

# Semantic Web Technologies

## Introduction and RDF

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# Outline

## Organization

## Semantic Web

- Limitations of the Web

- Machine-processable data

## Ontologies

## Resource Description Framework

- RDF Concepts

- RDF Containers and Collections

- RDF/XML Syntax

## Organization

- ▶ Lecture with labs
- ▶ Lecture
  - ▶ Wednesdays 08:30 – 10:30
  - ▶ Fridays 16:00 – 18:00
- ▶ Labs
  - ▶ Wednesdays 14:00 – 16:00
- ▶ Structure
  - ▶ 50 mins lecture
  - ▶ 15 mins break
  - ▶ 50 mins lecture
- ▶ Exams
  1. June 26th 09:00 - 11:00
  2. September 2006
  3. February 2007
- ▶ Web site: <http://www.debruijn.net/teaching/swt/>

## Organization (cont'd)

- ▶ Questions about the lecture or exercises can be asked after the lecture or by email: `jos.debruijn@deri.org`
- ▶ Appointments can be made via email (only for Wednesdays, Fridays)
- ▶ Solutions to labs to be sent to `jos.debruijn@deri.org` by following Tuesday
- ▶ Grading
  - ▶ Exam: 100%
  - ▶ Labs are **required** to be completed to get a grade
- ▶ Questions?

## Course Material

- ▶ Presentation slides
- ▶ Additional reading on the slides and the Web site.
- ▶ (Grigori Antoniou, Frank van Harmelen: **A Semantic Web Primer**, MIT Press, USA, 2004. ISBN: 0-262-01210-3.)

## Your Background

- ▶ First-Order Predicate Logic
- ▶ Description Logics
- ▶ Logic Programming
- ▶ Web Technology
- ▶ Web Services

# The Web

- ▶ What is the Web?
  - ▶ HTTP (how to transfer data)  
GET /index.html
  - ▶ URI (how to address data)  
http://www.deri.org/
  - ▶ HTML (how to mark up data for human reader)  
<html><head><title>.....

## The Problem with the Web

Billions of diverse documents online; problems in:

- ▶ Retrieving documents
- ▶ Extracting relevant data from retrieved documents
- ▶ Combining information from different sources to achieve a particular goal

# Retrieving documents

Google Search: de bruijn - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.google.com/search?q=de+bruijn&source=... Go de bruijn

Google Web Images Groups News Froogle Local<sup>New!</sup> more »

de bruijn Search [Advanced Search](#) [Preferences](#)

"de" is a very common word and was not included in your search. [\[details\]](#)

**Web** Results 1 - 10 of about 461,000 for **de bruijn**. (0.03 seconds)

Tip: Search for **English** results only. You can specify your search language in [Preferences](#)

[NJN HB 1956](#)  
www.gironet.nl/home/hmdb/ - 1k - [Cached](#) - [Similar pages](#)

[DE BRUIJN Project Support - Software Testen- Risico Analyse - Test ...](#)  
Advies, softwareselectie, ondersteuning bij het verbeteren van de kwaliteit van software en het ontwikkelen van een testomgeving.  
www.debruijn.nl/ - 20k - [Cached](#) - [Similar pages](#)

[de Bruijn Sequence -- from MathWorld](#)  
... A **de Bruijn** sequence can be generated using DeBruijnSequence[a, ... For example, a **de Bruijn** sequence of order n = 2 on the alphabet is given by . ...  
mathworld.wolfram.com/deBruijnSequence.html - 20k - 26 Feb 2005 - [Cached](#) - [Similar pages](#)

[Inge de Bruijn](#)  
Pictures,Pics, swimmer, olympic, gold, biography, foto, pics, news.  
www.netrover.com/~duracell/inge.html - 24k - [Cached](#) - [Similar pages](#)

- Grafimedia De **Bruijn**

Done

Where is  
Jos?

# Extracting Information

The screenshot shows the Amazon.com search results page for the query "web". The browser window title is "Amazon.com: All Products Search Results: web - Mozilla Firefox". The address bar shows the URL "http://www.amazon.com/exec/obidos/search-handle-form/002-1627595-93". The search bar contains "Search: Amazon.com for web" with a search button labeled "GO". Below the search bar, there are "Related Searches: web design; web development; internet".

