarpersCollins</a:p_name>
          …
      </rdf:Description>
  </a:publisher>
</rdf:Description>
```



Same in Turtle

```
<http://…/isbn/000651409X> a:publisher [
    a:p_name "HarpersCollins";
    …
].
```



Blank nodes: some more remarks

- Blank nodes require attention when merging
  - blanks nodes with identical nodeID-s in *different* graphs are *different*
  - implementations must be careful…
- Many applications prefer not to use blank nodes and define new URI-s “on-the-fly”

RDF in programming practice

- For example, using Java+Jena (HP's Bristol Lab):
  - a "Model" object is created
  - the RDF file is parsed and results stored in the Model
  - the Model offers methods to retrieve:
    - triples
    - (property,object) pairs for a specific subject
    - (subject,property) pairs for specific object
    - etc.
  - the rest is conventional programming…
- Similar tools exist in Python, PHP, etc.

Jena example

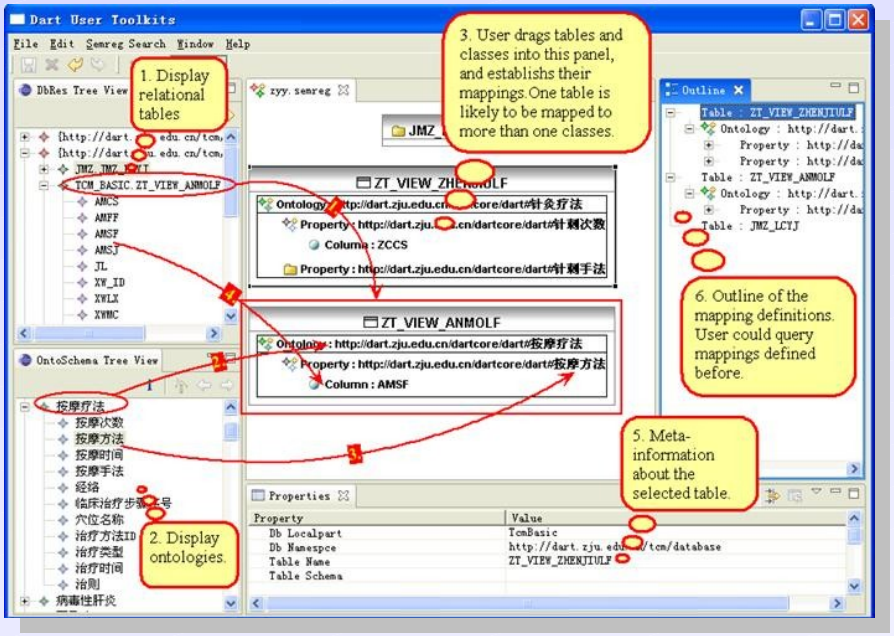
```
// create a model
Model model=new ModelMem();
Resource subject=model.createResource("URI_of_Subject")
// 'in' refers to the input file
model.read(new InputStreamReader(in));
StmtIterator iter=model.listStatements(subject,null,null);
while(iter.hasNext()) {
   st = iter.next();
   p = st.getProperty();
   o = st.getObject();
   do_something(p,o);
}
```

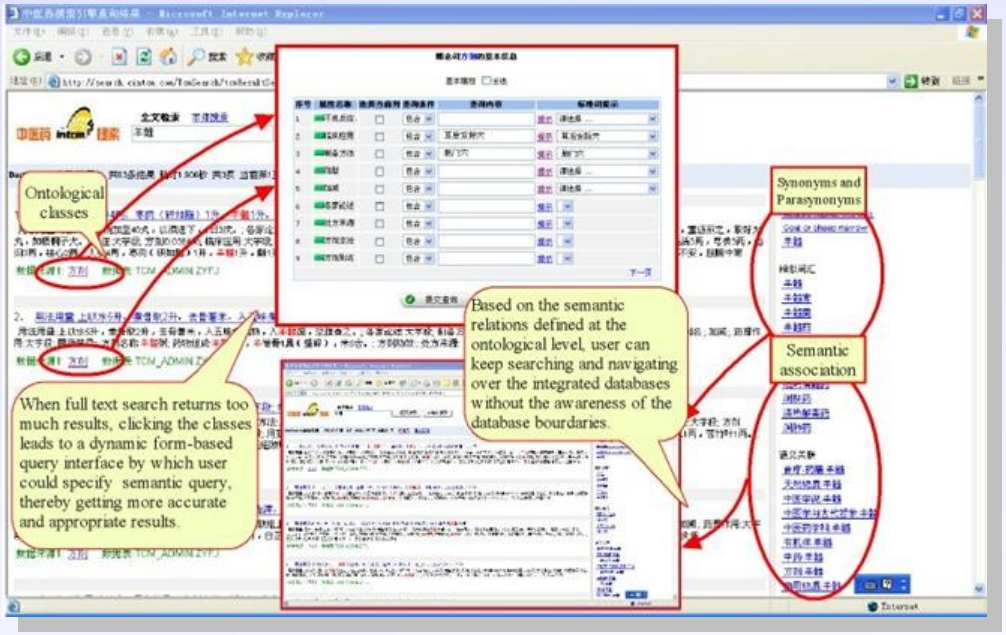
Merge in practice

- Environments merge graphs automatically
  - e.g., in Jena, the Model can load several files
  - the load merges the new statements automatically

Integrate knowledge for Chinese Medicine

- Integration of a large number of TCM databases
  - around 80 databases, around 200,000 records each
- Form based query interface for end users





Courtesy of Huajun Chen, Zhejiang University, (SWEO Case Study)

One level higher up
(RDFS, Datatypes)

Need for RDF schemas

- First step towards the “extra knowledge”:
  - define the terms we can use
  - what restrictions apply
  - what extra relationships are there?
- Officially: “RDF Vocabulary Description Language”
  - the term “Schema” is retained for historical reasons…

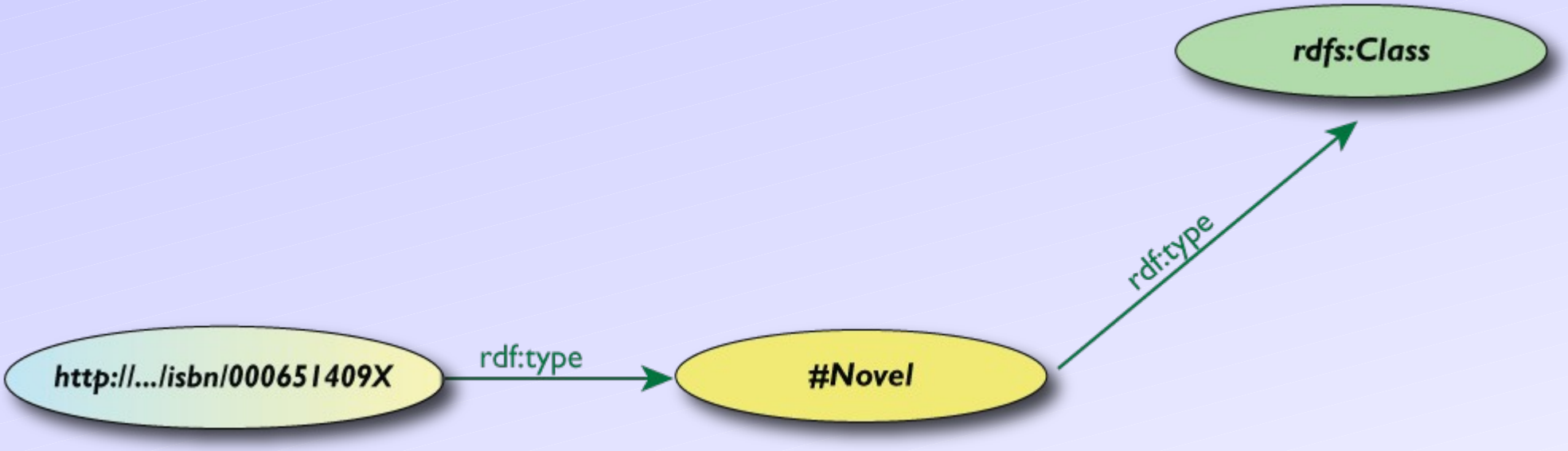
Classes, resources, …

- Think of well known traditional ontologies or taxonomies:
  - use the term “novel”
  - “every novel is a fiction”
  - “«The Glass Palace» is a novel”
  - etc.
- RDFS defines resources and classes:
  - everything in RDF is a “resource”
  - “classes” are also resources, but…
  - …they are also a collection of possible resources (i.e., “individuals”)
    - “fiction”, “novel”, …

Classes, resources, … (cont.)

- Relationships are defined among classes and resources:
  - "typing": an individual belongs to a specific class
    - "«The Glass Palace» is a novel"
    - to be more precise: "«http://.../**000651409X**» is a novel"
  - "subclassing": *all* instances of one are also the instances of the other ("every novel is a fiction")
- *RDFS formalizes these notions in RDF*

Classes, resources in RDF(S)



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

Schema example in RDF/XML

- The schema part:

```
<rdf:Description rdf:ID="Novel">
  <rdf:type
      rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
</rdf:Description>
```

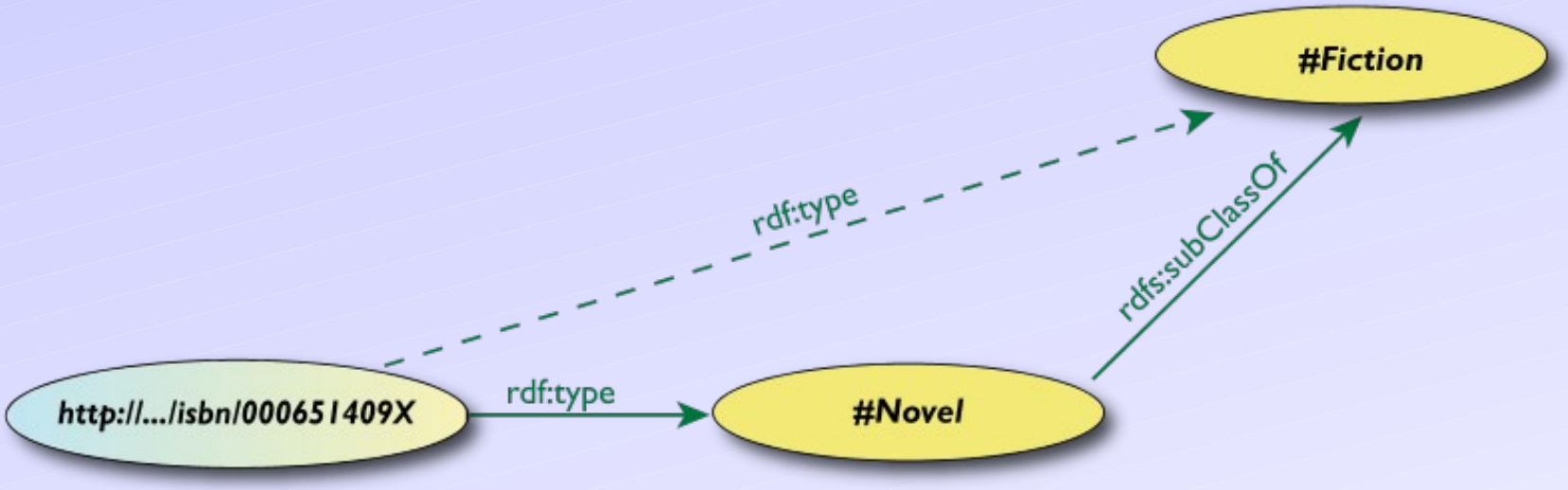
- The RDF data on a specific novel:

```
<rdf:Description rdf:about="http://…/isbn/000651409X">
   <rdf:type rdf:resource="http://…/bookSchema.rdf#Novel"/>
</rdf:Description>
```

Further remarks on types

- A resource may belong to several classes
  - rdf:type is just a property…
    - "«The Glass Palace» is a novel, but «The Glass Palace» is also an «inventory item»…"
  - i.e., it is *not* like a datatype!
- The type information may be very important for applications
  - e.g., it may be used for a categorization of possible nodes
  - probably the most frequently used RDF property…
    - (remember the "Person" in our example?)

Inferred properties




```
(<http://…/isbn/000651409X> rdf:type #Fiction)
```

- 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

- Property is a special class (`rdf:Property`)
  - properties are also resources identified by URI-s
- There is also a possibility for a “sub-property”
  - all resources bound by the “sub” are also bound by the other
- Range and domain of properties can be specified
  - i.e., what type of resources serve as object and subject

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.
```

What does this mean?

- Again, new relations can be deduced. Indeed, if

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

<http://…/isbn/000651409X> :title "The Glass Palace" .
```

- then the system can *infer* that:

```
<http://…/isbn/000651409X> rdf:type :Fiction .
```

Literals

- Literals may have a data type
  - floats, integers, booleans, etc, defined in XML Schemas
  - full XML fragments
- (Natural) language can also be specified

Examples for datatypes

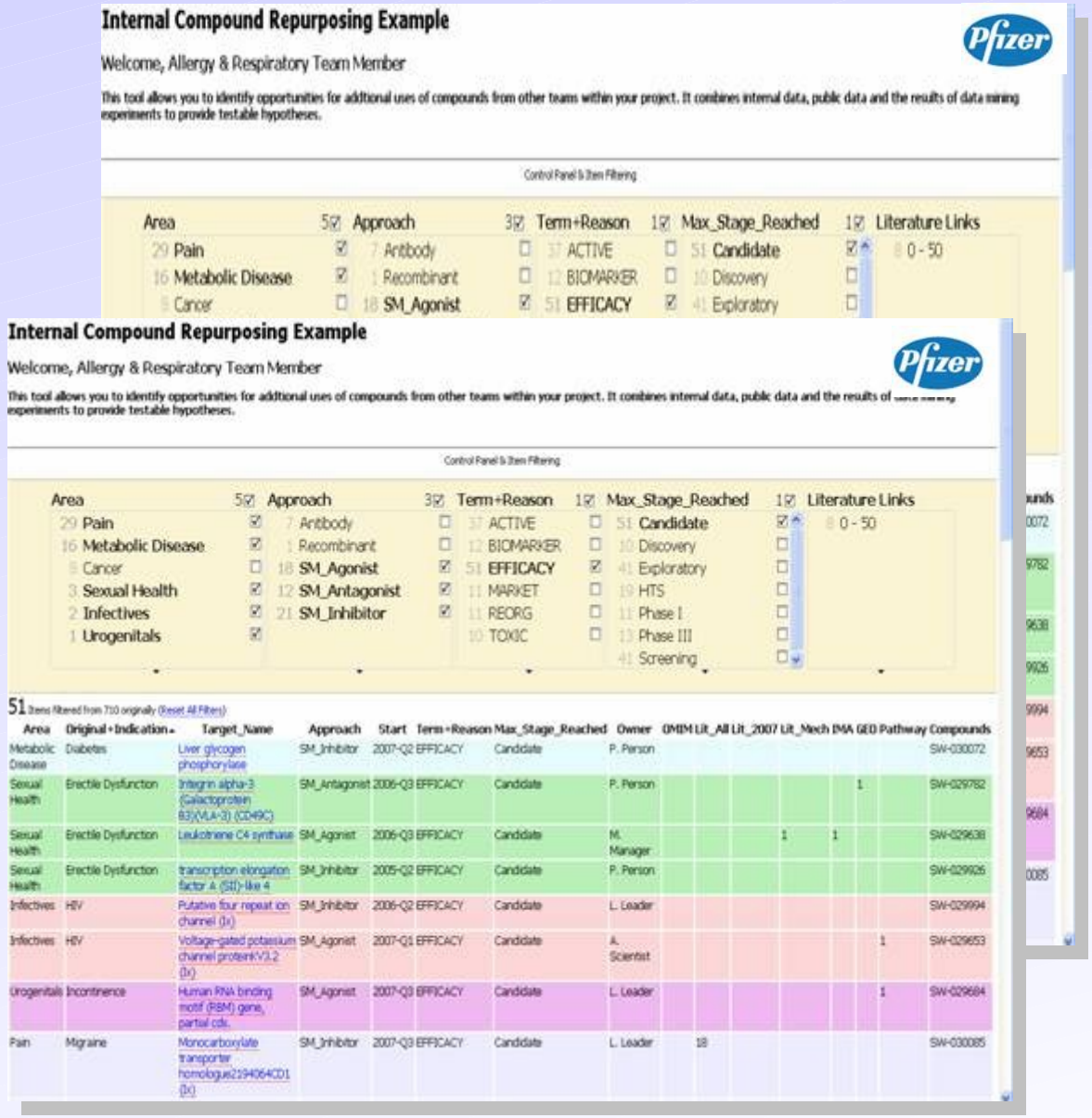
```
<http://…/isbn/000651409X>
      :page_number "543"^^xsd:integer ;
      :publ_date   "2000"^^xsd:gYear ;
      :price       "6.99"^^xsd:float .
```

A bit of RDFS can take you far…

- Remember the power of merge?
- We could have used, in our example:
  - **`f:auteur`** is a subproperty of **`a:author`** and vice versa (although we will see other ways to do that…)
- Of course, in some cases, more complex knowledge is necessary (see later…)

Another relatively simple application

- Goal: reuse of older experimental data
- Keep data in databases or XML, just export key "fact" as RDF
- Use a faceted browser to visualize and interact with the result



Courtesy of Nigel Wilkinson, Lee Harland, Pfizer Ltd, Melliyal Annamalai, Oracle (SWEO Case Study)

How to get RDF Data?
(Microformats, GRDDL, RDFa)

Simple approach

- Write RDF/XML or Turtle “manually”
- In some cases that is necessary, but it really does not scale…

RDF with XHTML and XML

- Obviously, a huge source of information
- By adding some “meta” information, the same source can be reused for, eg, data integration, better mashups, etc
  - typical example: your personal information, like address, should be readable for humans *and* processable by machines
- Two solutions have emerged:
  - extract the structure from the page and convert the content into RDF
  - add RDF statements directly into XHTML via RDFa

Extract RDF

- Use intelligent “scrapers” or “wrappers” to extract a structure (hence RDF) from a Web pages or XML files…
- … and then generate RDF automatically (e.g., via an XSLT script)
- GRDDL formalizes the this general scheme

Formalizing the scraper approach: GRDDL

- GRDDL formalizes the scraper approach. For example:

```
<html xmlns="http://www.w3.org/1999/">
  <head profile="http://www.w3.org/2003/g/data-view">
    <title>Some Document</title>
    <link rel="transformation" href="http:…/dc-extract.xsl"/>
    <meta name="DC.Subject" content="Some subject"/>
    ...
  </head>
  ...
  <span class="date">2006-01-02</span>
  ...
</html>
```

- yields, through **dc-extract.xsl**:

```
<>
   dc:subject "Some subject";
   dc:date "2006-01-02" .
```

GRDDL with XML

- The approach is very similar to the XHTML case
- The appropriate attributes are added to the XML namespace document
- Otherwise it is identical

Bridge to relational databases

- Data on the Web are mostly stored in databases
- "Bridges" are being defined:
  - a layer between RDF and the relational data
    - RDB tables are "mapped" to RDF graphs, possibly on the fly
    - different mapping approaches are being used
  - a number RDB systems offer this facility already (eg, Oracle, OpenLink, …)
- A survey on mapping techniques has been published at W3C
- A W3C group has just started to standardize this

Linking Data

Linking Open Data Project

- Goal: “expose” open datasets in RDF
- *Set RDF links among the data items* from different datasets
- Set up query endpoints
- Altogether billions of triples, millions of links…

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

Extracting Wikipedia structured data

Amsterdam

The Keizersgracht at dusk

Location of Amsterdam

Coordinates: 52°22'23"N 4°53'32"E

Country	Netherlands
Province	North Holland
Government	
- Type	Municipality
- Mayor	Job Cohen[1] (PvdA)
- Aldermen	Lodewijk Asscher Carolien Gehrels Tjeerd Herrema Maarten van Poelgeest Marijke Vos
- Secretary	Erik Gerritsen
Area [2][3]	
- City	219 km² (84.6 sq mi)
- Land	166 km² (64.1 sq mi)
- Water	53 km² (20.5 sq mi)
- Urban	1,003 km² (387.3 sq mi)
- Metro	1,815 km² (700.8 sq mi)
Elevation [4]	2 m (7 ft)
Population (1 October 2008)[5][6]	
- City	755,269
- Density	4,459/km² (11,548.8/sq mi)
- Urban	1,364,422
- Metro	2,158,372
- Demonym	Amsterdammer
Time zone	CET (UTC+1)
- Summer (DST)	CEST (UTC+2)
Postcodes	1011 – 1109
Area code(s)	020

Website: www.amsterdam.nl

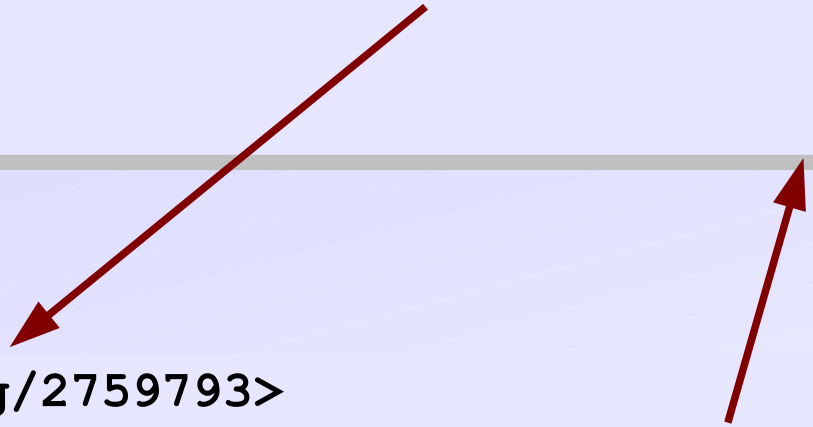
```
@prefix dbpedia <http://dbpedia.org/resource/>.
@prefix dbterm  <http://dbpedia.org/property/>.

