Smart Spaces

Chapter 3:

Semantic Web: Knowledge representation and reasoning

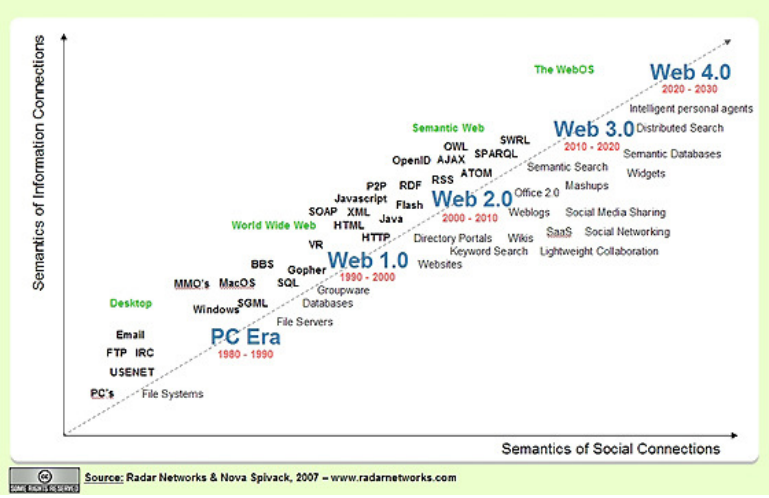
Outline

§ 1. Web Evolution

§ 2. Resource Description Framework (RDF)

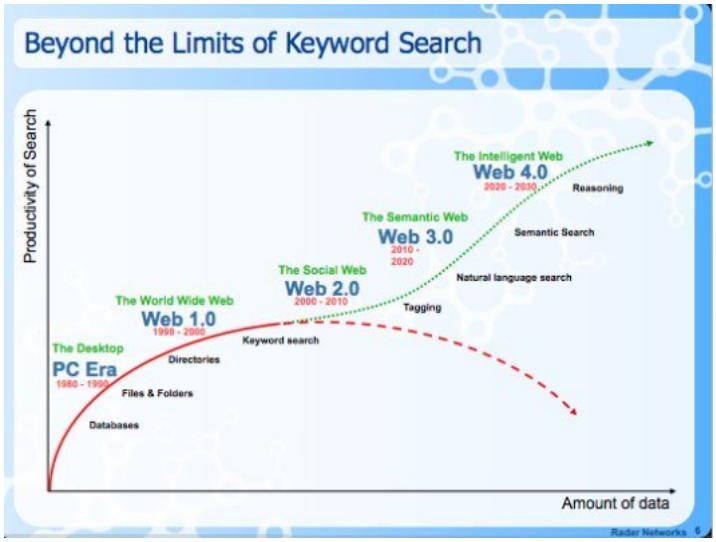
§ 3. Ontology representation model and OWL

§1. Web Evolution



From http://lifeboat.com/ex/web.3.0

The Web is Database



From Nova Spivack, 2009

Web 1.0

- WWW: World Wide Web
- Web 1.0: Collection of multimedia human-readable material
- HTML: HyperText Markup Language
- HTTP: HyperText Transfer Protocol
- Web site:
  its users are passive readers

Web 2.0

- Applications with information sharing, interoperability, user-centered design, and collaboration
  - Web services, eXtensible Markup Language (XML), and Service Oriented Architecture (SOA)
  - Collaborative self-publishing (blogs, wikis, ...)
  - Users interact and collaborate with each other in a social media dialogue as content creators in a virtual community
- A giant web of resources:
  Intelligence is in the connections

Semantic Web

- Provision of machine readable information in order to allow automating many tasks that the web is currently used for manually
- **Semantic Web**
  - Web of data that can be processed directly and indirectly by machines
- Social graph connects people;
  Semantic graph connects everything
- Tim Berners-Lee
  - World Wide Web Consortium (W3C)

The dream

- Each application in context tries to determine the meaning of the text or other data
- Then it creates connections for the user
- Users share and utilize computerized applications simultaneously in order to cross reference the time frame of activities with documentation and/or data
- The availability of machine-readable metadata would enable automated agents and other software to access the Web more intelligently
- The agents would be able to perform tasks automatically and locate related information on behalf of the user

