Semantic Web and Image Information Mining

Jose Emilio Labra Gayo
University of Oviedo, Spain
http://www.di.uniovi.es/~labra

The current Web

Current Web = the biggest repository of information ever compiled by Humanity

- Designed for direct human consumption
- Lots of information available in:
  - Natural Language in HTML
    - English, Spanish, Chinese, Italian, etc.
  - More and More multimedia
    - Images, audio, video, etc.

Too much data, not enough knowledge

Multimedia on the Web

- Large collections of multimedia assets
  - Data integration problem
  - Most of them driven by stand-alone databases
  - Data isolated syntactically and semantically
  - Need for Interoperability
    - Syntactic level
    - Semantic level

Syntactic Interoperability

- Data formats that we can share
  - XML technologies
- Web Services and mashups

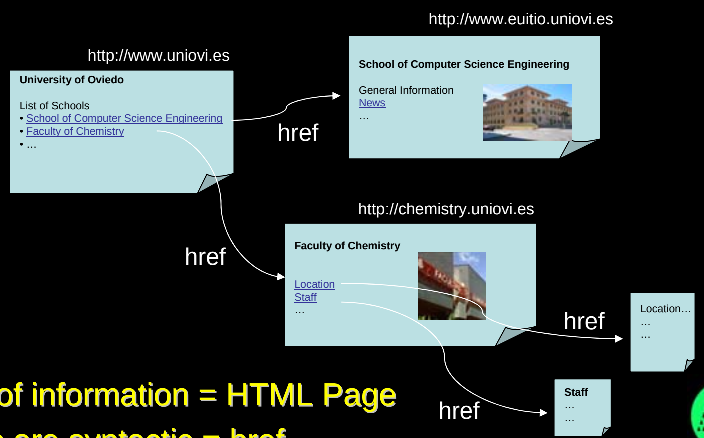
Levels of Interoperability

Semantic interoperability

- Share meaning / Concepts
- Finding and representing semantic links
- Standard ways to provide meta-data
- Automatically process the content

