The Semantic Web – an overview

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Øredev 2007 – Malmö, Sweden, Nov 13, 2007

SICS – Swedish Institute of Computer Science

National research institute
- R&D in information and communication technologies

Objective:
- conduct advanced and focused research in strategic areas of computer science

Sponsors:
TeliaSonera, Ericsson,
Saab Systems,
FMV (Defence Materiel Administration),
Green Cargo (Swedish freight railway operator),
ABB,
Bombardier Transportation

Contents

The aim: provide an overview of the semantic web.

Main parts of presentation:

1. Semantic Web – motivation and objectives
2. Semantic Web technologies
3. Illustrations of use
4. The larger landscape

1. Semantic Web: Motivation and Objectives

Why do we need a complementary approach?

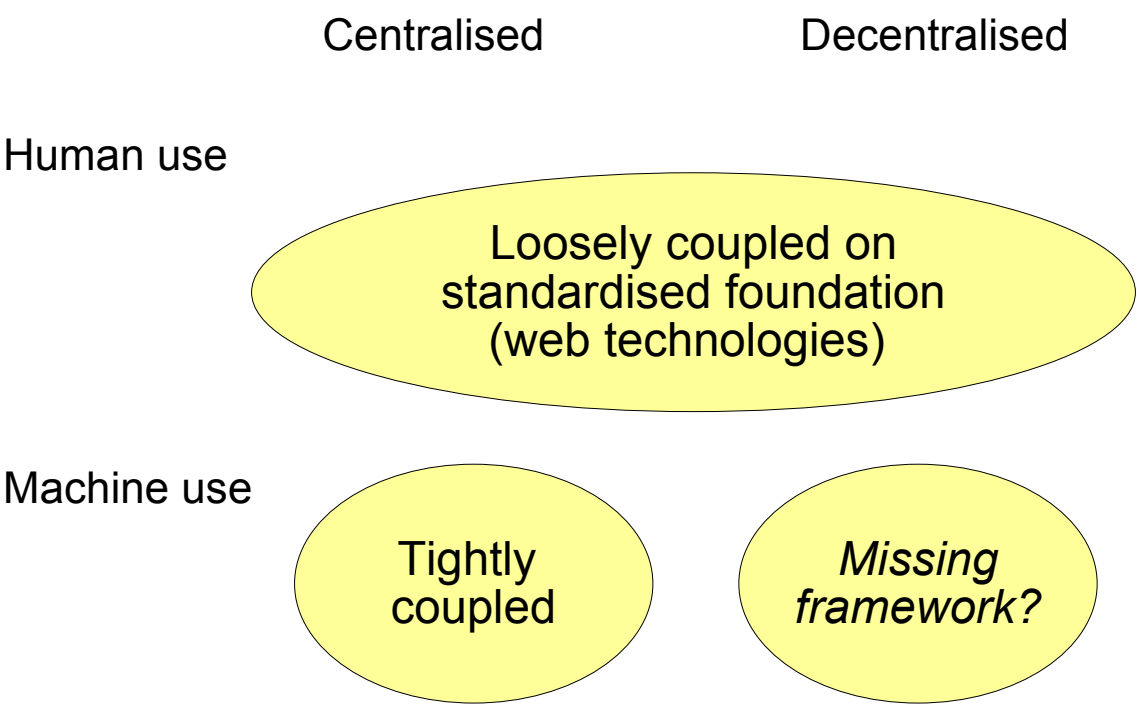
The web – content for humans

- 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!

Web content – machine usable?

- Automated use of web content is difficult
  - partial information is unusable
  - difficult to make sense of, e.g., an image
  - automated conclusions from analogies is difficult
  - difficult to combine information automatically
    - is `<foo:creator>` same as `<bar:author>`?
    - how to combine different XML hierarchies?
  - …

The missing link



The rationale for the Semantic Web

We have the web of documents (text, multimedia, ...)

- Interlinked network of documents
- Provided by independent sources
- Understandable representation and uniform access
- Web browsers make content available to users
- Users make use of content

We need the web of data

- Interlinked network of *data*
- Provided by independent sources
- Understandable representation and uniform access
- *Programs know how to relate data*
- *Programs* make use of *data*

- Semantic Web (SW) = programmable data web

The way ahead

Complications

- Data – stored in databases, applications, etc.
- Represented in various formats
- Structured in various data models
- Formats and models change over time
- Data interoperability difficult

Approach:

- Abstract from concrete representations
- Interoperability at abstraction level feasible
- Abstraction captures “semantics”

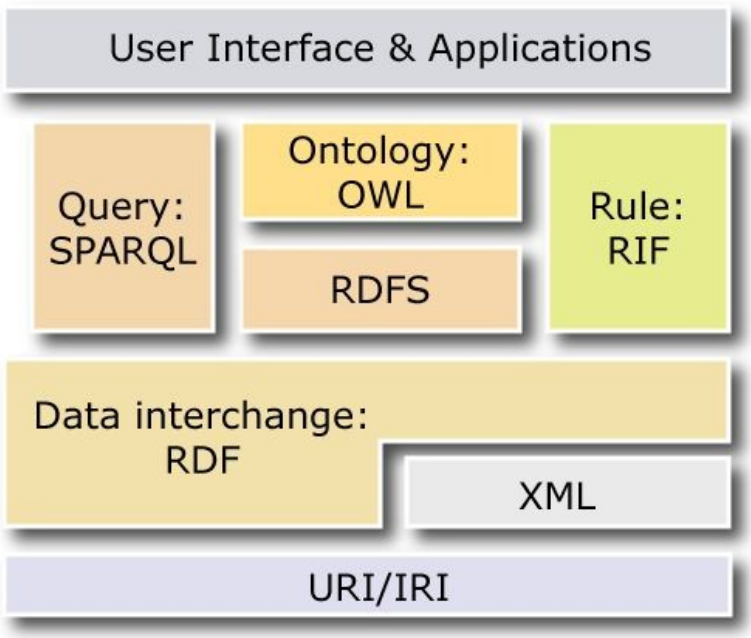
2. Semantic Web: Technologies

Characterizations of Technologies

What is needed?