The page features a navigation bar with categories: WELCOME, YOUR STORE, BOOKS, APPAREL & ACCESSORIES, ELECTRONICS, TOYS & GAMES, MUSIC, DVD, and SEE MORE STORES. There are also links for "VIEW CART", "WISH LIST", "YOUR ACCOUNT", and "HELP". A "Top Sellers in Sports & Outdoors" banner is visible on the right.

Under the heading "All results for: web", there is a "Refine your search:" section with the following categories and item counts:

- Home & Garden (34,706)
- Tools & Hardware (11,483)
- Health & Personal Care (Beta) (10,667)
- Books (8,875)
- Sports & Outdoors (Beta) (6,018)
- Kitchen & Housewares (4,468)
- Outdoor Living (2,416)
- Electronics (2,357)
- Wireless Plans (2,091)
- Software (1,151)
- Office Products (991)

The search results list three books:

- Creating Web Pages for Dummies, Sixth Edition** by Bud E. Smith, et al (**Paperback**)  
Books: [See all 8,875 items](#) ([Rate this item](#))  
**Buy new: \$16.49** **Used & new** from \$14.45 Usually ships in 24 hours
- By Order of the President** by W. E. B. Griffin (**Hardcover**)  
Books: [See all 8,875 items](#) ([Rate this item](#))  
**Buy new: \$16.17** **Used & new** from \$12.90 Usually ships in 24 hours
- Search Engine Optimization for Dummies** by Peter Kent (**Paperback**)  
Books: [See all 8,875 items](#) ([Rate this item](#))

# Extracting Information

The screenshot shows the Amazon.com search results for the query 'web'. The browser window title is 'Amazon.com: All Products Search Results: web - Mozilla Firefox'. The search bar contains 'Amazon.com' and 'for web'. Below the search bar, there are 'Related Searches' for 'web design', 'web development', and 'internet'. On the left side, there is a 'Refine your search' section with a list of categories: Home & Garden (34,706), Tools & Hardware (11,489), Health & Personal Care (Beta) (10,667), Books (8,875), Sports & Outdoors (Beta) (6,018), Kitchen & Housewares (4,468), Outdoor Living (2,416), Electronics (2,357), Wireless Plans (2,091), Software (1,151), and Office Products (991). The main search results list three books:

- Creating Web Pages for Dummies, Sixth Edition** by Bud E. Smith, et al (Paperback). Buy new: \$16.49. Used & new from \$14.45. Usually ships in 24 hours.
- By Order of the President** by W. E. B. Griffin (Hardcover). Buy new: \$16.17. Used & new from \$12.90. Usually ships in 24 hours.
- Search Engine Optimization for Dummies** by Peter Kent (Paperback). Buy new: \$16.99. Used & new from \$12.99. Usually ships in 24 hours.

Red circles and arrows highlight the search results and the question 'Which book is about the Web?'.

Which book is about the Web?

# Extracting Information

The screenshot shows the Amazon.com search results for the query 'web'. The browser window title is 'Amazon.com: All Products Search Results: web - Mozilla Firefox'. The search bar contains 'Amazon.com' and 'web'. The search results are filtered by 'Amazon.com'. The first result is 'Creating Web Pages for Dummies, Sixth Edition' by Bud E. Smith, et al (Paperback). The price is listed as 'Buy new: \$16.49' and 'Used & new from \$14.45'. The second result is 'By Order of the President' by W. E. B. Griffin (Hardcover). The price is listed as 'Buy new: \$16.17' and 'Used & new from \$12.90'. The third result is 'Search Engine Optimization for Dummies' by Peter Kent (Paperback). The price is listed as 'Buy new: \$16.17' and 'Used & new from \$12.90'. A blue arrow points from the text 'What is the price of the book?' to the price '\$14.45' of the first book.

Amazon.com: All Products Search Results: web - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.amazon.com/exec/obidos/search-handle-form/002-1627595-93

Go de bruijn

Shop in Jewelry & Watches

amazon.com

VIEW CART | WISH LIST | YOUR ACCOUNT | HELP

Top Sellers in Sports & Outdoors

WELCOME YOUR STORE BOOKS APPAREL & ACCESSORIES ELECTRONICS TOYS & GAMES MUSIC DVD SEE MORE STORES

INTERNATIONAL | NEW RELEASES | TOP SELLERS | TODAY'S DEALS | SELL YOUR STUFF

Hello. Sign in to get personalized recommendations. New customer? Start here.