dbpedia:Amsterdam
   dbterm:officialName "Amsterdam" ;
   dbterm:longd "4" ;
   dbterm:longm "53" ;
   dbterm:longs "32" ;
   ...
   dbterm:leaderTitle "Mayor" ;
   dbterm:leaderName dbpedia:Job_Cohen ;
   ...
   dbterm:areaTotalKm "219" ;
   ...
dbpedia:ABN_AMRO
   dbterm:location dbpedia:Amsterdam ;
   ...
```

W3C Semantic Web

Automatic links among open datasets

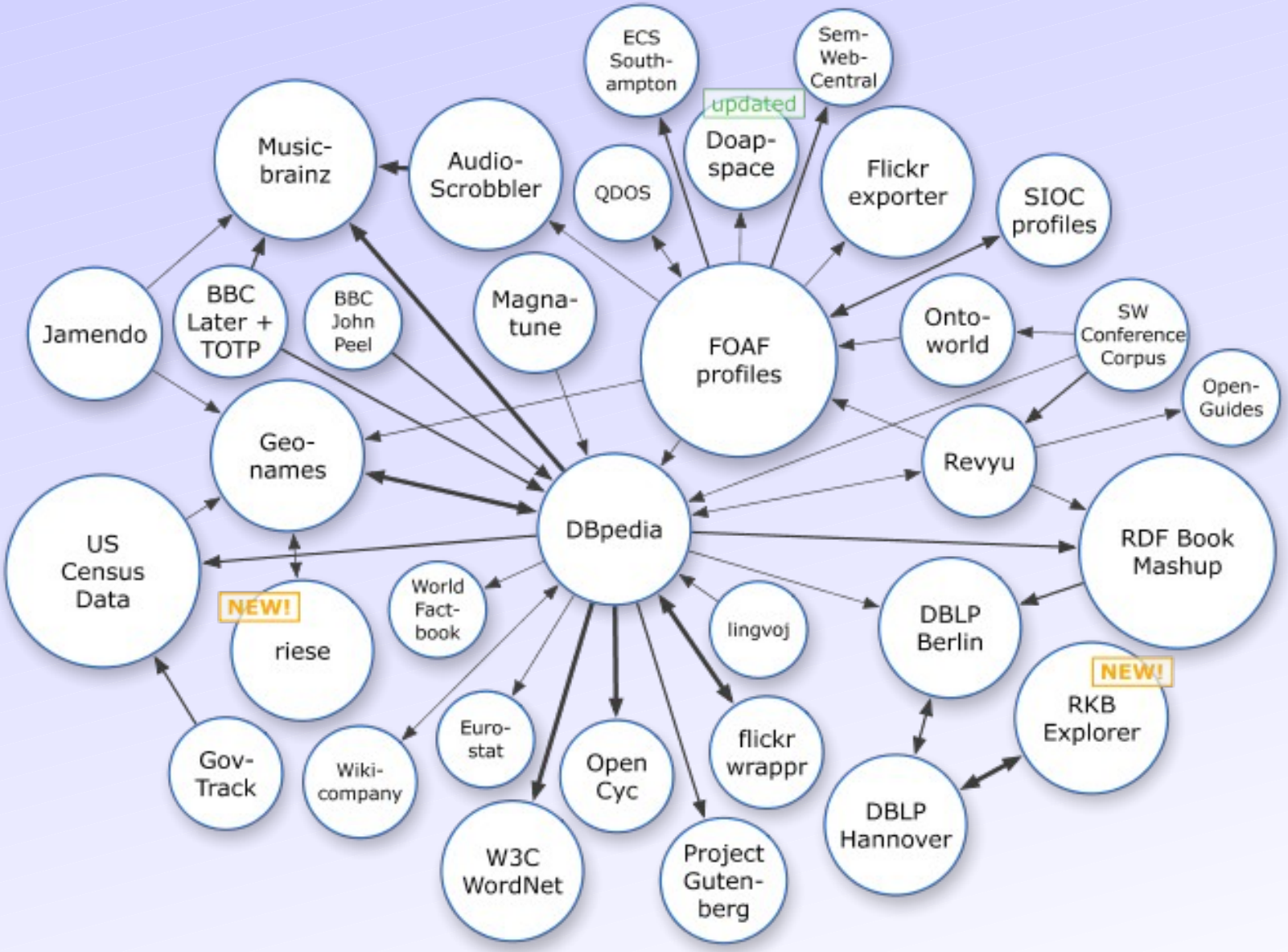
```
<http://dbpedia.org/resource/Amsterdam>
  owl:sameAs <http://rdf.freebase.com/ns/...> ;
  owl:sameAs <http://sws.geonames.org/2759793> ;
  ...
```



