

# Introduction to **Semantic Web**

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TOBB University of Economics and Technology



## **Outline**

- Motivation
  - Development of the Web: Web 1.0, 2.0, 3.0
  - Limitations of the current Web
- Technical solution
  - Introduction to Semantic Web
  - Semantic Web – architecture and languages
  - Semantic Web - data
  - Semantic Web – tools, processes
- Recent trends
- Summary
- References

## Semantic web

- What?
  - Web vs Internet
  - Semantics?
- How?

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3

## Before the Web



AMOROSI A. and COLALONGO M.L., 2005. The linkage between alluvial and coeval nearshore marine successions: evidence from the Late Quaternary record of the Po River Plain, Italy. In: Blum M.D., Marriott S.B. and Leclair S.F. (eds.) *Fluvial Sedimentology VII. International Association of Sedimentologists Special Publication 35*, 257-275.

BERNER K.B. and BERNER R.B. (eds), 1996. *Global Environment: Water, Air, and Geochemical Cycles*. Prentice Hall, Upper Saddle River, New Jersey.

BUDO D.A., 1988. *Freshwater diagenesis of Holocene ooid sands, Schooner Cays, Bahamas*. PhD Thesis, University of Texas, Austin.

CANN J., BELPERIO A. P., GOSTIN V.A. and MURRAY-WALLACE C. V., 1988. Sea-level history, 45,000 to 30,000 yr B.P., inferred from benthic foraminifera, Gulf St. Vincent, South Australia. *Quaternary Research* 29, 153-175.

CARBONI M.G., ESU D. and MATTEUCCI R., 1989. Oligotopia nei laghi costieri laziali. In: Di Geronimo S.I. (ed.) *Atti 3° Simposio di Ecologia e Paleoecologia delle Comunità Bentoniche*, 53-75.

CORTEGGI G., DINELLI E., LUCCHINI F. and VASELLI O., 2001. Hydrogeochemical and isotopic investigations in the abandoned Fe-Cu mine of Libiola (northern Italy). In: *Proceedings of the Tenth International Symposium on Water/Rock Interaction WRI-10, June 10-15, Vilasimus, Italy*. A.A. Balkema Publ., Lisse, The Netherlands, 1197-1200.

TZEDAKIS P.C., FRODLEY M.R. and HEATON T.H.E., 2003. Last Interglacial conditions in southern Europe: evidence from Ioannina, northwest Greece. *Global and Planetary Change* 36, 157-170.



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4

## Memex

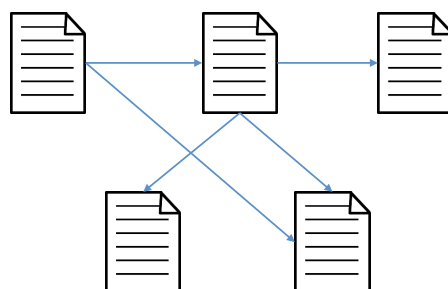
- "As We May Think", Vannevar Bush, 1945, *The Atlantic Monthly*
- **Mem(ory-Ind)ex**
- All information (books, communication, etc) in the form of microfilms and indexed using electromechanical device.

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5

## Web 1.0 (1990)

- Hyperlinked web documents



Abstracts away...

- Storage
- Networking

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6

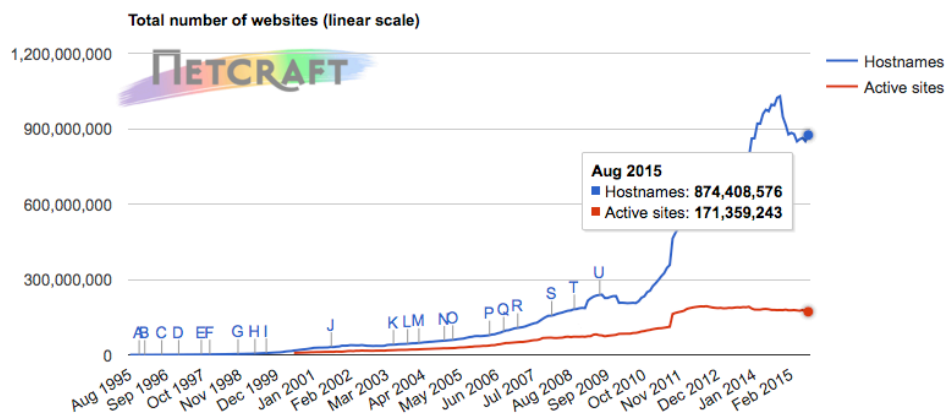
## Web 2.0 (2000)

- Applications and content
- Social web
  - Facebook, Twitter, Google+, LinkedIn
  - YouTube, Flickr
  - Blogs, wikis
  - Wikipedia
- Problem
  - Application silos
  - Disconnected data
  - Big data

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7

## Web is big!



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8



## #Web pages in billions...

**WorldWideWebSize.com**  
DAILY ESTIMATED SIZE OF THE WORLD WIDE WEB

**The size of the World Wide Web (The Internet)**

The Indexed Web contains **at least 3.32 billion pages** (Thursday, 10 July, 2014).  
The Dutch Indexed Web contains **at least 244.19 million pages** (Thursday, 10 July, 2014).