All results for: web

Search: Amazon.com for web

Related Searches: web design; web development; internet

Refine your search:

Find web in these categories:

- Home & Garden (34,706)
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Creating Web Pages for Dummies, Sixth Edition by Bud E. Smith, et al (Paperback)

Books: See all 8,875 items (Rate this item)

Buy new: \$16.49 Used & new from \$14.45 Usually ships in 24 hours

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Buy new: \$16.17 Used & new from \$12.90 Usually ships in 24 hours

Search Engine Optimization for Dummies by Peter Kent (Paperback)

Books: See all 8,875 items (Rate this item)

Done

What is the price of the book?

# Combining information

I want the cheapest copy of "A Semantic Web Primer".

Amazon.com: All Products Search Results: A Semantic Web Primer - Mozilla Firefox

http://www.amazon.com/exec/obidos/search-handle-url/index%3Dblended%26field=ke Go de brujn

All results for: A Semantic Web Primer

Search: Amazon.com for A Semantic Web Primer

Refine your search:

Find A Semantic Web Primer in these categories:

Books (30)

So You'd Like to...

**A Semantic Web Primer (Cooperative Information Systems)** by Grigoris Antoniou, Frank van Harmelen (**Hardcover**)

Books: [See all 30 items](#) ([Rate this item](#))

Buy new: **\$34.82** Used & new from \$32.75 Usually ships in 24 hours

The Semantic Web: A Guide to the Future of XML, Web Services

Barnes & Noble.com - Book Search: A Semantic Web Primer - Mozilla Firefox

http://search.barnesandnoble.com/booksearch/results.asp?WRD=A%20 Go

**1. A Semantic Web Primer**  
Grigoris Antoniou, Frank Van Harmelen

Format: **Textbook Hardcover**  
Pub. Date: July 2004

**NEW FROM B&N**

List Price: \$40.00  
B&N Price: **\$38.00** (Save 5%)  
Member Price: **\$36.10** [Join>](#)

**Usually ships within 24 hours**

Pre-order the sixth Harry Potter book now!  
And sign up for JK Rowling Writer Alert below for updates on other Harry Potter items.

Your email here

SIGN UP >

# Combining information (cont'd)

I want the cheapest copy of "A Semantic Web Primer"; taking into account the price for shipping the book.

**Barnes & Noble.com - Mozilla Firefox**

File Edit View Go Bookmarks Tools Help

object shipping options

**Shipping Address**

**Confirm Shipping Address**  
 Work  
 Jos de Bruijn  
 University of Innsbruck  
 Technikerstrasse 13  
 Innsbruck A6020  
 Austria  
[Edit Shipping Address](#)  
[Change Recipient](#)

**Items Shipping from Barnes & Noble.com**

**FAST & FREE DELIVERY**  
 Your shipping selections do not qualify for Fast and Free Del

**Select a Shipping Method**

**International Airmail** 7 to 21 business days \$12.95  
 **International Priority** 4 to 14 business d. \$15.45

Quantity	Description
1	<b>A Semantic Web Primer</b> Ogoris Antoniou, Frank Van Hamelen <b>Hardcover</b> Our Price: \$39.00

Done cart2.barnesandnoble.com

**http://www.amazon.com - Amazon.com: Help / Shipping / Shipping Rate...**

For more information about total delivery time, [click here](#).

**Standard International Shipping**

- 11 to 18 business days
- [When will my order arrive?](#)

	Per Shipment	Per Item
CDs, DVDs, music cassettes, VHS videotapes, vinyl	\$4.49	\$2.49
Books*	\$4.49	\$4.49
Any combination of the above items	<b>Highest applicable per-shipment charge</b>	<b>As above</b>

\*Books with listed availabilities of more than 3 weeks may incur an additional shipping fee of \$1.99 per item.

**Expedited International Shipping**

- 5 to 10 business days
- [When will my order arrive?](#)

	Per Shipment	Per Item
CDs, DVDs, music cassettes, VHS videotapes, vinyl	\$7.49	\$2.99
Books*	\$7.49	\$5.49
Any combination of the above items	<b>Highest applicable per-shipment charge</b>	<b>As above</b>

\*Books with listed availabilities of more than 3 weeks may incur an additional shipping fee of \$1.99 per item.

