



Aalto University
School of Science



Semantic Web

An Introduction

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Outline

The idea of Semantic web

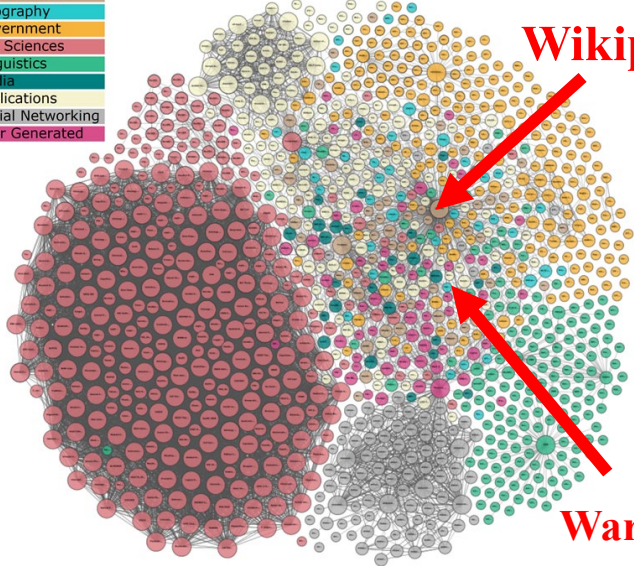
Core technological basis of Semantic web

- Metadata, ontologies, reasoning
- Review of the technological solutions and standards

Application domains

Linked Data & Semantic Web

Human Knowledge on the Web:
"Web of Data" for machines



Linked Open Data Stats 2018
(<http://stats.lod2.eu/>):
10 000 datasets, 150 billion triples

Traditional Web
"Web of Pages" for humans



Google Index (2020):
55 billion pages (excluding hidden web)

Big Boys Have Entered the Game: **Knowledge Graphs**

<http://schema.org>

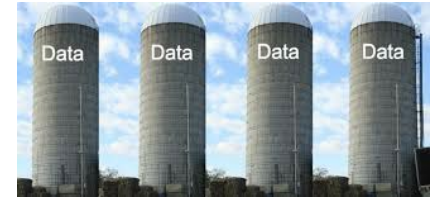
- Google Knowledge Graph
- Microsoft Satori
- IBM Watson
- eBay Products
- Facebook Open Graph
- ...

The Google logo, featuring the word "Google" in its characteristic multi-colored font (blue, red, yellow, blue, green, red).The Microsoft logo, consisting of a four-colored square (red, green, blue, yellow) followed by the word "Microsoft" in a grey sans-serif font.The IBM logo, featuring the word "IBM" in a blue, horizontally-striped font with a registered trademark symbol.The eBay logo, featuring the word "eBay" in a multi-colored font (red, blue, yellow, green).The Facebook logo, consisting of a dark blue square with the word "facebook" in white lowercase letters.

Why Linked (Open) Data?

- Enriching everybody's data collaboratively from separate silos
 - Everybody wins by collaboration!
- Creating **F**indable, **A**ccessible, **I**nteroperable, **R**e-usable data
 - The value of data increases!
- Creating more intelligent applications for the public, curators, and researchers
 - The machine “understands” linked data!

FAIR



<https://www.go-fair.org/fair-principles/>



Fundamental barrier for the development of the Web of Data: machine-”understandability”

The web contents are created for human readers

- HTML, PDF, JPEG, ...

Machine mediates and displays, but does not “understand” contents of the web

- E.g., a Finnish text article

A web service \approx machine helps human

- Requires machine-”understandability” of the contents

➔ A fundamental contradiction

How can we build a more intelligent Web?

1. Applications are programmed to be more intelligent

- The contents stay as they are
- The machines operate more human-like (Artificial Intelligence)

2. Contents are represented in a more intelligent way

- The contents are easier to understand
- Machines stay more or less as they are

In practice, both ways are needed

- More intelligent systems process more intelligently represented contents

Approach 1: Develop more intelligent applications using AI

Automatic interpretation of natural language is difficult

- Free form of the documents
- Semantics of the content

Non-textual contents

- Pictures, sound, music, video, software, ...
- How to interpret algorithmically unstructured data?

More than the document itself is needed for interpretation

- Context + common sense needed
- Fundamental problems of Artificial Intelligence, easy for humans!
- Great scientific and technological challenges

Approach 2: Contents represented in a more intelligent way

The foundation of Semantic web

- The information is stored in a way that a machine understands it!
- Human helps the machine
 - *Machine can also help in this (user-friendly tools for semantic content creation)*

The development was boosted in the beginning of the 2000s

- W3C Semantic Web Activity 2001
- W3C Web Services Activity 2002

Web Generations

1G WWW: early 1990's

- WWW pages for human interpretation
- HTML language

2G WWW: late 1990's

- Structured web documents for human/machine interpretation
- XML-based languages

3G WWW: Semantic Web, Web of Data, 2000's

- Explicit meaning of documents for human/machine use
- RDF-based languages

⇒ **Semantics = new foundation for intelligent web services**

- Semantic = “understandable” to machines

Limitations of non-semantic web: case MuseumFinland

```
<artifact>  
  <id>NBA:H26069:467</id>  
  <target>cup and plate</target>  
  <material>porcelain</material>  
  <creationLocation>Germany</creationLocation>  
  <creator>Meissen</creator>  
</artifact>
```



- This metadata cannot answer the following questions:
 - Find all vessels?
 - Find all ceramic products?
 - Find artifacts manufactured in Europe?
 - Does the city of Meissen manufacture ceramics?

Semantic Web solution: ontologies

NBA-H26069-467

:object "cup and plate" ;

:object_concept **object:cup** ;

:object_concept **object:plate** ;

:material "porcelain" ;

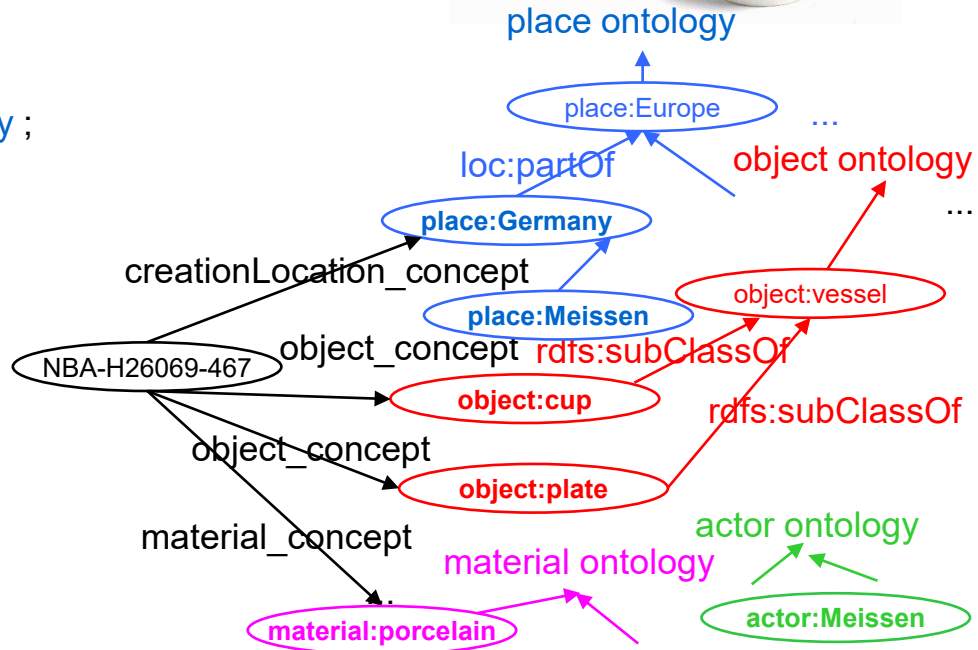
:material_concept **object:porcelain** ;

:creationPlace "Germany" ;

:creationPlace_concept **place:Germany** ;

:creator "Meissen"

:creator_concept **actor:Meissen** .



Find all vessels?
Find all ceramic products?
Find artifacts manufactured in Europe?
Does the city of Meissen manufacture ceramics?

Case Rijksmuseum Amsterdam: CHIP Demonstrator

Example in Turtle notation

- VRA metadata schema
(extension of Dublin Core)
- (Aroyo et al., 2007)

```
rijks:artefactSK-C-K
  vra:type vra:Work ;
  vra:title "The Night Watch" ;
  vra:date "1642" ;
  vra:creator: 500011051 ;           # Rembrandt
  vra:subject iconclass:45F31 ;     # Call to arms
  vra:culture tgn:7006952 ;         # Amsterdam
  vra:material aat:30015050 .      # Oil paint
```