```
<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> ;
 ...
```

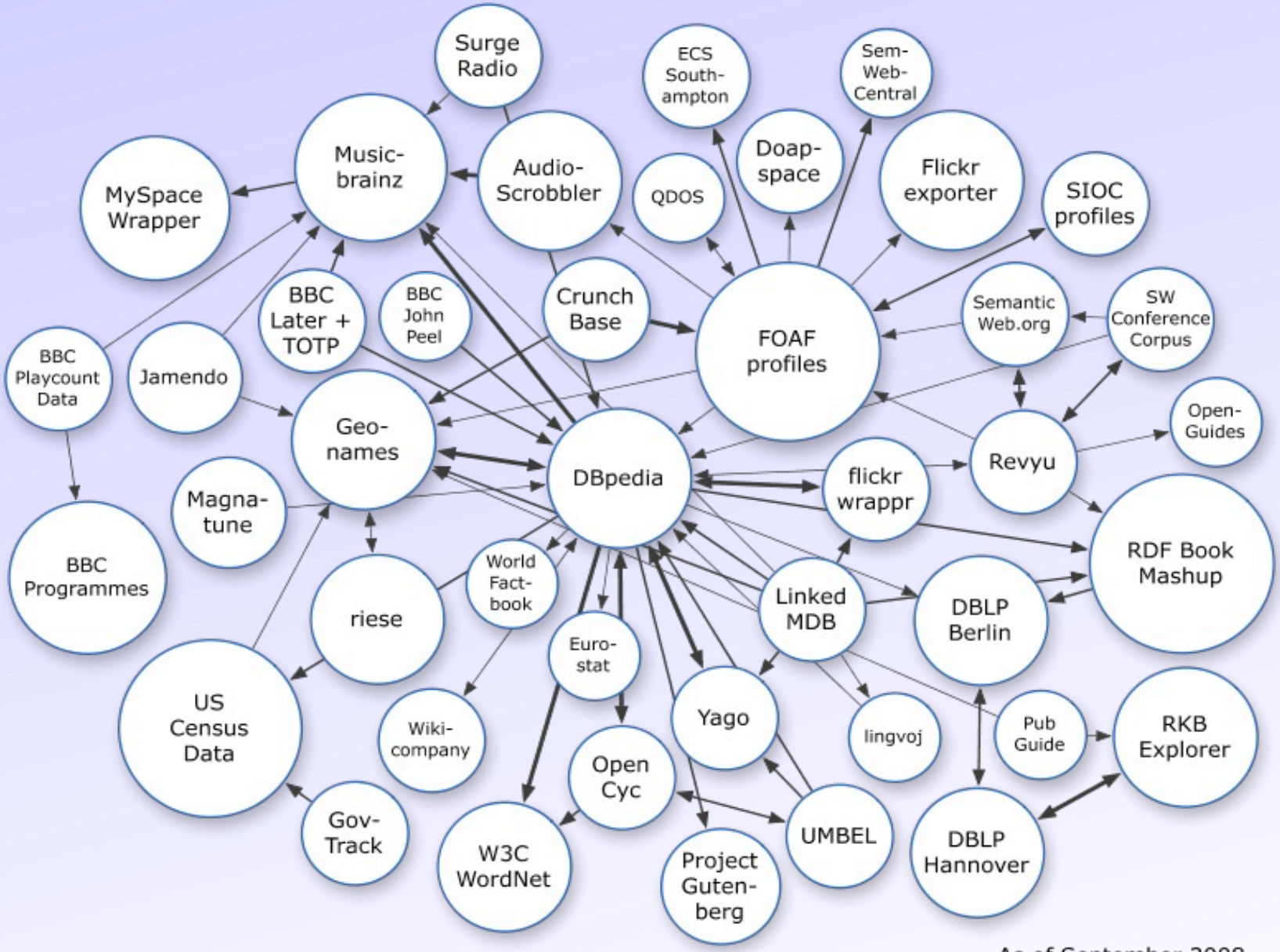
Processors can switch automatically from one to the other…

The LOD "cloud", March 2008

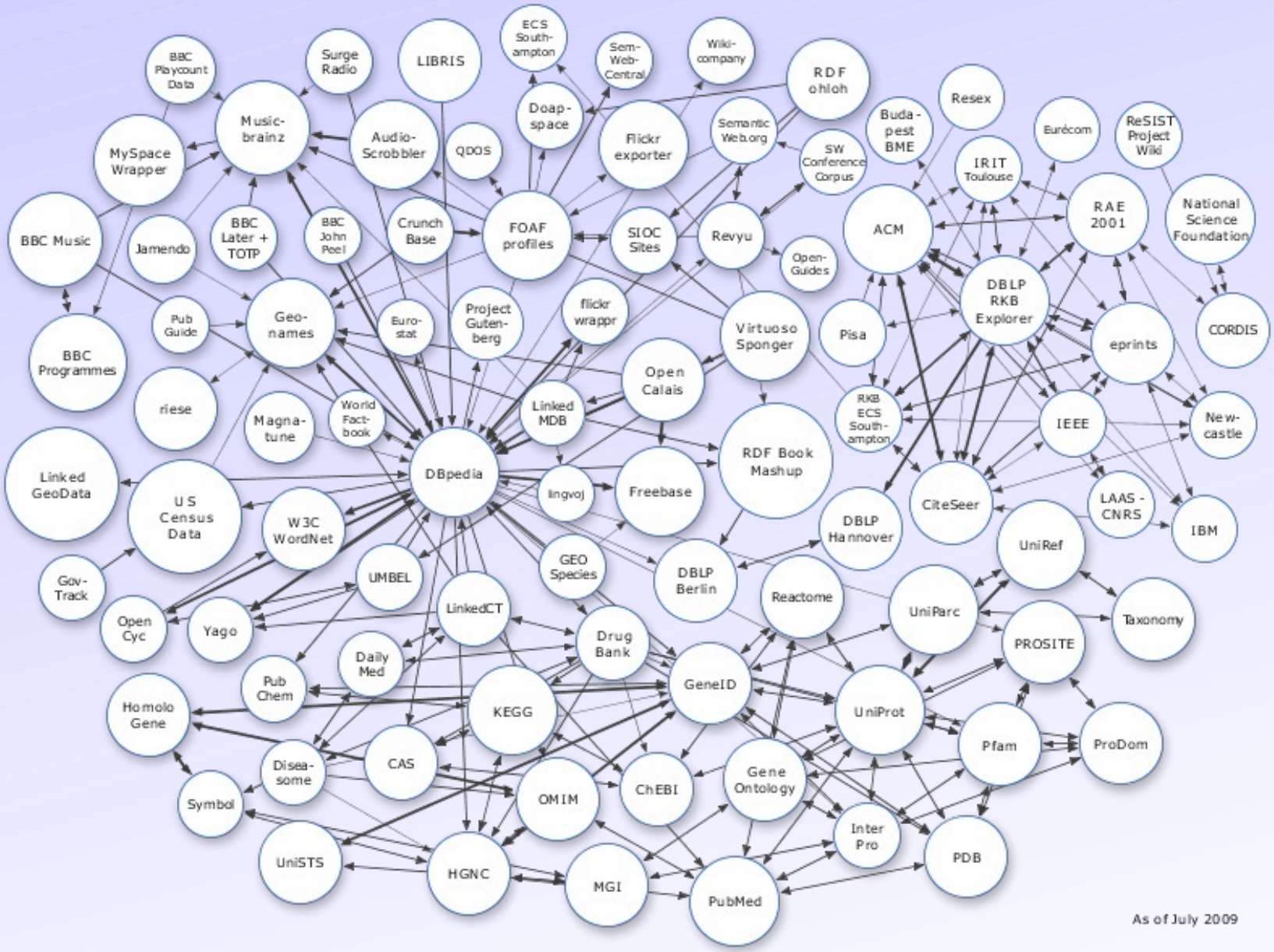


W3C Semantic Web

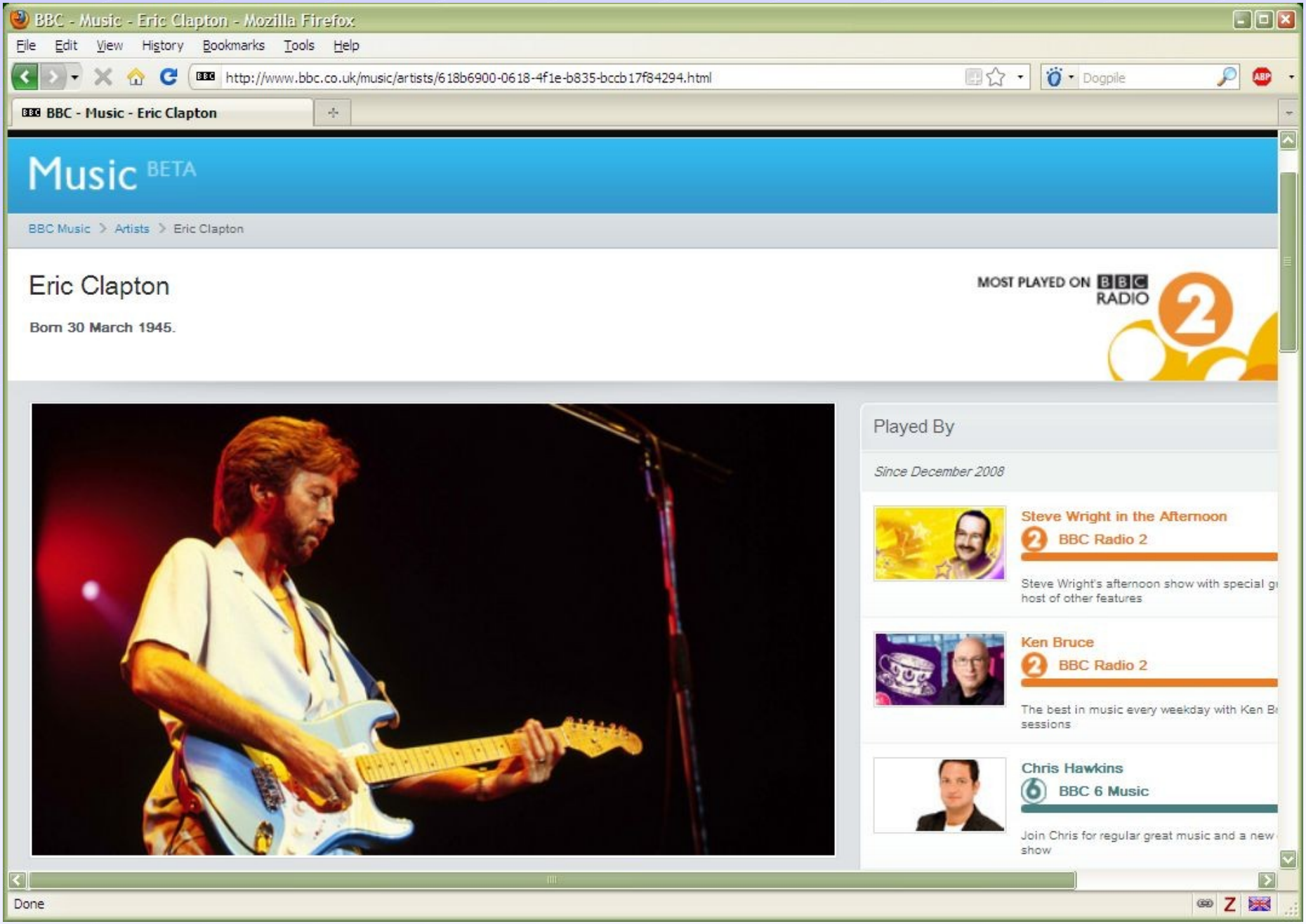
The LOD "cloud", September 2008



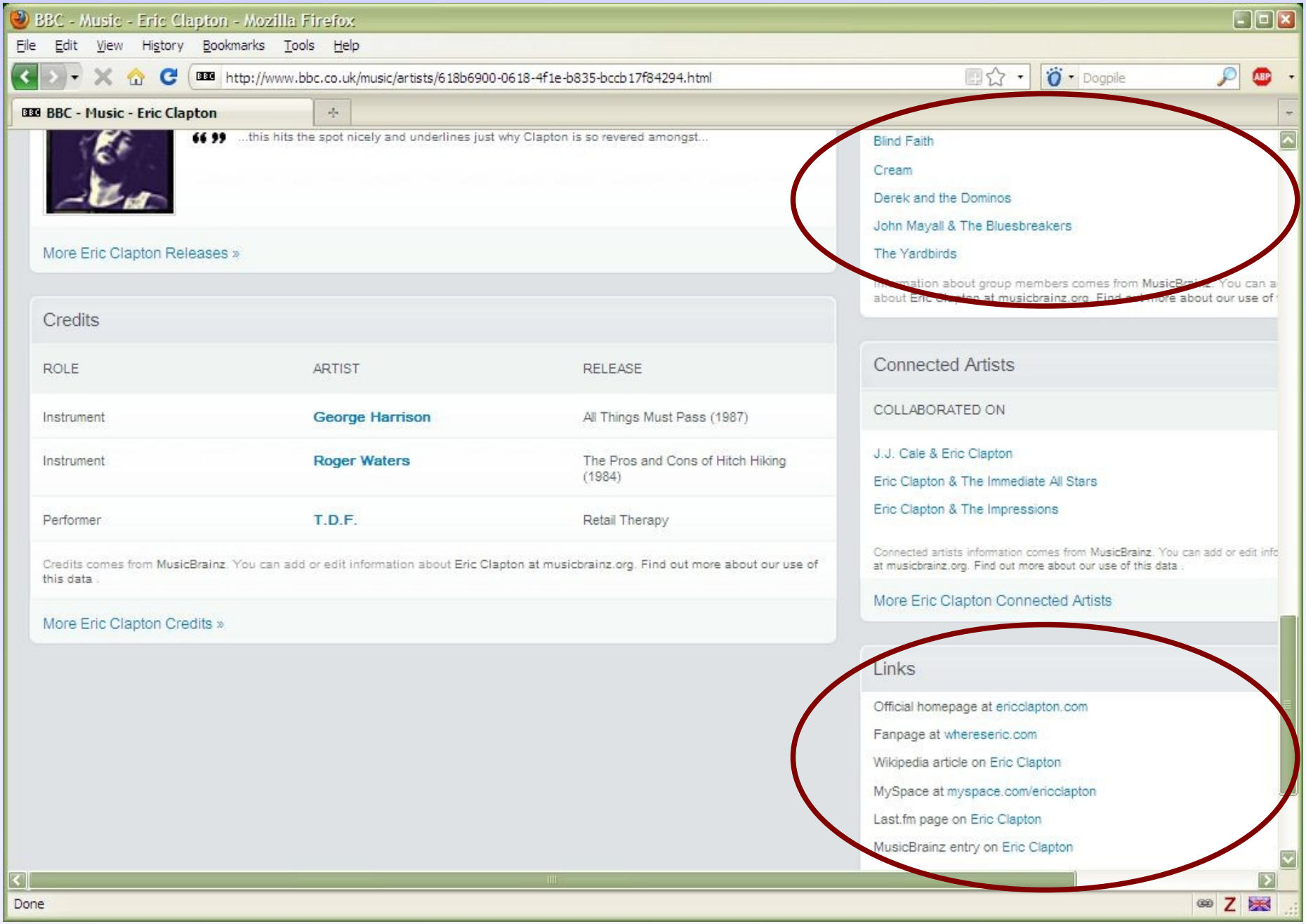
The LOD "cloud", July 2009



Using the LOD to build Web site: BBC

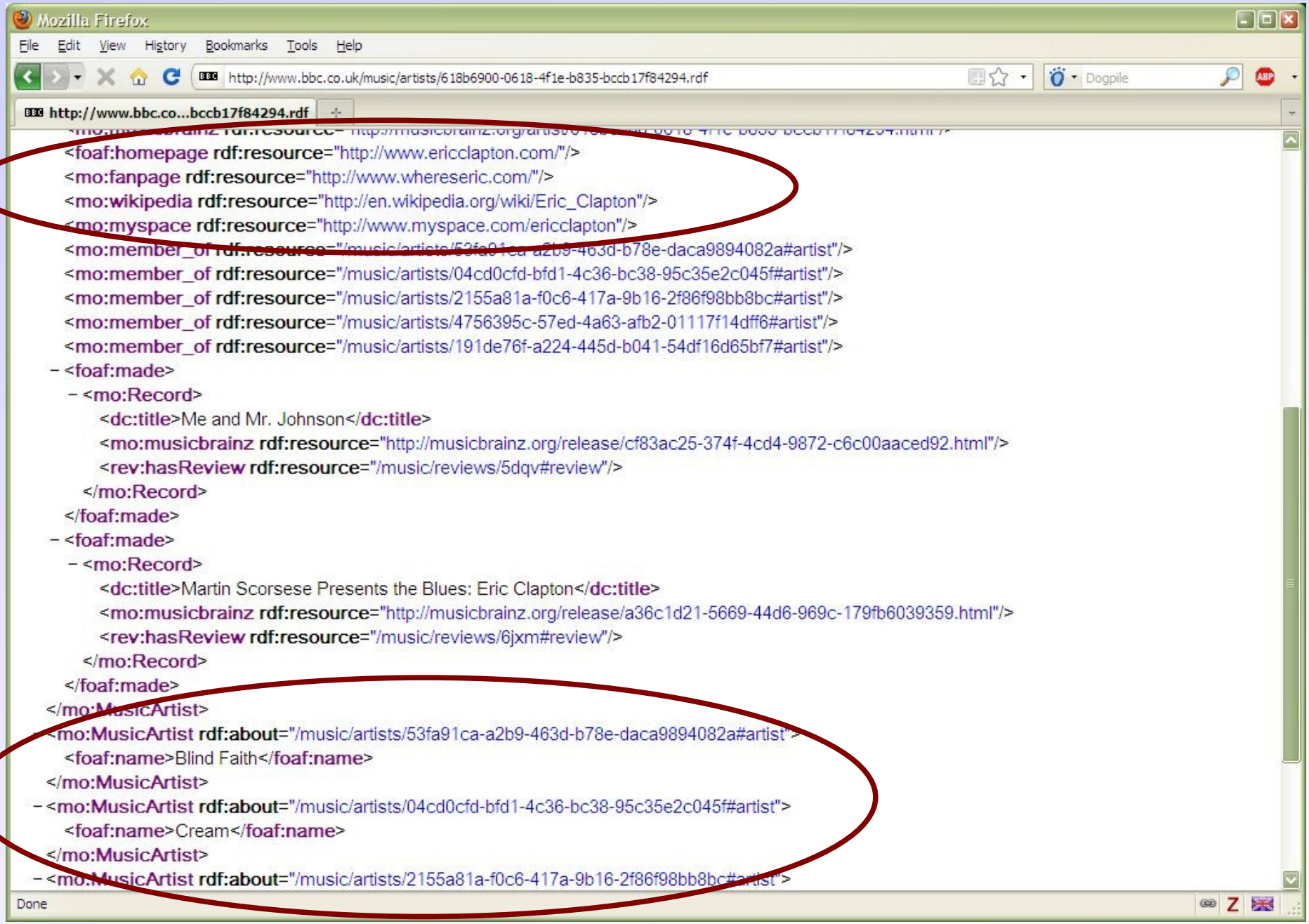


Using the LOD to build Web site: BBC



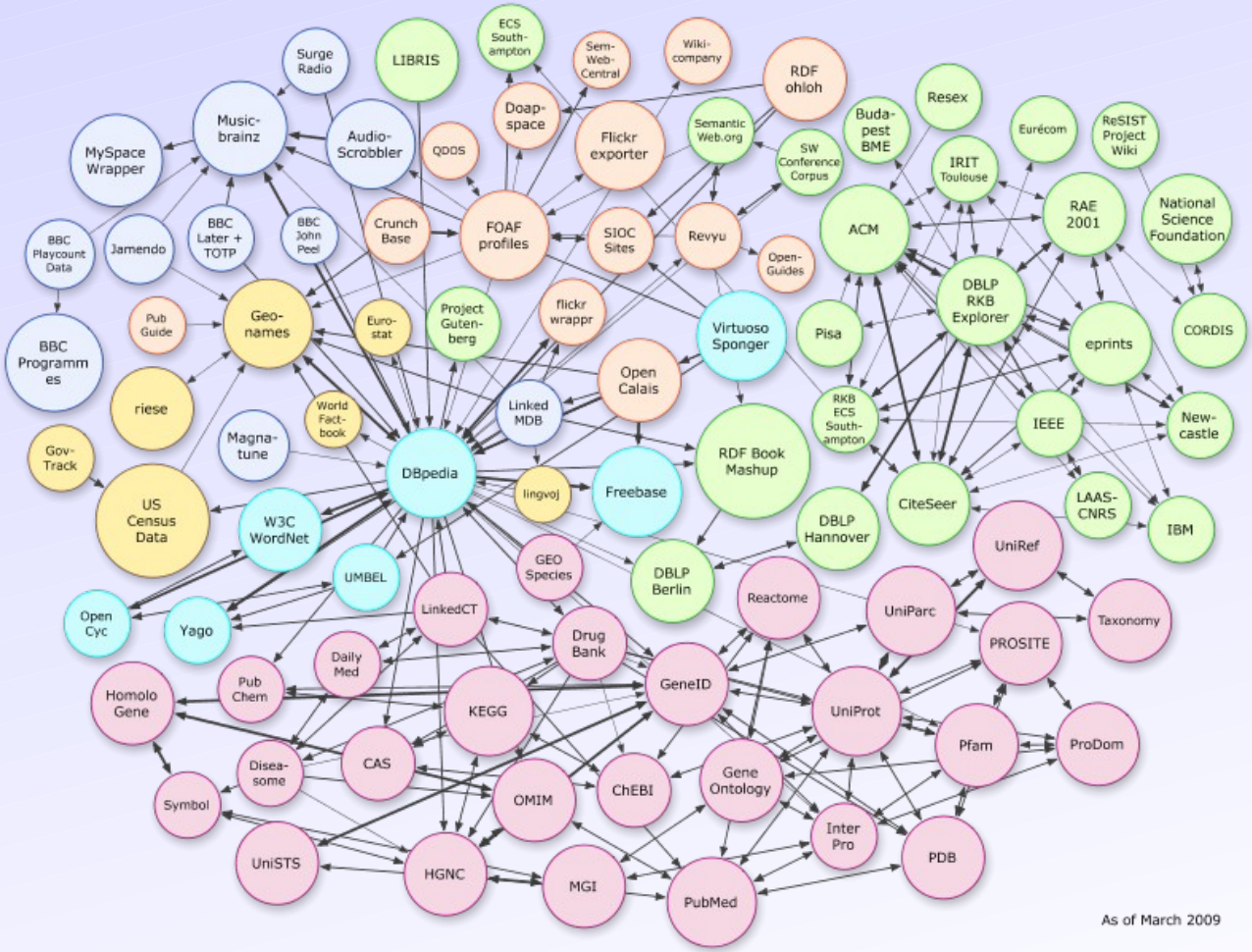
W3C Semantic Web

Using the LOD to build Web site: BBC

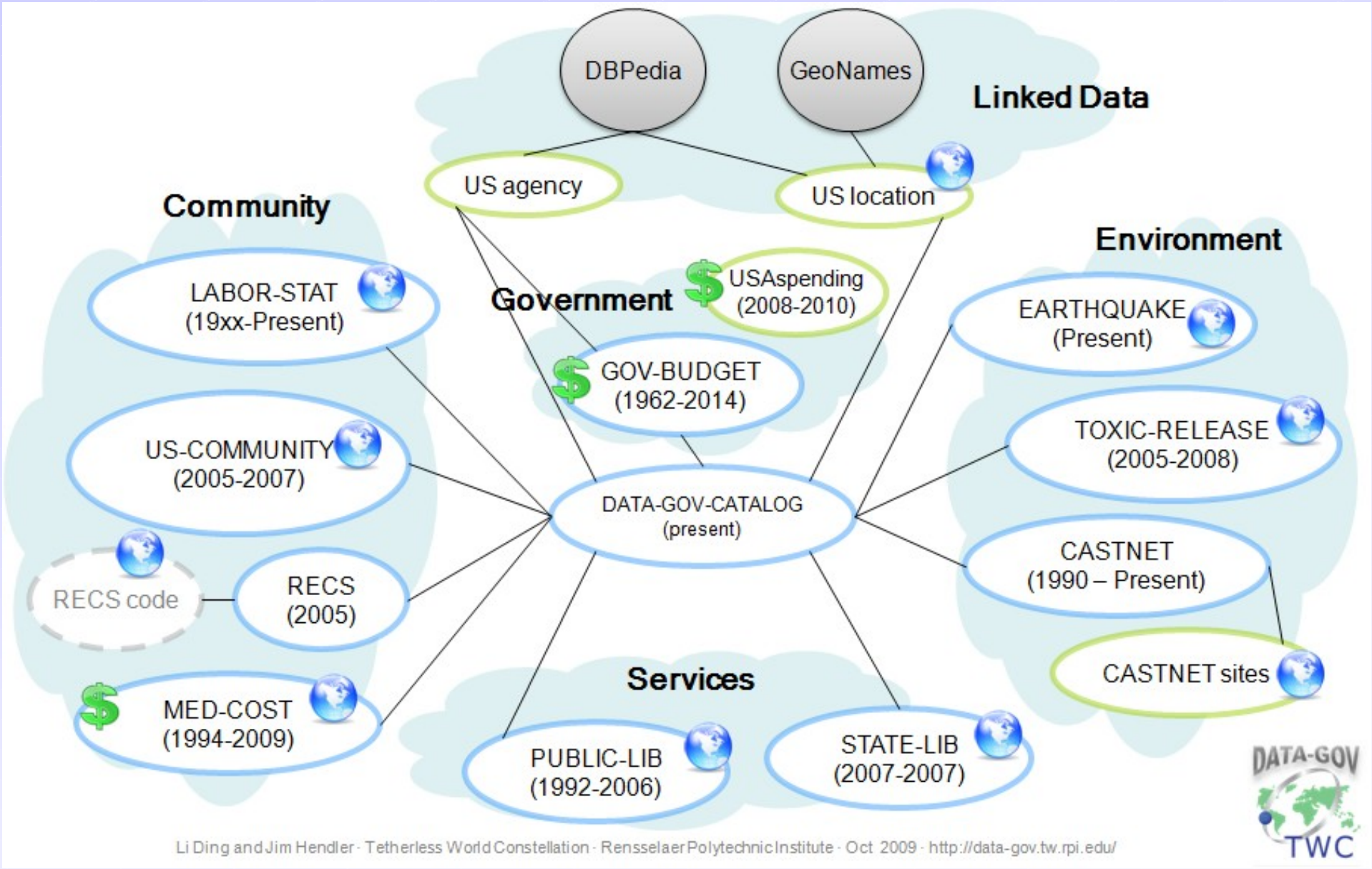


Application specific portions of the cloud

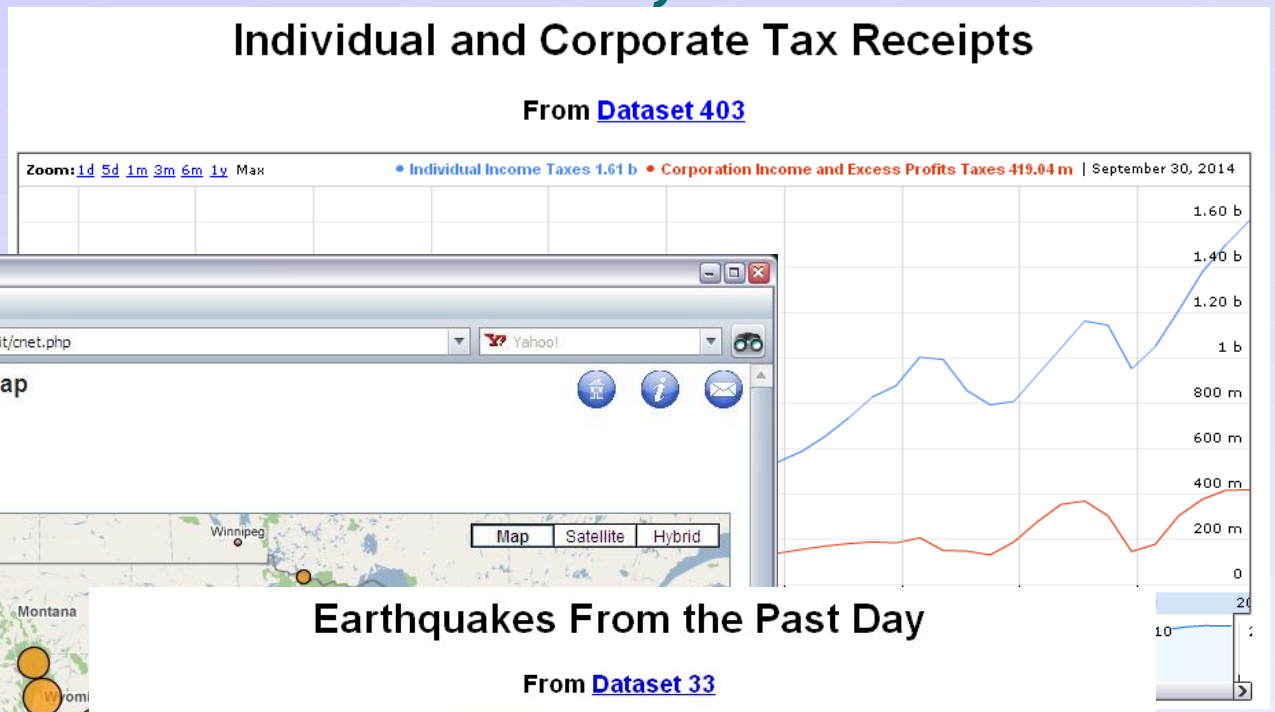
- Eg, “bio” related datasets
  - done, partially, by the “Linking Open Drug Data” task force of the HCLS IG at W3C

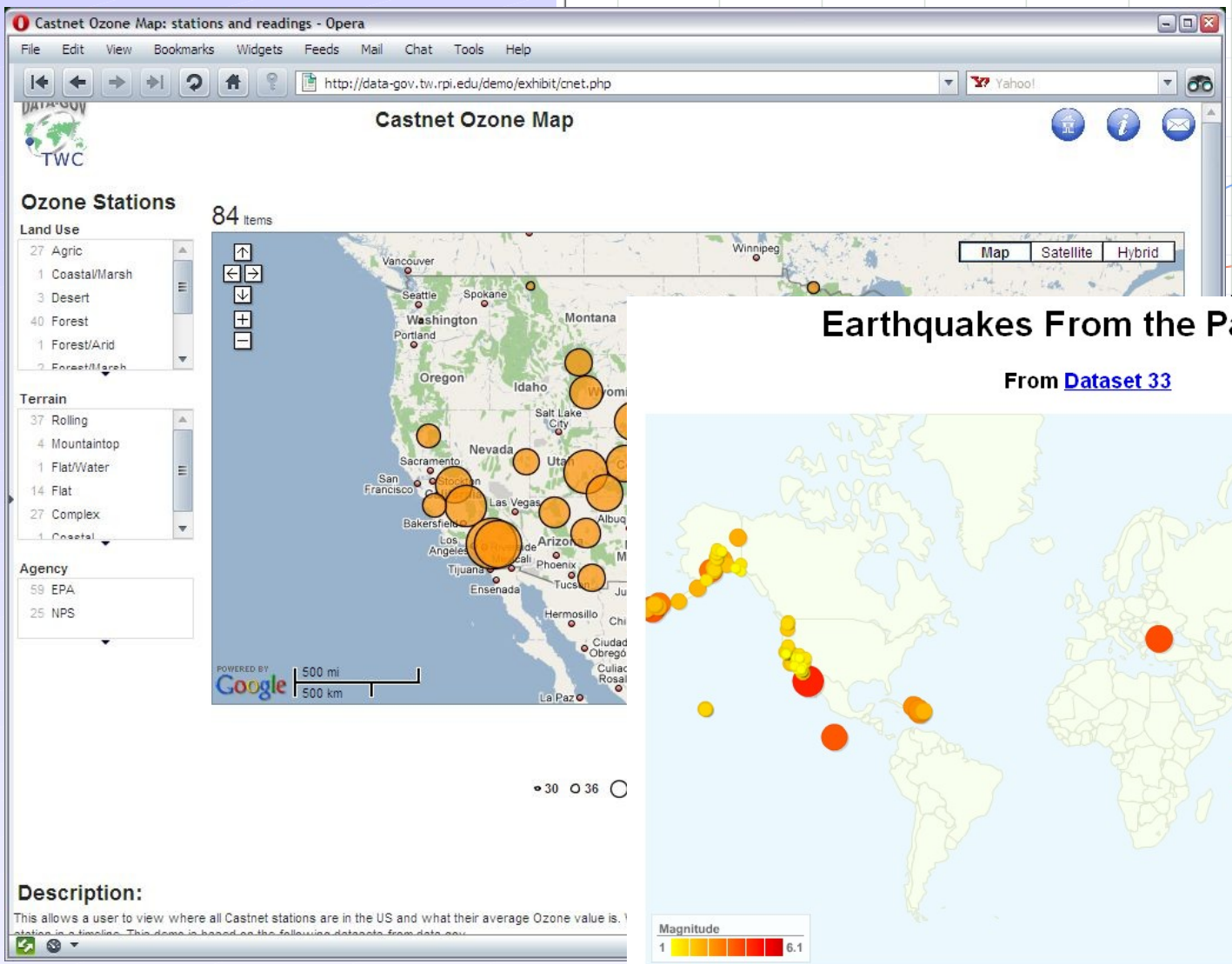


Linked Open eGov Data



You publish the raw data, we use it…





Examples from RPI's Data-gov Wiki, Jim Hendler & al.

W3C Semantic Web

Query RDF Data
(SPARQL)

RDF data access

- How do I *query* the RDF data?
  - e.g., how do I get to the DBpedia data?

Querying RDF graphs

- Remember the Jena idiom:

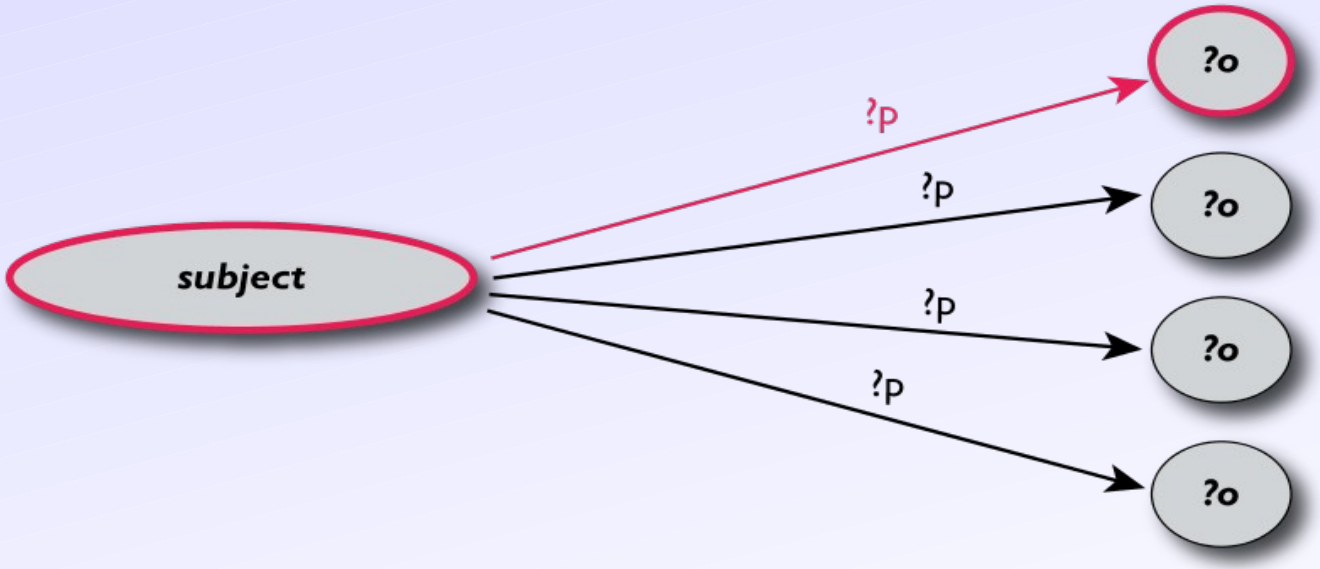
```
StmtIterator iter=model.listStatements(subject,null,null);
while(iter.hasNext()) {
    st = iter.next();
    p = st.getProperty(); o = st.getObject();
    do_something(p,o);
```

- 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)

Analyse the Jena example