Examples

- Semantic Publishing
  - real-time publishing and sharing of scientific data on the Internet
- Semantic Blogging
  - changing the way blogs are read (search, ranking, clustering, aggregation, ...)
- Web 3.0
  - Covers semantic web (or equal)

Smart Data

- Smart Data = Data that carries whatever is needed to make use of it
- The smartness moves into the data itself rather than being hard-coded into the software

Five Approaches to Semantics

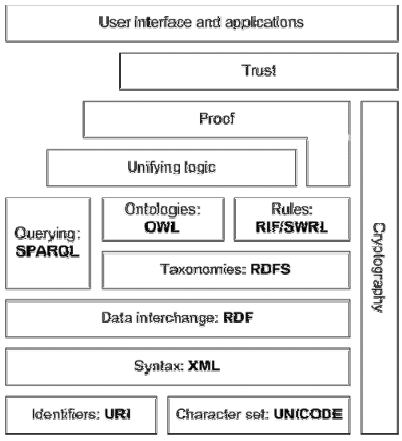
- Tagging (Flickr, Wikipedia)
- Statistics (Google)
- Linguistics
- Semantic Web
- Artificial Intelligence (WolframAlpha)

W3C and Semantic Web

Methods/tools for formal description of concepts, terms, and relationships within a given knowledge domain

- Resource Description
- Data interchange formats
- Semantic rules
- ...

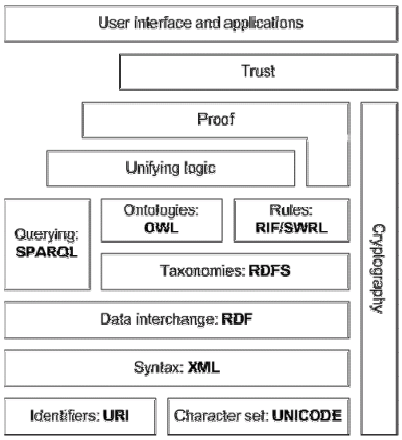
Semantic web stack



Hypertext Web technologies

- URI (Unified Resource Identifier)
  - unique identification of resources
- Unicode
  - texts in many languages
- XML
  - documents composed of structured data

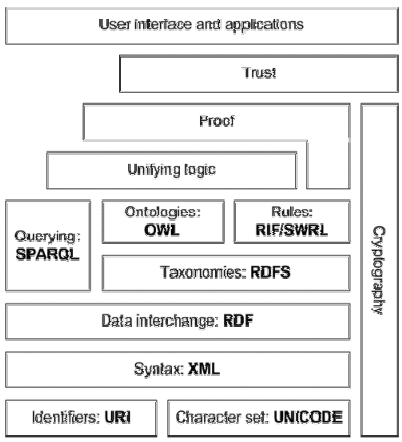
Semantic web stack



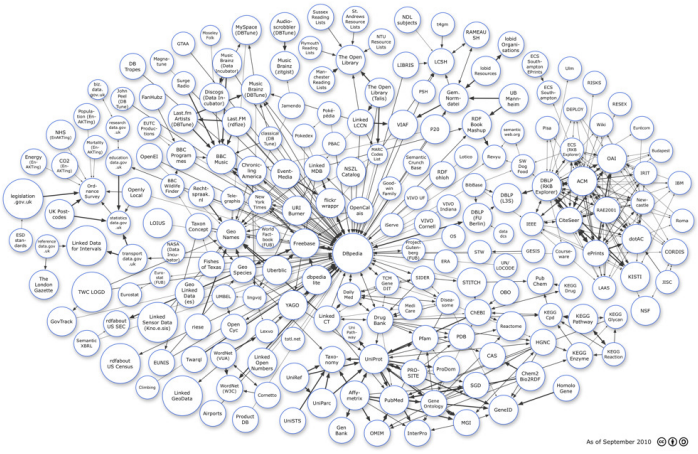
Resources: One giant global graph

- Resource Description Framework (RDF)
  - Information is represented as a set of triples
- RDF triple store
- One giant graph describes all resources of the web