**Priority International Courier**

- 2 to 4 business days
- [When will my order arrive?](#)

Done

On average 10 clicks to find out what the shipping rate is!

## The solution

- ▶ Instead of publishing natural language, publish machine-processable data!
- ▶ Publish information in terms understandable for a machine
- ▶ Ask questions in terms understandable for a machine
- ▶ And: make sure all machines understand your terms!

# What it's like to be a machine on the Web

## 林克昌 根留台灣 可能增高

在愛戴者熱心奔走之下，華裔名指揮家林克昌根留台灣的可行性又提升了幾分。兩廳院主任李炎、國家音樂廳樂團副團長黃奕明日前親赴林克昌、石聖芳寓所拜會，並提出多場客席邀約。此外，台灣省立交響樂團團長陳澄雄也早早「下訂」，邀請林克昌赴台中霧峰，從八月十日起訓練省交，為期長達一個月。

在台灣諸多公家樂團中，陳澄雄是以實際行動表達對林克昌肯定的樂界人士之一，曾多次公開表示對林克昌指揮才華的欽佩，而且幾乎每個樂季都邀請林克昌客席演出。

此外，林克昌上個月赴俄羅斯與頂尖的「俄羅斯國家管絃樂團」灌錄了柴可夫斯基晚期三大交響曲以及「羅密歐與茱麗葉」、「斯拉夫進行曲」、「義大利隨想曲」，最後的DAT母帶也在前兩天寄回台灣。製作人楊忠衛與林克昌試聽之後，都對錄音效果—尤其音質表現感到相當滿意，楊忠衛估計呈現了七分林克昌指揮神韻。

俄羅斯國家管絃樂團首席布魯尼日前也讚譽林克昌的指揮藝術有三大特點：一是控制自如的彈性速度；二是強烈的動態對比；三是宛如呼吸歌唱的旋律處理。這些對錄音師而言都構成很大挑戰。俄國錄音師雖然採用多軌混音，但定位、場面都有可觀之處。。

Slide originally presented by Frank van Harmelen

<http://www.cs.vu.nl/%7Efrankh/spool/SemWebSlides/SemWeb-tour-Brussels.ppt>

## Publishing and querying machine processable data

- ▶ Publishing:
  - ▶ B **related-to** A
  - ▶ C **related-to** A
  - ▶ D **related-to** C
- ▶ Querying (give me all things related to A):
  - ▶ ?x related-to A
  - ▶ Answer:
    - ▶ ?x = B
    - ▶ ?x = C

## Publishing and querying machine processable data (cont'd)

- ▶ Publishing (**related-to** is transitive):
  - ▶ **B related-to A**
  - ▶ **C related-to A**
  - ▶ **D related-to C**
  - ▶ **?x related-to ?y and ?y related-to ?z  $\Rightarrow$  ?x related-to ?z**
  
- ▶ Querying (give me all things related to A):
  - ▶ ?x related-to A
  
  - ▶ Answer:
    - ▶ ?x = B
    - ▶ ?x = C
    - ▶ **?x = D**

## Course Overview

- ▶ Ontologies
- ▶ Resource Description Framework (RDF)
- ▶ A query language for RDF: SPARQL
- ▶ Lightweight ontologies: RDF Schema
- ▶ Web Ontology Language (OWL)
- ▶ Ontologies and Rules in F-Logic
- ▶ Exchange of rules over the Web: RuleML
- ▶ Semantic Web Services

# Ontologies

- ▶ **Formal**
- ▶ **explicit** specification of a
- ▶ **shared**
- ▶ **conceptualization**
- ▶ of a **domain**.

## Ontologies I: Formal Ontologies

- ▶ Meaning of ontology is **unambiguous**;
- ▶ avoids **misunderstanding**;
- ▶ specification using **formal language**:
- ▶ enables **reasoning**: making implicit information explicit:
- ▶ Hampers **consensus**

## Ontologies II: Explicit specifications

- ▶ Make domain assumptions **explicit**
  - ▶ for **reasoning**,
  - ▶ for **clarifying** understanding of domain.
- ▶ **Minimal ontological commitment**
  - ▶ Too much explicit  $\Rightarrow$  **no consensus**
  - ▶ Too little explicit  $\Rightarrow$  ontology **unusable**
  - ▶ Minimal ontological commitment = “make as little as explicit as possible, while keeping ontology useful”.

