UNIVERSITÄT MANNHEIM

Ontologies and the Semantic Web

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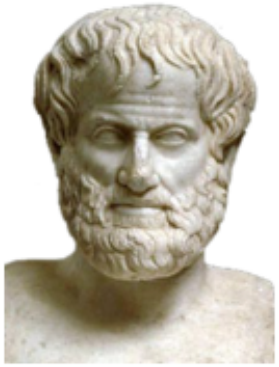
Overview

1 Ontology vs. Ontologies



- Philosophy
  - Ontology is the study of the **nature of being**, e.g.
    - What is existence?
    - What entities (can) exist?
    - Which properties of an entity are essential?
  - Aristoteles, Sokrates, Thomas von Aquin, Descartes, Kant, Hegel, Wittgenstein, Heidegger, Quine, …
- Computer science
  - Ontologies are **domain models**, i.e. abstract representations of knowledge about a certain field
  - Essentially, hierarchies of classes and binary relationships

1.1 What are Ontologies?

„An ontology is an explicit specification of a conceptualization.“
[Gruber 1993]

“An ontology is a formal, explicit specification of a shared conceptualisation.
A ‘conceptualisation’ refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. ‘Explicit’ means that the type of concepts used, and the constraints on their use are explicitly defined. (...) ‘Formal’ refers to the fact that the ontology should be machine readable, which excludes natural language. ‘Shared’ reflects the notion that an ontology captures consensual knowledge, that is, it is not private to some individual, but accepted by a group.”
[Studer et al. 1998]

1.1 What are Ontologies?

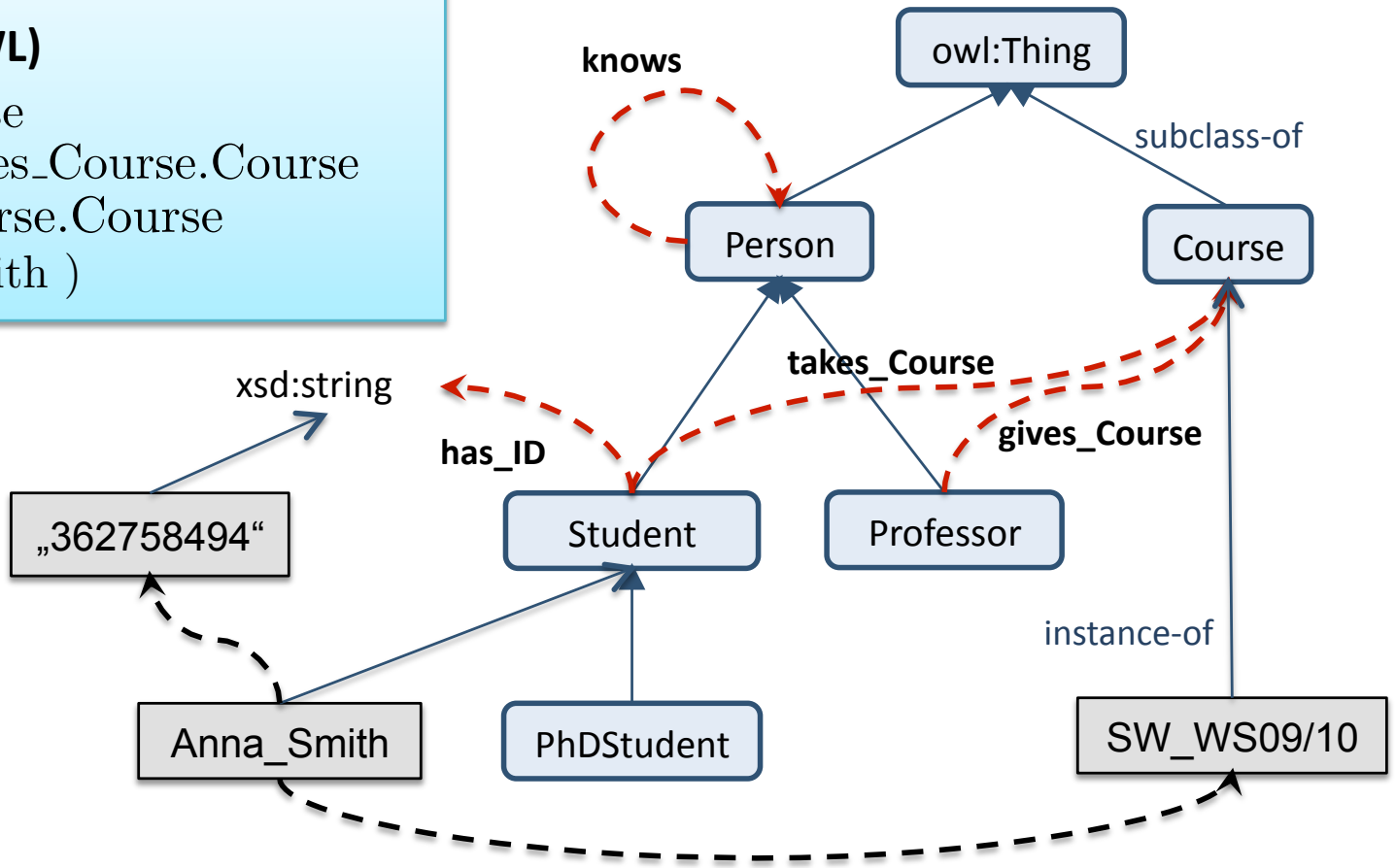
„An ontology may take a variety of forms, but it will necessarily include a vocabulary of terms and some specification of their meaning. This includes definitions and an indication of how concepts are inter-related which collectively impose a structure on the domain and constrain the possible interpretations of terms.“
[Uschold und Jasper 1999]