Semantic web stack



http://richard.cyganiak.de/2007/10/lod/lod-datasets_2010-09-22.html



W3C SWEO Linking Open Data project

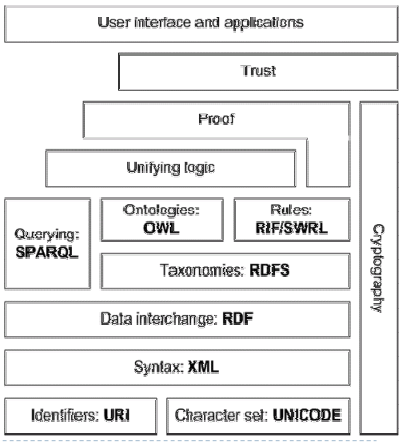
The 203 data sets

- consist of over 25 billion RDF triples
- interlinked by around 395 million RDF links

Ontological approach

- Ontology describes shared vocabulary for modeling a particular domain (thesaurus, taxonomy)
- Ontology structures a part of the graph needed at the moment

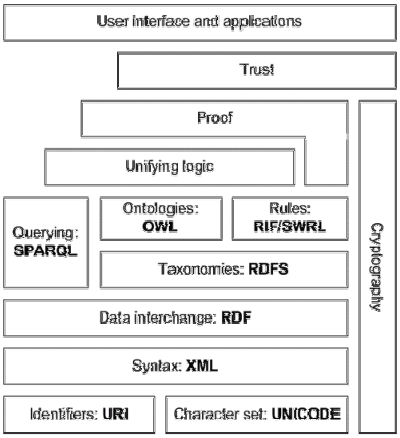
Semantic web stack



Representation languages

- RDF-Schema: RDFS
  - basic vocabulary for RDF
  - hierarchies of classes and properties
- Web ontology language: OWL
  - advanced constructions to describe semantics of RDF statements
  - cardinality, restrictions of values, transitivity, ...
  - based on description logic
  - reasoning

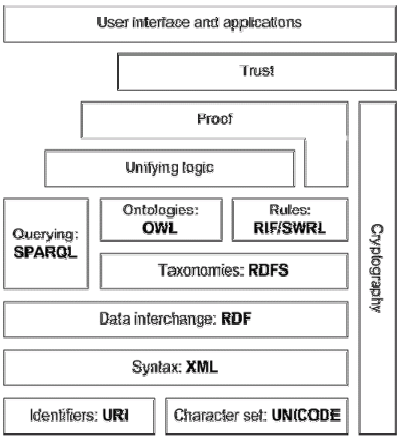
Semantic web stack



Querying languages

- Querying language is necessary to retrieve information for applications
- SPARQL is an RDF query language
- Simpler language: WQL (WilburQL) by Nokia (in original Smart-M3)

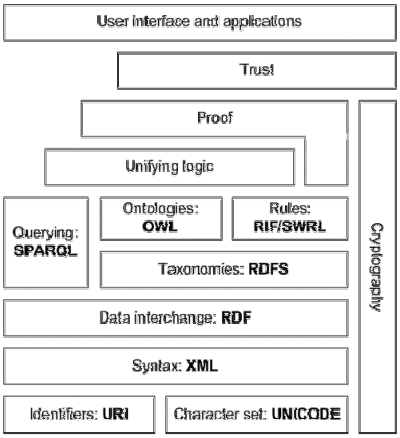
Semantic web stack



Semi-structured information

- Common ontology is similar to standardization
  - Difference: possibility of leaving information only partially defined
- The web is not the best platform for sharing the rapidly changing, dynamic local information about the immediate environment of a device