```
StmtIterator iter=model.listStatements(subject,null,null);
while(iter.hasNext()) {
    st = iter.next();
    p = st.getProperty(); o = st.getObject();
    do_something(p,o);
```

- The `(subject,?p,?o)` is a *pattern* for what we are looking for (with `?p` and `?o` as "unknowns")



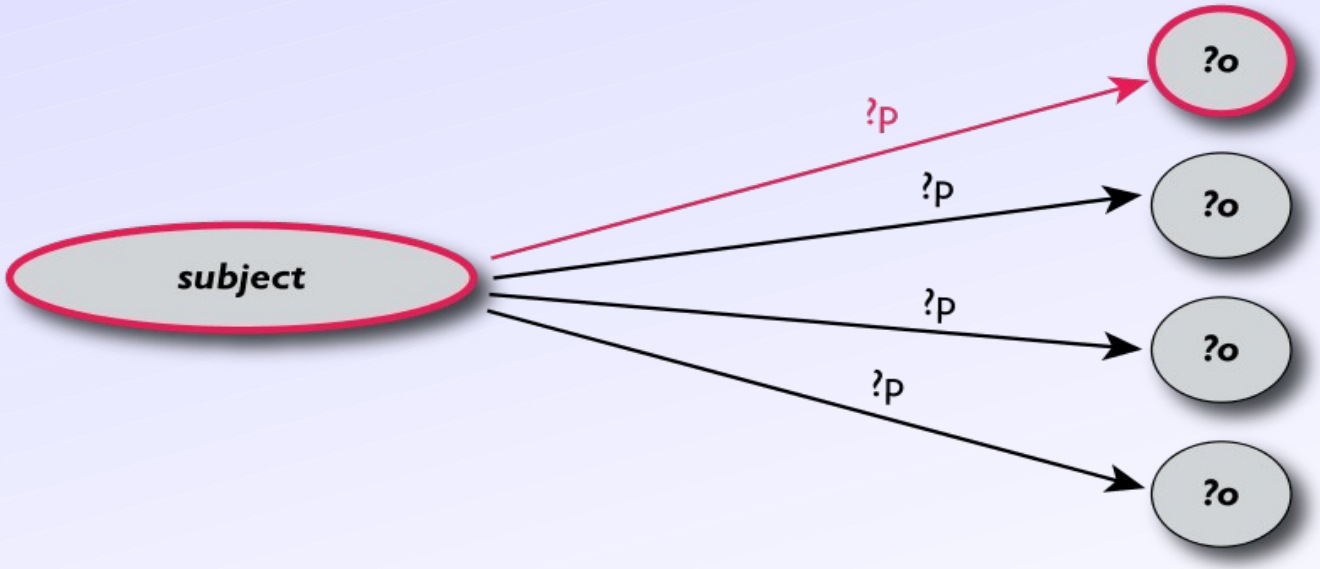
General: graph patterns

- 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 bound resources

Our Jena example in SPARQL

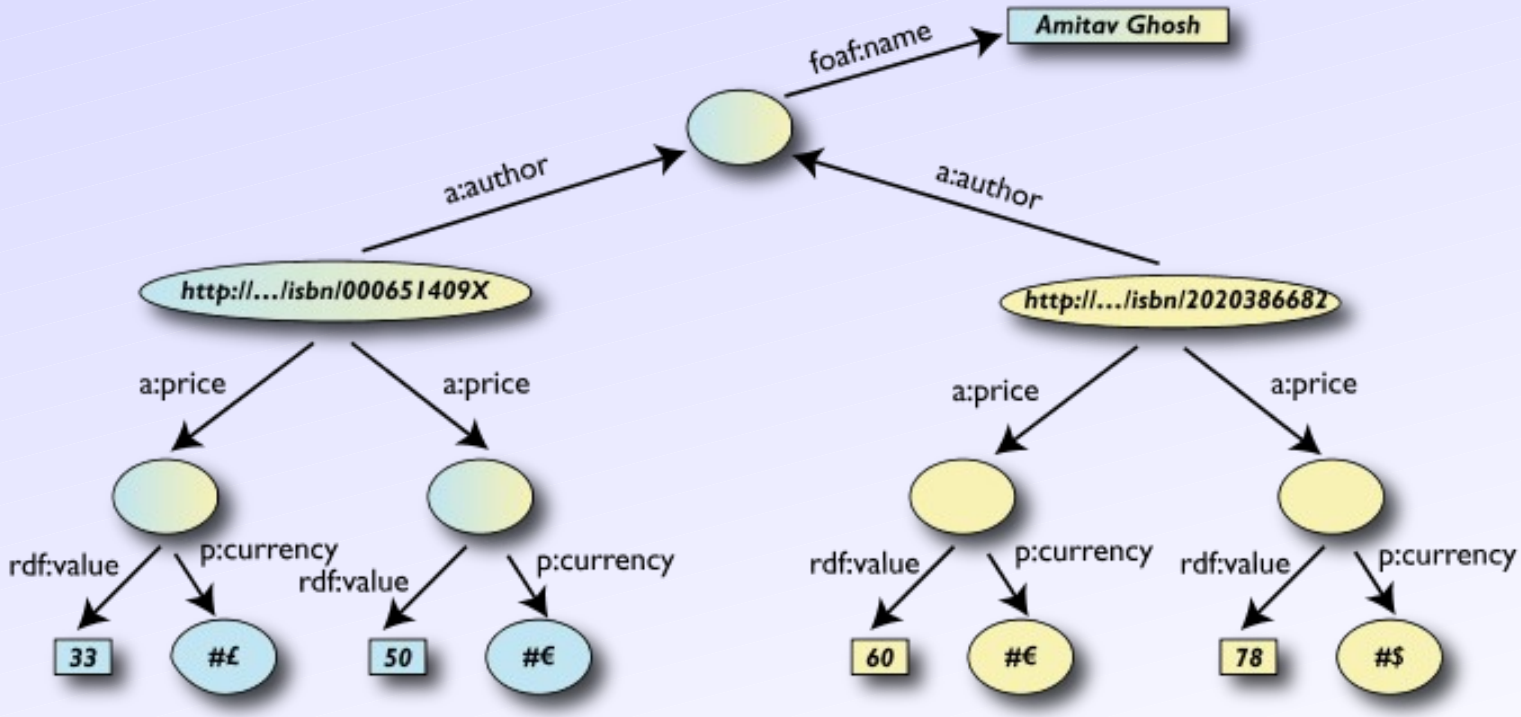
```
SELECT ?p ?o
WHERE {subject ?p ?o}
```

- The triples in **`WHERE`** define the graph pattern, with **`?p`** and **`?o`** "unbound" symbols
- The query returns *all* **`p`**,**`o`** pairs



Simple SPARQL example

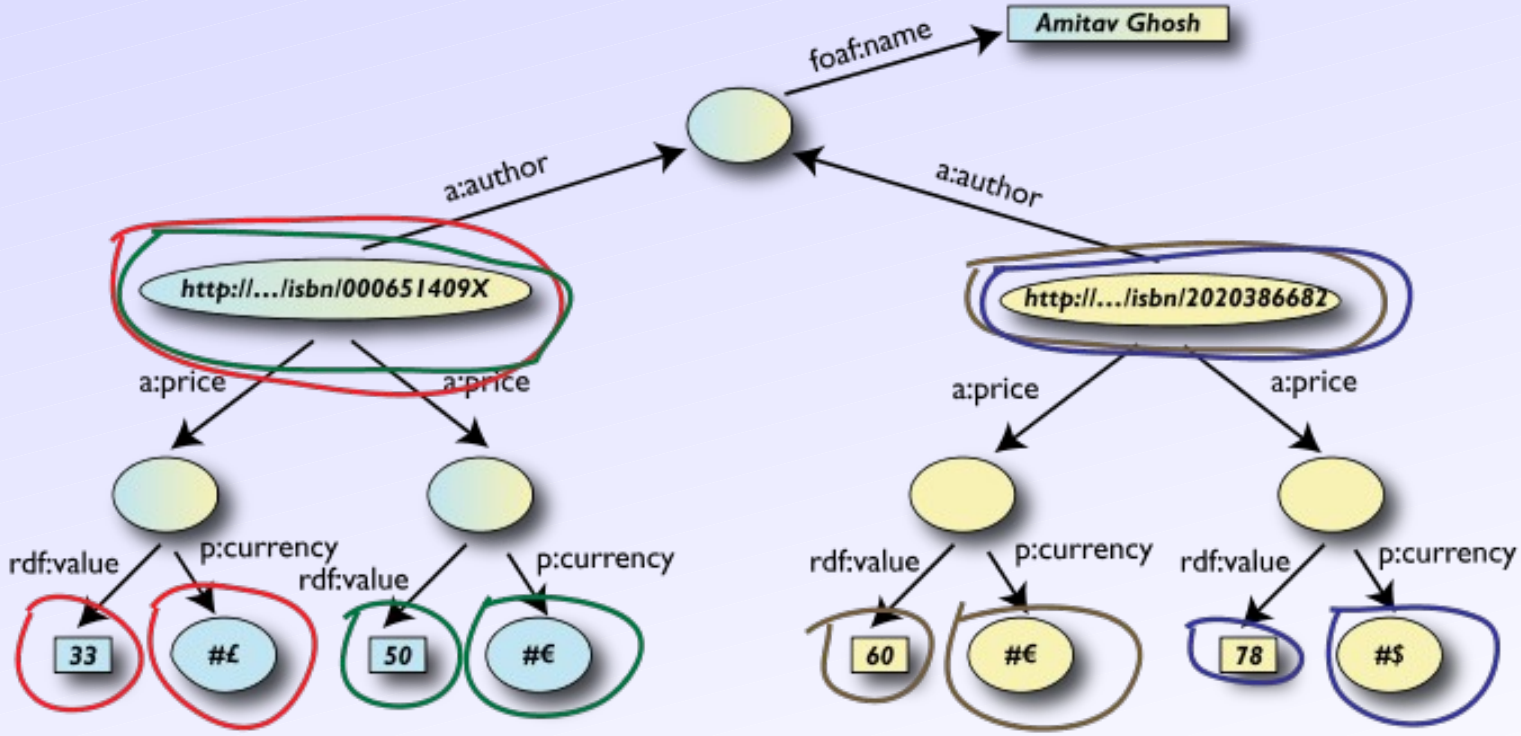
```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```



Simple SPARQL example

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

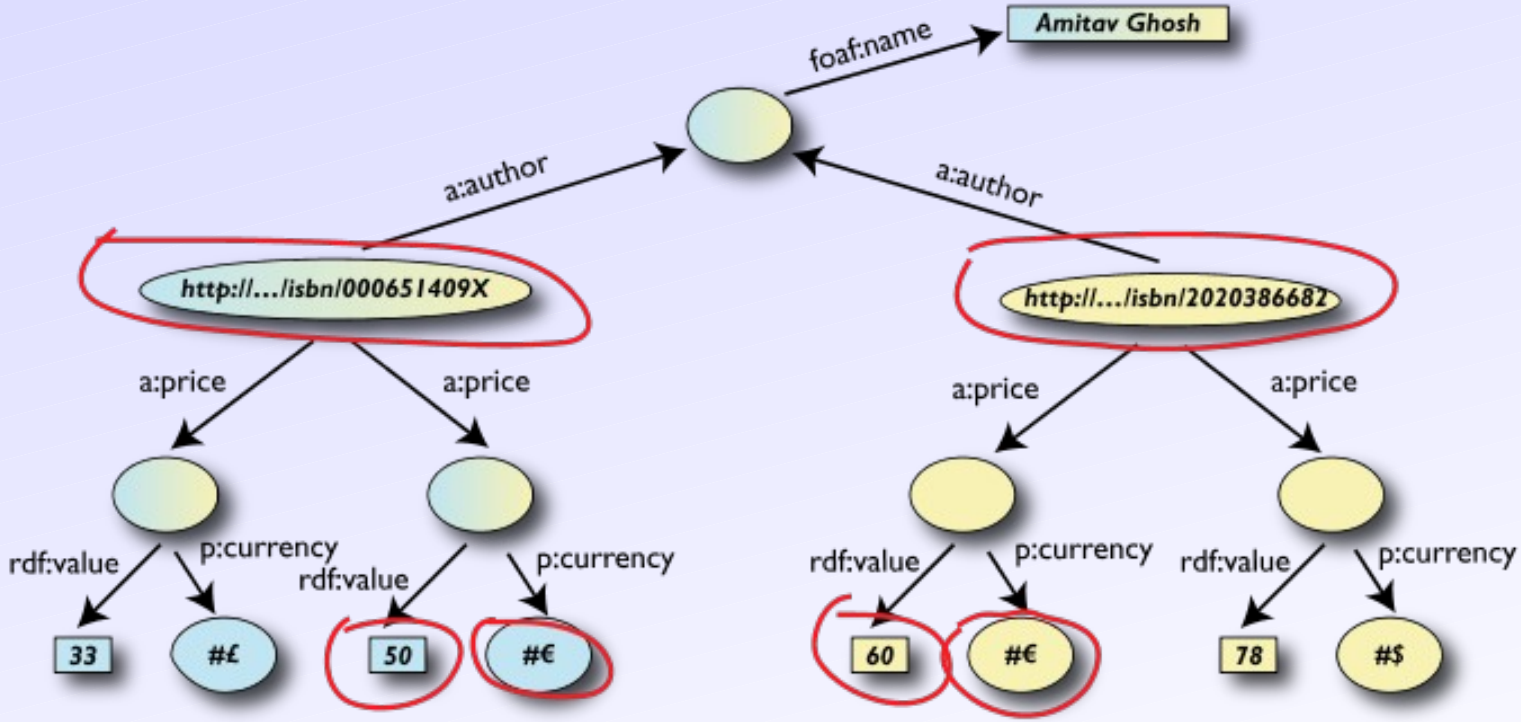
- Returns:
  [[<..49X>,33,£], [<..49X>,50,€], [<..6682>,60,€], [<..6682>,78,$]]



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,€]]



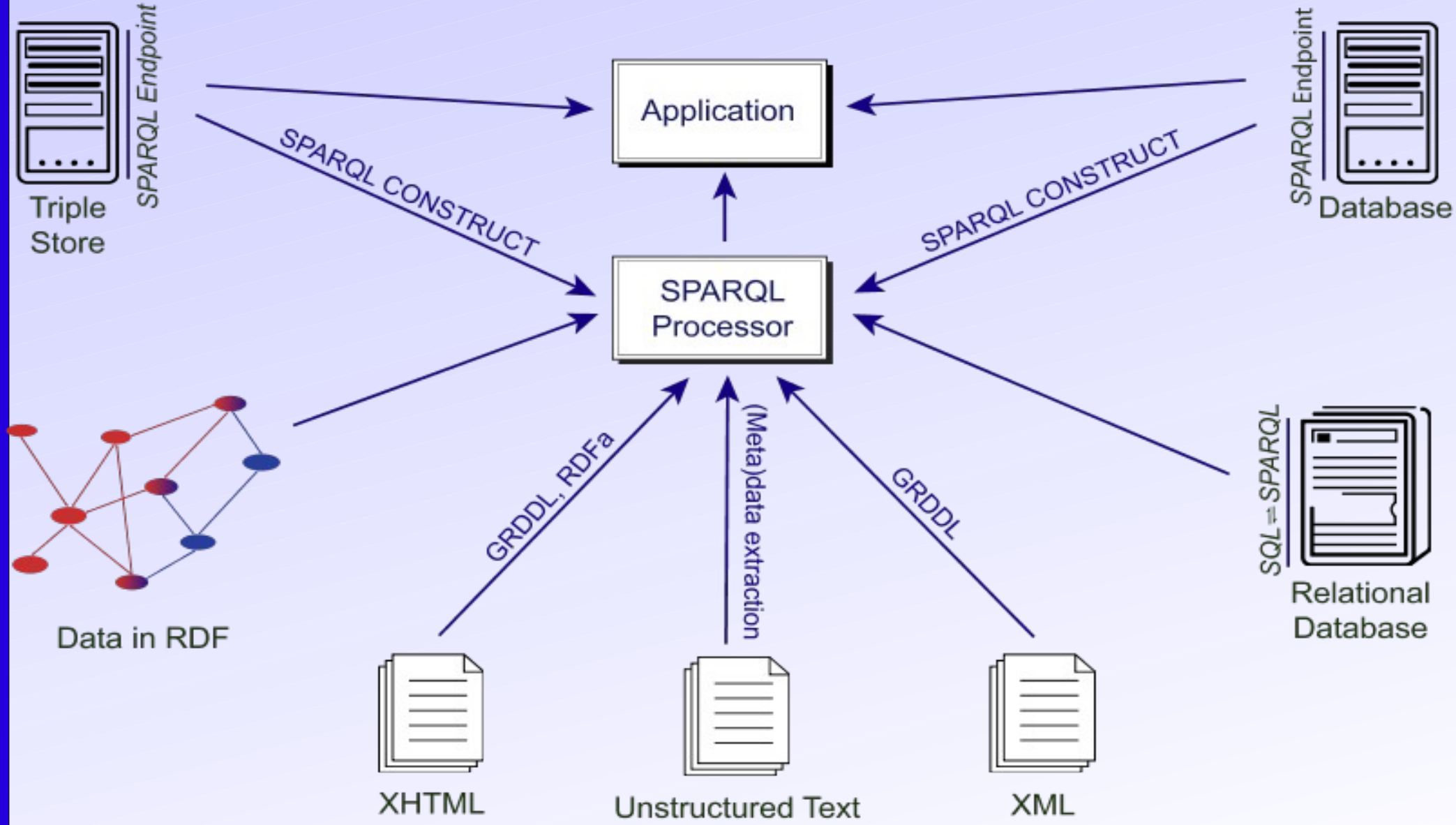
Other SPARQL features

- Limit the number of returned results; remove duplicates, sort them, …
- Optional branches in the query
- Specify several data sources (via URI-s) within the query (essentially, a merge!)
- *Construct* a graph combining a separate pattern and the query results
- Use datatypes and/or language tags when matching a pattern

SPARQL usage in practice

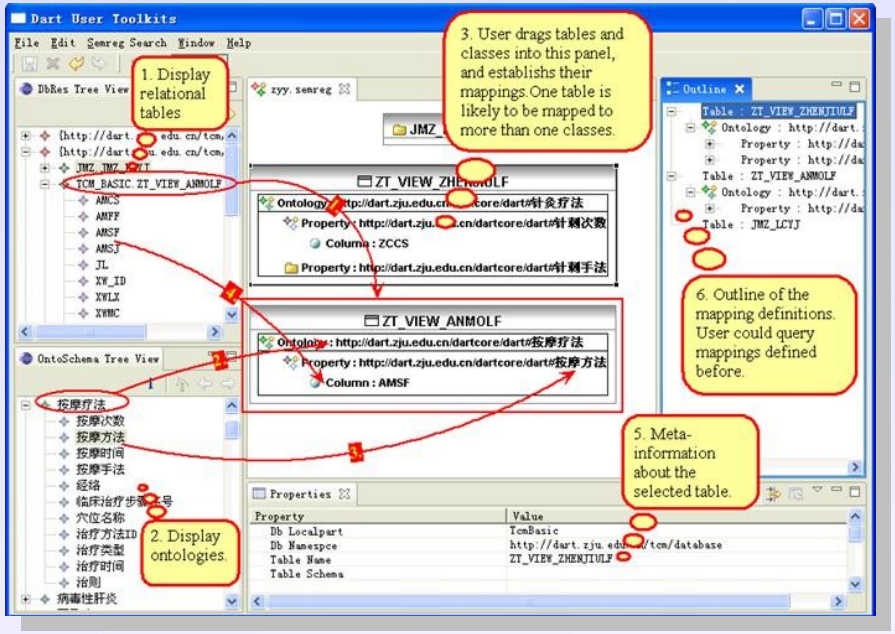
- SPARQL is usually used over the network
  - separate documents define the protocol and the result format
  - SPARQL Protocol for RDF with HTTP and SOAP bindings
  - SPARQL results in XML or JSON formats
- Big datasets usually offer “SPARQL endpoints” using this protocol
  - typical example: SPARQL endpoint to DBpedia

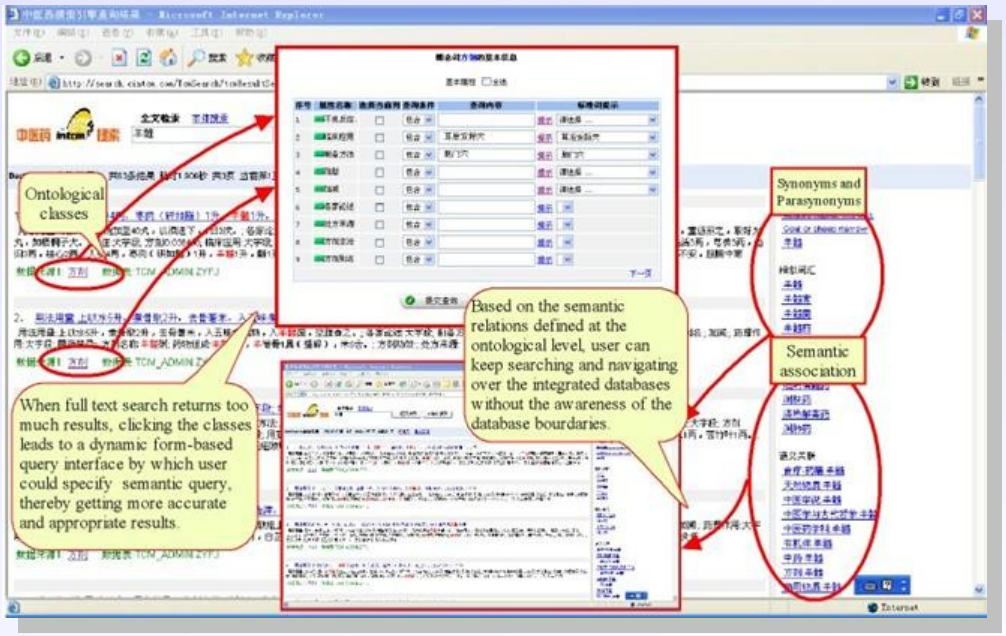
SPARQL as a unifying point



Remember this example?