- Languages for describing concrete data
  - E.g., “13.50” vs. “Price: 13.50; Currency: Euro”
- Languages for describing types of data (data models)
  - E.g., Price: numeric monetary value; currency; per quantity; ...”
- Methods/tools for mapping data models to data models
  - E.g., ebXML (UN/CEFACT) to eBay
- Methods/tools for searching data
  - Query languages
- Methods/tools for interoperation with other web technologies
  - E.g., with the document web
- Etc. ...

Semantic Web basic building blocks



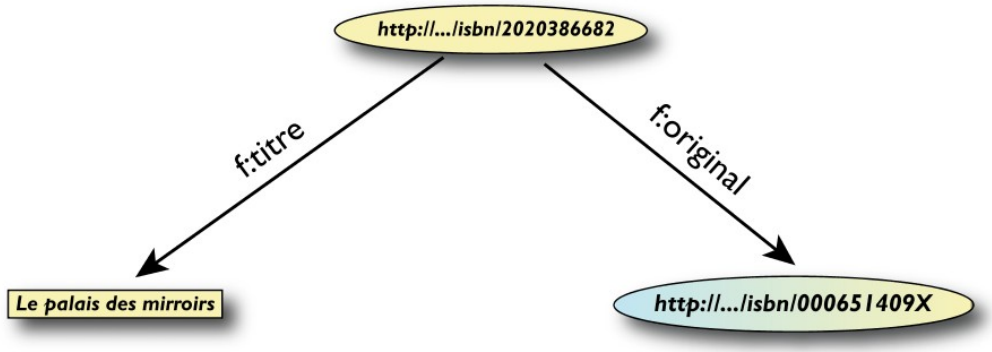
RDF – Resource Description Framework

- Basic data model – a "triple"
  - triple `(s,p,o)` is such that:
    - "`s`", "`p`", and "`o`" stand for "subject", "predicate", and "object", respectively
    - conceptually: "`p`" connects, or relates the "`s`" and "`o`"
- An example triple:

```
(
<http://…isbn…6682>,          # "Le palais des miroirs"
<http://…/original>,          # "is a derivative of the original"
<http://…isbn…409X>           # "The Glass Palace"
)
```

- *RDF* is a general model for such triples
  - machine readable formats like RDF/XML, Turtle, n3, RXR, …
- … *and that's it!*

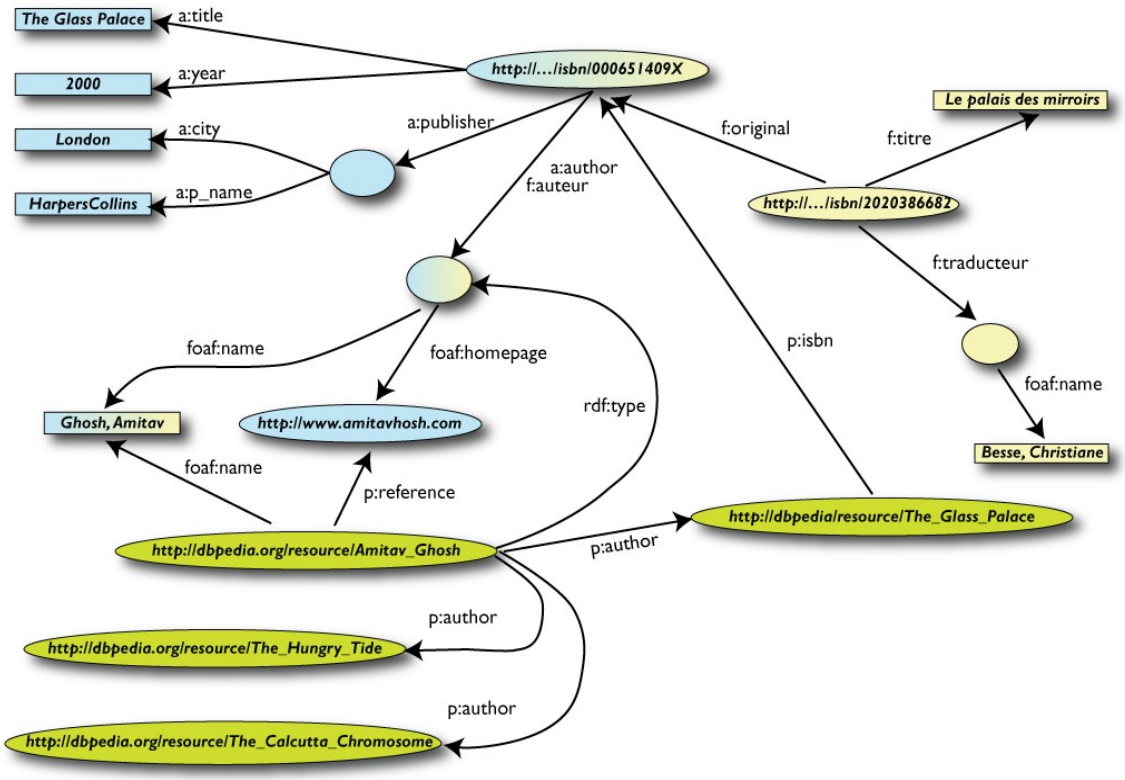
RDF Example




```
<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>
```

Set of triples form a graph – the *RDF graph*

RDF graph



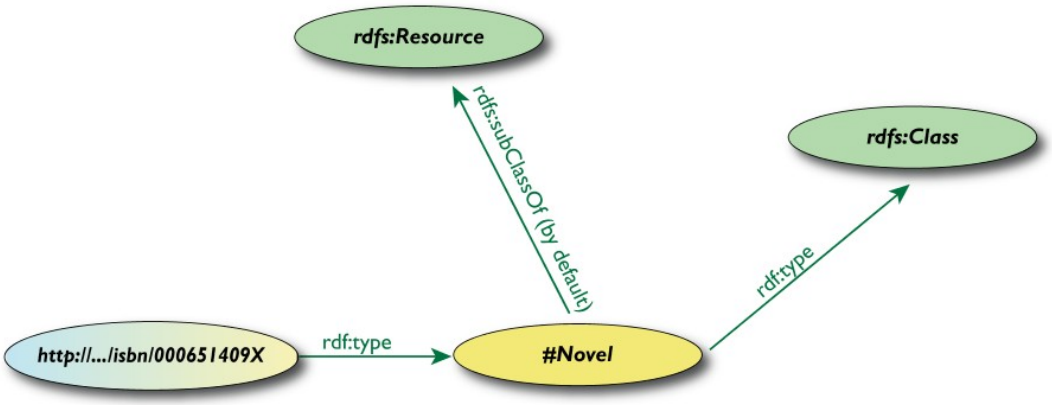
RDFS – RDF Schema

- Simple forms of critical "meta knowledge":
  - what terms to use
  - what restrictions must apply
  - what other relationships may hold
- RDF Schema
  - officially: "RDF Vocabulary Description Language"; the term "Schema" is retained for historical reasons…