293 963 438  
+1 Like Tweet Share

**The size of the World Wide Web (The Internet)**

The Indexed Web contains **at least 4.79 billion pages** (Monday, 07 September, 2015).  
The Dutch Indexed Web contains **at least 359 million pages** (Monday, 07 September, 2015).

50  
45

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## How many docs w/ «the»?

**Google** the

Web Books News Images Maps More Search tools

About 9,660,000,000 results (0.27 seconds) **2014**

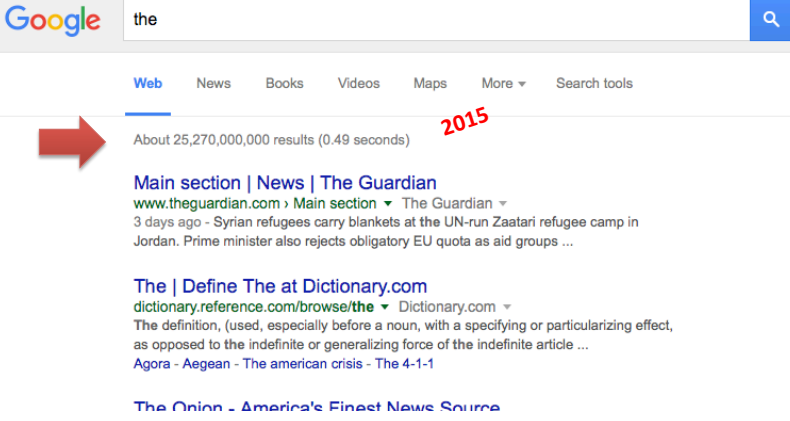
**The | Define The at Dictionary.com**  
dictionary.reference.com/browse/the Dictionary.com  
The definition, (used, especially before a noun, with a specifying or particularizing effect, as opposed to the indefinite or generalizing force of the indefinite article ...  
The adversary - The 4-1-1 - The african roscius - The 411

**The Age: Latest & Breaking News Melbourne, Victoria**  
www.theage.com.au/ The Age  
The Age has the latest local news from Melbourne, Victoria. Read National News from Australia, World News, Business News and Breaking News stories.

**The Onion - America's Finest News Source**  
www.theonion.com/ The Onion  
The Onion, America's Finest News Source, is an award-winning publication covering world, national, and local issues. It is updated daily online and distributed ...

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## How many docs w/ «the»?



Google the

Web News Books Videos Maps More Search tools

About 25,270,000,000 results (0.49 seconds) **2015**

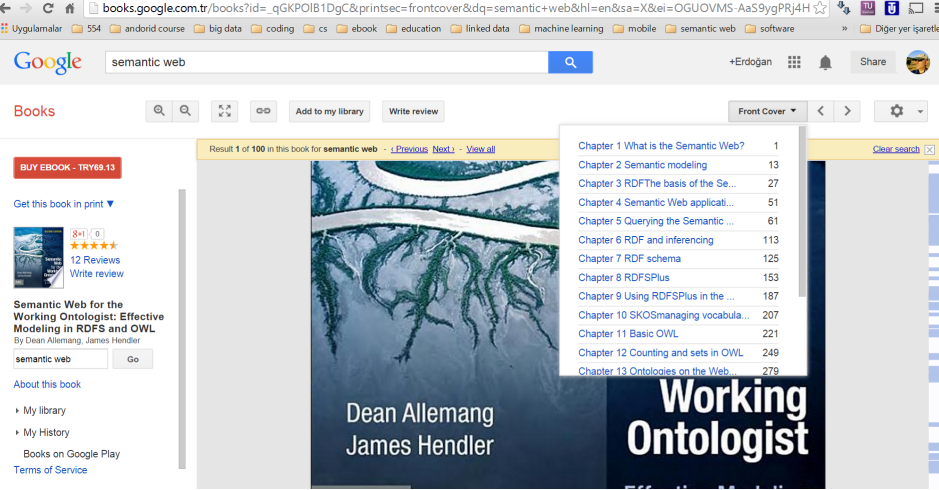
**Main section | News | The Guardian**  
[www.theguardian.com](http://www.theguardian.com) › Main section ▾ The Guardian ▾  
 3 days ago - Syrian refugees carry blankets at the UN-run Zaatari refugee camp in Jordan. Prime minister also rejects obligatory EU quota as aid groups ...