A resource in the TGN
ontology / vocabulary



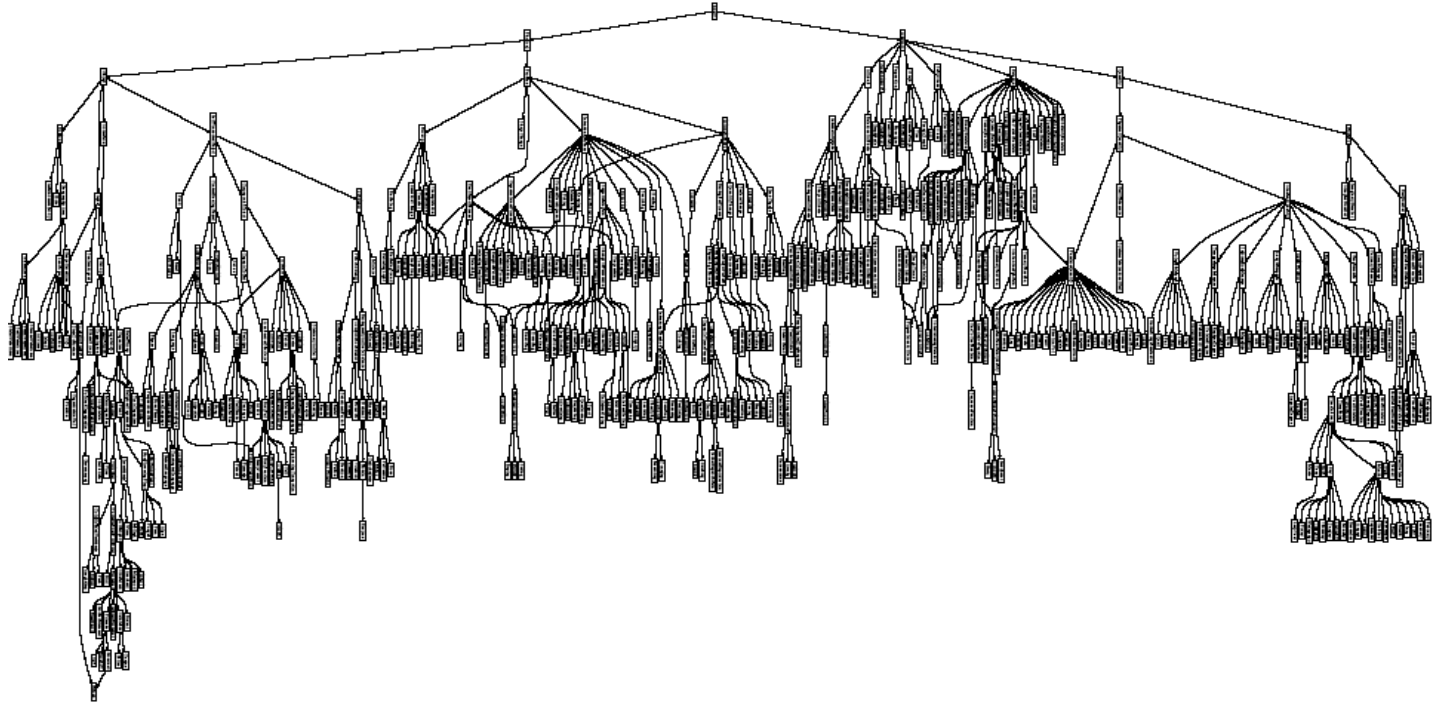
Amsterdam in TGN



A screenshot of a web browser window showing the full record for 'Amsterdam' in the Thesaurus of Geographic Names. The browser title is 'TGN Full Record Display, English (Getty Research) - Windows Internet Explorer'. The address bar shows the URL: http://www.getty.edu/vow/TGNFullDisplay?find=Amsterdam&place=&nation=&prev_page=1&english=Y&. The page content includes:

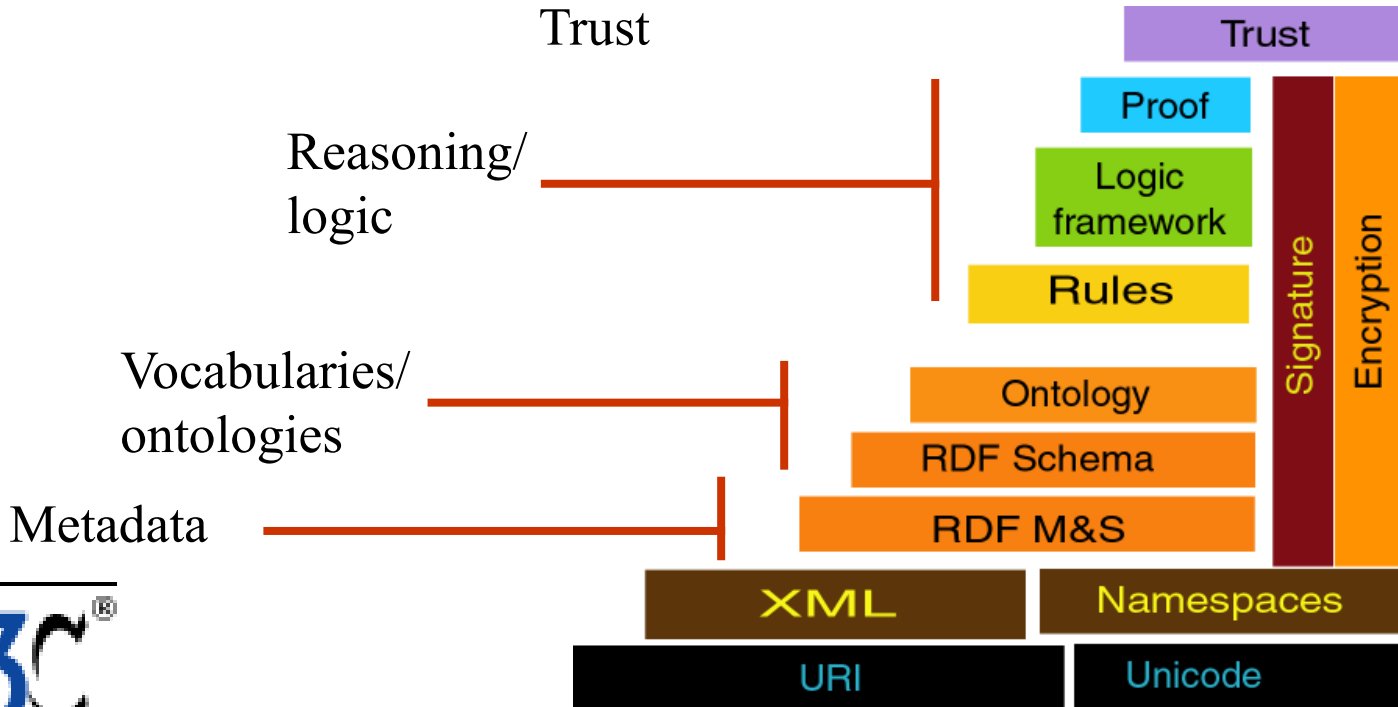
- Coordinates:** Lat: 52 21 00 N degrees minutes; Lat: 52.3500 decimal degrees; Long: 004 54 00 E degrees minutes; Long: 4.9000 decimal degrees.
- Notes:** Located on over 90 islands in the IJ arm of the IJsselmeer. Early inhabitants built dikes on both sides of the Amstel River to prevent flooding, and a dam was built between the dikes in 1270. Chartered in 1306. Became afloat in the 15th century due to trade with Baltic seaports, and was the financial center of the world by 17th century. United Dutch East India Company was founded in 1602, followed by the West India Company in 1621. Capital of the Batavian Republic under Napoleon, later of the kingdom of Holland, and became part of the French Empire in 1810. Under German occupation from 1940-1945. Center of the world's diamond trade.
- Names:**
 - Amsterdam** (preferred, C, V, N, English-P, Dutch-P)
 - Amstel-dam** (N, V, N) documented in 13th cen., meaning 'dam on the Amstel (river)'
 - Amsteldam** (N, V, N)
 - Amsteldamme** (N, V, N) earliest form of the name, 13th cen.
 - Amsteddamum** (N, D, N)
 - Amsteddamum** (N, D, N)
 - Amsteddamum** (N, D, N)
 - Amsteddamum oppidum** (N, D, N)
- Hierarchical Position:**
 - World (face)
 - Europe (continent)
 - Netherlands (nation)
 - North Holland (province)
 - Amsterdam (inhabited place)
- Place Types:**
 - inhabited place** (preferred, C) there possibly was a Roman settlement in the area; modern town probably originated as a fishing village in 13th century
 - city** (C)
 - capital** (C) nominal capital of The Netherlands, though government is located in s-Gravenhage
 - port** (C)
- Sources and Contributors:**
 - Amsteddamum** [VP] Orbis Latinus (1971) 18
 - Amstel-dam** [VP] Encyclopaedia Britannica (1988) 1:357
 - Amsterdam** [VP] Knopf Guides, Amsterdam (1993) 28
 - Amsteldamme** [VP] Knopf Guides, Amsterdam (1993) 28
 - Amsteddamum** [VP] Orbis Latinus (1971) 18
 - Amsteddamum oppidum** [VP] Orbis Latinus (1971) 18
 - Amsteddamum** [VP] Orbis Latinus (1971) 18
 - Amsterdam** [BNA, GRIPSC, VP] Canby, Historic Places (1984) 1:30; Columbia Lippincott Gazetteer (1961); Encyclopaedia Britannica (1988) 1:357-358; Times Atlas of the World (1992) 12; Webster's Geographical Dictionary (1984)
 - Amsterdamum** [VP] Orbis Latinus (1971) 18
- Subject:** [BNA, GRIPSC, VP] Canby, Historic Places (1984) 1:30; Columbia Lippincott Gazetteer (1961); Encyclopaedia Britannica (1988) 1:357-358; Knopf Guides, Amsterdam (1993) 28; Orbis Latinus (1971) 18; Phadon Art Guide: Holland (1987) 18; Times Atlas of the World (1992) 12; Webster's Geographical Dictionary (1984); Webster's Geographical Dictionary (1988) 46
- Notes:** [VP]