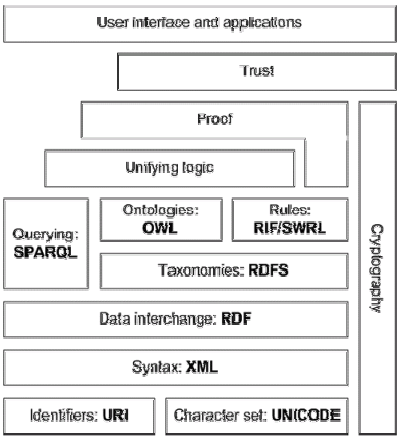
Semantic web stack



Unrealized Technologies

- Top layers contain technologies that are not yet standardized or contain just ideas
- RIF/SWRL
  - Rule Interchange Format
  - Semantic Web Rule Language
  - describing relations that cannot be directly described using OWL
- Cryptography, Trust
- User interface
  - enable humans to use semantic web applications

Semantic web stack



Literature

- Tim Berners-Lee, James Hendler, and Ora Lassila. The Semantic Web. Scientific American Magazine, 2001
- Web Evolution by Nova Spivack (2009) http://www.slideshare.net/novaspivack/web-evolution-nova-spivack-twine

§2. Resource Description Framework (RDF)

- Knowledge representation model
  1. Data structures (memory cells, pointers): no a priori semantics
  2. **Logical:** formal semantics in terms of relations among objects
- Given a problem domain
  - Shared vocabulary
  - Entities: objects and their properties
  - Relations

Ideas from Theory

- Artificial intelligence
- Logical facts as n-tuples
  - Predicates in descriptive logic

P(X1,X2,...,Xn)

- n-ary relations

(X1,X2,...,Xn)

- Simpler? n=2

P(X1,X2)

Ideas from Practice

- Web: pages and links
- X1 –> X2
  - ... or P(X1,X2)
- Triple:

(X1, P, X2)
Subject – Predicate – Object

Subject: http://dig.csail.mit.edu/data#DIG
Predicate: http://xmlns.com/foaf/0.1/member
Object: http://www.w3.org/People/Berners-Lee/card#i

Subject: http://data.linkedmdb.org/resource/film/77
Predicate: http://www.w3.org/2002/07/owl#sameAs
Object: http://dbpedia.org/resource/Pulp_Fiction_%28film%29

RDF triple

- Encoding model for knowledge:

  Subject – Predicate – Object
- URI – URI – URI
- URI – URI – String

- A, B are people:
  - A knows B
- C is a person, D is a book:
  - C is the author of D

RDF store

- Description of a domain:
  a list of many triples
- Knowledge base
  - Actual data (facts)
  - Deduction rules

RDF graph

- Composite descriptions: chains of knowledge
- Some objects, predicates, and subjects concise

Example

- Volunteer?
- Ideas from your projects?

Linked data

- Uniform Resource Identifiers (URI)
  - Initially: addresses of documents located on the Web
  - Generally: identification of any entity that exists in the world
- Data sets and their namespaces
  - Hierarchy and ID readability
- HyperText Transfer Protocol (HTTP)
  - Dereferencing a URI
  - Retrieving resources serialized as a stream of bytes
  - Retrieving descriptions of entities that cannot be sent across the network

Uniform Resource Identifier

- URL + semantics

<scheme name> : <hierarchical part> [? <query>] [# <fragment>]

- Scheme name

"http", "ftp", "mailto" or "file "

- Hierarchical part

cs.karelia.ru

- Query

type=animal

- Fragment

http://en.wikipedia.org/wiki/URI#Examples_of_URI_references

Knowledge Encoding

- Structured formalism (graph)
- Natural for web resources (links)
- Understandable to experts of the problem domain
- Understandable to software agents searching for information

§3. Ontology representation model and OWL

Terminological clarifications

- Conceptualization
  - A system of categories
  - Independent of specific language
- Engineering artifact
  - Specific vocabulary to describe a certain reality
  - Assumptions for intended meaning of the vocabulary words

Basic Idea

- Extending RDF
  - Triples are natural for web resources
- OO-approach
  - Classes, objects, properties, hierarchies
  - OO class: operational properties (methods)
  - Ontology: structural properties
- OO-model != Ontology model