RDF Schema

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

RDF & RDFS



- RDFS defines:
  - Nodes: **`rdfs:Resource`**, **`rdfs:Class`**
  - Properties: **`rdf:type`**, **`rdfs:subClassOf`**

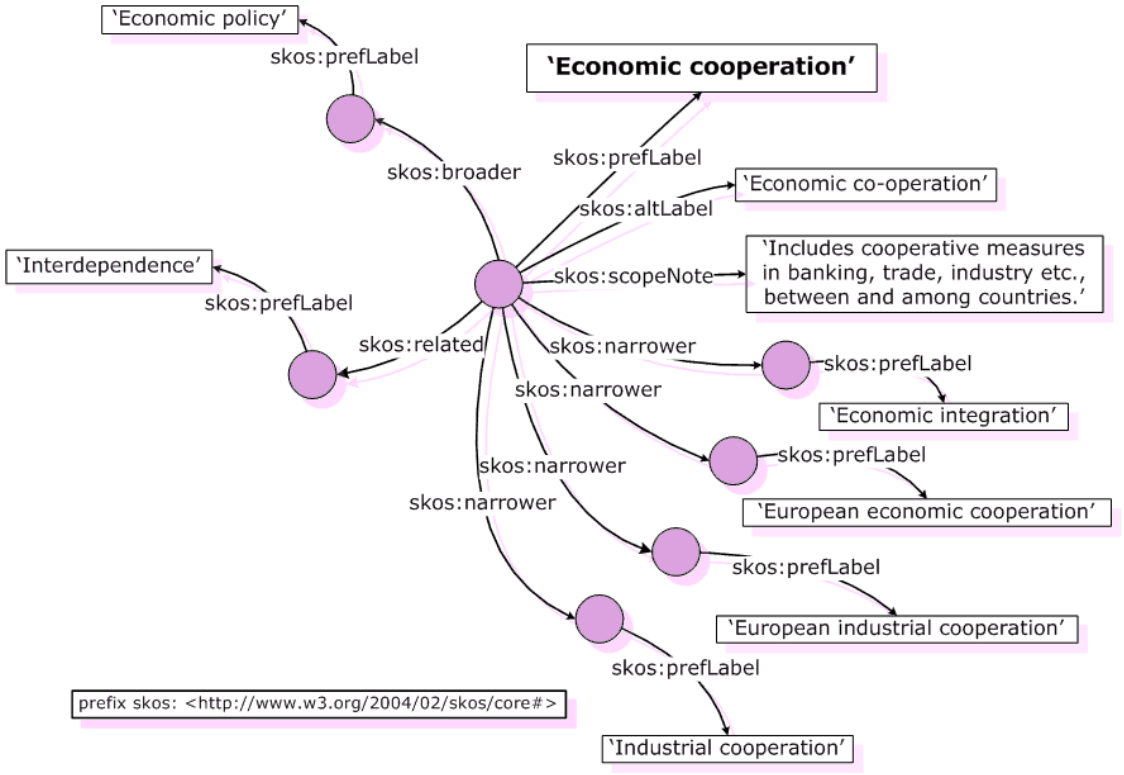
RDF summary

- RDF basic model
  - Triples <subject, predicate, object>
- RDF syntax
  - Textual representation of sets of triples
  - XML, N3, ...
- RDF semantics
  - Intended meaning of sets of triples
  - Constraints
  - Implications

SKOS – Simple Knowledge Organisation Systems

- Practical need: simplified representation frameworks
  - for conceptual models
- A system must be simple to allow for a quick port of traditional data
- SKOS is a specialised representation framework
- Suitable for thesauri, classification schemes, subject heading systems and taxonomies
  - Dewey Decimal Classification, Art and Architecture Thesaurus, ACM classification of keywords and terms…
  - DMOZ categories (a.k.a. Open Directory Project)
- Wrapper around RDF
- Adapt/define classes and properties within certain limits

SKOS example



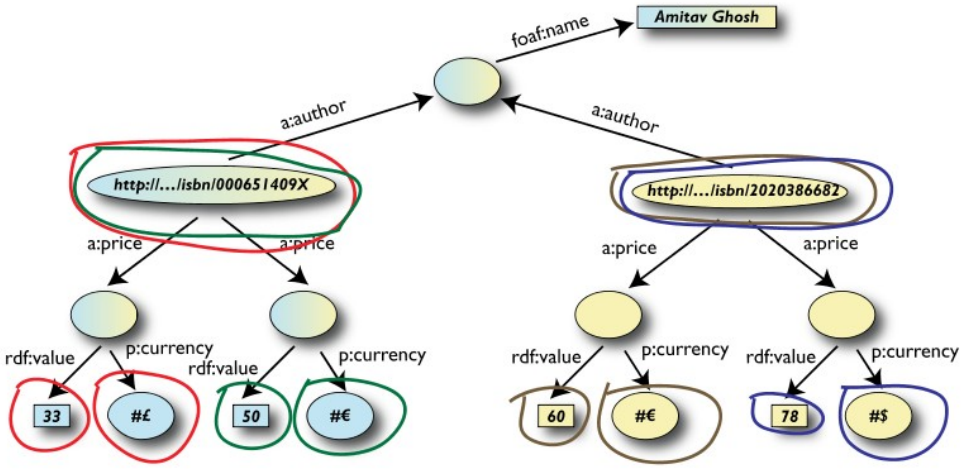
SPARQL – Query Language for RDF

- How to use data represented in RDF?
- Extract / match / find data in RDF graphs
- Basic need: language for query on RDF graphs
  - example: "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)
  - such conditions may be simple or complex
- Queries very important for distributed RDF data!
  - Queries across distributed data bases
- This is the goal of SPARQL (Query Language for RDF)

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,$]]