**The | Define The at Dictionary.com**  
[dictionary.reference.com/browse/the](http://dictionary.reference.com/browse/the) ▾ Dictionary.com ▾  
 The definition, (used, especially before a noun, with a specifying or particularizing effect, as opposed to the indefinite or generalizing force of the indefinite article ...  
 Agora - Aegean - The american crisis - The 4-1-1

**The Onion - America's Finest News Source**

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## books.google.com



books.google.com.tr/books?id=\_qGKPOIB1DgC&printsec=frontcover&dq=semantic+web&hl=en&sa=X&ei=OGUOVMS-Aa59ygPRj4H

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Google semantic web +Erdogan Share

Books

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**Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL**  
 By Dean Allemang, James Hendler

semantic web Go

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- My History
- Books on Google Play
- Terms of Service

Result 1 of 100 in this book for semantic web - Previous Next View all

Chapter 1 What is the Semantic Web? 1

Chapter 2 Semantic modeling 13

Chapter 3 RDFThe basis of the Se... 27

Chapter 4 Semantic Web applicati... 51

Chapter 5 Querying the Semantic ... 61

Chapter 6 RDF and inferencing 113

Chapter 7 RDF schema 125

Chapter 8 RDFSPlus 153

Chapter 9 Using RDFSPlus in the ... 187

Chapter 10 SKOSmanaging vocabula... 207

Chapter 11 Basic OWL 221

Chapter 12 Counting and sets in OWL 249

Chapter 13 Ontologies on the Web 279

Dean Allemang  
James Hendler

**Working Ontologist**

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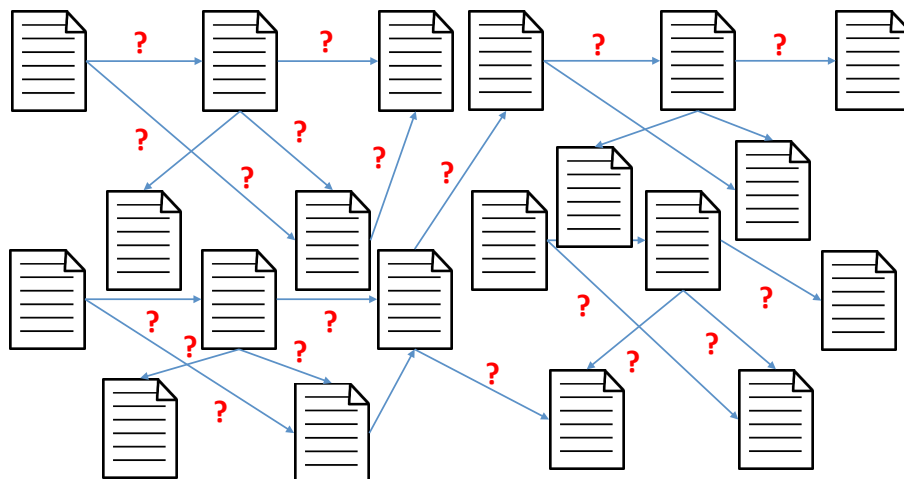
## books.google.com

- How many?
  - **>30 million** books scanned b/w 2004-2013
- How many books in the world?
  - Google estimated around **130 million** books
- When will Google complete scanning?
  - **2020**

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13

## Problem with the web



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14

## Problem with the web (cnt.)

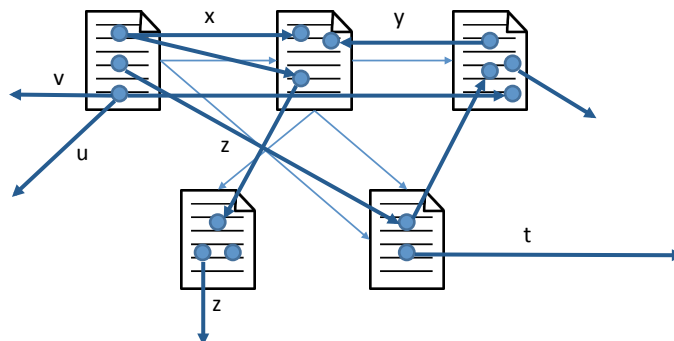
- Software cannot use the web automatically and easily,
  - Requires custom parsing, interpretation, ...
- Very big to use just by browsing
  - 500 million tweets per day

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15

## Web 3.0 (2010)

- Web of Documents (web1.0) to
- Web of Data



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16

# What is Semantic Web?

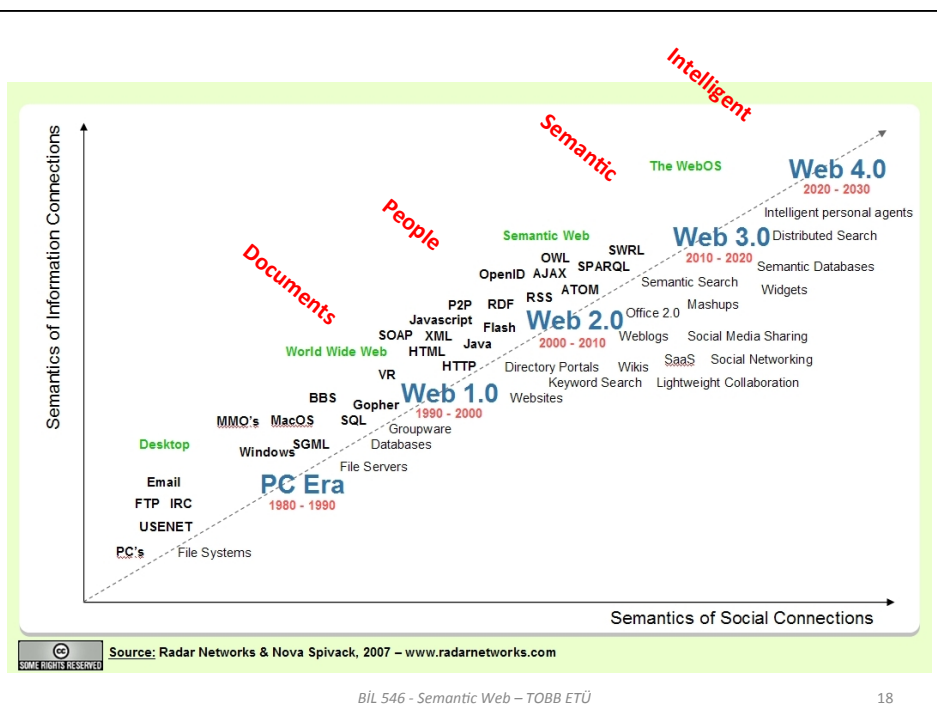
- “The Semantic Web is **not a separate Web but an extension** of the current one, in which **information is given well-defined meaning**, better **enabling computers and people to work in cooperation**.”