- The access to all the data is based on SPARQL queries





Courtesy of Huajun Chen, Zhejiang University, (SWEO Case Study)

Ontologies
(OWL)

Ontologies

- RDFS is useful, but does not solve all possible requirements
- Complex applications may want more possibilities:
  - characterization of properties
  - identification of objects with different URI-s
  - disjointness or equivalence of classes
  - construct classes, not only name them
  - can a program reason about some terms? E.g.:
    - “if «Person» resources «A» and «B» have the same «`foaf:email`» property, then «A» and «B» are identical”
  - etc.

Ontologies (cont.)

- The term *ontologies* is used in this respect:

"defines the concepts and relationships used to describe and represent an area of knowledge"

- RDFS can be considered as a simple ontology language
- Languages should be a compromise between
  - rich semantics for meaningful applications
  - feasibility, implementability

Web Ontology Language = OWL

- OWL is an extra layer, a bit like RDF Schemas
  - own namespace, own terms
  - it relies on RDF Schemas
- It is a separate recommendation
  - actually… there is a 2004 version of OWL (“OWL 1”)
  - and there is an update (“OWL 2”) to be published in 2009

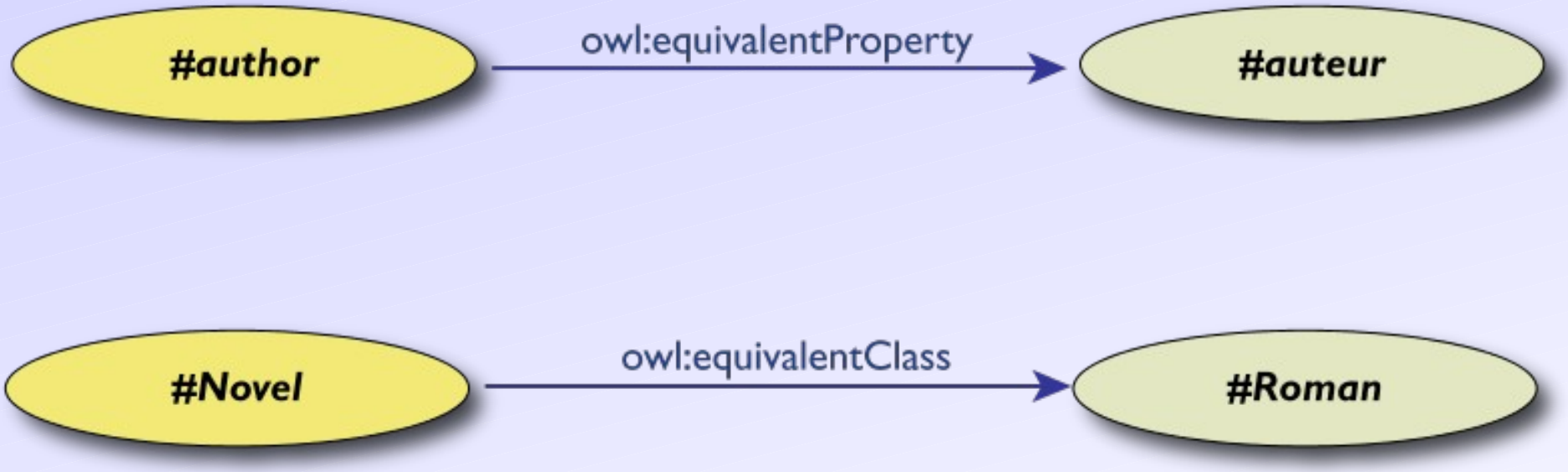
OWL is complex…

- OWL is a large set of additional terms
- We will not cover the whole thing here…

Term equivalences

- For classes:
  - **owl:equivalentClass**: two classes have the *same* individuals
  - **owl:disjointWith**: no individuals in common
- For properties:
  - **owl:equivalentProperty**
    - remember the **a:author** vs. **f:auteur**
  - **owl:propertyDisjointWith**
- For individuals:
  - **owl:sameAs**: two URIs refer to the same concept ("individual")
  - **owl:differentFrom**: negation of **owl:sameAs**

Connecting to French…



Typical usage of owl:sameAs

- Linking our example of Amsterdam from one data set (DBpedia) to the other (Geonames):

```
<http://dbpedia.org/resource/Amsterdam>
  owl:sameAs <http://sws.geonames.org/2759793>;
```

- This is the main mechanism of “Linking” in the Linking Open Data project

Property characterization

- In OWL, one can characterize the behaviour of properties (symmetric, transitive, functional, inverse functional…)
- One property may be the inverse of another
- OWL also separates *data* and *object* properties
  - “datatype property” means that its range are typed literals

What this means is…

- If the following holds in our triples:

```
:email rdf:type owl:InverseFunctionalProperty.
<A> :email "mailto:a@b.c".
<B> :email "mailto:a@b.c".
```

then, processed through OWL, the following holds, too:

```
<A> owl:sameAs <B>.
```

- I.e., *new relationships* were discovered again (beyond what RDFS could do)

Property chains (OWL 2)

- Properties, when applied one after the other, may be subsumed by yet another one:
  - "if a person «P» was born in city «A» and «A» is in country «B» then «P» was born in country «B»"
  - more formally:

```
ex:born_in_country owl:propertyChainAxiom
            (ex:born_in_city ex:city_in_country).
```

- More than two constituents can be used
- There are some restrictions to avoid "circular" specifications

Keys (OWL 2)

- Inverse functional properties are important for identification of individuals
  - think of the email examples
- But… identification based on *one* property may not be enough

Keys (OWL 2)

"if two persons have the same emails *and* the same homepages then they are identical"

- Identification is based on the identical values of *two* properties
- The rule applies to persons only

Previous rule in OWL 2

```
:Person rdf:type owl:Class;
   owl:hasKey (:email :homepage) .
```

What it means is…

If:

```
<A> rdf:type :Person ;
    :email    "mailto:a@b.c";
    :homepage "http://www.ex.org".

<B> rdf:type :Person ;
    :email    "mailto:a@b.c";
    :homepage "http://www.ex.org".
```

then, processed through OWL 2, the following holds, too:

```
<A> owl:sameAs <B>.
```

Classes in OWL

- In RDFS, you can subclass existing classes… that's all
- In OWL, you can *construct* classes from existing ones:
  - enumerate its content
  - through intersection, union, complement
  - Etc

Classes in OWL (cont)

- OWL makes a stronger conceptual distinction between *classes* and *individuals*
  - there is a separate term for **`owl:Class`**, to make the difference (a specialization of the RDFS class)
  - individuals are separated into a special class called **`owl:Thing`**
- Eg, a precise classification would be:

```
ex:Person rdf:type owl:Class.

<uri-for-Amitav-Ghosh>
    rdf:type owl:Thing;
    rdf:type owl:Person .
```

Classes contents can be enumerated

```
:£ rdf:type owl:Thing.
:€ rdf:type owl:Thing.
:¥ rdf:type owl:Thing.
:Currency
    rdf:type owl:Class;
    owl:oneOf (:€ :£ :¥).
```

- I.e., the class consists of *exactly* of those individuals

Union of classes can be defined

```
:Novel              rdf:type owl:Class.
:Short_Story        rdf:type owl:Class.
:Poetry             rdf:type owl:Class.
:Literature rdf:type owl:Class;
   owl:unionOf (:Novel :Short_Story :Poetry).
```

- Other possibilities: **`complementOf`**, **`intersectionOf`**, …

For example…

If:

```
:Novel            rdf:type owl:Class.
:Short_Story      rdf:type owl:Class.
:Poetry           rdf:type owl:Class.
:Literature rdf:type owl:Class;
   owl:unionOf (:Novel :Short_Story :Poetry).

<myWork> rdf:type :Novel .
```

then the following holds, too:

```
<myWork> rdf:type :Literature .
```

It can be a bit more complicated…

If:

```
:Novel              rdf:type owl:Class.
:Short_Story        rdf:type owl:Class.
:Poetry             rdf:type owl:Class.
:Literature rdf:type owlClass;
   owl:unionOf (:Novel :Short_Story :Poetry).

fr:Roman owl:equivalentClass :Novel .

<myWork> rdf:type fr:Roman .
```

then, through the *combination* of different terms, the following still holds:

```
<myWork> rdf:type :Literature .
```

What we have so far…

- The OWL features listed so far are already fairly powerful
- E.g., various databases can be linked via **`owl:sameAs`**, functional or inverse functional properties, etc.
- Many inferred relationship can be found using a traditional rule engine

However… that may not be enough

- Very large vocabularies might require even more complex features
  - typical usage example: definition of all concepts in a health care environment
  - a major issue: the way classes (i.e., “concepts”) are defined
- OWL includes those extra features but… the inference engines become (much) more complex 

Property value restrictions

- Classes are created by *restricting* the property values on its individuals
- For example: how would I characterize a “listed price”?
  - it is a price (which may be a general term), but one that is given in one of the “allowed” currencies (say, €, £, or ¥)
  - more formally:
    - the value of “`p:currency`”, when applied to a resource on listed price, *must* be of one of those values…
    - …thereby defining the class of “listed price”

Restrictions formally

- Defines a class of type **`owl:Restriction`** with a
  - reference to the property that is constrained
  - definition of the constraint itself
- One can, e.g., subclass from this node when defining a particular class

```
:Listed_Price rdfs:subClassOf [
      rdf:type              owl:Restriction;
      owl:onProperty        p:currency;
      owl:allValuesFrom     :Currency.
    ].
```

Possible usage…

If:

```
:Listed_Price rdfs:subClassOf [
      rdf:type              owl:Restriction;
      owl:onProperty        p:currency;
      owl:allValuesFrom     :Currency.
    ].

:price rdf:type :Listed_Price .

:price p:currency <something> .
```

then the following holds:

```
<something> rdf:type :Currency .
```

Other restrictions

- **`allValuesFrom`** could be replaced by:
  - **`someValuesFrom`**
    - e.g., I could have said: there should be a price given in *at least one* of those currencies
  - **`hasValue`**, when restricted to *one specific value*
- Cardinality restrictions: instead of looking at the values of properties, their number is considered
  - eg, a specific property should occur exactly once

Datatypes in OWL

- RDF Literals can have a datatypes, OWL adopts those
- But more complex vocabularies require datatypes "restrictions"; eg, numeric intervals
  - "I am interested in a price range between €5 and €15"
- RDF allows any URI to be used as datatypes
  - ie, one could use XML Schemas to define, eg, numeric intervals
  - but it is very complex, and reasoners would have to understand a whole different syntax

Datatype restrictions (OWL 2)

- For each datatype, XML Schema defines possible restriction “facets”: min and max for numeric types, length for strings, etc
- OWL uses these facets to define *datatype ranges* for its own use

Definition of a numeric interval in OWL 2

```
:AllowedPrice rdf:type rdfs:Datatype;
    owl:onDatatype xsd:float;
    owl:withRestriction (
        [ xsd:minInclusive 5.0 ]
        [ xsd:maxExclusive 15.0 ]
    ) .
```

- The possible facets depend on the datatype: **`xsd:pattern`**, **`xsd:length`**, **`xsd:maxLength`**, ...

Typical usage of OWL 2 datatype restrictions

```
:Affordable_book rdf:type owl:Class;
    rdfs:subClassOf [
      rdf:type                    owl:Restriction;
      owl:onProperty              p:price_value;
      owl:allValuesFrom [
           rdf:type rdfs:Datatype;
           owl:onDatatype xsd:float;
           owl:withRestriction (
                [ xsd:minInclusive 5.0 ]
                [ xsd:maxExclusive 15.0 ]
           )
      ]
   ].
```

ie: an affordable book has a price between 5.0 and 15.0

But: OWL is hard!

- The combination of class constructions with various restrictions is extremely powerful
- What we have so far follows the same logic as before
  - extend the basic RDF and RDFS possibilities with new features
  - define their semantics, ie, what they "mean" in terms of relationships
  - expect to infer new relationships based on those
- However… a full inference procedure is hard
  - not implementable with simple rule engines, for example

OWL "species"

- OWL species comes to the fore:
  - restricting *which* terms can be used and *under what circumstances (restrictions)*
  - if one abides to those restrictions, then simpler inference engines can be used
- They reflect compromises: expressibility vs. implementability

Unrestricted OWL (a.k.a. "OWL Full")

- No constraints on any of the constructs
  - **`owl:Class`** is just syntactic sugar for **`rdfs:Class`**
  - **`owl:Thing`** is equivalent to **`rdfs:Resource`**
  - this means that:
    - Class can also be an individual, a URI can denote a property as well as a Class
      - e.g., it is possible to talk about class of classes, apply properties on them
      - etc
  - etc.
- Extension of RDFS in all respects
- But: no system may exist that infers everything one might expect

OWL Full usage

- Nevertheless OWL Full is essential
  - it gives a generic framework to *express* many things with precise semantics
  - some application actually just need to express and interchange terms (even with possible scruffiness)
- Applications may control what terms are used and how
  - in fact, they may define their own sub-language via, eg, a vocabulary
    - thereby ensuring a manageable inference procedure

OWL DL

- A number of restrictions are defined
  - classes, individuals, object and datatype properties, etc, are fairly strictly separated
  - object properties must be used with individuals
    - i.e., properties are really used to create relationships *between individuals*
  - no characterization of *datatype* properties
  - …
- But: *well known inference algorithms exist!*

Examples for restrictions

- The following is not “legal” OWL DL:

```
<q> rdf:type <A>.          # A is a class, q is an individual

<r> rdf:type <q>.          # error: q cannot be used for a class, too

<A> ex:something <B>.      # error: properties are for individuals only

<q> ex:something <s>.      # error: same property cannot be used as
<p> ex:something “54”.     #   object and datatype property
```

OWL DL usage

- Abiding to the restrictions means that very large ontologies can be developed that require precise procedures
  - eg, in the medical domain, biological research, energy industry, financial services (eg, XBRL), etc
  - the number of classes and properties described this way can go up to the many thousands
- OWL DL has become a language of choice to define and manage formal ontologies in general
  - even if their usage is not necessarily on the Web

OWL 2 defines further species a.k.a. "profiles"

- Further restrictions on how terms can be used and what inferences can be expected

OWL 2 profiles: EL

- Goal: classification and instance queries in polynomial time
- Suitable for
  - very large number of classes and/or properties
  - not require complex expressions
    - eg: SNOMED
- Some excluded features
  - no cardinality restrictions, fewer property restrictions
  - no inverse, reflexive, disjoint, symmetric, asymmetric, functional or inverse functional properties
  - class disjunction
  - …

OWL 2 profiles: QL

- Goal: conjunctive queries on top of relational databases (essentially: query rewriting to SQL)
- Suitable for
  - lightweight ontologies, but large data
- Some excluded features
  - functional and inverse functional properties, sameAs, keys
  - fewer property restrictions
  - no cardinality restrictions
  - transitive properties, property chains
  - …

OWL 2 profiles: RL

- Goal: polynomial reasoning on top of rule engines
- Suitable for
  - relatively lightweight ontologies, but large data
- Some excluded features
  - fewer property restrictions
  - fewer cardinality restrictions (at most 0/1)
  - constraints on class expressions (union, intersections, etc) when used in subclass expressions
  - no datatype restrictions
  - …

Ontology development

- The hard work is to *create* the ontologies
  - requires a good knowledge of the area to be described
  - some communities have good expertise already (e.g., librarians)
  - *OWL is just a tool to formalize ontologies*
  - large scale ontologies are often developed in a community process
- Ontologies should be *shared* and *reused*
  - can be via the simple namespace mechanisms…
  - …or via explicit import

***Must* I use large ontologies?**

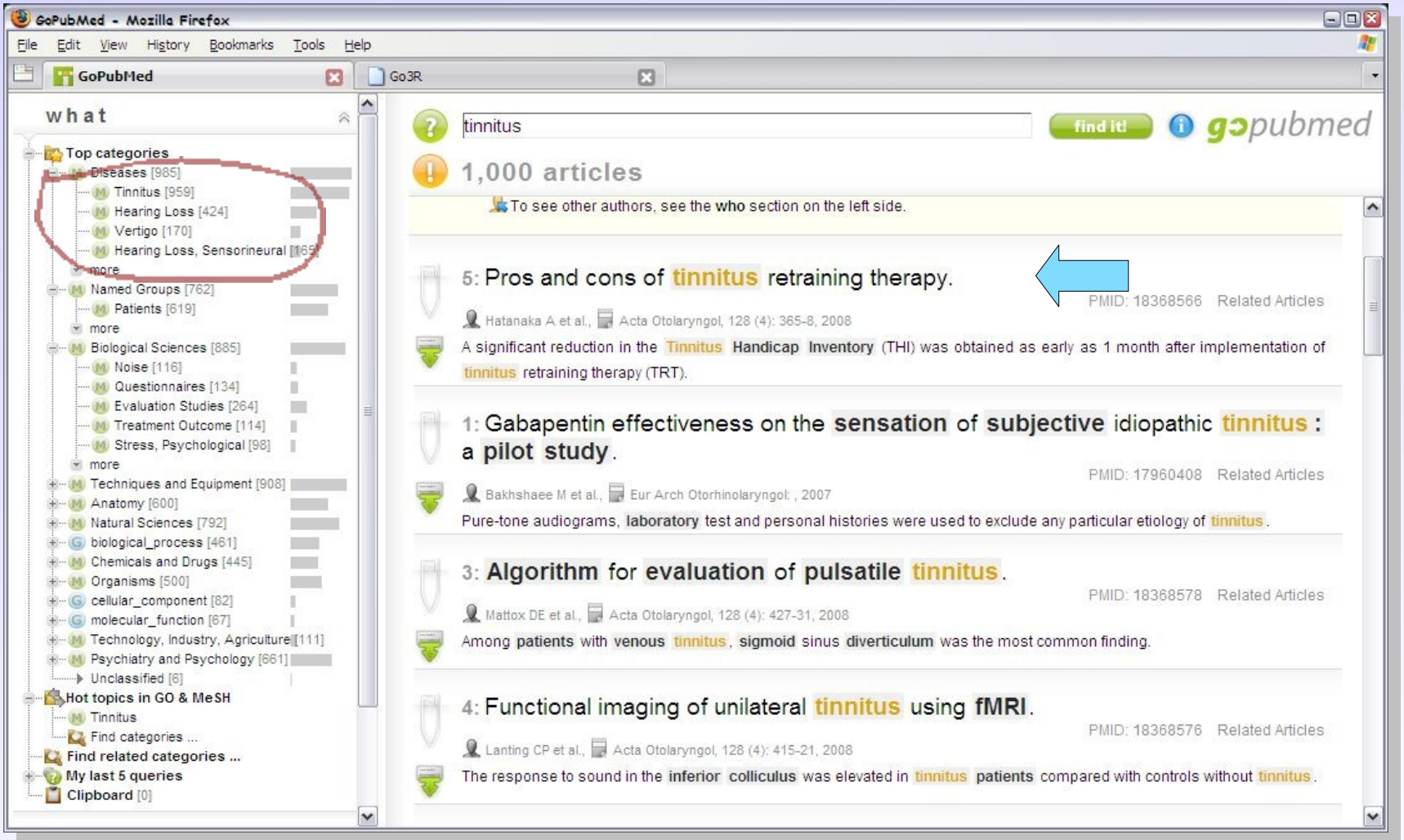
- NO!!!
- Many applications are possible with RDFS and a just a little bit of OWL
  - a few terms, whose meaning is defined in OWL, and that application can handle directly
  - OWL RL is a step to create such a generic OWL level
- Big ontologies can be expensive (both in time and money); use them only when really necessary!