SPARQL Usage

- Locally, i.e., bound to some programming environments
  - Querying local RDF databases
- Remotely, i.e., 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 often offer "SPARQL endpoints" for this protocol

OWL – Web Ontology Language

- RDFS cumbersome for complex use
- Complex applications may want more possibilities:
  - similarity and/or differences of terms (properties or classes)
  - construct classes, not just 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.
- OWL – "Web Ontology Language"

OWL objectives

- A conceptual model describes some domain
- *Ontology*: formal description of a conceptual model
- OWL is a language for defining ontologies
  - OWL is a meta modelling language – a logical language
- Three layers of OWL are defined: Lite, DL, and Full
  - "OWL Full" is the whole thing
    - Complete logic
  - "OWL DL (Description Logic)" restricts Full in some respects
    - Mechanisable logic
  - "OWL Lite" restricts DL even more
    - Easily implementable

Creating RDF for document resources

- Intelligent “scrapers” or “wrappers” extract structure information from a Web page…
  - using conventions in, e.g., class names or meta elements
- … and generate RDF automatically (e.g., via an XSLT script)
- Similar to what “microformats” do (typically non-RDF)
  - They might not extract RDF, but use data directly in Web 2.0 applications.
  - other applications may extract it to yield RDF (e.g., RSS1.0)

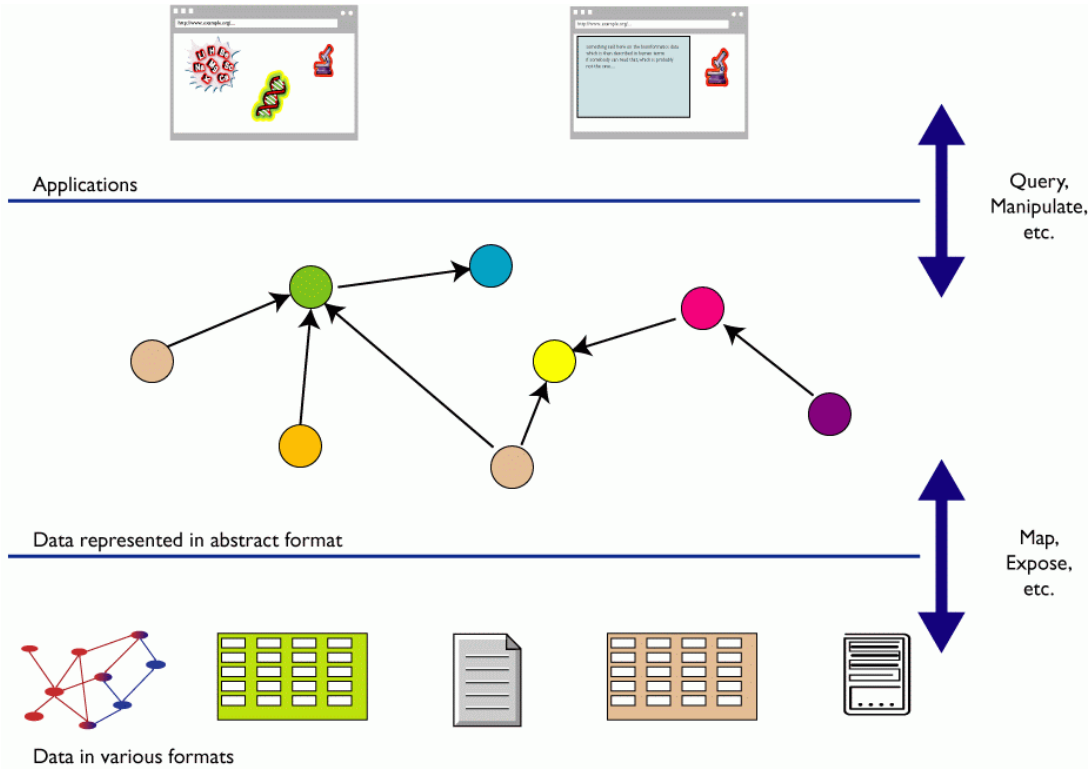
GRDDL – Gleaning Resource Descriptions...

- Existing documents may already contain useful descriptions
- Create RDF data by systematic extraction
- GRDDL – Gleaning Resource Descriptions from Dialects of Languages
- GRDDL offers a mechanism for retrieving descriptive data from document
- GRDDL introduces
  - markup for declaring that an XML document includes gleanable data
  - Describing an algorithm, typically represented in XSLT, for gleaning the resource descriptions from the document.

RDFa

- Enriching web documents by semantical annotations
  - Without disrupting ordinary web document use
  - Enabling extraction of RDF and access as RDF
- RDFa slightly extends (X)HTML by:
  - defining general attributes to add metadata to any elements (c.f. “class” in microformats, but via dedicated properties)
  - provides an almost complete “serialization” of RDF in XHTML
- Similar to microformats approach but with more rigor and fully generic
  - makes it easy to mix different vocabularies (which is difficult in microformats)