- Tim-Berners Lee, Scientific American, May 2001



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17



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18

## Internet to Web

- Internet (1960s)
- Web 1.0 (1990)
  - pull web, read-web
- Web 2.0 (2000s)
  - pull+push, read-write web, collective content generation
- Web 3.0 (2010-)
  - Semantic web
- Web 4.0 (*future*)
  - Intelligent web

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19

## How to realize semantic web?

- Data modelling
  - Ontologies, ontology languages
- Storage
  - In web docs or in datastores
- Querying
  - SPARQL
- Applications
  - Many

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20

# What is Ontology?

- “An ontology is a specification of a conceptualization.”

- Tom Gruber

- *Ontologies provide a shared understanding of a domain.*

Google scholar ontology gruber

About 22,800 results (0.05 sec)

[\[PDF\] A translation approach to portable ontology specifications](#)  
 TR Gruber - Knowledge acquisition, 1993 - 163.15 202.88  
 Abstract To support the sharing and reuse of formally represented knowledge among AI systems, it is useful to define the common vocabulary in which shared knowledge is represented. A specification of a representational vocabulary for a shared domain of ...  
 Cited by 9952 Related articles View as HTML BL Direct All 75 versions

[\[PDF\] Toward principles for the design of ontologies used for knowledge sharing](#)  
 TR Gruber - International journal of human computer studies, 1995 - civ.utoronto.ca  
 Recent work in Artificial Intelligence (AI) is exploring the use of formal ontologies as a way of specifying content-specific agreements for the sharing and reuse of knowledge among software entities. We take an engineering perspective on the development of such ...  
 Cited by 5832 Related articles BL Direct All 108 versions

[\[PDF\] What Is an Ontology](#)  
 T Gruber - Encyclopedia of Database Systems, 2008 - quekiewkhon.tripod.com  
 In the context of knowledge sharing, I use the term **ontology** to mean a specification of a conceptualization. That is, an **ontology** is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of ...  
 Cited by 377 Related articles View as HTML All 2 versions

[\[BOOK\] Ontolingua: A mechanism to support portable ontologies](#)  
 TR Gruber - 1992 - greenstone.isofts.kiev.ua  
 Abstract An **ontology** is a set of definitions of content-specific knowledge representation

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21

# Ontology

- Conceptualization (of domain knowledge)
  - Classes, relationships, instances, ...
- Specification (formally)
  - RDF, RDFS, OWL

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22

## W3C

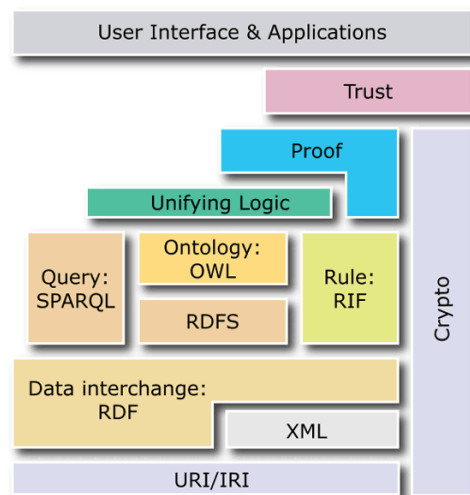
- World Wide Web Consortium (W3C)
  - Int. community defining web stds
  - Founded in 1994 by Tim Berners-Lee
  - 377 member (now)
- Semantic Web standards
  - <http://www.w3.org/standards/semanticweb/>

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23

## Layered Cake / Protocols

- Standards
  - Basic
    - RDF
    - RDFS
    - OWL
    - SPARQL
  - More
    - RDFa
    - Schema.org



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24



## Semantic Web Vision (W3C)

- Extend principles of the Web **from documents to data**
- Data should be accessed using the general Web architecture (e.g., URI-s, protocols, ...)
- Data should be related to one another just as documents are already
- Creation of a common framework that allows:
  - Data to be **shared** and **reused** across applications
  - Data to be **processed automatically**
  - New relationships between pieces of data to be **inferred**