An Ontology Concept Hierarchy: Standard Upper Merged Ontology SUMO



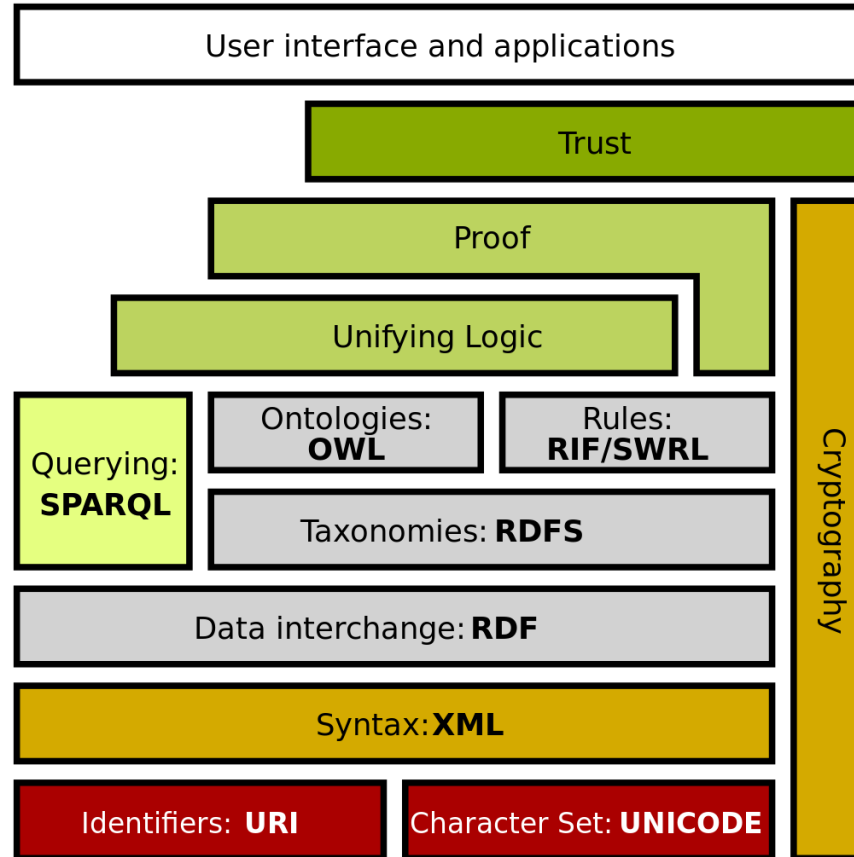
Technological basis of Semantic Web

The Original "Layer Cake Model" of Semantic Web



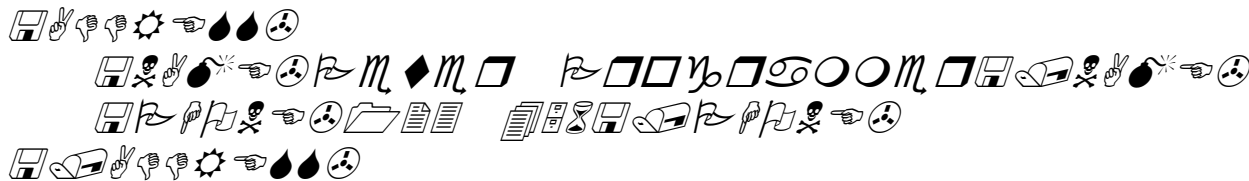
(Tim Berners-Lee)

Newer Version of Layer Cake Model



Metadata Level

Why isn't XML alone sufficient for the basis of Semantic web?

- Interpretation of XML languages has to be defined in a domain-specific way
- Combining different XML languages is often difficult
- We need a markup language, whose interpretation is:
 - *Machine-"understandable"*
 - *Shared across different application domains*
 - *Commonly agreed*
- The semantics of XML is only in human brain
 - `<ADDRESS>`
 - `<NAME>Peter Programmer</NAME>`
 - `<PHONE>123 456</PHONE>`
 - `</ADDRESS>`
 - 

The Semantic Web solution for Metadata: RDF Resource Description Framework

- General metadata description model and language for web resources
- Relational model, *not* a syntax (as opposed to XML)
 - *RDF description = directed (knowledge) graph*
- Semantics is defined based on logic
- RDF has syntaxes/serializations, too
 - *XML-based RDF/XML, especially for machines*
 - *Simpler notations (Turtle, N-triples, N3) for humans*
- Standardized and commonly used
 - *W3C draft 1999*
 - *W3C recommendation RDF 1.0, 10.2.2004*
 - *W3C recommendation RDF 1.1, 25.2.2014*



RDF Example

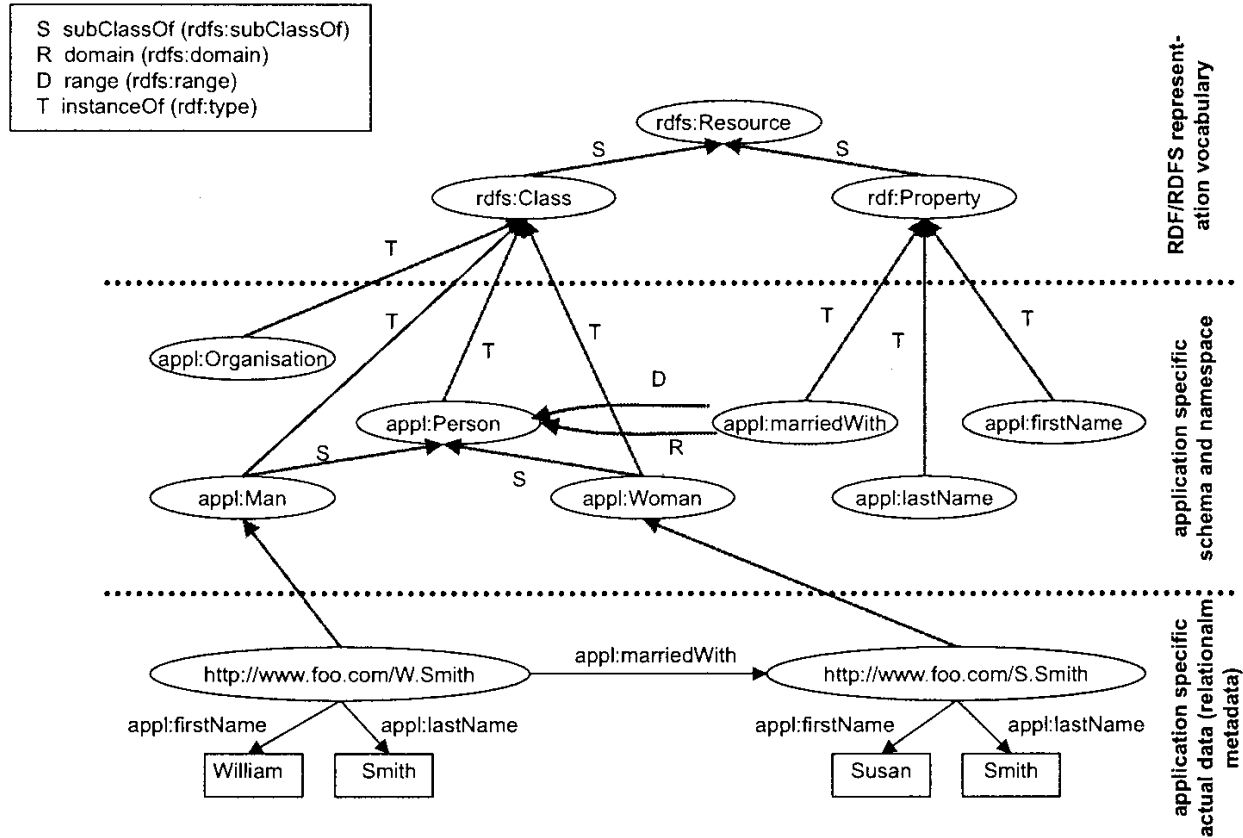


Figure 3.4. An RDF-Schema Example

(Maedche, 2002)

Metadata Schemas

Standardized templates for representing (meta)data

- A set of elements (properties) describing object types
 - *E.g author, publisher, and publishing year of books*
- Value specifications for the properties describing individual objects
 - *Literal values for data (text, number, date, ...)*
 - *URI identifier for related concepts/resources*

Different content types typically require different schemas (element sets)

- E.g. books, persons, paintings, places, ...

Example: Dublin Core metadata schema for describing web documents

Set of 15 general properties for different content types

- Dublin Core Metadata Element Set (ISO Standard 15836)
 - *Title*
 - *Creator*
 - *Subject*
 - *Description*
 - *Publisher*
 - *Contributor*
 - *Data*
 - *Type*
 - *Format*
 - *Identifier*
 - *Relation*
 - *Source*
 - *Language*
 - *Coverage*
 - *Rights*

Metadata Schema in HealthFinland

Table 1. HEALTHFINLAND Metadata Schema. Obligatory fields are marked in **bold**. Cardinalities are presented in the column C.

	Name	QName	C	Value type	Value range
General metadata	Identifier	dc:identifier	1	URI	
	Locator	ts:url	0..1	URL	
	Title	dc:title	1 ^a	Free text	Non-empty string.
	Abstract	dcterms:abstract	1 ^a	Free text	Non-empty string.
	Language	dc:language	1..*	String	RFC 3066
	Publication time	dcterms:issued	1	String	W3CDTF (ISO 8601)
	Acceptance time	dcterms:dateAccepted	0..*	String	W3CDTF (ISO 8601)
	Modification time	dcterms:modified	0..*	String	W3CDTF (ISO 8601)
	Publisher	dc:publisher	1..*	Instance	foaf:Organization
	Creator	dc:creator	0..*	Instance	foaf:Organization, foaf:Person or foaf:Group
Content classification	Subject	dc:subject	1..*	Concept	YSO, MeSH and HPMulti Ontologies
	Audience	dcterms:audience	1..*	Concept	Audience Ontology
	Genre	ts:genre	1..*	Concept	Genre Ontology
	Presentation type	dc:type	1..*	Concept	DCMI Type vocabulary
	Format	dc:format	1	String	IANA MIME types
	Medium	dcterms:medium	1	Concept	Medium Ontology
	Spatial coverage	dcterms:spatial	0..*	String or concept	DCMI Point, DCMI Box or Location Ontology
Relations	Temporal coverage	dcterms:temporal	0..*	String or concept	W3CDTF, DCMI Period or Time Ontology
	Part of	dcterms:isPartOf	0..*	Document	URI
		dc:rights	0..*	Free text or document	URI or textual description
	Source	dc:source	0..*	Free text or document	URI (e.g., ISBN) or bibliographical reference
	Reference	dcterms:references	0..*	Free text or document	URI (e.g., ISBN) or bibliographical reference
Translation of	ts:isTranslationOf	0..*	Document	URI	
	dcterms:isFormatOf	0..*	Document	URI	

^a Multilingual values are allowed, but only one value in each language.

HealthFinland portal: Maija's eyeglasses – PDF document on the web



http://www.ttl.fi/NR/rdonlyres/142A177B-FE02-4A77-A434-3049C37EBC61/0/maijan_lasit_tulosta.pdf - Windows Internet Explorer

http://www.ttl.fi/NR/rdonlyres/142A177B-FE02-4A77-A434-3049C37EBC61/0/maijan_lasit_tulosta.pdf

Save a Copy Hand Tool Select Snapshot Tool Zoom In 84% Rotate Clockwise Check Spelling Undo Copy Search Web Yahoo! Download New Reader Now

TTL - Maijan uudet näyttöpäätelasit <http://www.ttl.fi/ergonomia>

Maijan uudet näyttöpäätelasit

Sopivien silmälasien hankinta tietotyöhön voi useinkin olla pulmallista. Seuraavassa näet, miten ikäniököinen Maija päätyi silmälasiratkaisuunsa.