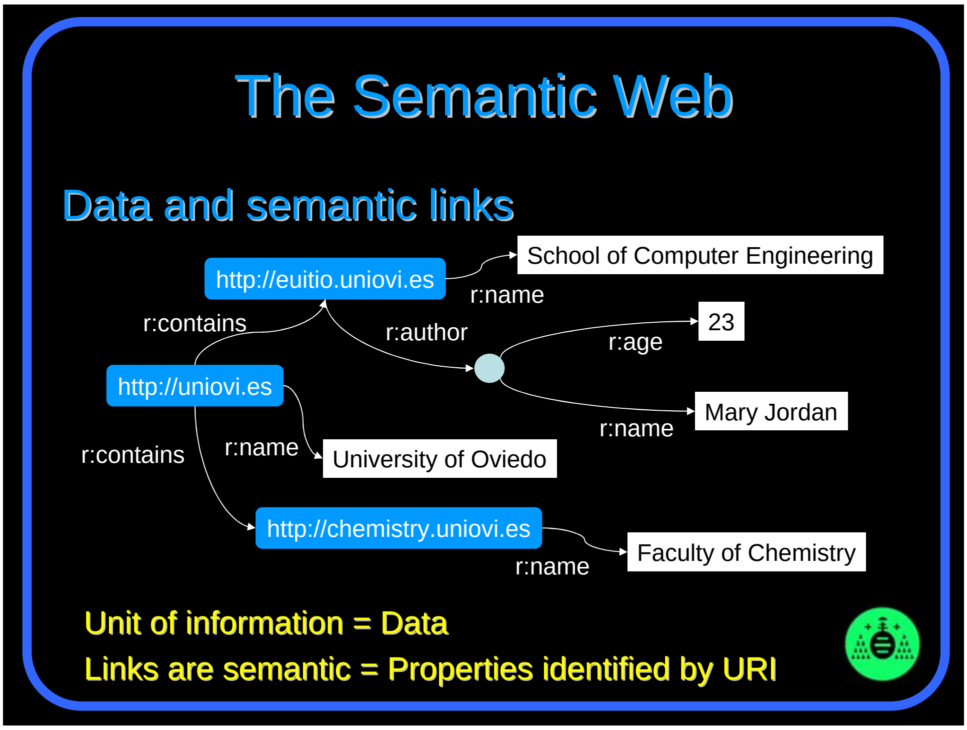
The Syntactic Web

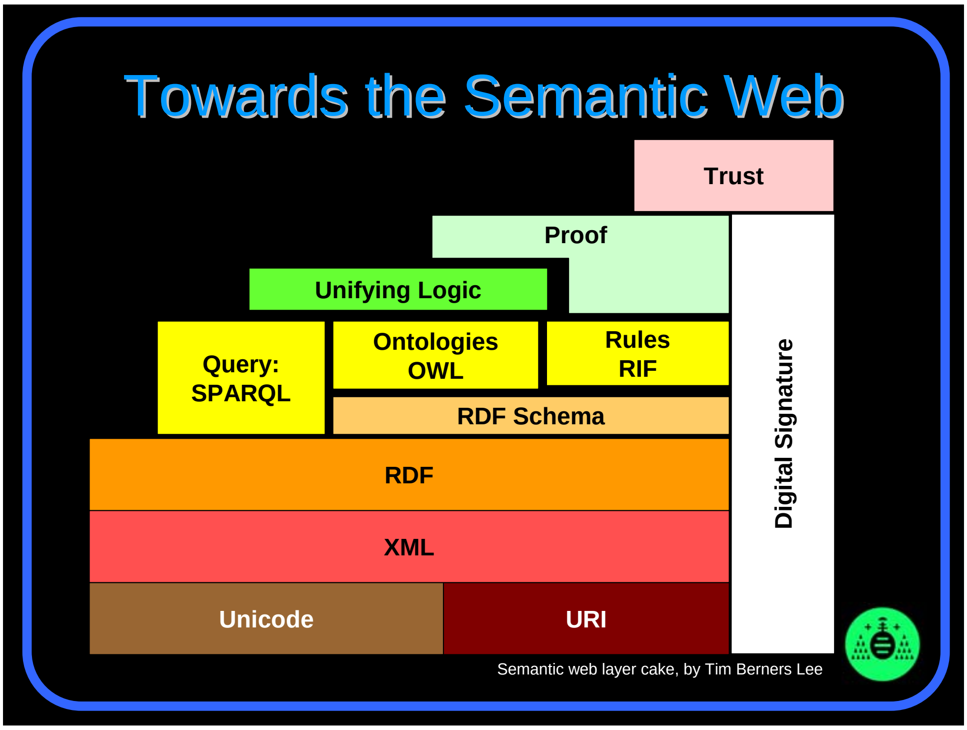
Pages and links



Unit of information = HTML Page

Links are syntactic = href


The Semantic Web
Data and semantic links
http://euitio.uniovi.es
r:name
School of Computer Engineering
r:contains
r:author
23
r:age
http://uniovi.es
Mary Jordan
r:name
r:contains
r:name
University of Oviedo
http://chemistry.uniovi.es
Faculty of Chemistry
r:name
Unit of information = Data
Links are semantic = Properties identified by URI


Towards the Semantic Web
Trust
Proof
Unifying Logic
Query: SPARQL
Ontologies OWL
Rules RIF
RDF Schema
RDF
XML
Unicode
URI
Digital Signature
Semantic web layer cake, by Tim Berners Lee

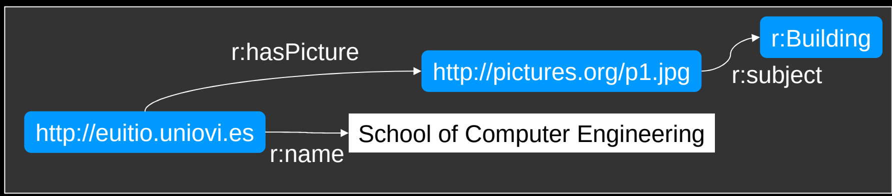
RDF

- Resource Description Framework (1998)
- Description of resources
  - Resources = entities identified by URI
  - Binary Relationships between resources
    - Property = global name of the relationship (URI)
  - Subject → Predicate → Object

RDF Triples

- Subject
  - A resource identified by URI
  - Can also be a blank node (bNode)
- Predicate
  - Global Property identified by URI
- Object
  - Value of property
  - Can be URI, Literal or bNode

RDF Graph Model



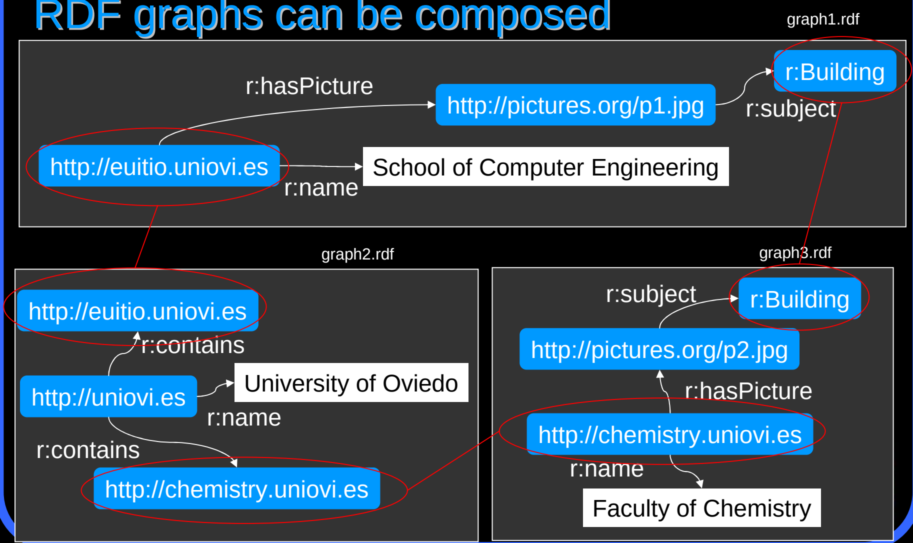
Can be represented in N-Triples

```
@prefix r: <http://example.org#> .

<http://euitio.uniovi.es>       r:hasPicture   <http://pictures.org/p1.jpg>.
<http://euitio.uniovi.es>       r:name          "School of Computer Engineering".
<http://pictures.org/p1.jpg>  r:subject       r:Building .
```