Ontologies examples

- eClassOwl: eBusiness ontology for products and services, 75,000 classes and 5,500 properties
- National Cancer Institute's ontology: about 58,000 classes
- Open Biomedical Ontologies Foundry: a collection of ontologies, including the Gene Ontology to describe gene and gene product attributes in any organism or protein sequence and annotation terminology and data (UniProt)
- BioPAX: for biological pathway data

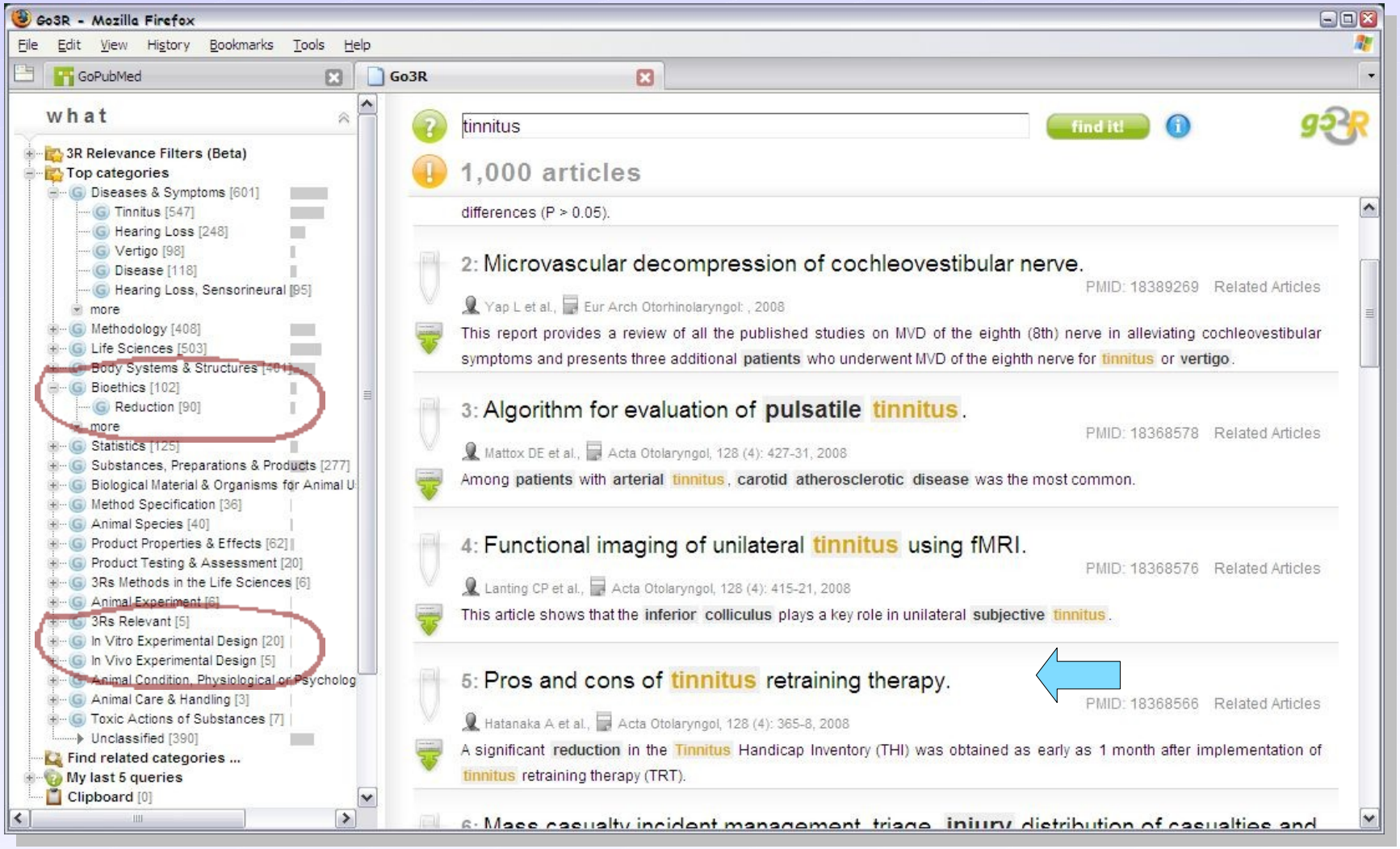
Example: improved search via ontology

- Search results are re-ranked using ontologies
- Related terms are highlighted, usable for further search



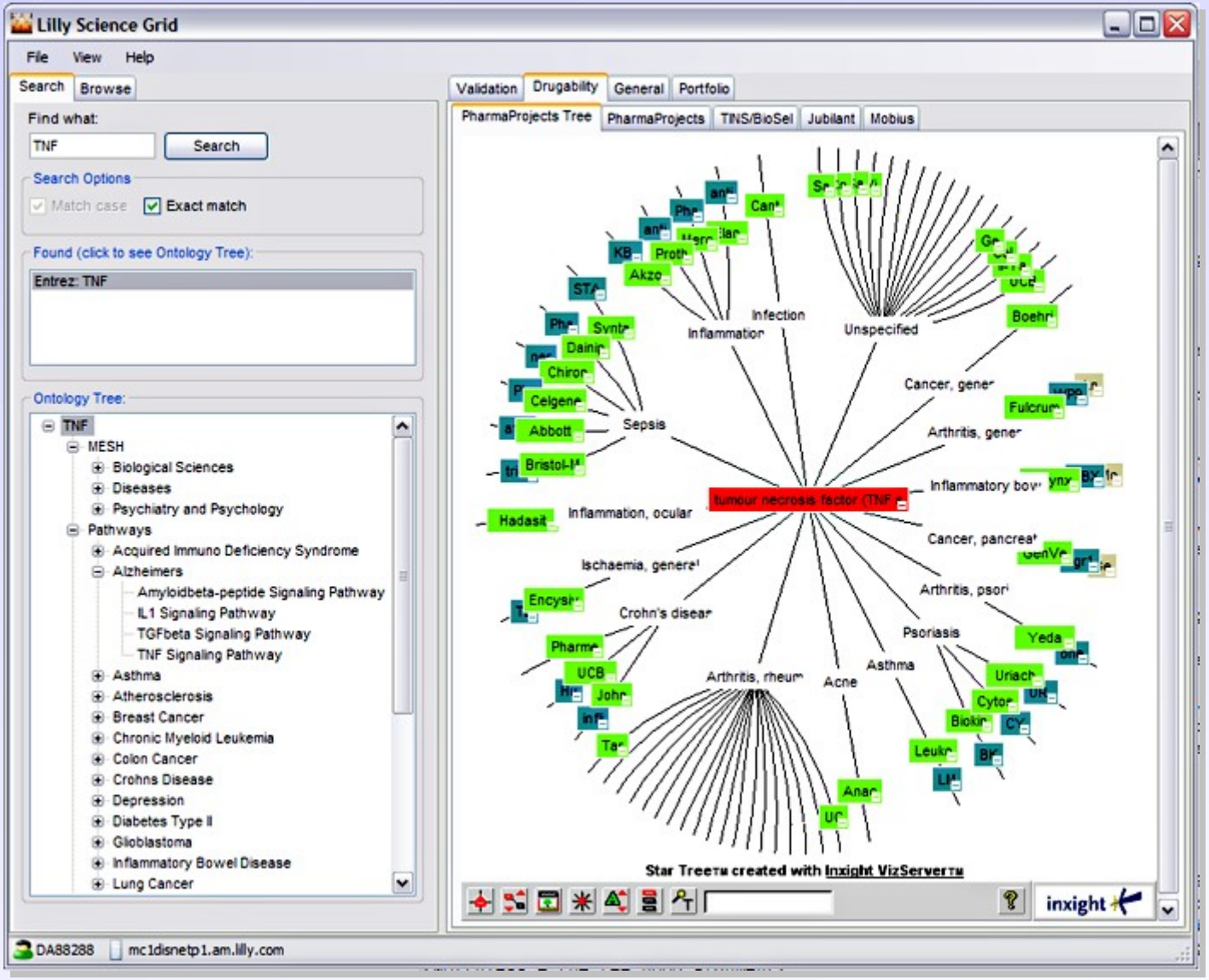
Example: improved search via ontology

- Same dataset, different ontology
  - (ontology is on non-animal experimentation)



Eli Lilly's Target Assessment Tool

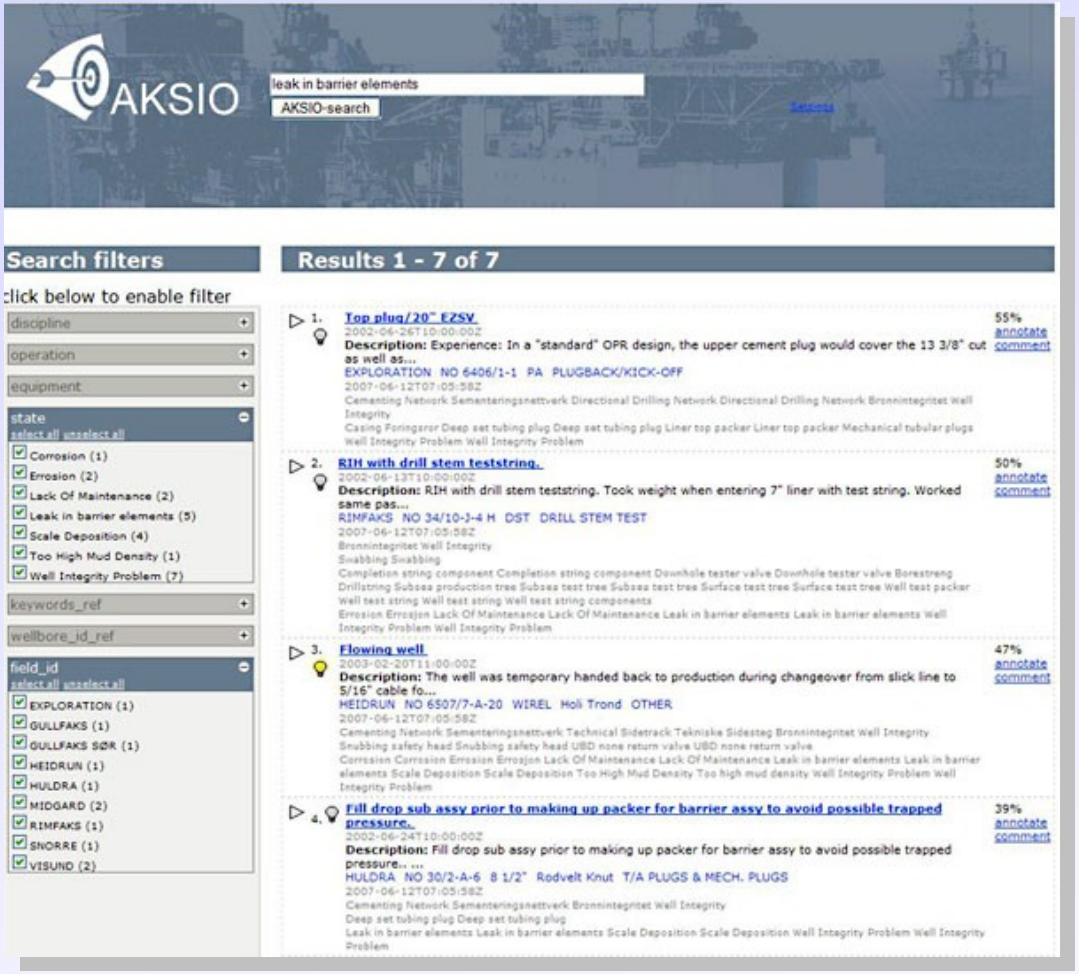
- Prioritization of drug target, integrating data from different sources and formats
- Integration, search via ontologies (proprietary and public)



Courtesy of Susie Stephens, Eli Lilly (SWEO Case Study)

Help for deep sea drilling operations

- Integration of experience and data in the planning of deep sea drilling processes
- Discover relevant experiences
  - uses an ontology backed search engine



Courtesy of David Norheim and Roar Fjellheim, Computas AS (SWEO Use Case)

Rules
(RIF)

Rules

- There is a long history of rule languages and rule-based systems
  - eg: logic programming (Prolog), production rules
- Lots of small and large rule systems (from mail filters to expert systems)
- Hundreds of niche markets

Why rules on the Semantic Web?

- There are conditions that ontologies (ie, OWL) cannot express
  - a well known example is Horn rules: (P1 ∧ P2 ∧ …) → C
    - (though OWL 2 property chains cover *some* cases)
- A different way of thinking — people may feel more familiar in one or the other

Things you may want to express

- An example from our bookshop integration:
  - "a novel with over 500 pages and costing less than €5 is a cheap book"
  - something like (in an ad-hoc syntax):

```
If { ?x rdf:type p:Novel;
        p:page_number ?p;
        p:price [
            p:currency p:€;
            rdf:value  ?z
        ].
      ?p > "500"^^xsd:integer.
      ?z < "5.0"^^xsd:double. }
then { ?x rdf:type p:CheapBook }
```

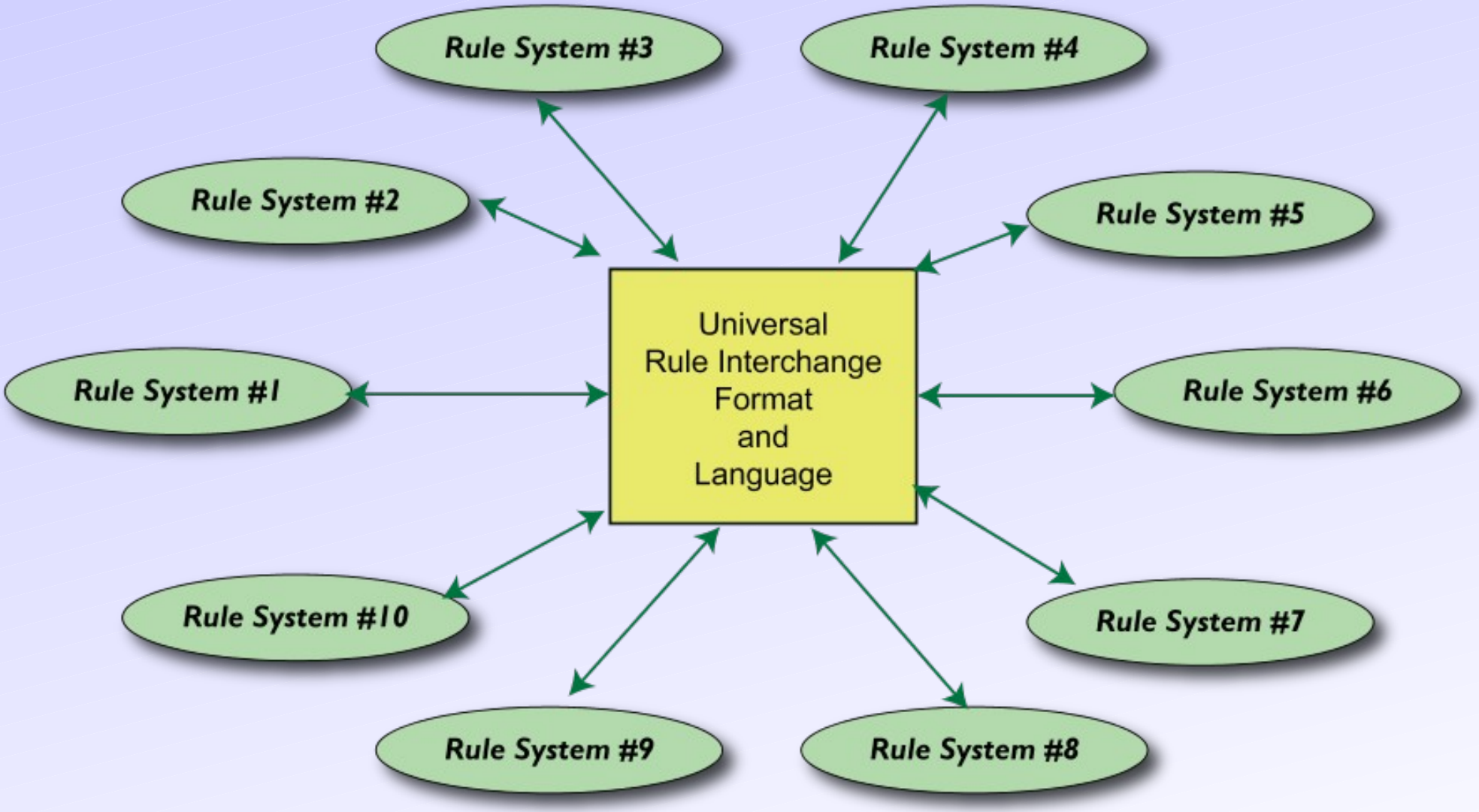
A new requirement: exchange of rules

- Applications may want to exchange their rules:
  - negotiate eBusiness contracts across platforms: supply vendor-neutral representation of your business rules so that others may find you
  - describe privacy requirements and policies, and let clients "merge" those (e.g., when paying with a credit card)
- Hence the name of the working group: *Rule Interchange Format*
  - goal is a language that
    - expresses the rules a bit like a rule language
    - can be used to exchange rules among engines

Notes on RIF (cont)

- RIF does not concentrate on RDF only
  - ie, certain constructions go beyond what RDF can express
- But there is a “subset” that is RDF and also OWL related
- For the coming few slides, forget about RDF 
  - we will come back to it. Promise!