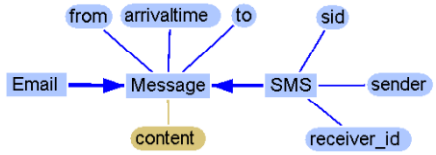
Ontology

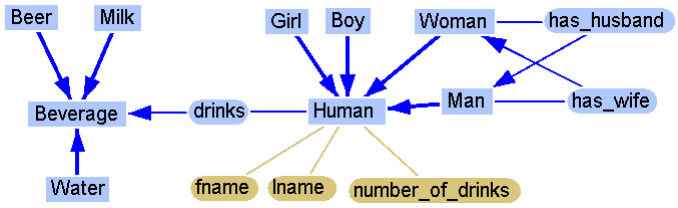
A formal explicit specialization of a conceptualization

- Classes ~ Concepts
  - A class ~ a set of individuals (instances)
- Properties of each concept
  - Features, attributes, roles
- Restrictions on properties

Example

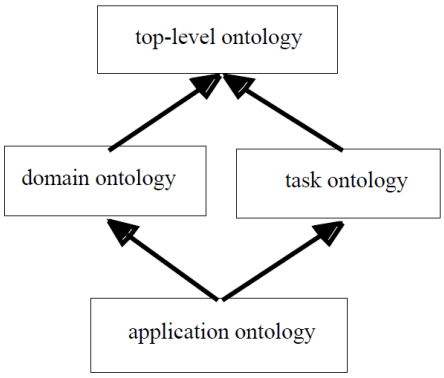
- Volunteer?
  - class ~ rectangle
  - data property ~ brown oval
  - object property ~ blue oval
  - subclass-of ~ arrow
  - property ~ edge





Granularity

- Accuracy or generality levels
- Top-level: general concepts
  - space, time, event, human, ...
- Domain vocabularies
  - medicine, automobiles
- Task or activity vocabularies
  - diagnosing, messaging
- Application: specialization of both a domain ontology and a task ontology (ontology library)
  - Blogging scenarios in a smart car



Knowledge Base

- Ontology describes state-independent information (the logical component)
  - Concept model (with particular syntax)
  - Ontology class graph
- "Core knowledge base" contains state-dependent information (the actual data component)
  - All individual instances
  - Ontology instance graph (~ RDF graph)
- Inference mechanism

OWL to RDF

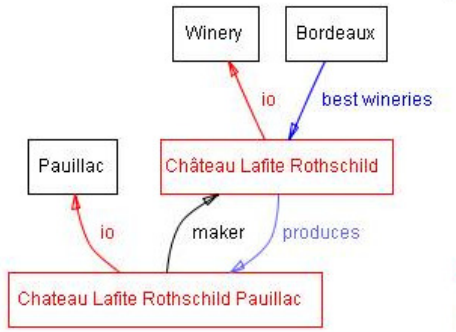
OWL is a particular language to write ontologies

- OWL ontology models a structure of a given problem domain
  - Ontology class graph
- High-level knowledge encoding by the ontology (individuals and their properties)
  - Ontology instance graph (~ RDF graph)
- At the lowest level, RDF triples are used
  - RDF store

Class + Instance graph

Wine domain

- Classes are in black
- Individuals are in red
- Links
  - instance-of (io)
  - subclass-of
  - data properties
    - sugar level
    - flavor
    - ...
  - object properties
    - maker
    - produces



Properties

- Data properties
  - Datatype values
- Object properties
  - Relationships to other individuals
- Restrictions
  - Cardinality
  - Value type (string, number, Boolean, enumerated, instance)
  - Range (allowed classes for type "instance")
  - Domain (classes a property is attached to)
  - ...

Development of a Knowledge Base

The basic scheme:

- Classes in the ontology
- Class structure as a subclass-superclass hierarchy (composition of several tree-like structures, multiple inheritance)
- Properties and allowed values
- Individual instances (individuals) and values of their properties

Remarks

- Reusing existing ontologies
- Tools for constructing ontologies
  - Protégé
  - ...

Literature

- C.Bizer, T.Heath, T.Berners-Lee. Linked Data - The Story So Far (2009)
- N.Guarino. The Ontological Level- Revisiting 30 Years of Knowledge Representation (2009)
- N.F. Noy, D.L. McGuinness. Ontology Development 101: A Guide to Creating Your First Ontology