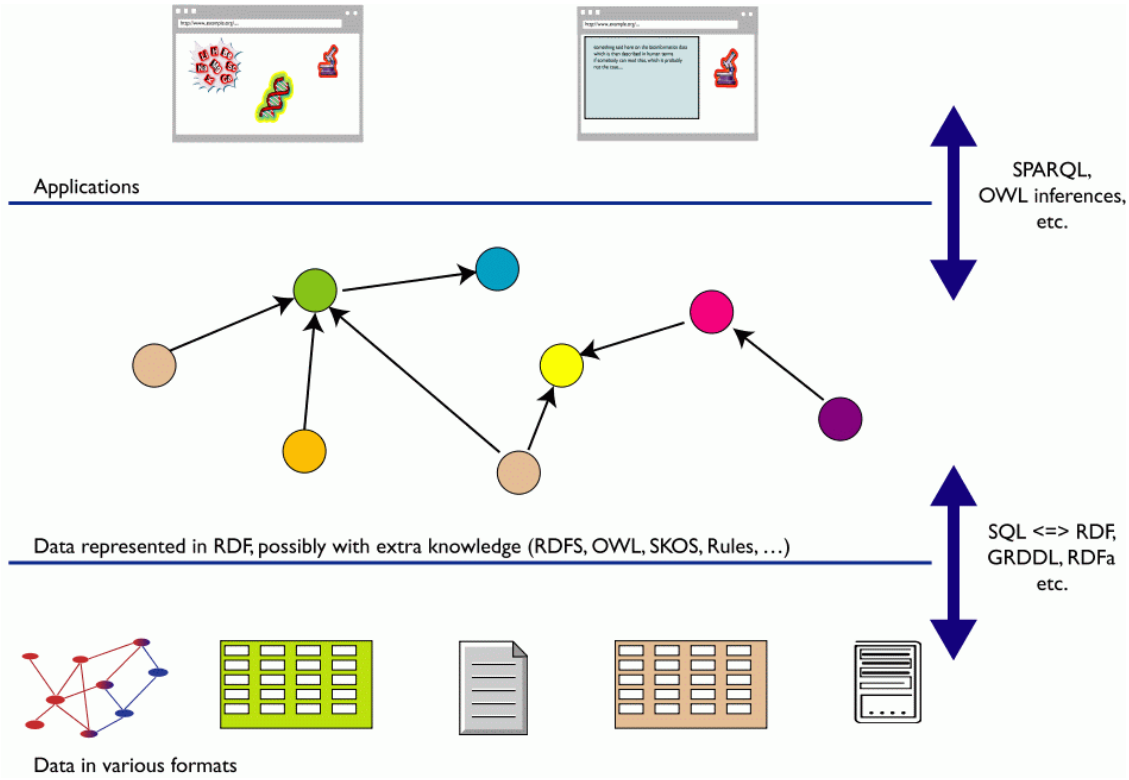
Where do technologies fit in?



Uses of Semantic Web Technologies

- The Semantic Web provides technologies supporting such needs! For example:
  - an abstract model for the relational graphs: **RDF**
  - extract RDF information from XML (eg, XHTML) pages: **GRDDL**
  - add structured information to XHTML pages: **RDFa**
  - a query language adapted for the relational graphs: **SPARQL**
  - characterize the relationships, categorize resources: **RDFS**, **OWL**, **SKOS**, **Rules**
    - applications may choose among the different technologies
    - some of them may be relatively simple with simple tools (RDFS), whereas some require sophisticated systems (OWL, Rules)
  - reuse of existing "ontologies" that others have produced (**FOAF** in our case)

Where do technologies fit in? (cont.)



Examples of implemented SW Tools

- **Triple Stores**
  - RDFStore, AllegroGraph, Tucana
  - RDF Gateway
  - Mulgara, MySQL+SPASQL
  - Jena's SDB, D2R Server, SOR
  - Virtuoso
  - Oracle Spatial 10.2
  - Sesame, OWLIM
  - Talis Platform
  - …
- **Reasoners**
  - Pellet, RacerPro, KAON2, FaCT++
  - Ontobroker, Ontotext
  - SHER
  - …
- **Converters**
  - flickurl, TopBraid Composer
  - GRDDL, Triplr, jpeg2rdf
  - …
- **Middleware**
  - IODT, Open Anzo, DartGrid
  - Ontology Works, Ontoprise
  - Oracle Fusion 11g
  - Profium Semantic Information Router
  - Software AG's EII
  - Thetus Publisher, Asio, SDS
  - …
- **Semantic Web Browsers**
  - Disco, Tabulator, Zitgist
  - OpenLink Viewer
  - …
- **Development Tools**
  - SemanticWorks, Protégé
  - Jena, Redland, RDFLib, RAP
  - Sesame, SWI-Prolog
  - TopBraid Composer
  - DOME
  - …

Inspired by "Entreprise Semantic Web in Practice", Jeff Pollock, Oracle. See also W3C's Wiki Site.

3. Illustrations of use

Where we see Semantic Web technologies in use

Application trends

- Use of SW technologies
  - Creating added value within user organizations
  - Taking advantage of the investment in XML as a common format
- Used internally in various software tools, e.g.:
  - Configuration descriptions
  - Process descriptions
  - Error reports, etc
- Used for *metadata descriptions* of digital resources
  - Obvious usage, of course
- Used for *data integration*
  - Big payoff! Lots of examples.

SW data begins to accumulate on the Web

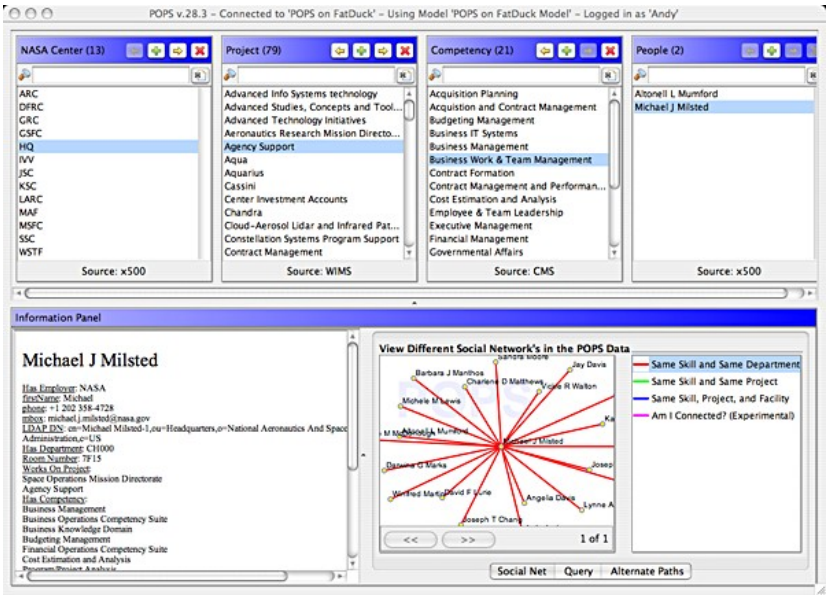
- IgentaConnect bibliographic metadata storage: over 200 million triples
- Tracking the US Congress: data stored in RDF (around 25 million triples)
- RDFS/OWL Representation of WordNet: also downloadable as 150MB of RDF/XML
- "Département/canton/commune" structure of France published by the French Statistical Institute
- Geonames Ontology and associated RDF data: 6 million (and growing) geographical features
- RDF Book Mashup, integrating book data from, eg, Amazon
- "dbpedia": get infobox data of Wikipedia into RDF
- See, for example, the linked data index