Maija sai lähinnä huonoutuessa ahuksi luvulasit. Hän hankki kymmenen vuoden aikana kolmet luvulasit: uudet aina hiukan entistä vahvemmat.

Päätteitä lukeminen alkoi käydä ongelmalliseksi. Maija ei osannut kirjoittaa sokkona joten näppäimistölle näkeminen oli myös välttämätöntä. Niska ja hartat jomottivat, silmiä kurveli ja vasemmassa silmässä oli elohiiri vuokkoauksia.

Luvulasit käytössä.
Maija joutuu istumaan epämiellyttävään lähellä päätettä. Kynnäpäiden voimakas koukistaminen sitoo käsiä ja vaikeuttaa näppäilytyötä.

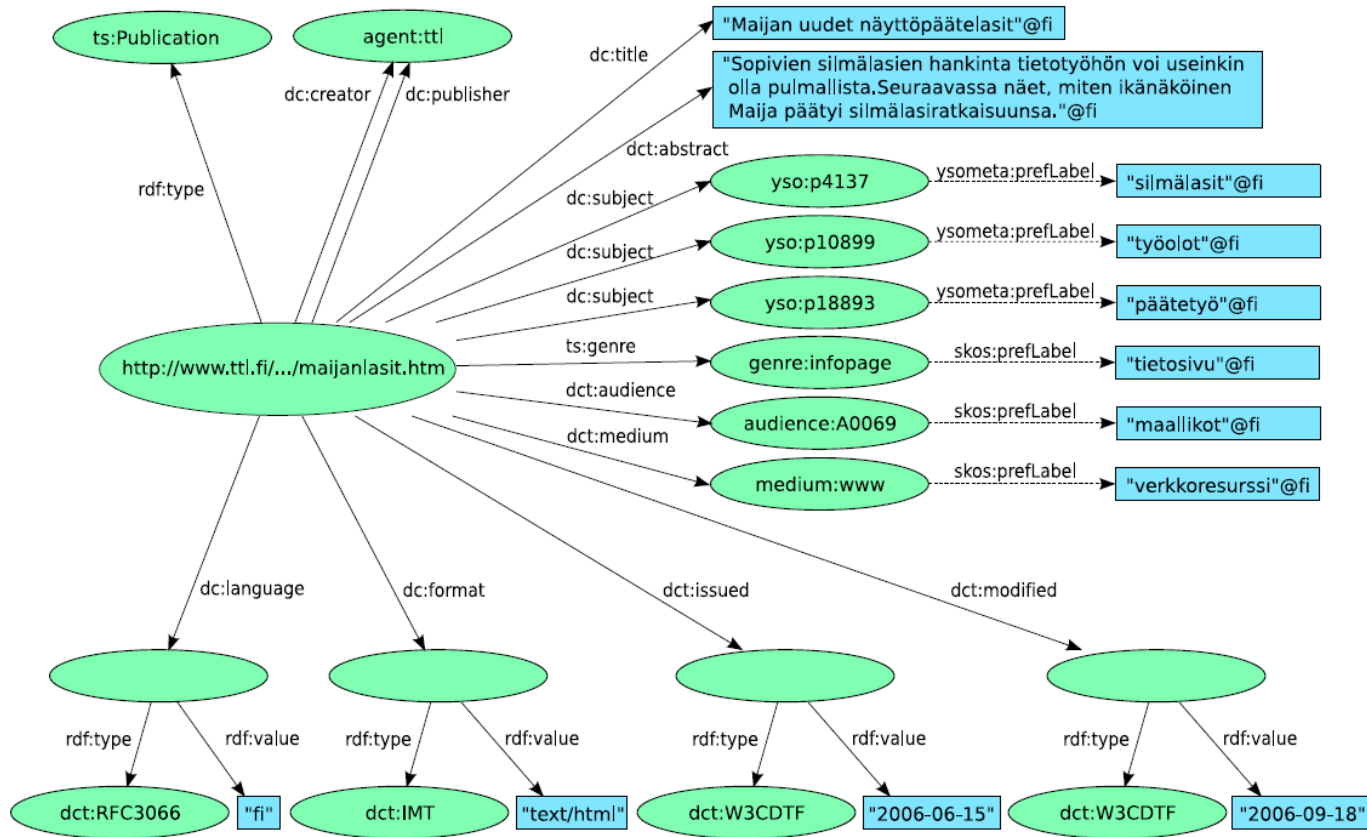


Luvulasit käytössä.
Maija joutuu taivuttamaan niskaa voimakkaasti eteen ahdakseen näppäimet. Päätteen ja näppäimistön vuorottainen katselu aiheuttaa jatkuvaa niskan liikettä.



Hide Toolbars 1 of 4 Unknown Zone

Maija's eyeglasses: metadata in RDF form



Ontology Level

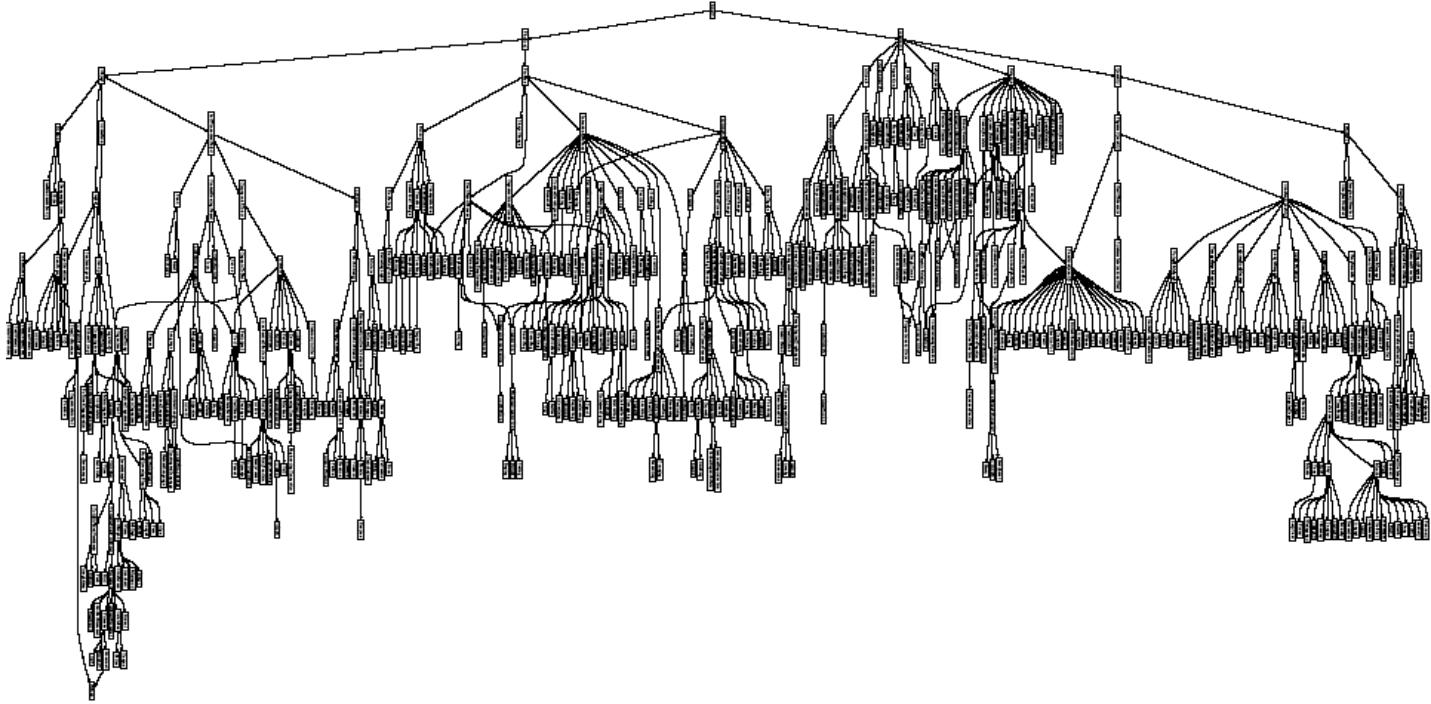
What is an ontology?

**“An ontology is an explicit specification of a conceptualization
...definitions need to be couched in some common formalism”**

(Gruber, 1993)

- *Explicit: machine can understand*
- *Formal: precisely defined*
- *Common (shared): communication is possible*
- **Defines the concepts/objects and their relations in a given application domain**
- **A first requirement for the humans and machines to understand each other**

Standard Upper Merged Ontology SUMO



SUMO principal distinctions

- [Entity](#)
 - [Physical](#)
 - [Object](#)
 - [SelfConnectedObject](#)
 - [Substance](#)
 - [CorpuscularObject](#)
 - [Food](#)
 - [Region](#)
 - [Collection](#)
 - [Agent](#)
 - [Process](#)
 - [Abstract](#)
 - [SetOrClass](#)
 - [Relation](#)
 - [Quantity](#)
 - [Number](#)
 - [PhysicalQuantity](#)
 - [Attribute](#)
 - [Proposition](#)

SUMO Object:

- [Object](#)
 - [SelfConnectedObject](#)
 - [Substance](#)
 - [PureSubstance](#)
 - [ElementalSubstance](#)
 - [Metal](#)
 - [Atom](#)
 - [SubatomicParticle](#)
 - [AtomicNucleus](#)
 - [Electron](#)
 - [Proton](#)
 - [Neutron](#)
 - [CompoundSubstance](#)
 - [Water](#)
 - [Molecule](#)
 - [Mixture](#)
 - [Solution](#)
 - [Mineral](#)
 - [BodySubstance](#)
 - [BiologicallyActiveSubstance](#)
 - [Nutrient](#)
 - [Hormone](#)
 - [CorpuscularObject](#)
 - [OrganicObject](#)
 - [Organism](#)
 - [AnatomicalStructure](#)
 - [Artifact](#)
 - [ContentBearingObject](#)
 - [Food](#)
 - [Region](#)
 - [GeographicArea](#)
 - [AstronomicalBody](#)
 - [Hole](#)
 - [Collection](#)
 - [Group](#)
 - [GroupOfPeople](#)
 - [Organization](#)
 - [Agent](#)
 - [Organism](#)
 - [Group](#)
 - [GeopoliticalAgent](#)
 - [SentientAgent](#)




[New Search](#)











[Previous Page](#)

[View Selected Records](#)

[Clear All](#)

Click the  icon to view the hierarchy.