## Ontologies III: Specification of a shared conceptualization of a domain

- ▶ Domain: specific part of the world
- ▶ Conceptualization
  - ▶ Forming **idea** of domain
  - ▶ in the **minds** of people
- ▶ **Shared** among its users
  - ▶ facilitates **accepting** the ontology.

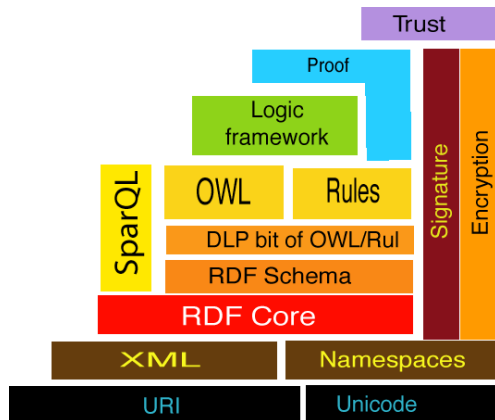
## Classes, Properties, Instances, Axioms

- ▶ Classes
  - ▶ Grouping of individuals
  - ▶ with common properties
  - ▶ cf. UML
  - ▶ **Intentional** classes
  - ▶ e.g. Persons, Cars, Universities, ...
- ▶ Relations
  - ▶ Connections **between** individuals
  - ▶ May be **attached** to classes
  - ▶ e.g. hasName, hasChild, hasColor, owns, ...
- ▶ Individuals
  - ▶ **Objects** in the domain
  - ▶ May be **instances** of classes
- ▶ Axioms
  - ▶ Additional statements about the domain
  - ▶ Specified in logical language
  - ▶ e.g. “hasName has one value”

# Ontologies

- ▶ Form the **backbone** of the Semantic Web,
- ▶ define the **basic vocabulary** for the annotations,
- ▶ enable reasoning with **background knowledge**,
- ▶ based on **formal** languages,
- ▶ interweave meaning for
  - ▶ **humans** and
  - ▶ **machines**,
- ▶ are **shared**.

# Semantic Web Layer Cake



## Principles of RDF

- ▶ Resources (identified by URIs)
  - ▶ A URI **identifies** a resources, but does not necessarily **point** to it
  - ▶ Correspond to nodes in a graph
  - ▶ E.g. `http://www.w3.org/`, `http://example.org/#john`,  
`http://www.w3.org/1999/02/22-rdf-syntax-ns#Property`
- ▶ Properties (identified by URIs)
  - ▶ Correspond to labels of edges in a graph
  - ▶ Binary relation between two resources
  - ▶ E.g. `http://www.example.org/#hasName`,  
`http://www.w3.org/1999/02/22-rdf-syntax-ns#type`
- ▶ Literals
  - ▶ concrete data values
  - ▶ E.g. "John Smith", "1", "2006-03-07"

## Principles of RDF (cont'd)

- ▶ Triple data model:

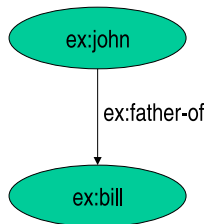
*⟨subject, predicate, object⟩*

- ▶ Subject: Resource or blank node
- ▶ Predicate: Property
- ▶ Object: Resource, literal or blank node
- ▶ Example:

*⟨ex:john, ex:father-of, ex:bill⟩*

- ▶ Labeled, directed graphs

- ▶ Nodes: resources, literals
- ▶ Labels: properties
- ▶ Edges: statements



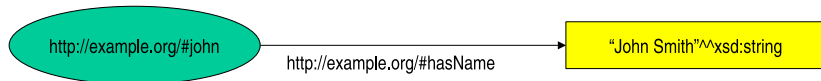
## Resources

- ▶ A resource may be:
  - ▶ Web page (e.g. `http://www.w3.org/`)
  - ▶ A person (e.g. `http://www.debruijn.net/`)
  - ▶ A book (e.g. `urn:isbn:0-345-33971-1`)
  - ▶ Anything denoted with a URI!
- ▶ A URI is an **identifier** and **not** a location on the Web
- ▶ RDF allows making statements about resources (meta-data):
  - ▶ `http://www.w3.org/` **has the format** `text/html`
  - ▶ `http://www.debruijn.net/` **has first name** `Jos`
  - ▶ `urn:isbn:0-345-33971-1` **has the author** `Tolkien`