3. Illustrations of use – part 1

... data integration

Find the right experts at NASA

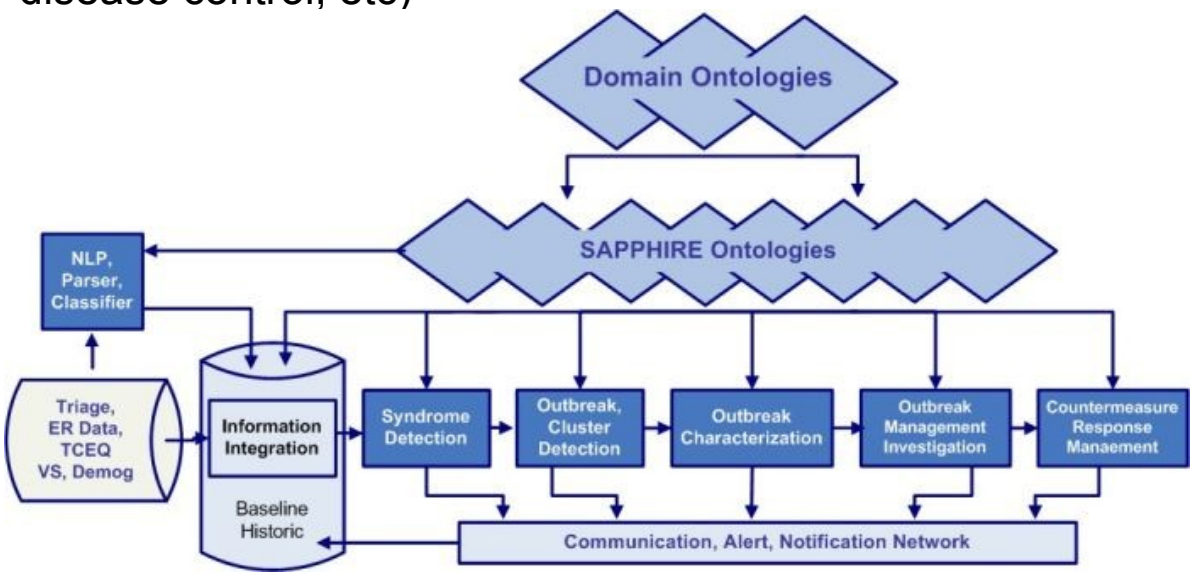
- Expertise locater for nearly 20,000 NASA civil servants using RDF integration techniques over 6 or 7 geographically distributed databases, data sources, and web services…



Courtesy of Kendall Clark, Clark & Parsia, LLC

Public health surveillance

- Integrated biosurveillance system (biohazards, bioterrorism, disease control, etc)

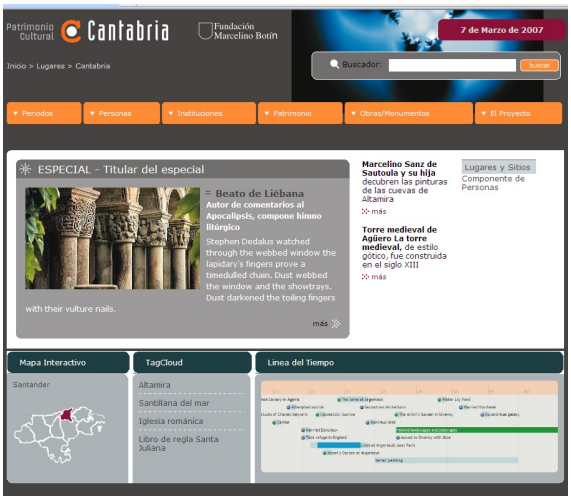


Courtesy of Parsa Mirhaji, School of Health Information Sciences, University of Texas (SWEO Case Study)

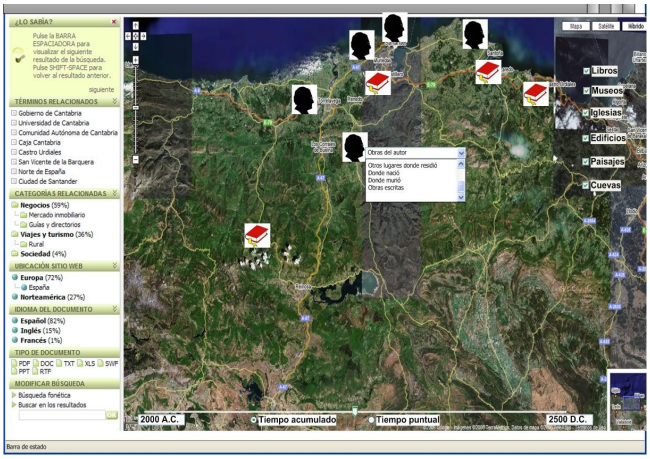
Web sites, portals, local site search

- Portal's internal organization makes use of semantic data, ontologies
  - integration with external and internal data
    - these are, often, extensions of data integration projects
  - better queries, often based on controlled vocabularies or ontologies…

Semantic portal for cultural heritage



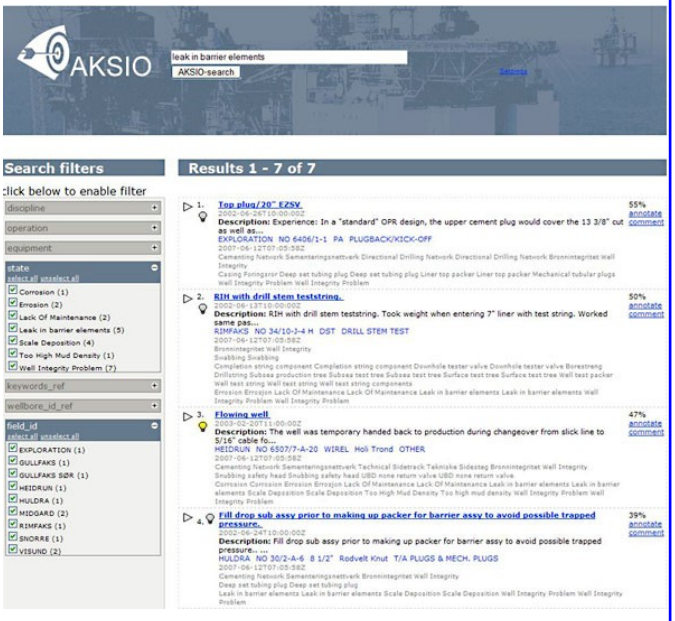
Fundación Marcelino Botín



Courtesy of Francisca Hernández, Fundación Marcelino Botín, and Richard Benjamins, iSOCO, (SWEO Case Study)