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25

## New Vision for the Web

Web of Documents



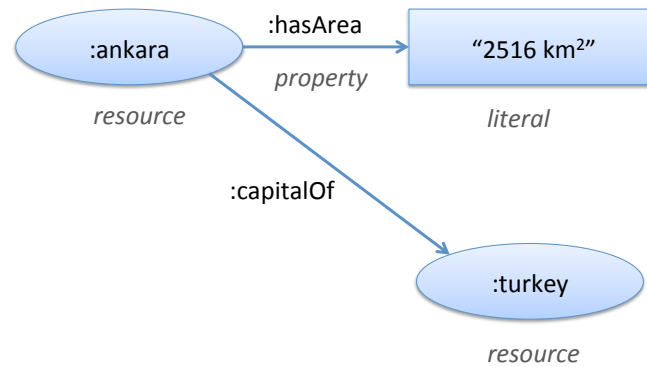
Web of Data

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26

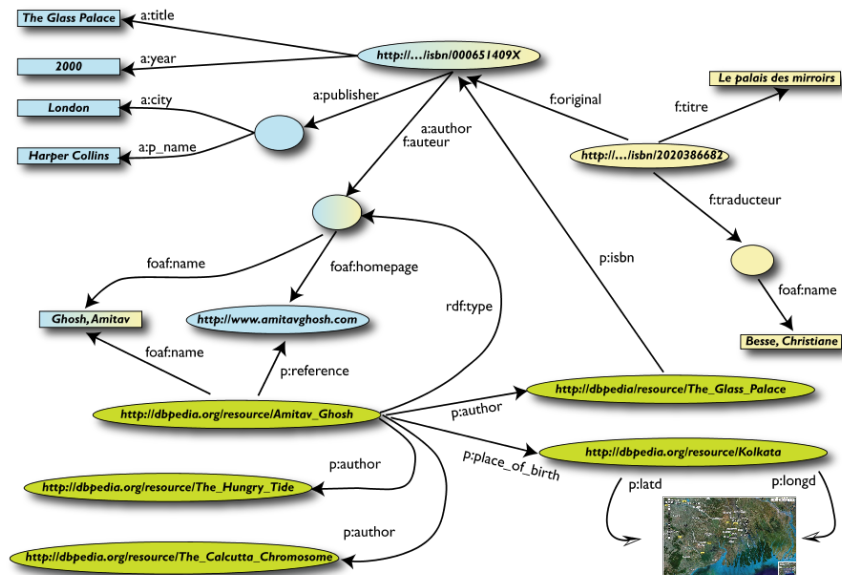
# RDF

## • Resource Description Framework



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27



Source: Ivan Herman slides

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28

## Semantic Web Tools

- Protege
  - Ontology editor
- Jena
  - Open source framework in Java for app development
- Openlink Virtuoso
  - Storage
- Many more
  - <http://www.mkbergman.com/sweet-tools/>

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29

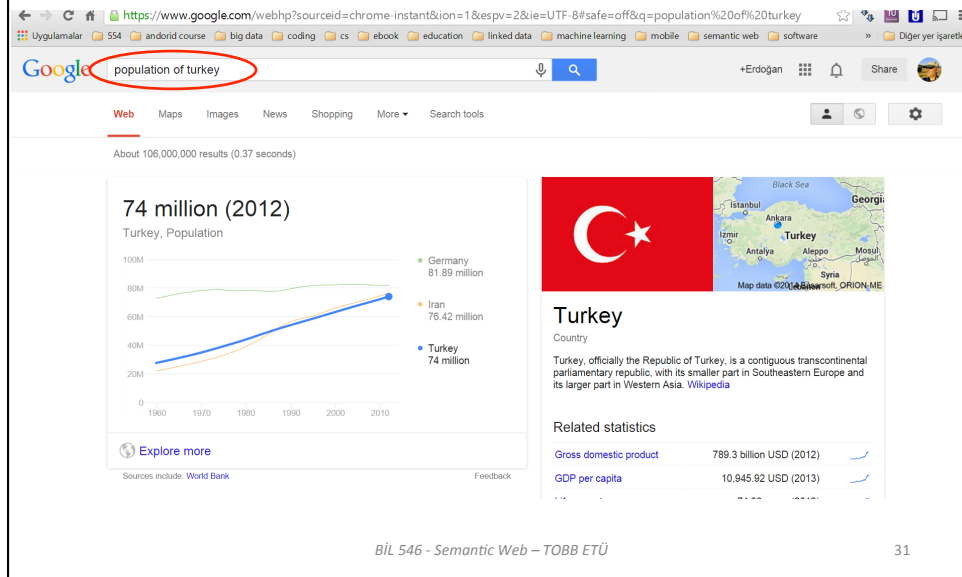
## Where is Semantic Web?

- Many applications utilize semantic technologies
  - Apple's Siri
  - BBC (music, sports, etc.)
    - <http://www.w3.org/2001/sw/sweo/public/UseCases/BBC/>
  - Web search
    - Schema.org, Google Knowledge Graph, Facebook Open Graph Protocol, RDFa, ...
  - IBM Watson
  - Linked Data
  - ...