## Literals

- ▶ Plain literals
  - ▶ E.g. "blabla"
  - ▶ Optional language tag, e.g. "Hello, how are you?"@en-GB
- ▶ Typed literals
  - ▶ E.g. "hello"^^xsd:string, "1"^^xsd:integer
  - ▶ Recommended datatypes: XML Schema datatypes
  - ▶ Datatype mechanism extensible
  - ▶ Type checking not in RDF
- ▶ Only as **object** of a triple, e.g.:

```
<<http://example.org/#john>,  
<http://example.org/#hasName>," John Smith"^^xsd:string>
```



# Datatypes

- ▶ One pre-defined datatype: `rdf:XMLLiteral`
- ▶ Recommended datatypes are XML Schema datatypes, e.g.:
  - ▶ `xsd:string`
  - ▶ `xsd:integer`
  - ▶ `xsd:float`
  - ▶ `xsd:anyURI`
  - ▶ `xsd:boolean`
- ▶ A datatype has (example is for `xsd:boolean`):
  - ▶ Lexical space, e.g. `{"0", "1", "true", "false"}`
  - ▶ Value space, e.g. `{T, F}`
  - ▶ Lexical-to-value mapping, e.g. `{⟨"true", T⟩, ⟨"1", T⟩, ⟨"0", F⟩, ⟨"false", F⟩}`

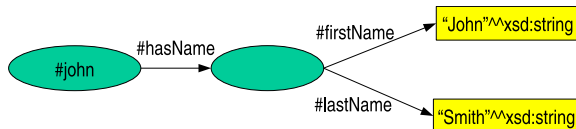
## Blank nodes

- ▶ Blank nodes are nodes **without** a URI
  - ▶ Unnamed resources
  - ▶ More complex constructs
- ▶ Representation of blank nodes is **syntax-dependent**
- ▶ For example:

```
<#john>, <#hasName>, .:johnsname
```

```
<.:johnsname, <#firstName>, "John"^^xsd:string
```

```
<.:johnsname, <#lastName>, "Smith"^^xsd:string
```



## Reification

- ▶ Reification: statements about statements

Mary claims that John's name is " John Smith".

```
<<#myStatement>,rdf:type,rdf:Statement>  
<<#myStatement>,rdf:subject,<#john>>  
<<#myStatement>,rdf:predicate,<#hasName>>  
<<#myStatement>,rdf:object," John Smith">  
  
<<#mary>,<#claims>,<#myStatement>>
```

## RDF Vocabulary

- ▶ RDF defines a number of resources and properties
- ▶ We have already seen: `rdf:XMLLiteral`, `rdf:type`, ...
- ▶ RDF vocabulary is defined in the namespace:  
`http://www.w3.org/1999/02/22-rdf-syntax-ns#`
- ▶ Classes:  
`rdf:Property` `rdf:Statement` `rdf:XMLLiteral` `rdf:Seq` `rdf:Bag`  
`rdf:Alt` `rdf>List`
- ▶ Properties:  
`rdf:type` `rdf:subject` `rdf:predicate` `rdf:object` `rdf:first` `rdf:rest`  
`rdf:_n` `rdf:value`
- ▶ Resources:  
`rdf:nil`

## RDF Vocabulary (cont'd)

- ▶ Typing using `rdf:type`:  
     $\langle A, \text{rdf:type}, B \rangle$   
    " *A* belongs to class *B*"
- ▶ All properties belong to class `rdf:Property`:  
     $\langle P, \text{rdf:type}, \text{rdf:Property} \rangle$   
    " *P* is a property"

$\langle \text{rdf:type}, \text{rdf:type}, \text{rdf:Property} \rangle$   
" `rdf:type` is a property"

## RDF containers

► Grouping property values:

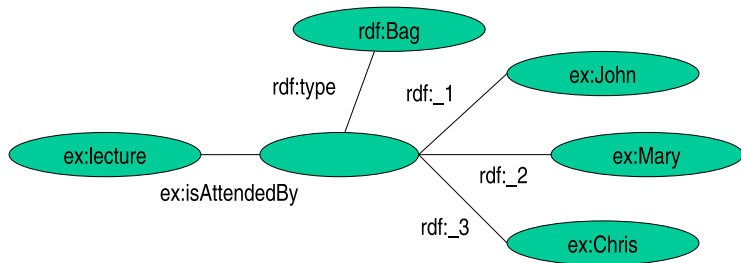
"The lecture is attended by John, Mary and Chris"      Bag