RDF is Compositional

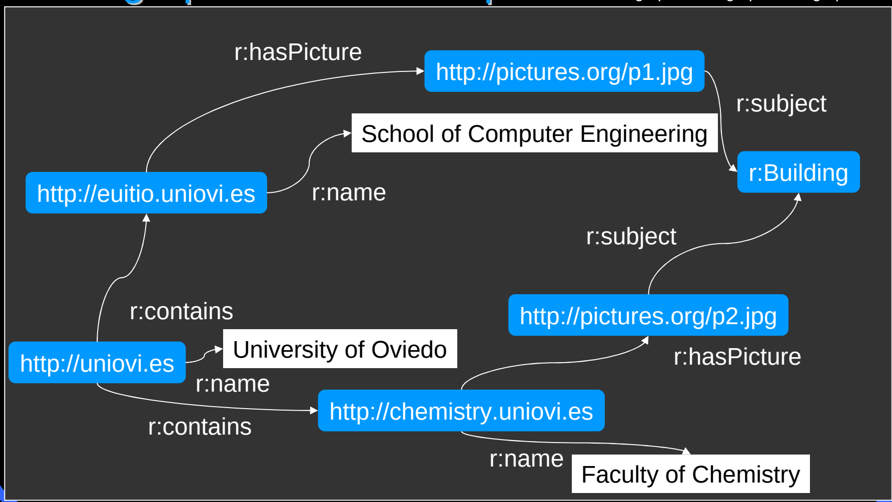
RDF graphs can be composed



RDF is Compositional

RDF graphs can be composed

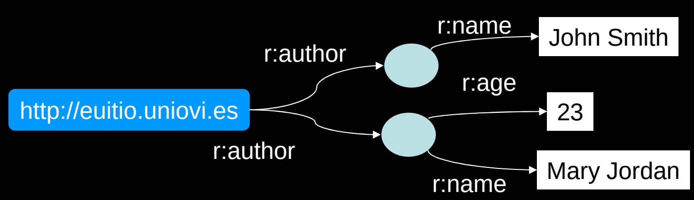
graph1.rdf + graph2.rdf+ graph3.rdf



Blank Nodes in RDF

Blank nodes are used to identify things that have no URI

Example: *The author of a web page is a person, not a URI*



Blank nodes are represented as _:number in N-Triples

<http://euitio.uniovi.es>	r:author	_:1 .
<http://euitio.uniovi.es>	r:author	_:2 .
_:1	r:name	"John Smith" .
_:1	r:age	"23"^^xsd:positiveInteger .
_:2	r:name	"Mary Jordan" .

RDF/XML

RDF/XML = serialization of RDF in XML format

- Several abbreviations
- Difficult to integrate with other XML technologies

```
<rdf:RDF xmlns:s="http://subjects.org#"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns="http://example.org#">
 <rdf:Description rdf:about="http://pictures.org/p1.jpg">
   <subject rdf:resource="http://subjects.org#Building"/>
 </rdf:Description>
 <rdf:Description rdf:about="http://euitio.uniovi.es">
   <name>School of Computer Engineering</name>
   <hasPicture rdf:resource="http://pictures.org/p1.jpg"/>
 </rdf:Description>
</rdf:RDF>
```

RDF as an Integration Language

A lot of information is currently published in RDF

- Example:
  - DBPedia offers RDF triples of more than 80,000 persons, 293,000 places, 62,000 music albums, 36,000 films, etc.

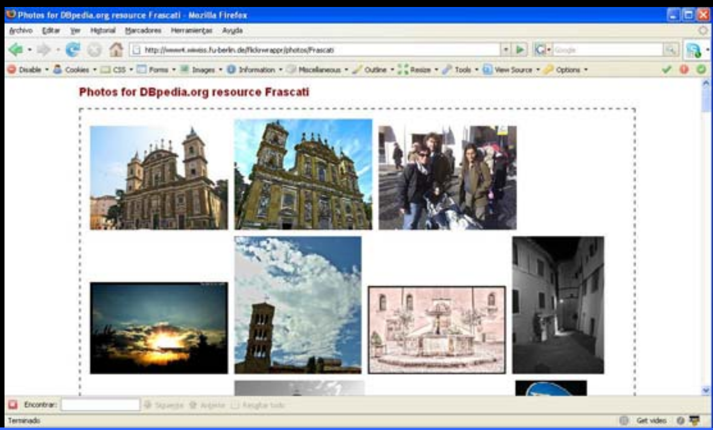
RDF enables better integration of data

- Transform the Web from fileserver to database

RDF as an integration language

Example: Flickr Wrappr

http://www4.wiwiss.fu-berlin.de/flickrwrappr/photos/Frascati

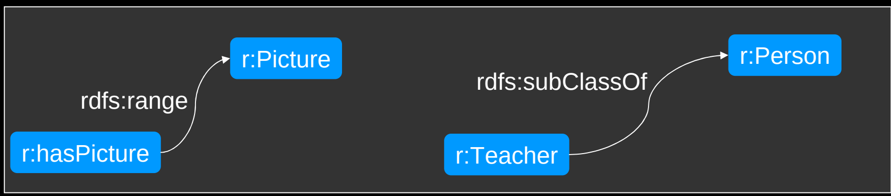


RDF Schema

- Extends RDF with a Schema vocabulary
  - Class, Property, Resource,…
  - type, subClassOf, subPropertyOf,…
  - range, domain,…
- RDF Schema enables simple inferences