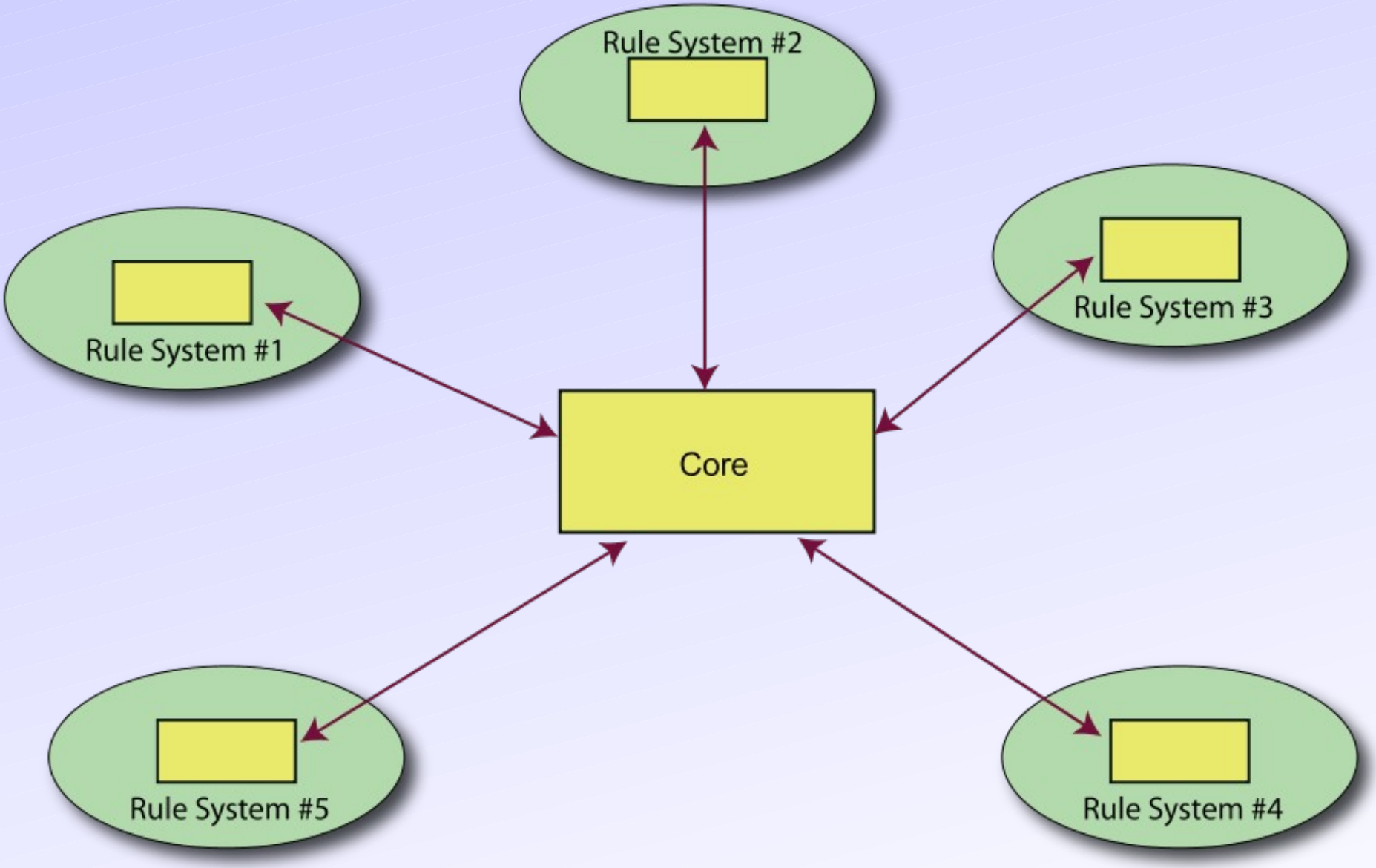
In an ideal World



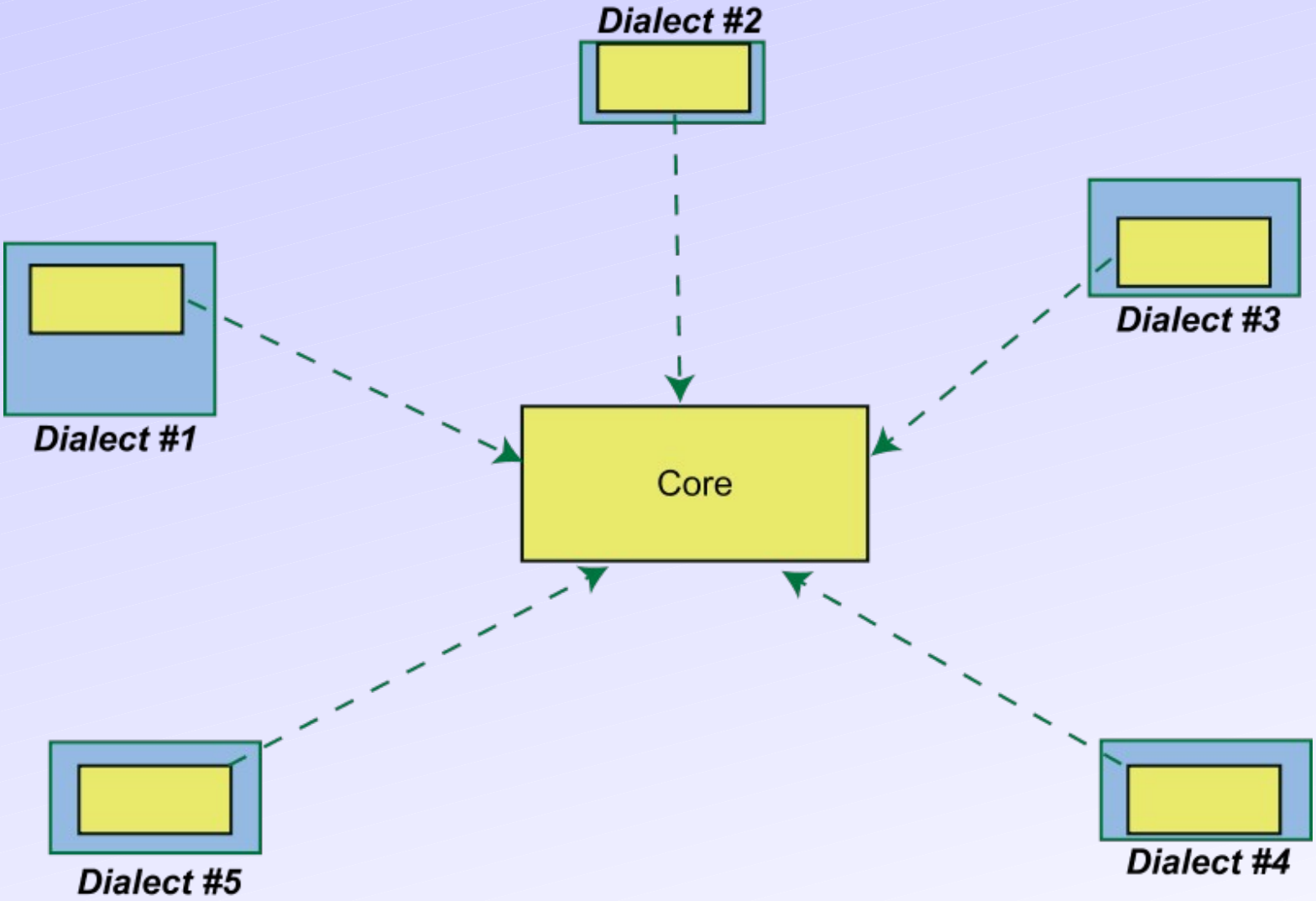
In the real World…

- Rule based systems can be very different
  - different rule semantics (based on various type of model theories, on proof systems, etc)
  - production rule systems, with procedural references, state transitions, etc
- Such universal exchange format is not feasible
- The idea is to define “cores” for a family of languages with “variants”

RIF “core”: only partial interchange

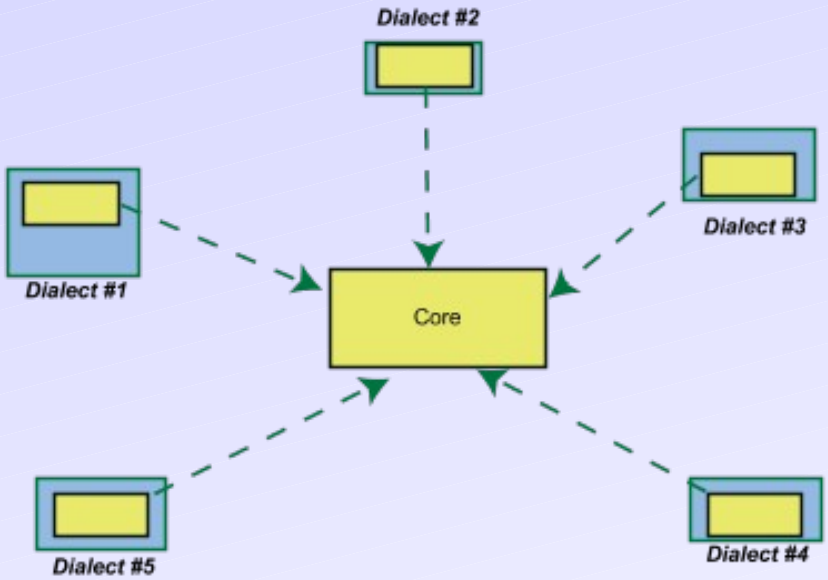


RIF "dialects"

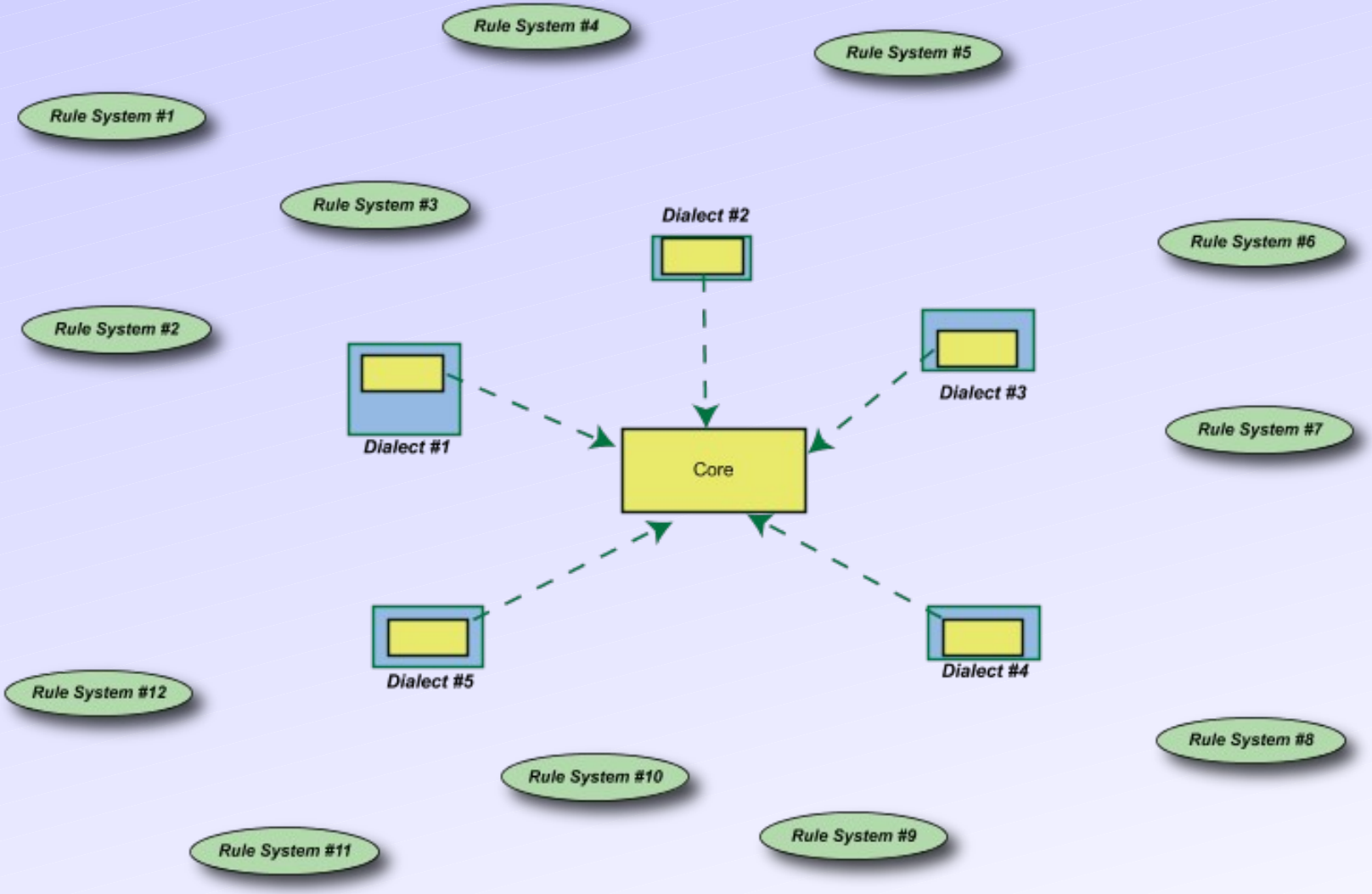


- Possible dialects: F-logic, production rules, fuzzy or probabilistic logic, …

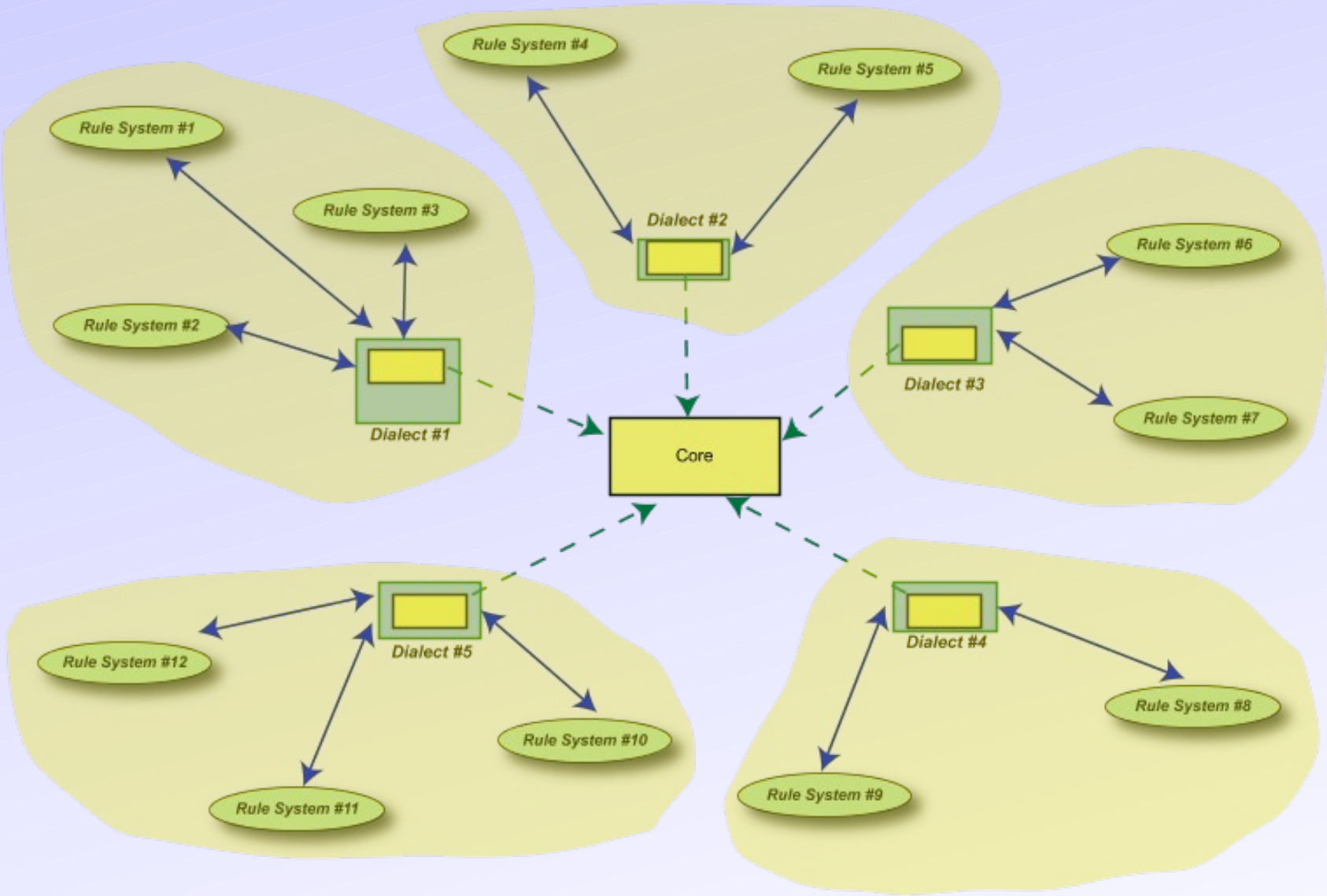
Role of dialects



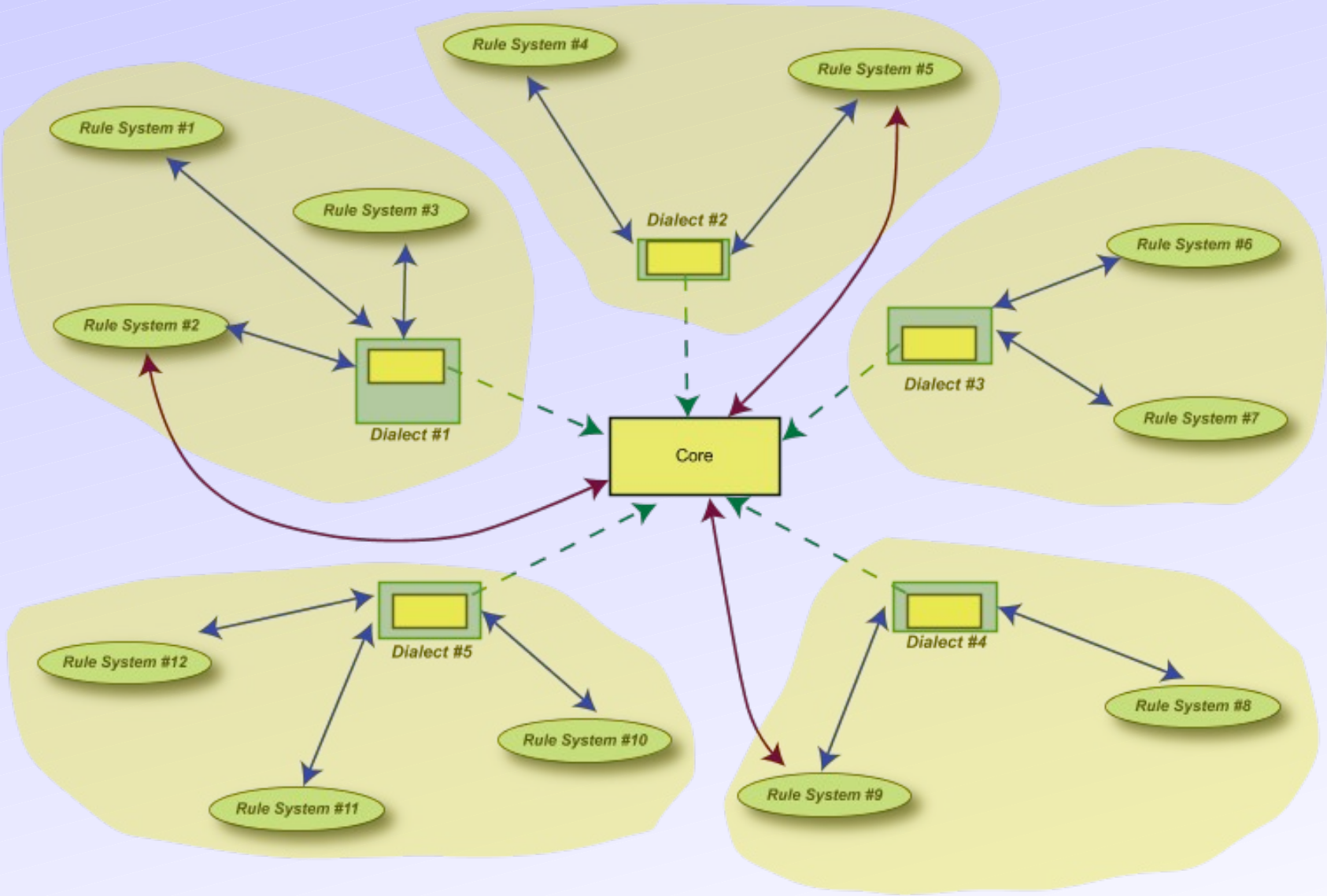
Role of dialects



Role of dialects



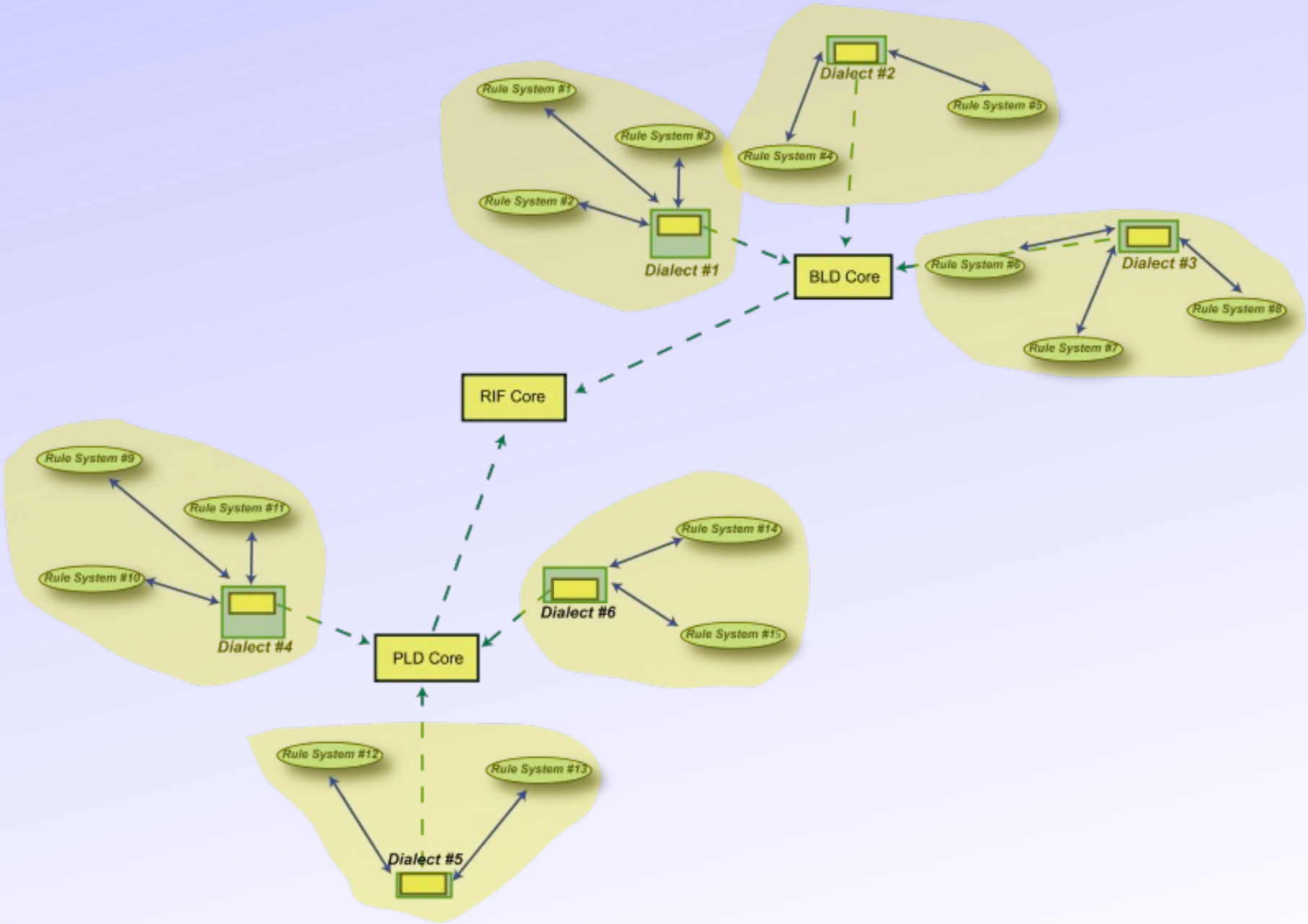
Role of dialects



However…

- Even this model does not completely work
- The gap between production rules and “traditional” logic systems is too large
- A hierarchy of cores is necessary:
  - a *Basic Logic Dialect* and *Production Rule Dialect* as “cores” for families of languages
  - a common *RIF Core* binding these two