Check the boxes to view multiple records at once.

-  Top of the AAT hierarchies
-  Associated Concepts Facet
-  Associated Concepts (hierarchy name)
-  Physical Attributes Facet
-  Attributes and Properties (hierarchy name)
-  Conditions and Effects (hierarchy name)
-  Design Elements (hierarchy name)
-  Color (hierarchy name)
-  Styles and Periods Facet
-  Styles and Periods (hierarchy name)
-  Agents Facet
-  People (hierarchy name)
-  Organizations (hierarchy name)
-  Living Organisms (hierarchy name)
- agents (general) [N]
-  Activities Facet
-  Disciplines (hierarchy name)
-  Functions (hierarchy name)
-  Events (hierarchy name)
-  Physical and Mental Activities (hierarchy name)
-  Processes and Techniques (hierarchy name)
- activities (general context)
-  Materials Facet
-  Materials (hierarchy name)
-  Objects Facet
-  Built Environment (hierarchy name)
-  Components (hierarchy name)
-  Furnishings and Equipment (hierarchy name)
-  Object Genres (hierarchy name)
-  Object Groupings and Systems (hierarchy name)
-  Visual and Verbal Communication (hierarchy name)
-  <temporary alphabetical list: objects>
-  <temporary list/DIBAM-CDBP-SNPC test TRP contributions holding>
-  Brand Names Facet
-  Brand Names (hierarchy name)

AAT Art & Architecture Thesaurus
 - maintained by Getty Research Institute
 - 7 main classes, 125 000 concepts


Universal List of Artist Names ULAN

- Over 300 000 artists with 720 000 names as Linked Open Data (2018)


Example: Eero Saarinen data

Research

Research Home ▶ Tools ▶ Union List of Artist Names ▶ Full Record Display

 Union List of Artist Names® Online
Full Record Display


[New Search](#) [Previous Page](#) [Help](#)

Click the  icon to view the hierarchy.

[Semantic View \(JSON, JSONLD, RDF, N3/Turtle, N-Triples\)](#)

ID: 500006141 **Record Type:** [Person](#)

Page Link: <http://vocab.getty.edu/page/ulan/500006141>

 **Saarinen, Eero** (American architect, designer, 1910-1961)

Note: Son of Eliel Saarinen and Louise (Loja) Gesellius, the sculptor and weaver. Eero Saarinen emigrated with his family to the United States in 1923. He attended the Académie de la Grande Chaumière, Paris, France, (1929-1930/1931), studied architecture at Yale University, New Haven, Connecticut, and worked in his father's architectural firm, Saarinen and Saarinen, in Ann Arbor, Michigan (1936/1937-1941). He was partner with his father and J. Robert Swanson as Saarinen-Swanson-Saarinen in Ann Arbor (1941-1947) and partner with his father as Saarinen and Associates in Ann Arbor (1947-1950). He directed Eero Saarinen and Associates, Birmingham, Michigan, 1950-1961. He acted as a consultant for the Architects Advisory Panel for the Unesco buildings (built 1955-1958) in Paris, France. American architect.

Names:
Saarinen, Eero ([preferred](#), [V.index](#), [English-P.NA,U](#))
Eero Saarinen ([V.display](#))
סריקן, אירו ([U.Hebrew-P.NA,U](#))

Nationalities:
American ([preferred](#))
Finnish

Roles:
artist ([preferred](#))
designer
architect
furniture designer

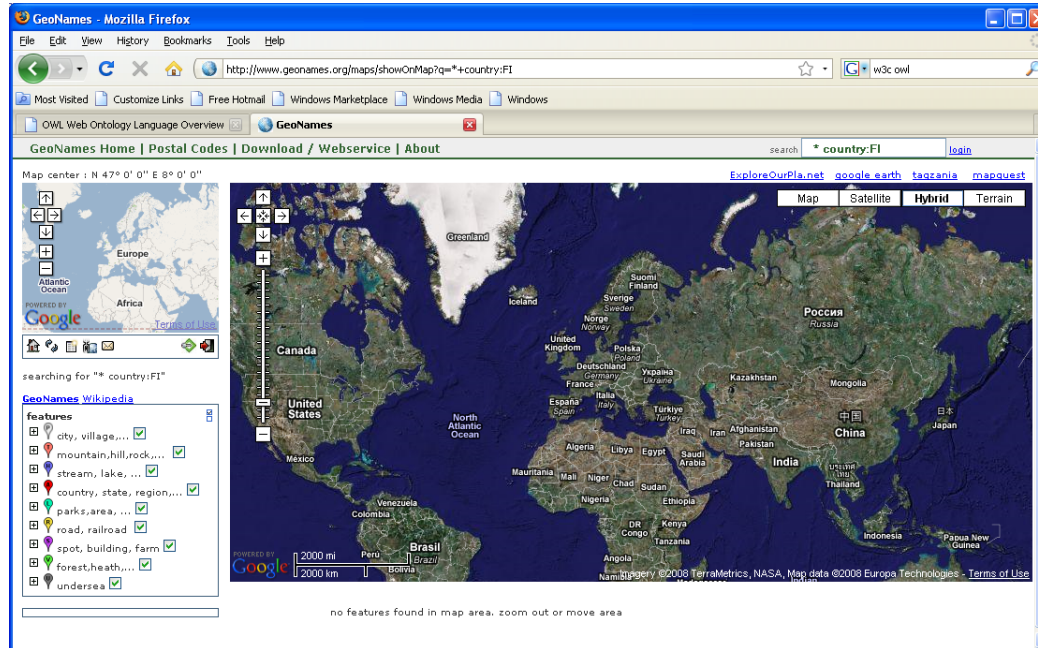
Gender: male

Events:
active: [United States \(North and Central America\)](#) ([nation](#))
active: [Finland \(Europe\)](#) ([nation](#))

Related People or Corporate Bodies:
child of [Saarinen, Eliel](#)
..... (Finnish architect, 1873-1950, active in the United States) [500027014]
employee of [Eklund, Jari](#)
..... (Finnish architect, 1876-1962) [500069436]
employee was [Pelli, Cesar](#)
..... (American architect and teacher, 1926-2019, born in Argentina) [500023533]
founder of [Eero Saarinen & Associates](#)
..... (American architectural firm, active 1950-1961) [500119694]
member of [Saarinen, Saarinen and Associates](#)
..... (American architectural partnership, active 1947-1950) [500229797]
member of [Saarinen, Swanson, Saarinen](#)
..... (American architectural partnership, active 1941-1947) [500229808]
partner of [Saarinen, Eliel](#) 1941-1950
..... (Finnish architect, 1873-1950, active in the United States) [500027014]
partner of [Swanson, J. Robert F.](#) 1941-1947
..... (American architect, active late 20th century) [500113110]
related to [Saarinen and Saarinen](#)
..... (Finnish architectural firm, contemporary) [500291347]

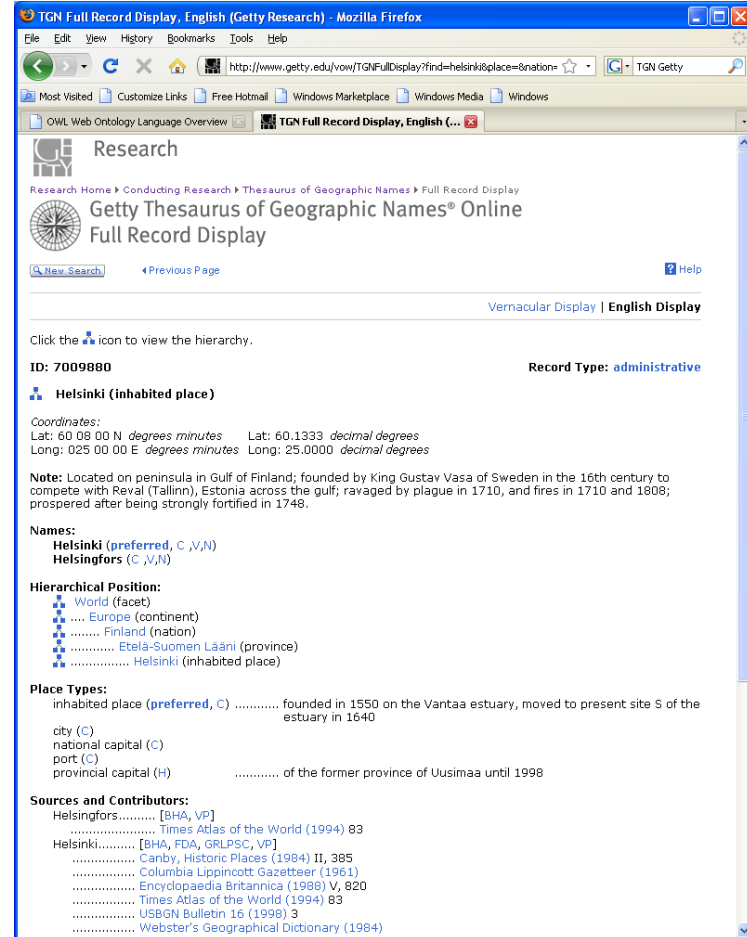
Geonames

- Classes: 9 feature classes, 645 feature codes
- Instances:
 - 8 million geographical names, 6.5 million unique features, 2.2 million populated places, 1.8 million alternate names
 - Registries and Wiki used for populating the ontology