RDF Schema

Example



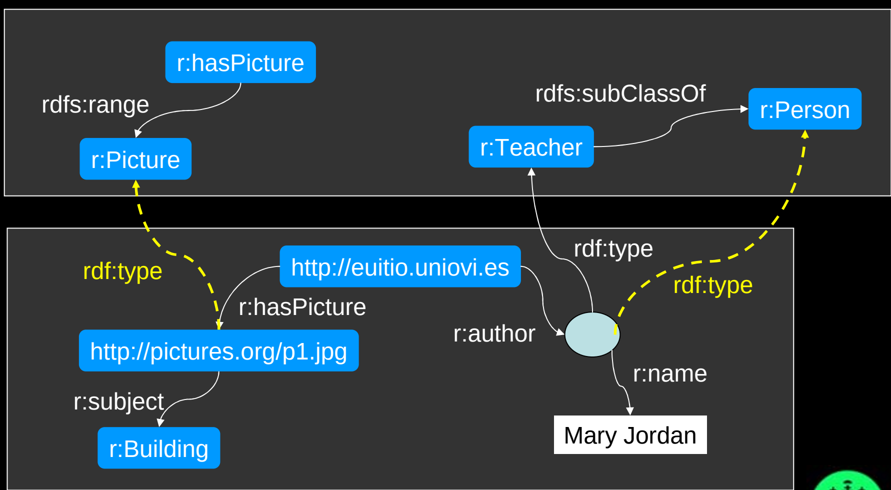
Meaning:

if x r:hasPicture y ∧
r:hasPicture rdfs:range r:Picture
then
y rdf:type r:Picture

Meaning:

if x rdf:type r:Teacher ∧
r:Teacher rdfs:subClassOf r:Person
then
x rdf:type r:Person

RDFS Inference



SPARQL

Simple Protocol and RDF Query Language

- Query language for the semantic web
  - Graph matching language
- A protocol
  - Defines a way of invoking a service
  - WSDL description file
  - HTTP and SOAP bindings
- It also defines XML vocabulary for results