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30

## Google search

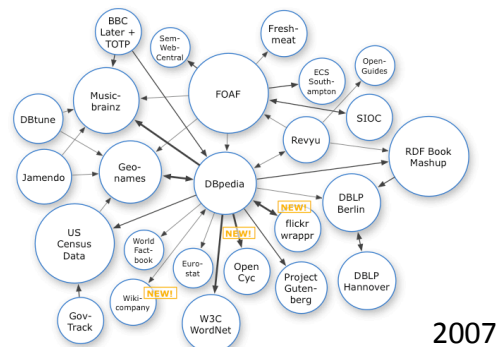


## IBM Watson

- An artificially intelligent computer system **capable of answering questions posed in natural language**
- <http://www.ibm.com/smarterplanet/us/en/ibmwatson/>
- [http://en.wikipedia.org/wiki/Watson\\_\(computer\)](http://en.wikipedia.org/wiki/Watson_(computer))
- IBM's Watson Supercomputer Destroys Humans in Jeopardy
  - [http://www.youtube.com/watch?v=WFR3IOm\\_xhE](http://www.youtube.com/watch?v=WFR3IOm_xhE)

# Linked Data

- RDF data in big volumes (billions!)
- **Linking Open Data Project**
  - [linkeddata.org](http://linkeddata.org)

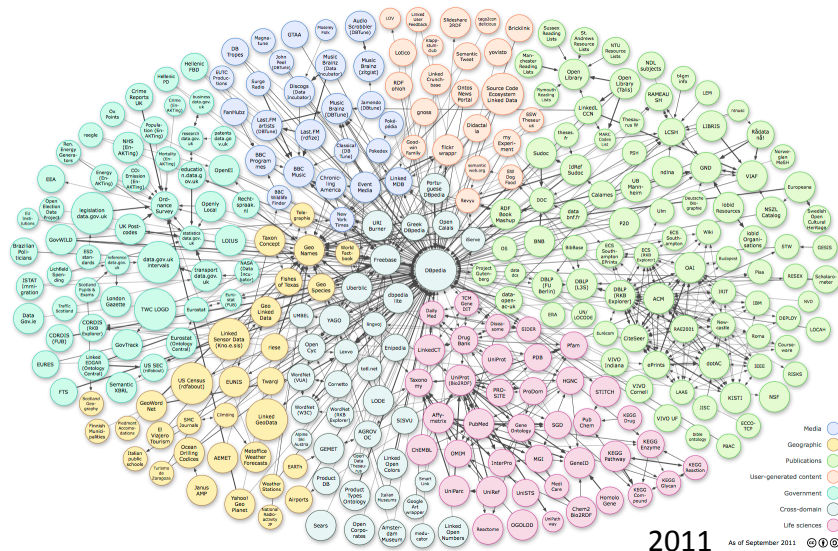


2007

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33

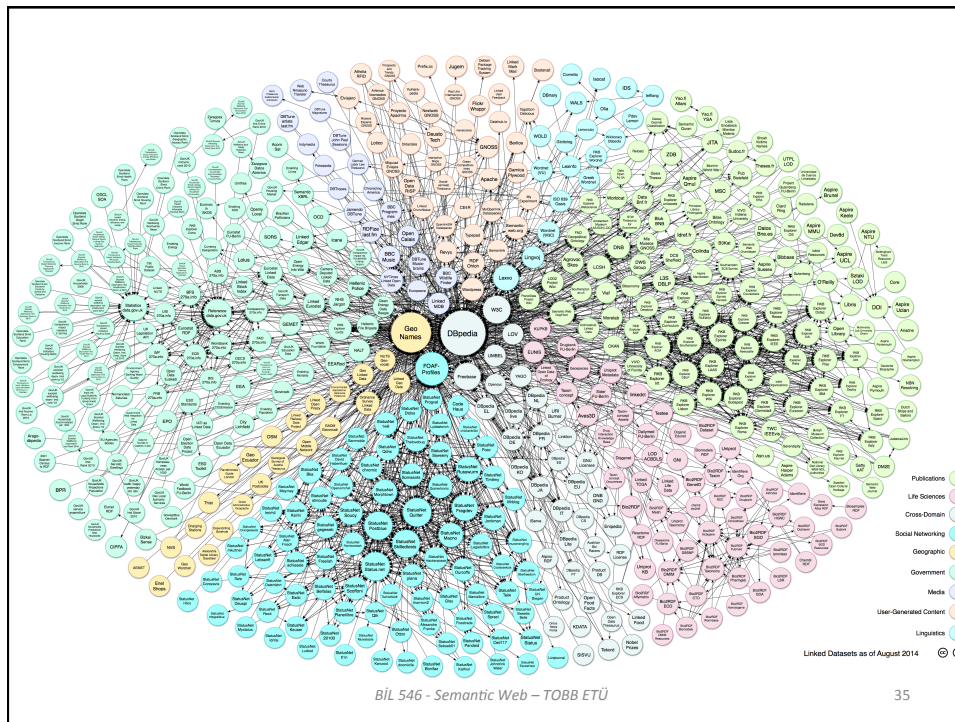
# Linked Data



2011

As of September 2011

34



## Wikipedia → DBpedia

Article Talk

Read Edit View history Search

**Ankara**  
From Wikipedia, the free encyclopedia

**Ankara** (Turkish pronunciation: [anˈka.ɾa]; historically known as *Angora*) is the capital of Turkey and the country's second largest city after Istanbul. The city has a mean elevation of 536 metres (3,077 ft).<sup>[1]</sup> Centrally located in Anatolia, Ankara is an important commercial and industrial city. It is the center of the Turkish Government, and houses all foreign embassies. It is an important crossroads of trade, strategically located at the centre of Turkey's highway and railway networks, and serves as the marketing centre for the surrounding agricultural area. The city was famous for its long-haired Angora goat and its prized wool (*mohair*), a unique breed of cat (*Angora cat*), Angora rabbits and their prized wool (*Angora wool*), pears, honey, and the region's muscat grapes.