TGN Thesaurus of Geographical Names

- 912,000 records
- 1.1 million names, place types, coordinates, and descriptive notes
- Places important for the study of art and architecture
- Available in a Linked Open Data service: [Getty Thesaurus of Geographic Names \(Getty Research Institute\)](#)



W3C Standards for Semantic Web Ontologies/Vocabularies

RDF Schema

- Class and property hierarchies

SKOS Simple Knowledge Organization System

- Light-weight semantics
- E.g., for representing existing glossaries, thesauri, and classifications

OWL Web Ontology Language

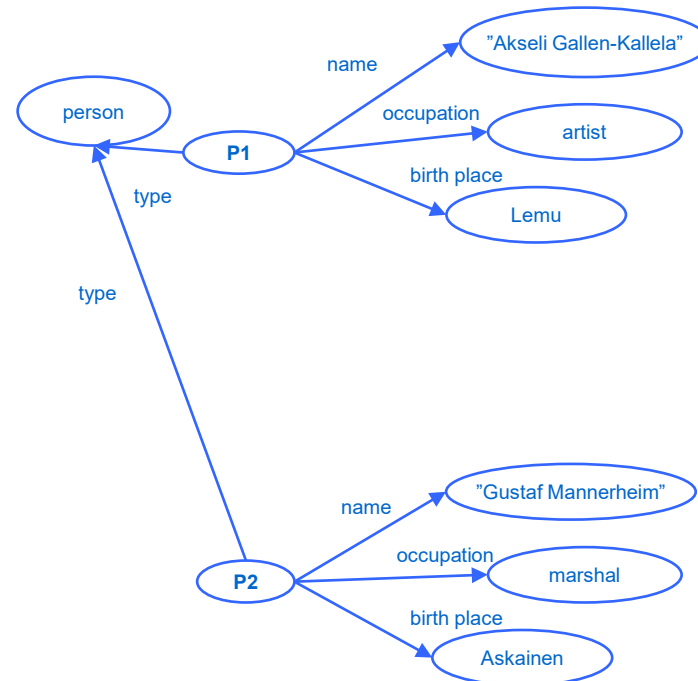
- Rich semantics based on logic
- Supports more advanced reasoning

**Metadata + Ontologies =
Linked Data (Web of Data)**

**Enriching Data by Data Linking
through Shared Ontologies:
An Example**

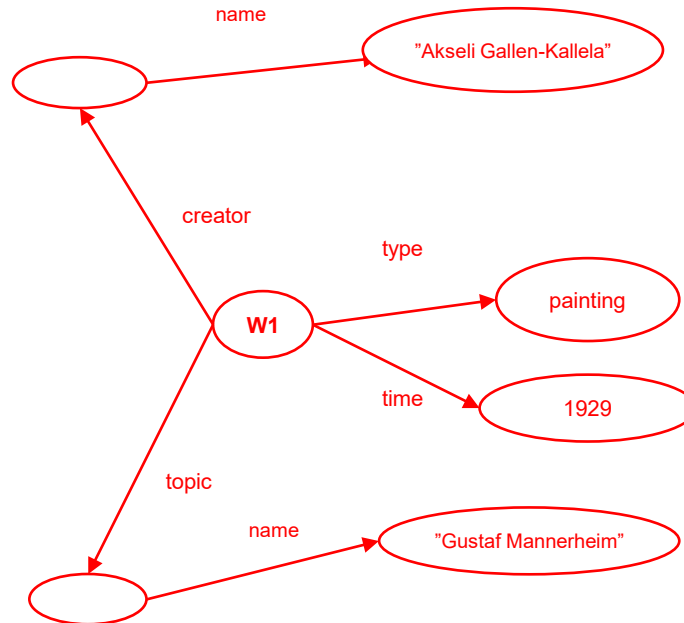
Biography Centers and Libraries Have Databases of about Historical People

person	name	occupation	birth place	...
P1	Akseli Gallen-Kallela	artist	Lemu	
P2	Gustaf Mannerheim	marshal	Askainen	
...				



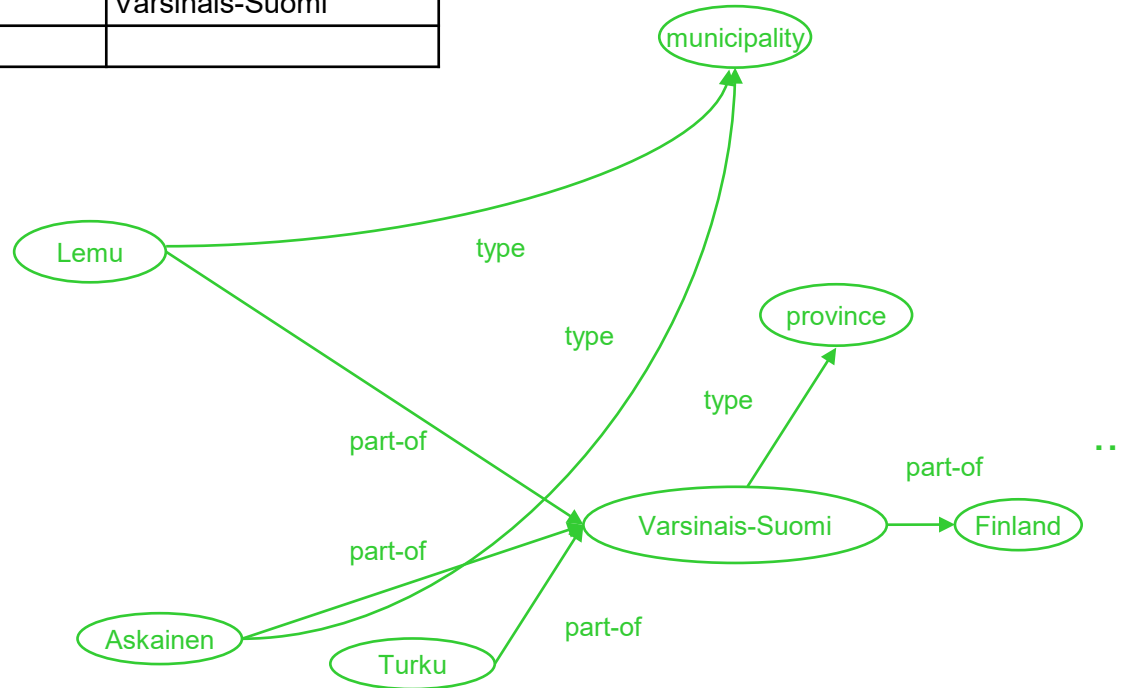
Museums Catalogue Paintings

Work	name	creator	time	Topic	...
W1	Portrait of Mannerheim	Akseli Gallen-Kallela	1929	Gustaf Mannerheim	
W2	Aino Triptych	Akseli Gallen-Kallela	1891	Aino, Kalevala	
...					



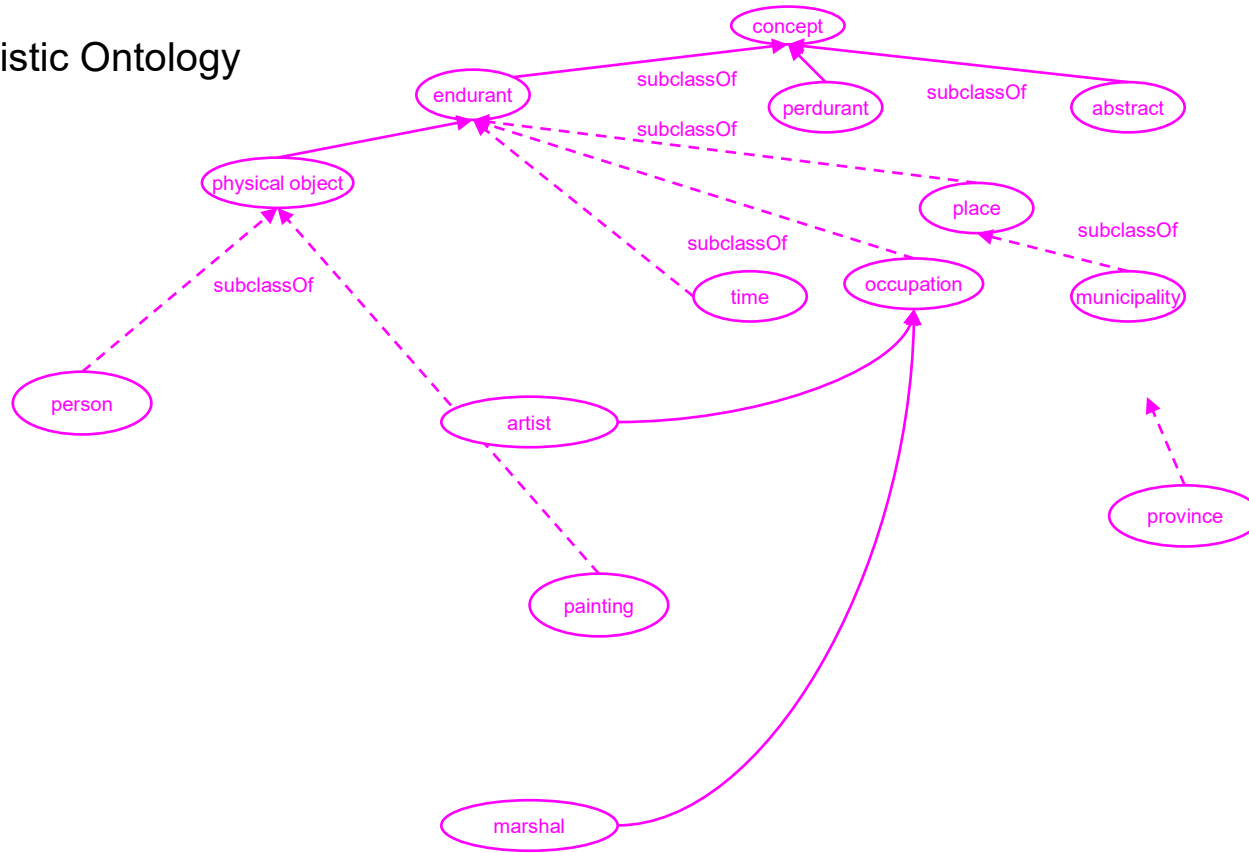
Land Surveys Maintains Place Registries

municipality	province
Askainen	Varsinais-Suomi
Helsinki	Uusimaa
Lemu	Varsinais-Suomi
Turku	Varsinais-Suomi
...	