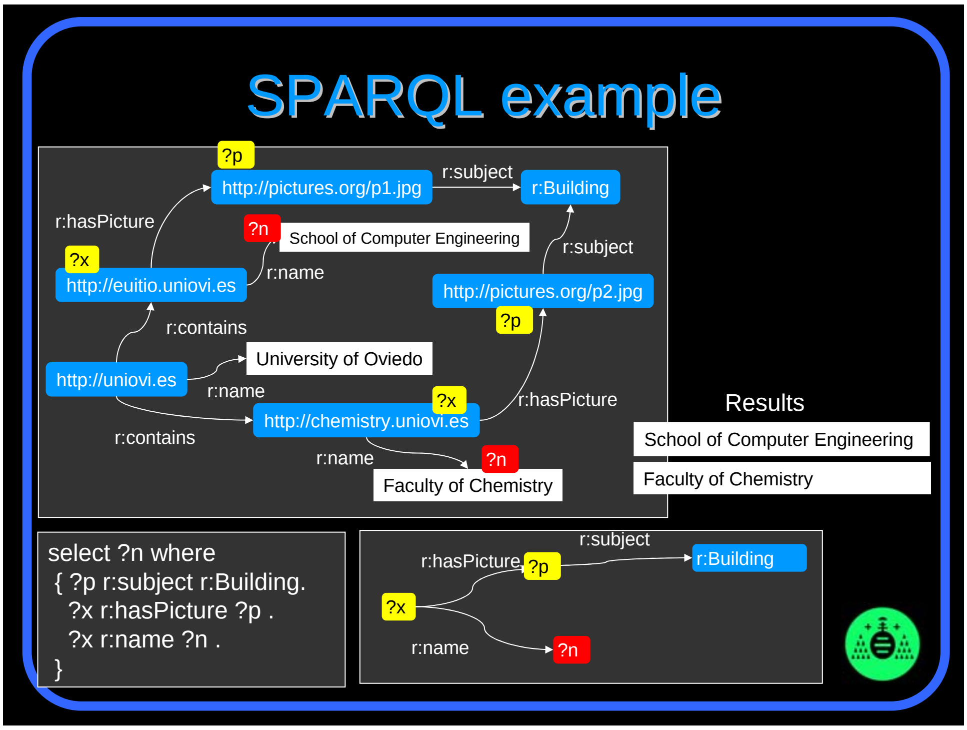
SPARQL

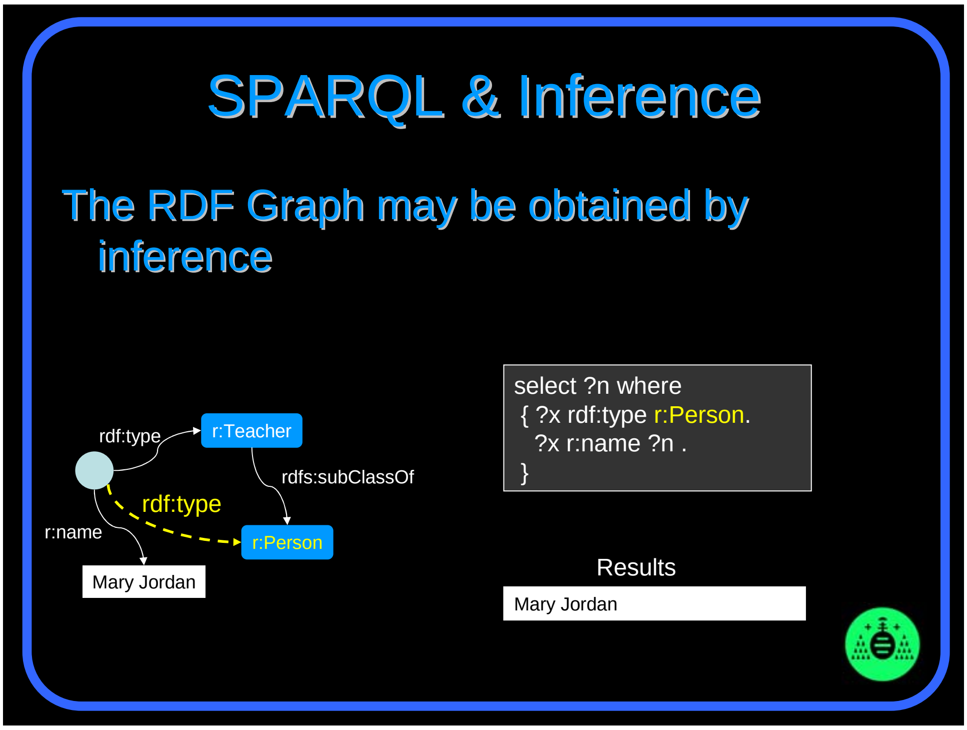
Example

```
prefix r: <http://example.org#>

select ?n where
 { ?p r:subject r:Building.
   ?x r:hasPicture ?p .
   ?x r:name ?n .
 }
```

"Find names of resources who have a picture whose subject is Building"


SPARQL example
?p
http://pictures.org/p1.jpg
r:subject
r:Building
r:hasPicture
?n
School of Computer Engineering
r:subject
?x
http://euitio.uniovi.es
r:name
http://pictures.org/p2.jpg
?p
r:contains
University of Oviedo
http://uniovi.es
r:name
?x
r:hasPicture
http://chemistry.uniovi.es
r:contains
r:name
?n
Faculty of Chemistry
Results
School of Computer Engineering
Faculty of Chemistry
select ?n where
{ ?p r:subject r:Building.
?x r:hasPicture ?p .
?x r:name ?n .
}
r:subject
r:hasPicture
?p
r:Building
?x
r:name
?n


SPARQL & Inference
The RDF Graph may be obtained by inference
rdf:type
r:Teacher
rdfs:subClassOf
rdf:type
r:name
r:Person
Mary Jordan
select ?n where
{ ?x rdf:type r:Person.
?x r:name ?n .
}
Results
Mary Jordan

SPARQL

- More features
  - Limit the number of returned results; remove duplicates, sort them, …
  - Optional subpatterns (match if possible…)
  - Specify several data sources within the query
  - Construct a graph combining a separate pattern and the query results, or simply ask whether a pattern matches
  - Use datatypes and/or language tags when matching a pattern

Obtaining RDF

- SPARQL Endpoints offer an integration mechanism
  - Big RDF datasets accesible to applications
    - Example: DBPedia
- Nowadays Data is mostly in Databases
  - It is not feasible to convert all databases to RDF
    More practical to convert on the fly
  - Several systems: Oracle 11g, Sesame, …

RDF and HTML

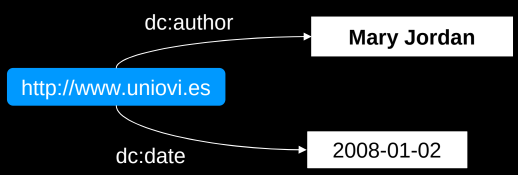
- Problems to embed RDF/XML in (x)HTML
  - It can be linked from an HTML page
- There are some “scrappers” to extract the structure of web pages and dynamically generate RDF
  - Can be a solution for legacy web content
  - Not very elegant
- 2 proposals for a more systematic way:
  - GRDDL
  - RDFa