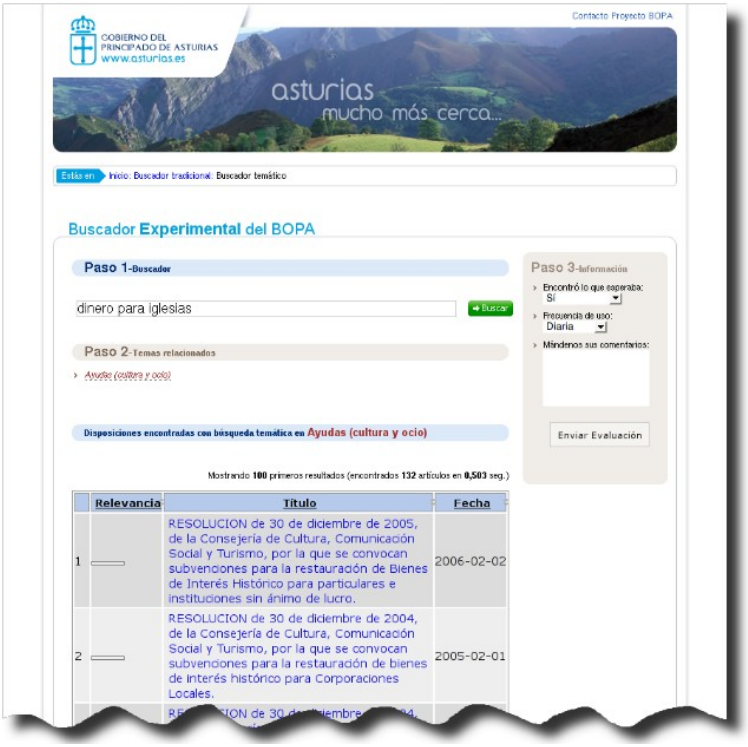
Help for deep sea drilling operations

- Integration of experience and data in the planning and operation of deep sea drilling processes
- Discover relevant experiences that could affect current or planned drilling operations
  - uses an ontology backed search engine



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

Portal to Principality of Asturias' documents

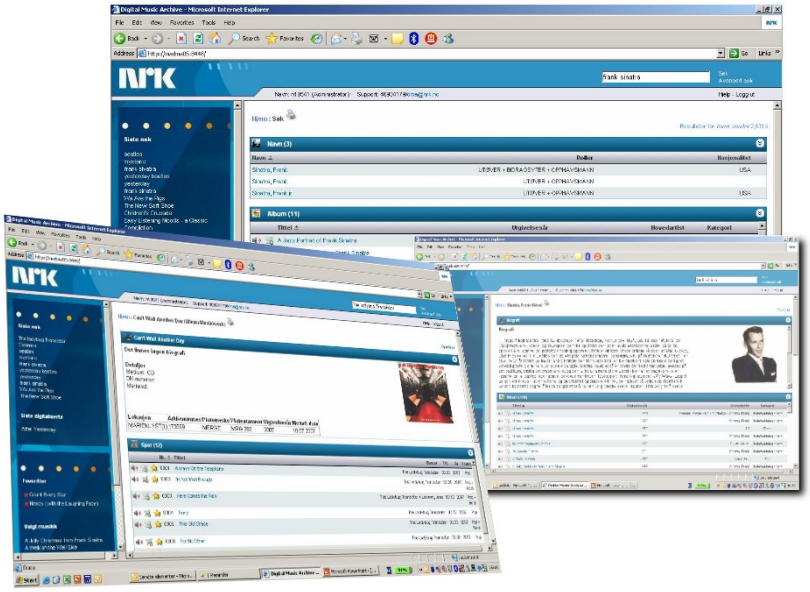


- Search through governmental documents
- A "bridge" is created between the users and the formal bureaucratic jargon using SW vocabularies and tools

Courtesy of Diego Berrueta and Luis Polo, CTIC, U. of Oviedo, and the Principality of Asturias, (SWEO Case Study)

Digital music asset portal at NRK

- Used by program production to find the right music in the archive for a specific show



Courtesy of Robert Engels, ESIS, and Jon Roar Tønnesen, NRK (SWEO Case Study)

Intelligent search for public services

- Semantic Web based search engine for public services at the municipality of Zaragoza (Spain)
- The search is based a local ontology, natural language processing and ontological reasoning

Courtesy of Jesús Fernando Ruíz, Municipality of Zaragoza (SWEO Use Case)

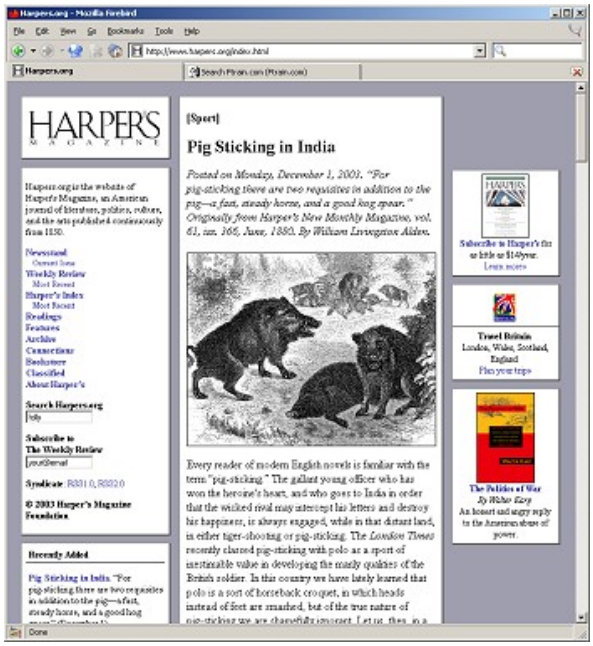
Vodafone live!