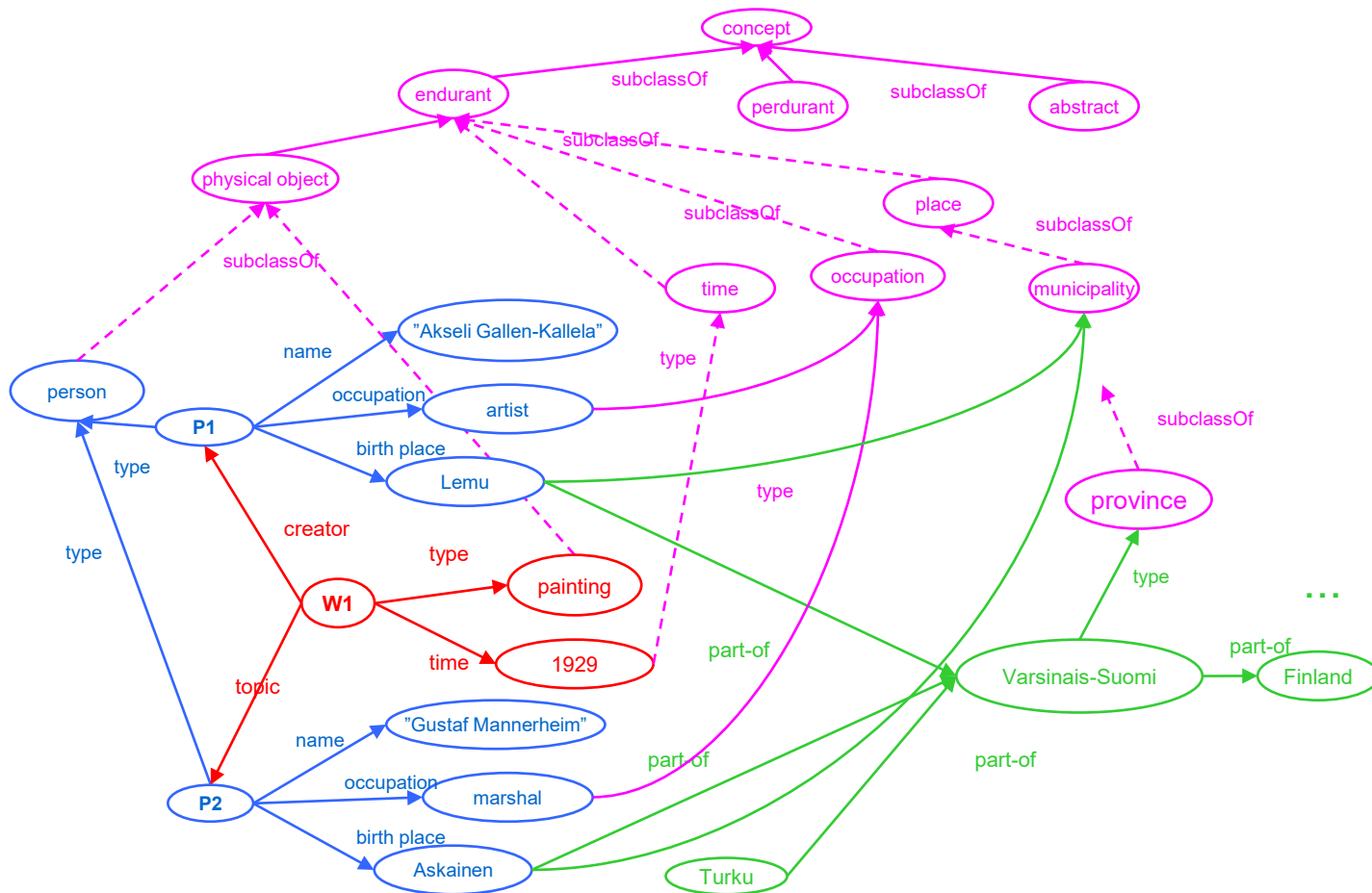


National Library Builds Ontologies

Holistic Ontology



Semantic RDF Graph Combines All Data: Web of Data



Two Key Challenges in Aggregating Data by Data Linking

Ontologies used is metadata descriptions must be **shared** by collaborating parties

- Otherwise the data just does not link properly!
- Multiple concepts for the same thing emerge

Metadata models have to be **aligned**

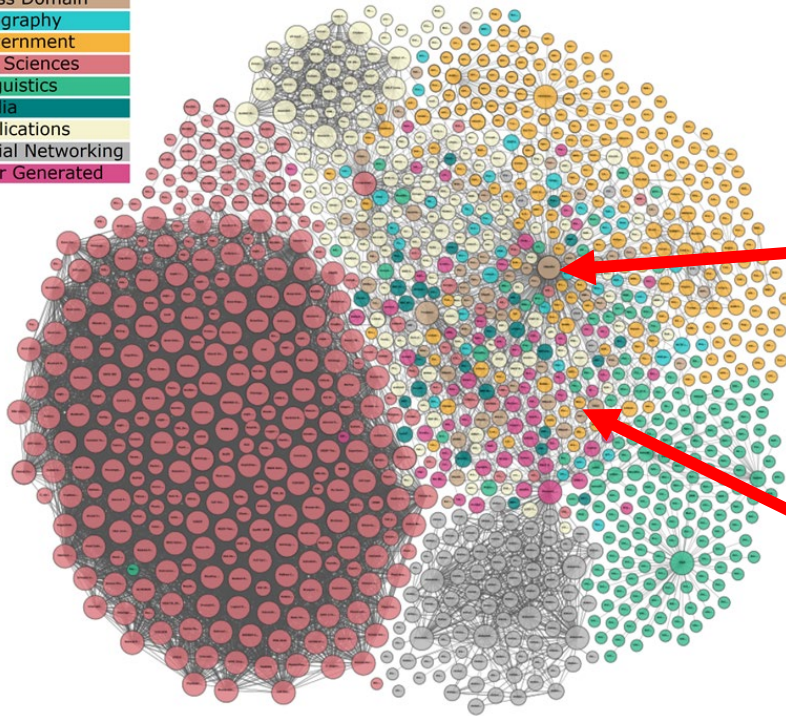
- E.g. two libraries providing data about books in different forms
- Otherwise the data is not interoperable

Web of Data: Linked Open Data Cloud

Human Knowledge on the Semantic Web

Legend

Cross Domain
Geography
Government
Life Sciences
Linguistics
Media
Publications
Social Networking
User Generated



Wikipedia

WarSampo

**LODStats 2018 (<http://stats.lod2.eu/>):
10 000 datasets, 150 billion triples**

Application Example: WarSampo – Finnish WW2 on the Semantic Web



- <https://vimeo.com/212249404>

Rule Level - Logic

The Idea of Rules

- Semantic web semantics is based on **logic**
- Logic = “new” information can be derived from old by (rule-based) reasoning

Rule Markup Language RuleML

Standardized XML notation for rules

$\text{hasParent}(?x1, ?x2) \wedge \text{hasBrother}(?x2, ?x3) \Rightarrow \text{hasUncle}(?x1, ?x3)$

```
<ruleml:imp>
  <ruleml:_rlabel ruleml:href="#example1"/>
  <ruleml:_body>
    <swrlx:individualPropertyAtom swrlx:property="hasParent">
      <ruleml:var>x1</ruleml:var>
      <ruleml:var>x2</ruleml:var>
    </swrlx:individualPropertyAtom>
    <swrlx:individualPropertyAtom swrlx:property="hasBrother">
      <ruleml:var>x2</ruleml:var>
      <ruleml:var>x3</ruleml:var>
    </swrlx:individualPropertyAtom>
  </ruleml:_body>
  <ruleml:_head>
    <swrlx:individualPropertyAtom swrlx:property="hasUncle">
      <ruleml:var>x1</ruleml:var>
      <ruleml:var>x3</ruleml:var>
    </swrlx:individualPropertyAtom>
  </ruleml:_head>
</ruleml:imp>
```

Application Example: MuseumFinland Recommends

Inference rules tell machine about the world

- E.g., that "student's cap" is related to "parties"
- E.g., that entities are related to each other if their superclasses are related to each other

Based on the graph of metadata+ontologies, machine can:

- Reason interesting new relations between museum items, and
- Provide them to end users as recommendation links

Application example: MuseumFinland



The screenshot shows the MuseumSuomi website interface. At the top, there's a navigation bar with links like 'Uusi haku', 'Takaisin hakusivulle', 'Ohjeet', 'Tietoa ohjelmasta', 'MuseoSuomi-palautte', 'English Tutorial', and 'About MuseumFinland'. The main content area displays a search result for 'Pullonsuojus, 2 kpl:istuva koira'. On the left, there are three images of the knitted dog toy. The main text provides detailed information about the object, including its material (glass bottle and wool), manufacturer (Tapio Wirkkala), and date (1962-1970). A red circle highlights the right-hand side of the page, which contains several categorized lists of related items: 'Sama käyttäjä' (Eero Kallio), 'alkoholijuoma' (kanisteri taskumatti), 'eläimet' (kuvakirja, kangasta), 'koriste-esineet' (luonnettauki, mietelausetaulu), and 'Sama materiaali' (neuletakki, taulukehystetty kirjontavo).