GRDDL

page.html

```
<html xmlns="http://www.w3.org/1999/">
  <head profile="http://www.w3.org/2003/g/data-view">
    <title>University of Oviedo</title>
    <link rel="transformation" href="http:…/dc-extract.xsl"/>
    <meta name="DC.author" content=“Mary Jordan"/>
    …
  </head>
  …
  <span class="date">2008-01-02</span>
  …
</html>
```

http:…/dc-extract.xsl

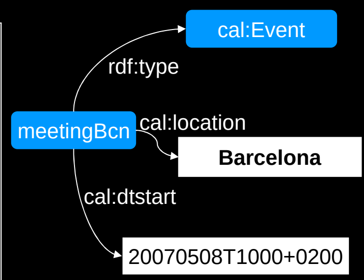


RDFa

RDFa defines attributes to add meta-data to HTML elements

- Similar to microformats

```
<html
  xmlns:cal="http://www.w3.org/2002/12/cal/ical#"> …
<body>
<p class="cal:Event" about="#meetingBcn">
   I will attend a meeting in
   <span property="cal:location">
    Barcelona</span>, on
    <span property="cal:dtstart"
          content="20070508T1000+0200">
      May 8th at 10am
    </span> </p>  ...
  </body>
</html>
```



Ontologies

RDFS does not solve all requirements

- Applications need more expressivity and reasoning
- In RDFS, it is not possible to create new subclasses

OWL (Web Ontology Language) offers a common language to define ontologies

Ontology = specification of a conceptualization

- Specifies classess and their relationships
- Shared by different agents

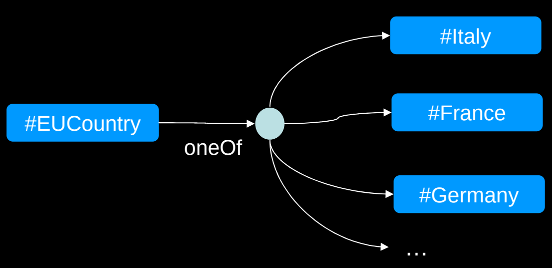
OWL

- OWL enables the description of new classes
  - By enumeration
  - Through intersection, union, complement
  - Through property restrictions
- It is based on *Description Logics*
  - Well defined semantics
  - A subset of Predicate Logic
    - Limited use of variables
    - Binary predicates = Relationships
    - Unary predicates = Classes

OWL: Classes by enumeration

- Example: "*The European Union is formed by Italy, France, Germany, etc.*"

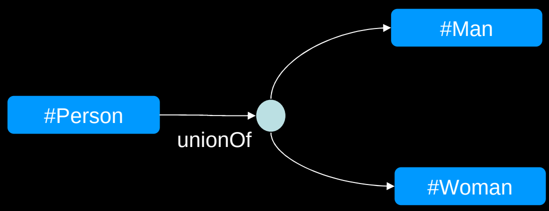
EUCountry = { Italy, France, Germany, … }



OWL: Set theoretic definitions

Example: *A person is a man or a woman*

Person = Man ∪ Woman



It also has IntersectionOf and complementOf

OWL: Property restrictions

It is possible to define new classes by restricting the property values of some class

- Reasoner acts as a classifier

OWL: Property restrictions

Value constraints

- *some* (∃) value must be from a class
- *all* (∀) values must be from a class

Example: "*An european is a person who has nationality from a European Union country*"

$European \equiv Person \cap \exists\ hasNationality\ EUCountry$

$\forall x\ (European(x) \leftrightarrow Person(x) \wedge \exists y\ (hasNationality(x,y) \wedge EUCountry(y)))$

hasNationality(#Sergio, #Italy)
Person(#Sergio)

inference → European(#Sergio)

OWL: Property restrictions

Cardinality constraints (ie, how many times the property is used on an instance?)

- exact cardinality
- minimum cardinality
- maximum cardinality

$Person \subseteq hasFather = 1$

$\forall x\ (Person(x) \rightarrow \exists y\ (hasFather(x,y) \wedge \forall z\ (hasFather(x,z) \rightarrow z = y)))$

OWL: Property characterizations

It is possible to characterize the behaviour of properties:

- Symmetric, transitive, functional, inverse functional, …

transitive(isPartOf)

isPartOf(#Rome, #Italy)
isPartOf(#Italy, #Europe)

inference → isPartOf(#Rome,#Europe)

OWL: Datatype properties

Properties whose range are typed literals

Example: age

datatypeProperty(#age)
range(#age, xsd:positiveInteger)
CanVote ≡ Person ∩ age > "18"

Person(#Sergio)
age(#Sergio, "20")

inference → CanVote(#Sergio)

OWL and Unique Name Assumption

Web = Open System

- 2 different URIs could identify the same object
- OWL does not support Unique Name Assumption

Person $\subseteq$ hasFather = 1

hasFather(#peter, #william)
hasFather(#peter, #bill)
Person(#peter)

There is no error in the model

It infers that "#william" y "#bill" are the same

OWL: Open World Assumption

Traditional systems used Closed World Assumption

OWL uses the *Open World Assumption*

Singleton $\equiv \neg \exists$ isMarriedWith Person Married $\equiv \exists$ isMarriedWith Person

Person(#Peter) Person(#Mary) Person(#James) isMarriedWith(#mary,#peter) Married(#james)

It infers: Married(#Mary)

It does not infer:

- Married(#Peter)
- Singleton(#Peter)

It also infers that James is married with someone… but it does not know with whom

OWL Layers

OWL was defined in 3 layers:

- OWL Full:
  - No constraints
  - Superset of RDFS
  - Undecidable
- OWL DL (DL comes from Description Logics)
  - Classes and individuals are separated
  - No characterization of datatype properties
  - Decidable
- OWL Fragments
  - Subsets of OWL DL more tractable
  - Examples: OWL Lite, DLP, EL++, etc.