The historical center of Ankara is situated upon a rocky hill, which rises 150 m (492 ft) above the plain on the left bank of the *Ankara Çayı*, a tributary of the *Sakarya* (*Sangarius*) river. The city is located at 39°42′30″ North, 32°42′ East (39.71°N 32.8333°E), about 450 km (280 mi) to the southeast of Istanbul, the country's largest city. Although situated in one of the driest places of Turkey and surrounded mostly by steppe vegetation except for the forested areas on the southern periphery, Ankara can be considered a green city in terms of green areas per inhabitant, which is 72 m² per head.<sup>[4]</sup>

Ankara is a very old city with various Hittite, Phrygian, Hellenistic, Roman, Byzantine, and Ottoman archaeological sites. The hill which overlooks the city is crowned by the ruins of the old castle, which adds to the picturesque view, but only a few historic structures surrounding the old citadel have survived to the present day. There are, however, many finely preserved remains of Hellenistic, Roman and Byzantine architecture, the most remarkable being the Temple of Augustus and Rome (20 BC) which is also known as the *Monumentum Ancyranum*.<sup>[5]</sup>

According to the Turkish Statistical Institute, as of 2011 the city of Ankara had a population of 4,338,620 and its metropolitan municipality 4,550,862.<sup>[1][2]</sup>

**Contents** [hide]

- 1 Etymology
- 2 History
  - 2.1 Ancient history
  - 2.2 Celtic history
  - 2.3 Roman history
  - 2.4 Turkish history
- 3 Climate
- 4 Demographics
- 5 Economy
- 6 Main sights
  - 6.1 Museums
  - 6.2 Archaeological sites
  - 6.2.1 Ankara Citadel

**Infobox**  
Structured data

<div><div><span></span><div><div><span><span></span></span></div><div><div>Ankara</div></div></div></div><div><div></div></div></div>	<div><div><div><div><span></span><div><div><span><span></span></span></div><div><div>Ankara</div></div></div></div><div><div></div></div></div></div></div>
<div> <div></div> </div>	
<span></span> <div>Ankara Tower and Atatürk Bridge in central Ankara</div>	
<div><div><div><div><span></span><div><div><span><span></span></span></div><div><div>Location of Ankara</div></div></div></div><div></div></div></div></div>	
Coordinates: <span><span><span><span><span>39°52′N</span> <span>32°52′E</span></span></span><span><span>﻿</span> / <span>﻿</span></span><span><span>39.867°N 32.867°E</span><span><span>﻿</span> / <span>39.867; 32.867</span></span></span></span></span>	
Country	<span><span><span></span></span> </span> Turkey
Region	Central Anatolia
Province	Ankara
Government <div></div>	
<span> </span> • <span> </span> Mayor	Metin Çoban (AKP)
<span> </span> • <span> </span> Governor	Ali Başoğlu (CHP)
Area <div></div>	
<span> </span> • <span> </span> City	2,516 <span> </span> km <sup>2</sup> (971 <span> </span> sq <span> </span> mi)
Elevation <div></div>	536 <span> </span> m (1,774 <span> </span> ft)

live.dbpedia.org/page/Ankara

**About: Ankara**

An Entity of Type [List of cities in Turkey](#), from Named Graph: <http://live.dbpedia.org>, within Data Space: [live.dbpedia.org](http://live.dbpedia.org)

Ankara (historically known as Angora) is the capital of Turkey and the country's second largest city after Istanbul. The city has a mean elevation of 938 metres (3,077 ft). Centrally located in Anatolia, Ankara is an important commercial and industrial city. It is the center of the Turkish Government, and houses all foreign embassies.

Property	Value
dbpedia-owl:PopulatedPlace/areaTotal	2516.0
dbpedia-owl:PopulatedPlace/populationDensity	1551.0
dbpedia-owl:abstract	Ankara (historically known as Angora) is the capital of Turkey and the country's second largest city after Istanbul. Centrally located in Anatolia, Ankara is an important commercial and industrial city. It is the center of the important crossroads of trade, strategically located at the centre of Turkey's highway and railway network surrounding agricultural area. The city was famous for its long-haired Angora goat and its prized wool, a unique product of the region, honey, and the region's muscat grapes. The historical center of Ankara is situated upon a rocky hill, the Ankara Çayı, a tributary of the Sakarya (Sangarius) river. The city is located at 39°52'30" North, 32°52' East. Although situated in one of the driest places of Turkey and surrounded mostly by steppe, Ankara can be considered a green city in terms of green areas per inhabitant, which is 72 m <sup>2</sup> per inhabitant. The hill which overlooks the city is crowned by the remains of Hellenistic, Roman, Byzantine, and Ottoman archaeological sites. The hill which overlooks the city is crowned by the remains of Hellenistic, Roman and Byzantine architecture, the most remarkable being the Temple of Augustus. According to the Turkish Statistical Institute, as of 2011 the city of Ankara had a population of 4,550,662.
dbpedia-owl:areaCode	312
dbpedia-owl:areaTotal	2516000000.000000 (xsd:double)
dbpedia-owl:country	dbpedia:Turkey
dbpedia-owl:elevation	938.000000 (xsd:double)
dbpedia-owl:isPartOf	dbpedia:Ankara_Province dbpedia:Central_Anatolia_Region
dbpedia-owl:leaderName	dbpedia:Mehmet_Gökçek