- Integrate various vendors' product descriptions via RDF
  - ring tones, games, wallpapers
  - manage complexity of handsets, binary formats
- A portal is created to offer appropriate content
- Significant increase in content download after the introduction

Courtesy of Kevin Smith, Vodafone Group R&D (SWEO Case Study)

Other examples…

- Sun's White Paper and System Handbook collections
- Nokia's S60 support portal
- Harper's Online Magazine
- Oracle's virtual pressroom
- Opera's community site
- Dow Jones' Synaptica

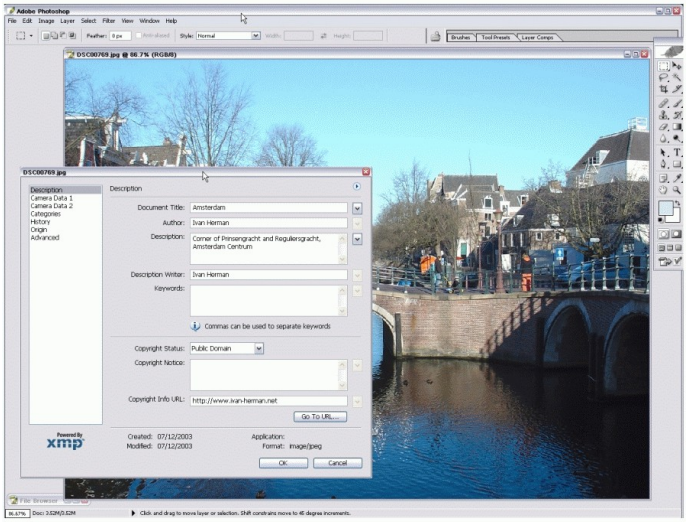


3. Illustrations of use – part 2

... other kinds of uses

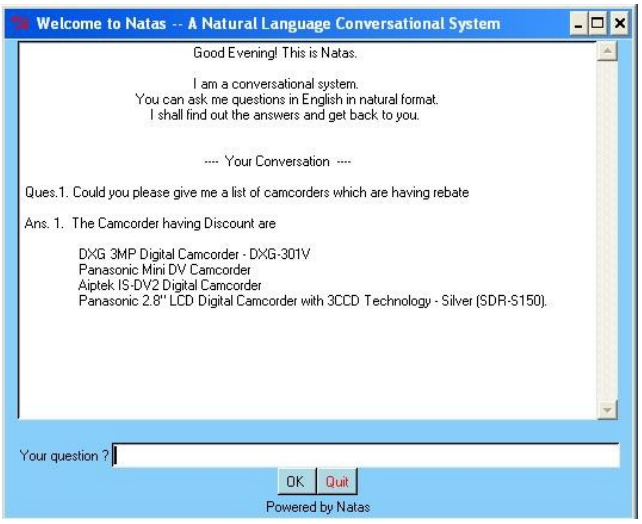
Adobe's XMP

- Metadata is added by, e.g., Photoshop into files in RDF
- XMP is a way of embedding + vocabulary + a set of (public) tools (there are also 3rd party tools to extract the RDF content)
- Used by a number of platform solutions



Natural interface to business applications

- Users interact with a business application (eg, via email) in natural language; OWL helps in the retrieval of relevant concepts

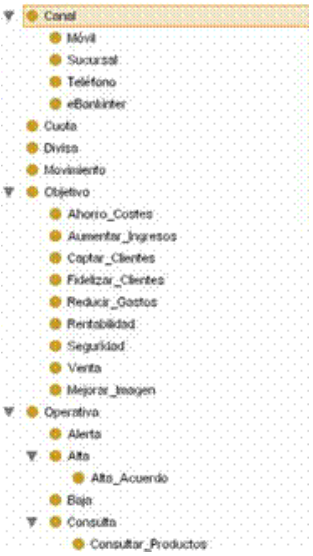


Courtesy of C. Anantaram, Tata Consultancy Services Limited (SWEO Case Study)

Suggestions' database…

bankinter

- Employees of the bank can submit new ideas for innovation, improving the business process, reduce costs, etc
- The entry system analyses the entry, shows similar ideas already in the system based on the *concepts* (not words)
- User gets immediate feedback, system gets better search, analysis, etc



Courtesy of José Luís Bas Uribe, Bankinter, and Richard Benjamins, iSOCO, (SWEO Case Study)

Other application areas come to the fore

- Content management
- Business intelligence
- Collaborative user interfaces
- Sensor-based services
- Linking virtual communities
- Grid infrastructure
- Multimedia data management
- Etc

3. The larger landscape

How the Semantic Web fits in

Semantic Web Technologies as tools

- Specific Semantic Web tools
  - Targeting specific needs not covered by other technologies
- SW adds value to your applications:
  - Makes "infeasible" functionality feasible
  - Provides an agile platform for data (data functionality)
  - Offers improved foundation for maintenance
- Must avoid fragmentation
  - The SW perspective is but one of many equally valid perspectives on data/information
  - Reuse of your investment in your data/information
- Interoperation – example domains:
  - Document web
  - Web services

Semantic Web in Document Domain

- Semantic perspective on document web resources
  - Preserve and support the document view of resources
  - Enable semantic access to descriptions embedded in resources
  - Example: RDFa, semantic annotations of XML-based resources
  -
- Document perspective on semantic web resources
  - Preserve and support the semantical access to resources
  - Enable a document view of semantically represented resources
  - Examples: generation of presentation structure and style sheets from data
  -
- Dual perspectives, but different objectives:
  - Supporting methods and tools: RDFa, GRDDL, ...

Semantic Web in Web Services

- The Web Services (WS) toolbox enables loose coupling between service user and service provider
  - Details in interaction controlled by descriptions – WSDL
- But content-related aspects of service use is not fully supported:
  - Service discovery, service characteristics, etc
- Emerging area: Semantic Web services
  - Semantic descriptions extend core WS descriptions
  - Support for semantic aspects on service use.
- The aim:
  - provide a flexible service framework that addresses the challenges of the web – *the dynamic character of services offered on the web*

Summary

Conclusions

- The Semantic Web is here to integrate data on the Web
  - The public web
  - Restricted webs
  - Intranet
- The goal is the creation of a *Web of Data*
- Core technologies/functionalities are standardised
  - RDF, OWL, SPARQL, ... RDFa, ...
- Additional needs/functionalities in the pipeline
  - By extensions to existing technologies
  - By additional tools and technologies

Thank You for your attention!