OWL 1.1

An extension of OWL (*in development*)

It is based on more expressive DL

More property characterization possibilities:

- Reflexive, Irreflexive, Antisymmetric

Increased datatype expressivity

- N-ary datatypes
- User-defined datatypes

Annotations and meta-logical statements

The name of the game

S often used for ALC extended with transitive roles (R+)
Additional letters indicate other extensions, e.g.:
- H for role hierarchy (e.g., hasDaughter ⊆ hasChild)
- O for nominals/singleton classes (e.g., {Italy})
- R for reflexive properties (e.g., knows)
- I for inverse roles (e.g., isChildOf ≡ hasChild⁻)
- N for number restrictions (e.g., ≥2 hasChild, ≤3 hasChild)
- Q for qualified number restrictions (e.g., ≥2 hasChild.Doctor)
- F for functional number restrictions (e.g., ≤1 hasMother)

S + role hierarchy (H) + inverse (I) + QNR (Q) = SHIQ
SHIQ is the basis for W3C's OWL Web Ontology Language
- OWL DL = SHIQ extended with nominals (i.e., SHOIQ)
- OWL Lite = SHIQ with only functional restrictions (i.e., SHIF)
- OWL 1.1 = SROIQ

Rules

Rules based systems have a long tradition
They can extend OWL expressivity
Examples:
- uncle(?x,?y) ← brother(?x,?z),parent(?z,?y)
- older(?x,?y) ← age(?x,?a),age(?y,?b), ?a > ?b.

Proposals:
- SWRL = Adds prolog-like rules to OWL
- Problem: Adding rules to OWL ⇒ Undecidable
- RIF Working group

Uncertainty

- Uncertainty handling = critical in practical applications
  - Specially in Image Information mining
- Several approaches:
  - Extend DL with temporal and modal operators
  - Probabilistic Description Logics
  - Fuzzy Description Logics

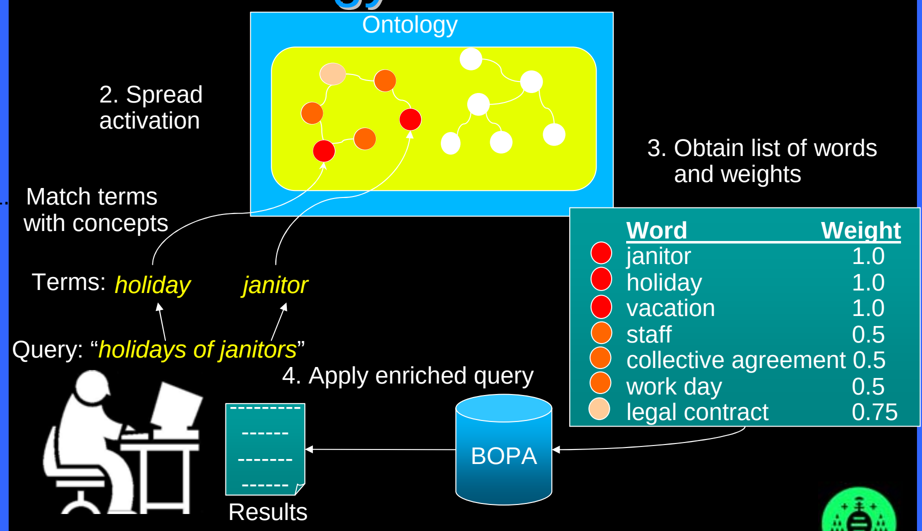
Some Applications

- BOPA Project
  - Ontology based search through governmental documents
- WESONet Project
  - Multimedia information search
- MultimediaN E-Culture
  - Art collections search & annotation

BOPA Project

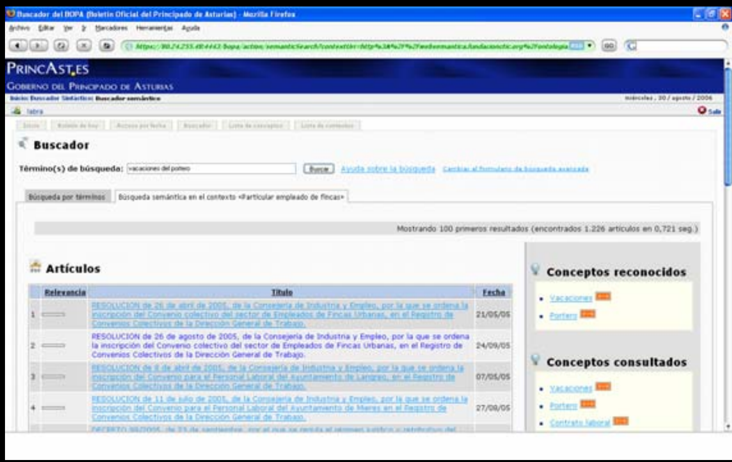
- Goal: create a "bridge" between citizens and juridical jargon
  - We used semantic Web vocabularies and tools
  - Applied to Administrative documents
  - Large dataset
    - More than 35,000 legal documents
    - 150,000 different terms
  - Ontology based query expansion
    - Pre-Query: Ask user to disambiguate meanings
    - Post-Query: Sort results