Hierarchy of cores



Current status

- Candidate Recommendation published in October 2009
  - what this means: technical work is done, cross-checked against implementations

RIF Core

- Core defines
  - a “presentation syntax”, which is really to… present the constructions (is not necessarily implemented in tools)
  - a formal XML syntax to encode and exchange the rules
- A Core document is
  - some directives like import, prefix settings for URI-s, etc
  - a sequence of implications, possibly involving built-in predicates on datatypes

RIF Core example

```
Document(
  Prefix(cpt http://example.com/concepts#)
  Prefix(ppl http://example.com/people#)
  Prefix(bks http://example.com/books#)

  Group
  (
    Forall ?Buyer ?Item ?Seller (
        cpt:buy(?Buyer ?Item ?Seller):- cpt:sell(?Seller ?Item ?Buyer)
    )
    cpt:sell(ppl:John bks:LeRif ppl:Mary)
  )
)
```

infers the following relationship:

```
cpt:buy(ppl:Mary bks:LeRif ppl:John)
```

Additional RIF Core features

- RIF Core includes some extra features
  - built-in datatypes and predicates
  - notion of “local names”, a bit like RDF’s blank nodes
  - “classification”, like typing in RDFS and OWL
    - `p # T`

What about RDF(S), OWL, and RIF?

- Typical scenario: applications exchange rules that refer to RDF data
- To make that work:
  - RDF facts/triples have to be representable in Core
  - harmonization on the concepts is necessary
  - the formal semantics of the two worlds should also be aligned
- There is a separate document that brings these together

Rules vs OWL?

- In a SW application, should I use RIF, OWL, or both?
- The two approaches are complimentary
  - there are things that rules cannot really express or infer
    - eg, inferencing complex relationships among classes
  - there are things that ontologies cannot really express or in only a very complicated manner
    - eg, complex Horn rules
- Often, applications require both

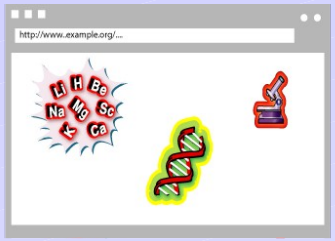
What have we achieved?

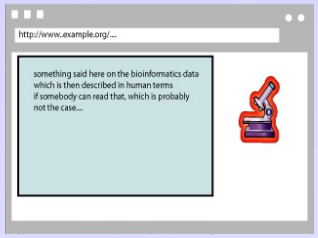
(putting all this together)

Other SW technologies

- There are other technologies that we do not have time for here
  - find RDF data associated with general URI-s: POWDER
  - bridge to thesauri, glossaries, etc: SKOS

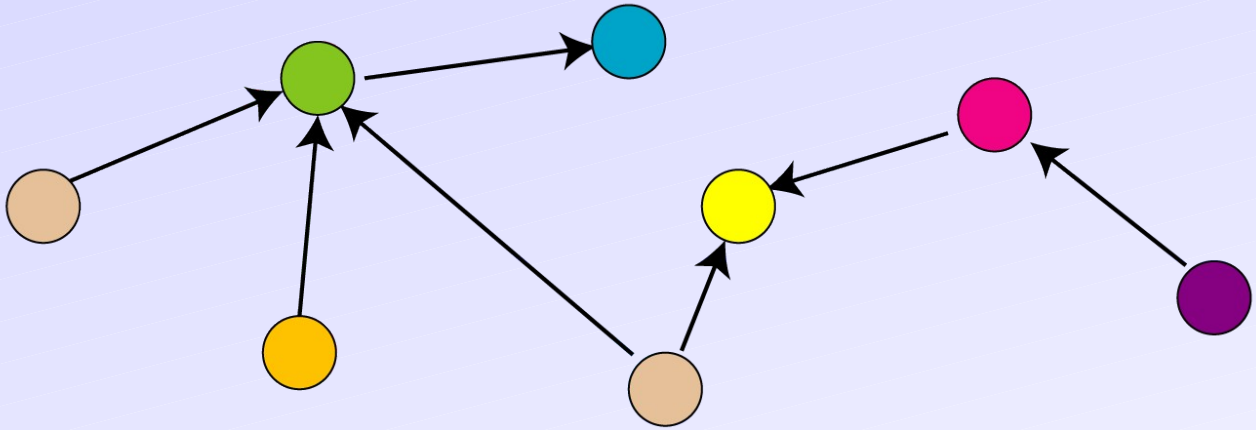
Remember the integration example?





Applications

Query, Manipulate, etc.



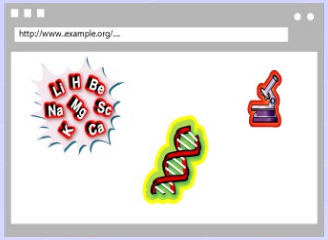
Data represented in abstract format

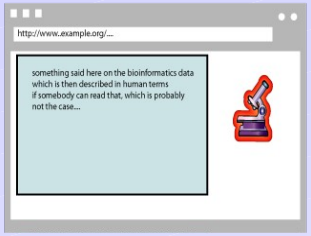
Map, Expose, etc.

Data in various formats

W3C Semantic Web

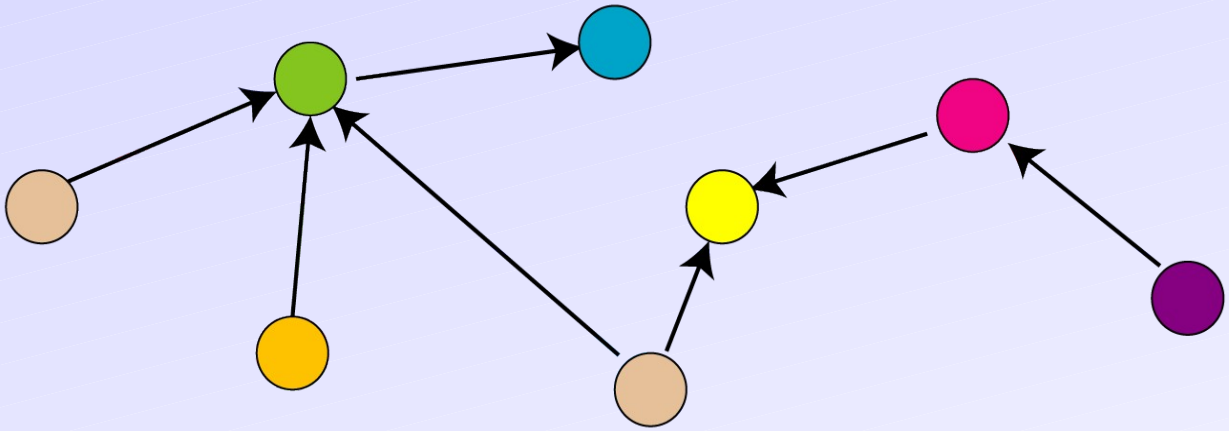
Same with what we learned





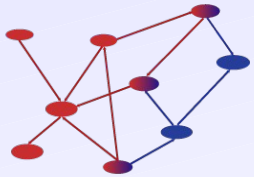
Applications

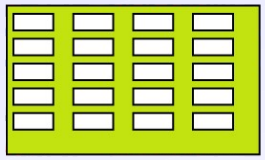
SPARQL,
OWL inferences,
etc.

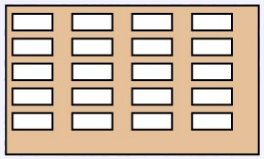


Data represented in RDF, possibly with extra knowledge (RDFS, OWL, SKOS, Rules, …)

SQL <=> RDF,
GRDDL, RDFa
etc.

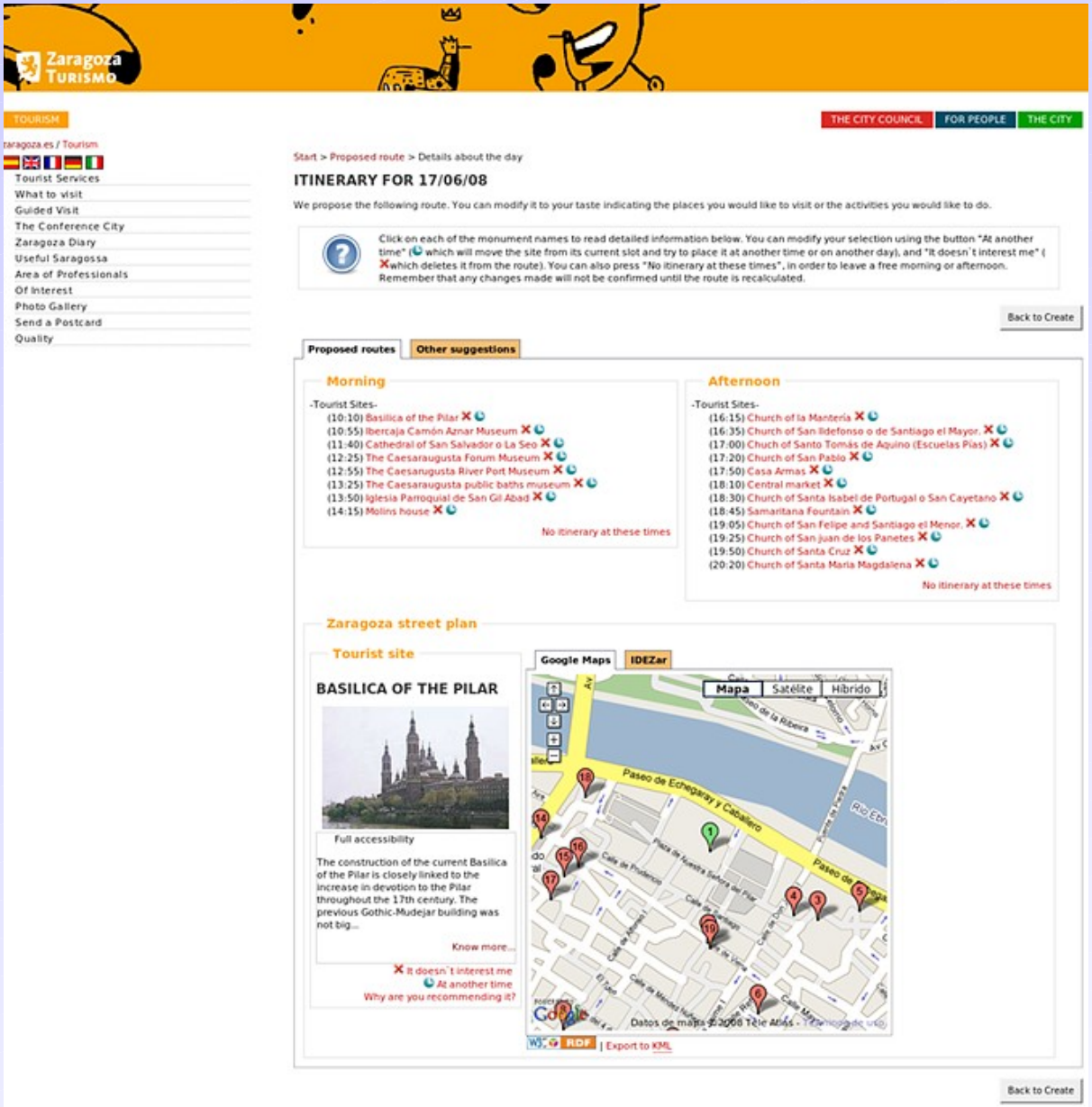






Data in various formats

Example: personalized tourist itinerary



Integration of relevant data in Zaragoza (using RDF and ontologies)

Use rules on the RDF data to provide a proper itinerary

Courtesy of Jesús Fernández, Mun. of Zaragoza, and Antonio Campos, CTIC (SWEO Use Case)

Available documents, resources

Available specifications: Primers, Guides

- The “RDF Primer” or “OWL 2 Primer” give a formal introduction to RDF(S) and OWL
- GRDDL and RDFa Primers have also been published
- The W3C Semantic Web Activity Homepage has links to all the specifications and guides:
  - http://www.w3.org/2001/sw/

"Core" vocabularies

- There are also a number widely used "core vocabularies"
  - Dublin Core: about information resources, digital libraries, with extensions for rights, permissions, digital right management
  - FOAF: about people and their organizations
  - DOAP: on the descriptions of software projects
  - SIOC: Semantically-Interlinked Online Communities
  - vCard in RDF
  - …
- One should never forget: ontologies/vocabularies must be shared and reused!

Some books

- J. Pollock: Semantic Web for Dummies, 2009
- G. Antoniu and F. van Harmelen: Semantic Web Primer, 2nd edition in 2008
- D. Allemang and J. Hendler: Semantic Web for the Working Ontologist, 2008
- P. Hitzler, R. Sebastian, M. Krötzsch: Foundation of Semantic Web Technologies, 2009
- …

See the separate Wiki page collecting book references: http://esw.w3.org/topic/SwBooks

Further information and Fora

- Planet RDF aggregates a number of SW blogs:
  - http://planetrdf.com/
- Semantic Web Interest Group
  - a forum developers with archived (and public) mailing list, and a constant IRC presence on freenode.net#swig
    - anybody can sign up on the list:
      - http://www.w3.org/2001/sw/interest/
  - there are also similar list for Linked Open Data, OWL developers, etc
    - contact me for details if you cannot find them

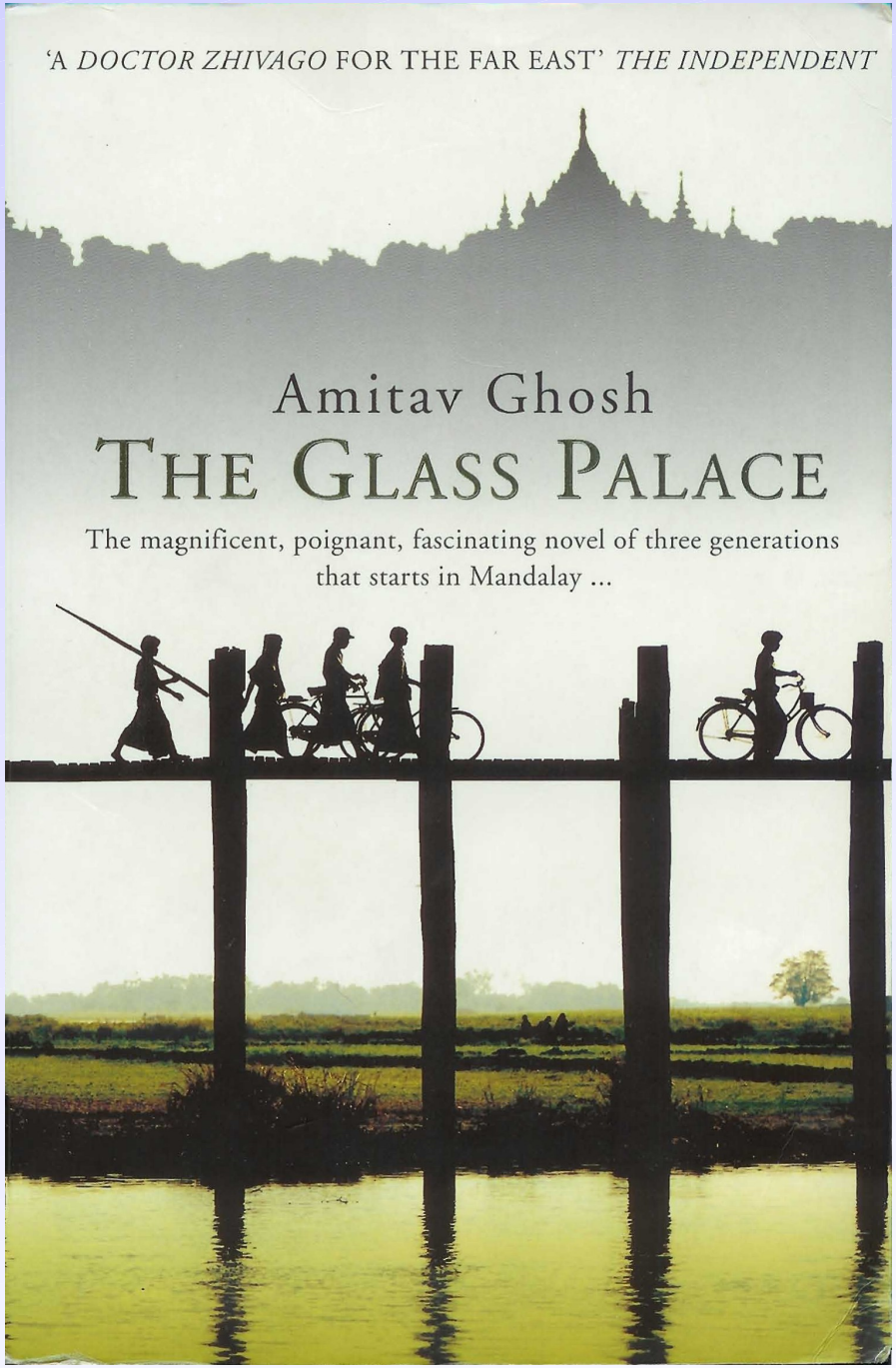
Lots of Tools (not an exhaustive list!)

- Categories:
  - Triple Stores
  - Inference engines
  - Converters
  - Search engines
  - Middleware
  - CMS
  - Semantic Web browsers
  - Development environments
  - Semantic Wikis
  - …
- Some names:
  - Jena, AllegroGraph, Mulgara, Sesame, flickurl, …
  - TopBraid Suite, Virtuoso environment, Falcon, Drupal 7, Redland, Pellet, …
  - Disco, Oracle 11g, RacerPro, IODT, Ontobroker, OWLIM, Tallis Platform, …
  - RDF Gateway, RDFLib, Open Anzo, DartGrid, Zitgist, Ontotext, Protégé, …
  - Thetus publisher, SemanticWorks, SWI-Prolog, RDFStore…
  - …

Conclusions

- The Semantic Web is about creating a Web of Data
- There is a great and very active user and developer community, with new applications

By the way: the book is real



Thank you for your attention!

These slides are also available on the Web:

http://www.w3.org/2009/Talks/1030-Philadelphia-IH/