"[RDF-Concepts] is edited by Graham and Jeremy (in  
that order)"      Seq

"The source code for the application may be found at  
ftp1.example.org, ftp2.example.org, ftp3.example.org"      Alt

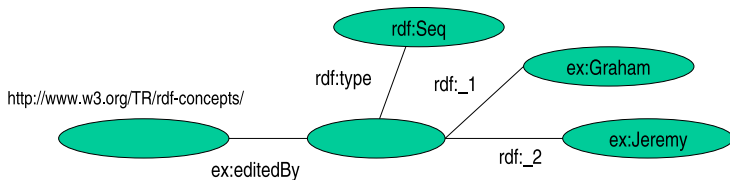
## RDF Containers: Bag

"The lecture is attended by John, Mary and Chris"



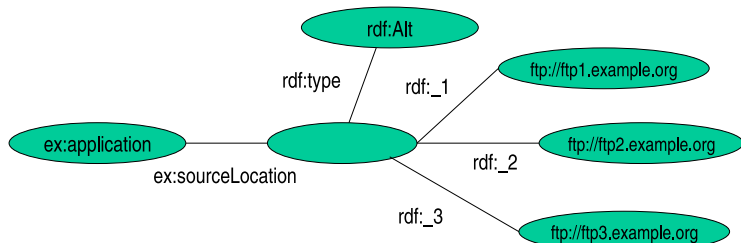
## RDF Containers: Seq

” [RDF-Concepts] is edited by Graham and Jeremy (in that order)”



## RDF Containers: Alt

” The source code for the application may be found at ftp1.example.org, ftp2.example.org, ftp3.example.org”



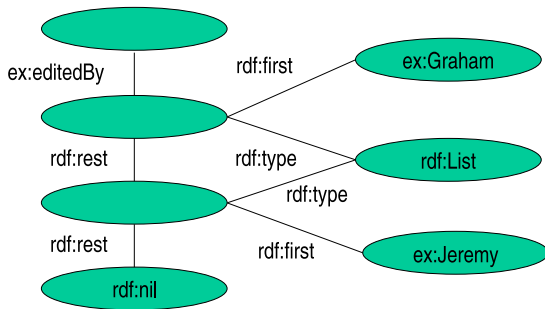
## RDF Containers

- ▶ Three types of containers:
  - ▶ `rdf:Bag` – unordered set of items
  - ▶ `rdf:Seq` – ordered set of items
  - ▶ `rdf:Alt` – set of alternatives
- ▶ Every container has a triple declaring the `rdf:type`
- ▶ Items in the container are denoted with `rdf:_1`, `rdf:_2`,  
..., `rdf:_n`
- ▶ Limitations:
  - ▶ Semantics of the container is up to the application
  - ▶ What about closed sets? How do we know whether Graham and Jeremy are the only editors of [RDF-Concepts]?

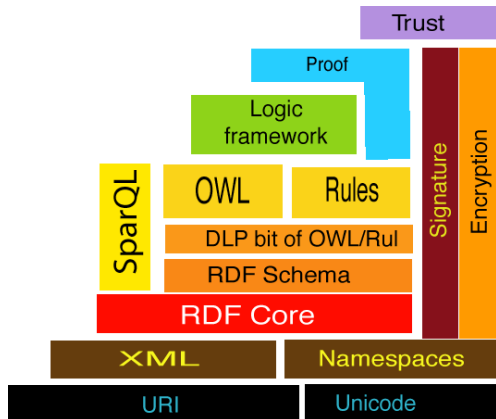
## RDF Collections

"[RDF-Concepts] is edited by Graham and Jeremy (in that order) and **nobody else**"

<http://www.w3.org/TR/rdf-concepts/>



# Semantic Web Layer Cake



## URIs and Namespaces

- ▶ Uniform Resource Identifier (URI):
  - ▶ Globally unique identifiers for resources
  - ▶ Not necessarily resources on the Web (e.g. 'urn:isbn:')
  - ▶ Thus: it is possible to make claims about the same resource in different locations!
- ▶ Namespaces: Syntactical space of XML names:
  - ▶ `< namespace, localname >`
  - ▶ Usually abbreviated using namespace prefixes:  
`prefix:localname`, e.g. `xs:integer`
  - ▶ Reused in RDF, but merely as abbreviations: `xs:integer` is equivalent to  
`http://www.w3.org/2001/XMLSchema#integer` and **not**  
`<"http://www.w3.org/2001/XMLSchema#", "integer">`