Ontology based search



Word	Weight
janitor	1.0
holiday	1.0
vacation	1.0
staff	0.5
collective agreement	0.5
work day	0.5
legal contract	0.75

Ontology based search



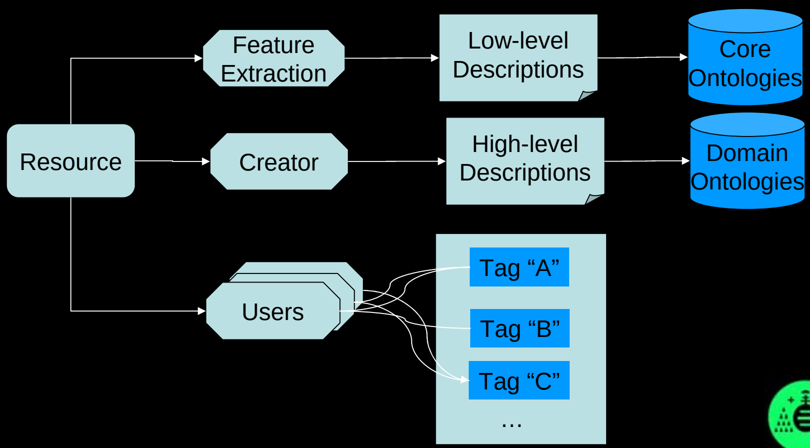
Available at: http://bopa.fundacionctic.org

WESONet Project

- WESO (WEb Semántica Oviedo) group
- Annotation and search over Multimedia assets
  - We apply it to our University domain
  - …but it could be applied to other domains

WESONet Project

3 levels of definition



Automatic Annotation

- Automatic Process obtains low level descriptions
  - Objective values: Date of creation, resolution,…
  - Feature extraction algorithms
    - Histogram, textural analysis, …
- Descriptions are linked to core-ontologies
  - Several MPEG-7 based ontologies
    - Example: http://comm.semanticweb.org/

Collaborative Tagging

- Users provide tags to multimedia-assets
- Tags are pseudo-free text
  - Tag recomendation systems improve quality
- Emergent semantics: folksonomies
  - Users participate in the image tagging process
  - Tags are not logically consistent
  - Users have reputation levels

Experts Annotations

- The creator of multimedia assets con give high-level descriptions
  - Descriptions link to concepts in high-level domain ontologies
    - Difficulty: Connecting different domain ontologies

We are developing/testing algorithms to combine these 3 levels of description

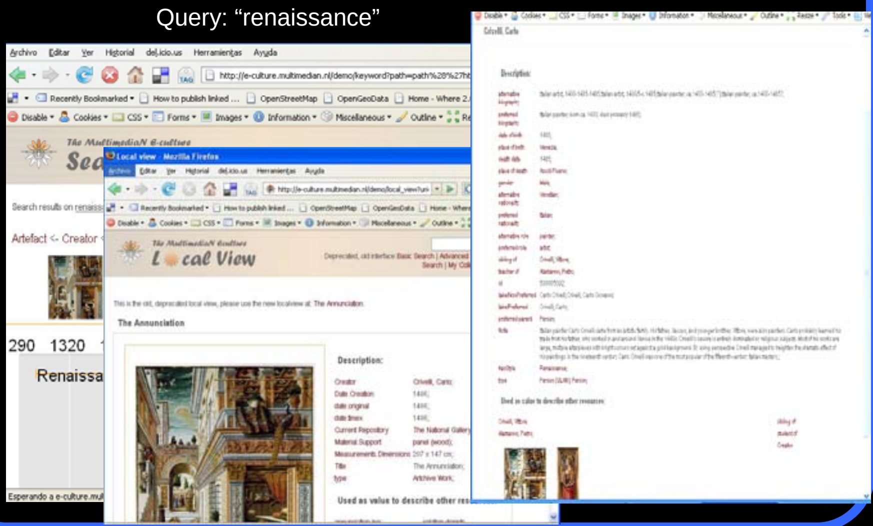
MultimediaN E-Culture

Searching and annotating cross-institutional heritage art collections

- Based on Semantic web technologies
- Interoperability between collections and vocabularies
  - Supports multiple distributed collections
- Works with a large dataset
  - Near 9,000,000 triples
  - 8 vocabularies

MultimediaN E-Culture

Query: “renaissance”



Conclusions

- Semantic Web technologies = ready for deployment
  - It is easy to publish something in RDF
    - There are already huge amounts of data in RDF
    - Linking to existing ontologies is already possible
- Social barriers have to be overcome
  - "Open door" policy
  - Use standards
  - Connect to others so others can connect to you
- A little semantics can have a lot of impact

The End

Questions?

More information:
http://www.di.uniovi.es/~labra