MuseoSuomi
- Suomen museot semanttisessa webissä -

Uusi haku | Takaisin hakusivulle | Ohjeet | Tietoa ohjelmasta | MuseoSuomi-palautte | English Tutorial | About MuseumFinland

(←) Kohteet (4132) (→)
(←) Pullonsuojus, 2 kpl:istuva koira (→ Ripustin:henkari, 'Finn Lassie')

Pullonsuojus, 2 kpl:istuva koira

Materiaali: viinapullo: lasi, pulonsuojus: lanka
Valmistaja: Karhulan lasitehdas, Tapio Wirkkala
Valmistusaika: 1962, 1970-1 n.
Valmistustekniikka: viinapullo: tehdasvalmisteinen, pulonsuojus: käsityötä
Käyttäjät: Eero Kallio
Käyttöpaiikka: Etelä-Suomen lääni, Suomi
Asiasana: ALKOHOLIJUOMAT, ELÄINHAHMOT, KORISTE-ESINEET
Mitat: pullon pohjan halkaisija 6,5cm, korkeus 22,5cm, pulonsuojuksen korkeus 29,0cm
Museokokoelma: LAHDEN HISTORIAALINEN MUSEO
Vastuumuseo: LAHDEN KAUPUNGINMUSEO
Asiasanasto: Lahden kaupunginmuseon sanasto
Esineen numero: LKMLHMLHMES.95073:154
ID: 95073154
Viinapullo: Alkon Koskenkorvapullo. Lieriömäinen, loivat hartiat. Korkeat ja etiketti puuttuvat. Pulonsuojus: istuvan koiran muotoinen pulonsuojus. Muodossa kahdesta osasta: koiran vartalosta ja päästä. Koiran vartaloon on ommeltu viisi leikkatupsua (jalat ja häntä), ylhäällä lankakiristys. Koiran pää on virkattu talouspaperirullasta leikatun leriön ympärille. Kasvoissa mustat napit silminä, erillinen pieni kuono ja kolme lankatupsua (posket ja päällella oleva otsanukka).

Esinetyyppi:

- [pukineet ja tekstiilit](#) (1803) > [tekstiilit](#) (338) > [sisustus- ja kodintekstiilit](#) (265) > [suoiatekstiilit](#) (24) > [irtoneualliset](#) (8)

Materiaali:

- [materiaalit](#) (3777) > [tekstiilmateriaalit](#) (691) > [lanka](#) (191)
- [materiaalit](#) (3777) > [muut materiaalit](#) (611) > [lasi](#) (193)

Valmistaja:

- [yrietykset](#) (1247) > [Karhulan lasitehdas](#) (3)
- [henkilöt](#) (867) > [mies](#) (413) > [Tapio Wirkkala](#) (5)

Valmistusaika:

Sama käyttäjä

Eero Kallio:

- [Keräilykortti, 14 kpl:tuotemainoskortti, erilaisia](#)
- [Kulho, 4 kpl:jalkiruokakulho](#)
- [Päähine, miehen: turkislakki, 'suikka'](#)
- [Taskuliina, miehen: taskuliinan korvake](#)
- [Jalkineet, miehen: koripallokengät](#)

Samaan aiheeseen liittyviä esineitä

alkoholijuoma:

- [kanisteri taskumatti](#)
- [kanisteri taskumatti](#)
- [kanisteri taskumatti](#)
- [viinipullo lasipullo](#)
- [pullo lasipullo](#)

eläimet:

- [kuvakirja, kuvakirja, kangasta](#)
- [helistin, purulelu](#)
- [muovikarhu: vinkuva karhulelu](#)
- [säästölipas: vanerilipas](#)
- [malja: punvat](#)

koriste-esineet:

- [luonnettauki: mietelausetaulu](#)
- [lyhty: öljylamppu](#)
- [kannu: koristekannu](#)
- [kynntilänjalja](#)
- [maljakko: maljakko](#)

Sama materiaali

lanka:

- [neuletakki: naisen neuletakki](#)
- [taulu: kehystetty kirjontavo](#)

Application Domains of Semantic web

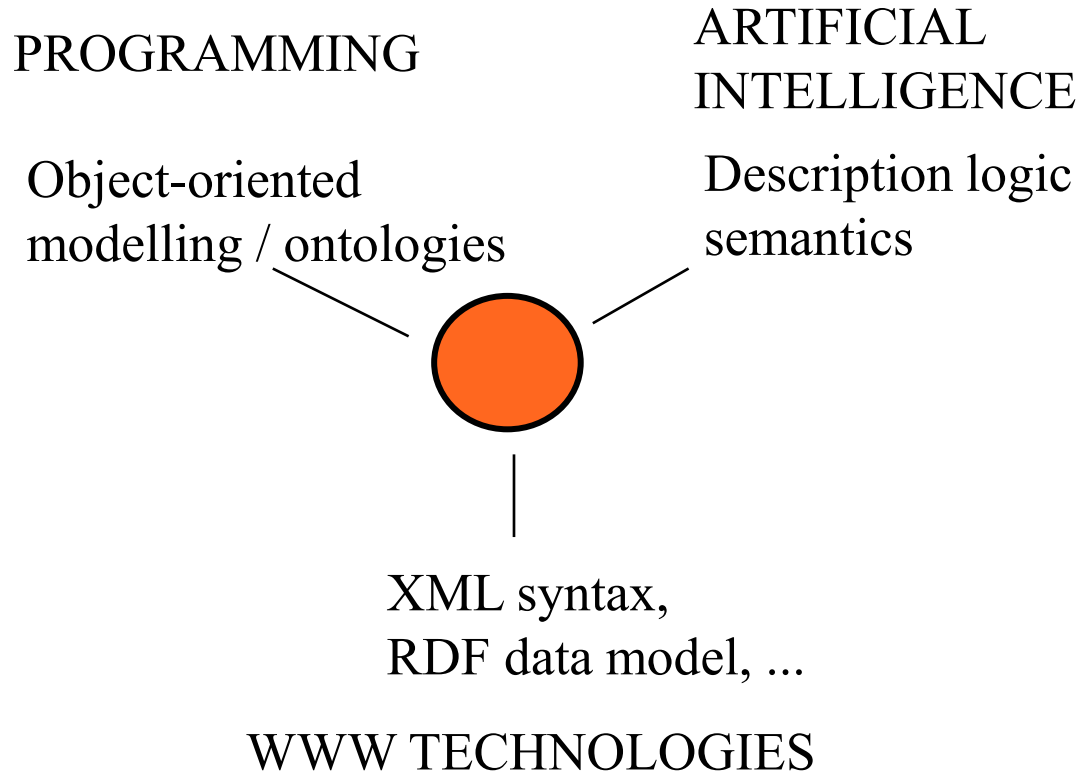
- **Semantic portals**
- **Information retrieval systems**
- **Recommender systems**
- **Knowledge management systems**
- **Personalized systems**

...

Examples of applications / domains have been collected here:

<https://www.w3.org/2001/sw/sweo/public/UseCases/>

What is New? Components of Semantic Web



What is the Semantic web?

Content perspective: A new metadata layer on the Web describing its contents in terms of shared vocabularies, i.e., ontologies

- Web as a global database system
- Web of Pages vs. Web of Data

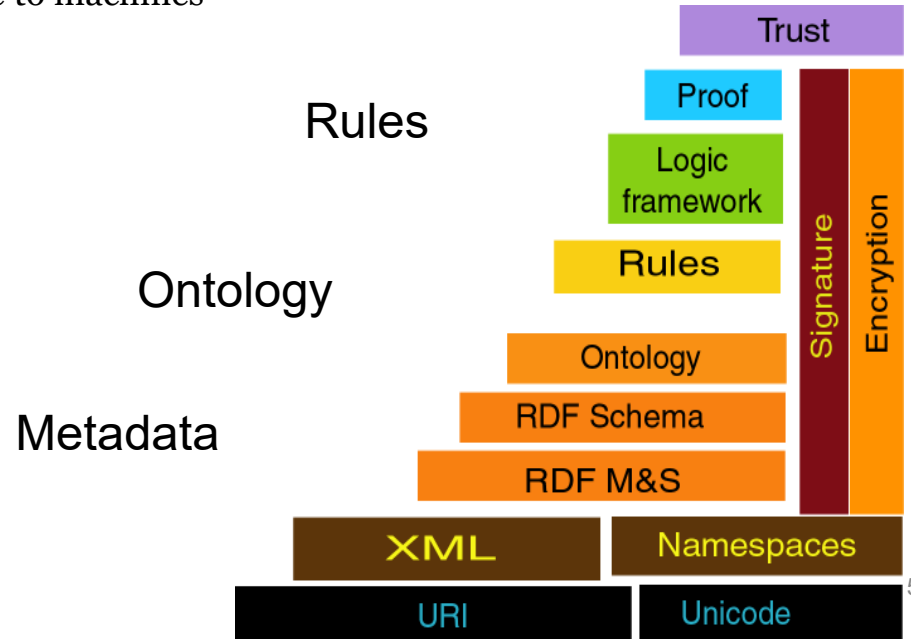
Application perspective: Machine-understandable web

- The meaning (semantics) of contents accessible to machines
- Enables human usage
 - *Intelligent web services*
 - *Semantic interoperability*

Technological perspective:

Next layers above XML

- W3C standards:
RDF(S), OWL , SPARQL, etc.



More Information – Questions?



Linked Open Infra for Digital Humanities in Finland: LODI4DH

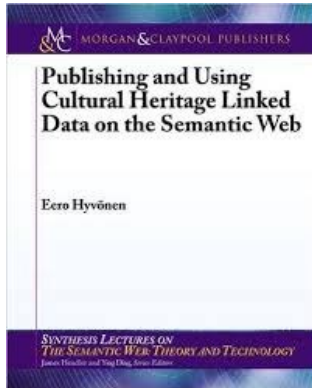
<https://seco.cs.aalto.fi/projects/lodi4dh/>

Sampo Model & Portal Series:

<https://seco.cs.aalto.fi/applications/sampo/>

Semantic Web & Linked Data Standards

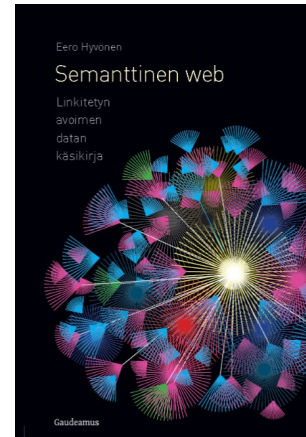
<http://www.w3.org/standards/semanticweb/>



In English

2012

<https://www.amazon.com/Publishing-Cultural-Heritage-Synthesis-Technology/dp/1608459977>



In Finnish

2018

<https://www.gaudeamus.fi/semanttinen-web/>