For more on XML, see Semantic Web Primer, Chapter 2

## RDF/XML

- ▶ Serializing RDF for the Web
  - ▶ XML as standardized interchange format:
    - ▶ Namespaces (e.g. `rdf:type`, `xsd:integer`, `ex:john`)
    - ▶ Encoding (e.g. UTF8, iso-8859-1)
    - ▶ XML Schema (e.g. datatypes)
    - ▶ DTD entities (e.g. `&xsd;`)
  - ▶ Reuse of existing XML tools:
    - ▶ Syntax checking (i.e. schema validation)
    - ▶ Transformation (via XSLT)
      - ▶ Different RDF representation
      - ▶ Layout (XHTML)
      - ▶ Different XML-based format
  - ▶ Parsing and in-memory representation/manipulation (DOM/SAX)
  - ▶ ...

## RDF/XML (cont'd)

<#john,#hasName, "John" >

<#john,#marriedTo,#mary >

```
<!ENTITY ex "http://example.org/#">
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:ex="http://example.org#"

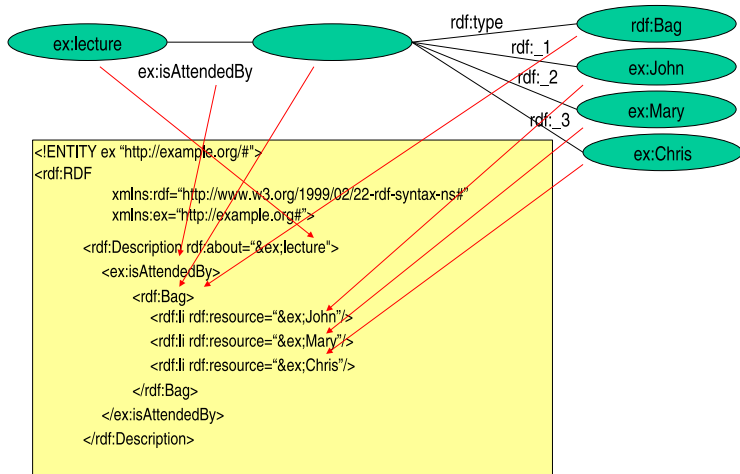
  <rdf:Description rdf:about="http://example.org/#john">
    <ex:hasName>John</ex:hasName>
    <ex:marriedTo rdf:resource="&ex;mary"/>
  </rdf:Description>
</rdf:RDF>
```

Head

Body

Foot

## RDF/XML (cont'd)



## Conclusion

- ▶ Advantages:
  - ▶ Reuse existing standards/tools
  - ▶ Provides some structure for free (e.g. for containers)
  - ▶ Standard format
- ▶ Disadvantages:
  - ▶ Verbose
  - ▶ Reconstructing RDF graph non-trivial

# Summary

## Organization

## Semantic Web

- Limitations of the Web

- Machine-processable data

## Ontologies

## Resource Description Framework

- RDF Concepts

- RDF Containers and Collections

- RDF/XML Syntax

## Required reading

- ▶ Ontology Development 101: [http://protege.stanford.edu/publications/ontology\\_development/ontology101-noy-mcguinness.html](http://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html)
- ▶ RDF Primer: <http://www.w3.org/TR/rdf-primer/>, Chapters 1–4

## Further reading

- ▶ Semantic Web Primer, Chapters 1,2 and Sections 3.1, 3.2, 3.3.
- ▶ Berners-Lee, T.; Hendler, J.; Lassila, O.: The Semantic Web. Scientific American, May 2001. <http://www.sciam.com/article.cfm?articleID=00048144-10D2-1C70-84A9809EC588EF21>
- ▶ Jos de Bruijn: **Using Ontologies**. <http://www.deri.org/publications/techpapers/documents/DERI-TR-2003-10-29.pdf>
- ▶ RDF Concepts and abstract syntax: <http://www.w3.org/TR/rdf-concepts/>
- ▶ RDF/XML syntax specification: <http://www.w3.org/TR/rdf-syntax-grammar/>