37

## DBpedia

- Project started in 2007, by Free Univ. of Berlin, Univ. of Leipzig, OpenLink Software
- Convert all infobox and structured data in wikipedia pages to linkeddata
- Current English dbpedia knowledgebase includes
  - 3.7 million things
    - including 764,000 persons, 573,000 places (including 387,000 populated places), 333,000 creative works (including 112,000 music albums, 72,000 films and 18,000 video games), 192,000 organizations (including 45,000 companies and 42,000 educational institutions), 202,000 species and 5,500 diseases.
- 1.89 billion triples for 111 languages.
- Nucleus for the Web of Data

## DBpedia

- [List people who were born in Ankara with their name, birthdate, and description \(click to run\)](#)

**SPARQL query:**

```
SELECT ?name ?birth ?description ?person
WHERE {
  ?person dbpedia2:birthPlace :Ankara .
  ?person dbpedia2:birthDate ?birth .
  ?person foaf:name ?name .
  ?person rdfs:comment ?description .
  FILTER (LANG(?description) = 'en') .
}
```

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39

## Linked Data

- 295 datasets
- >31 billion triples

[Source: http://www4.wiwiiss.fu-berlin.de/lodcloud/state/](http://www4.wiwiiss.fu-berlin.de/lodcloud/state/)

Domain	Number of datasets	Triples	%	(Out-)Links	%
<b>Media</b>	<a href="#">25</a>	1,841,852,061	5.82 %	50,440,705	10.01 %
<b>Geographic</b>	<a href="#">31</a>	6,145,532,484	19.43 %	35,812,328	7.11 %
<b>Government</b>	<a href="#">49</a>	13,315,009,400	42.09 %	19,343,519	3.84 %
<b>Publications</b>	<a href="#">87</a>	2,950,720,693	9.33 %	139,925,218	27.76 %
<b>Cross-domain</b>	<a href="#">41</a>	4,184,635,715	13.23 %	63,183,065	12.54 %
<b>Life sciences</b>	<a href="#">41</a>	3,036,336,004	9.60 %	191,844,090	38.06 %
<b>User-generated content</b>	<a href="#">20</a>	134,127,413	0.42 %	3,449,143	0.68 %
	<a href="#">295</a>	31,634,213,770		503,998,829	

40



## Linked Data (2014)

- 1014 datasets

Topic	Datasets	%
Government	183	18.05%
Publications	96	9.47%
Life sciences	83	8.19%
User-generated content	48	4.73%
Cross-domain	41	4.04%
Media	22	2.17%
Geographic	21	2.07%
Social web	520	51.28%
<b>Total</b>	<b>1014</b>	

Source: <http://linkeddatacatalog.dws.informatik.uni-mannheim.de/state/>

41

## Books

- **Semantic Web for the Working Ontologist**  
Dean Allemang, Jim Hendler  
2nd ed., Morgan Kaufmann, 2011
- **Practical Semantic Web and Linked Data Applications**  
Mark Watson, 2010
- **A Semantic Web Primer**  
Grigoris Antoniou and Frank van Harmelen  
2nd ed., MIT, 2008

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42

## Course

- Review standards
  - RDF, RDFS, OWL, SPARQL
- Rules, reasoning, linked data, tools
- 2-3 homeworks (15%)
  - Protege, Jena, Virtuoso
- 1 written exam (35%)
- Project or Paper (50%)

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43

## Paper topics

- Semantic search and information retrieval
- Information extraction
- Entity linking
- Question answering
- Document Classification
- ...

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44

## Paper work

- Review important and recent papers
- Analyse and propose a work plan
- Implement and test
- Write results

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45

## Conferences

- **ISWC** International Semantic Web Conference
- **IEEE ICSC** International Conference on Semantic Computing
- **ESWC** Extended Semantic Web Conference
- **WWW** World Wide Web Conference

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46

## Journals

- Semantic Web Journal, IOS
- Journal of Web Semantics, Elsevier
- International Journal on Semantic Web and Information Systems, IGI Global

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47

## References

- W3C Semantic Web Activity, <http://www.w3.org/2001/sw/>
- Michael K. Bergman, **A Decade in the Trenches of the Semantic Web** (2014)  
<http://www.mkbergman.com/1771/a-decade-in-the-trenches-of-the-semantic-web/>
- <http://semanticweb.com/>
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48

# The end