“(...) an ontology refers to an engineering artifact, constituted by a specific vocabulary used to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words.”
[Guarino 1995]

Ontologies

DL Axioms (e.g. OWL)

$\text{Person} \sqsubseteq \neg\ \text{Course}$
$\text{Professor} \sqsubseteq \exists\ \text{gives\_Course.Course}$
$\top \sqsubseteq \forall\ \text{takes\_Course.Course}$
$\text{Student}(\ \text{Anna\_Smith}\ )$



Rules (e.g. F-Logic)

$\text{takes\_Course}(?x,?y) \wedge \text{gives\_Course}(?z,?y) \rightarrow \text{knows}(?x,?z)$

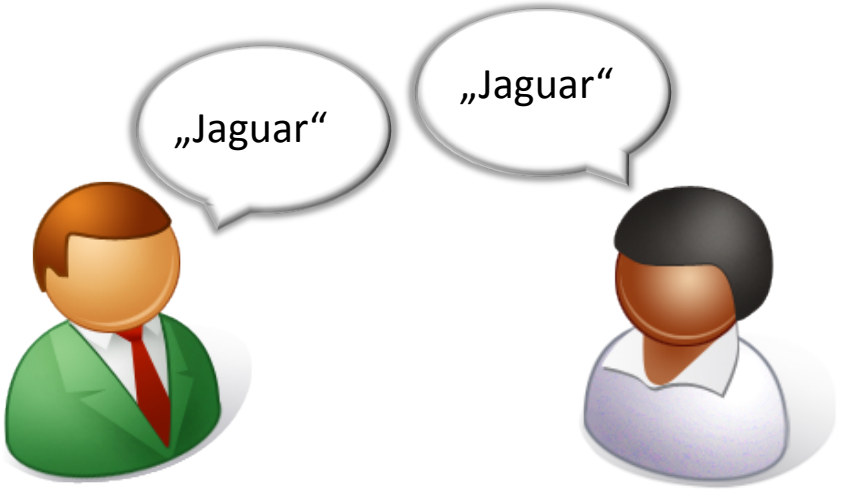
1.2 Why do we need ontologies?

„Some of the reasons are …

- to share common understanding of the structure of information among people or software agents
- to enable reuse of domain knowledge
- to make domain assumptions explicit
- to separate domain knowledge from the operational knowledge
- to analyze domain knowledge”

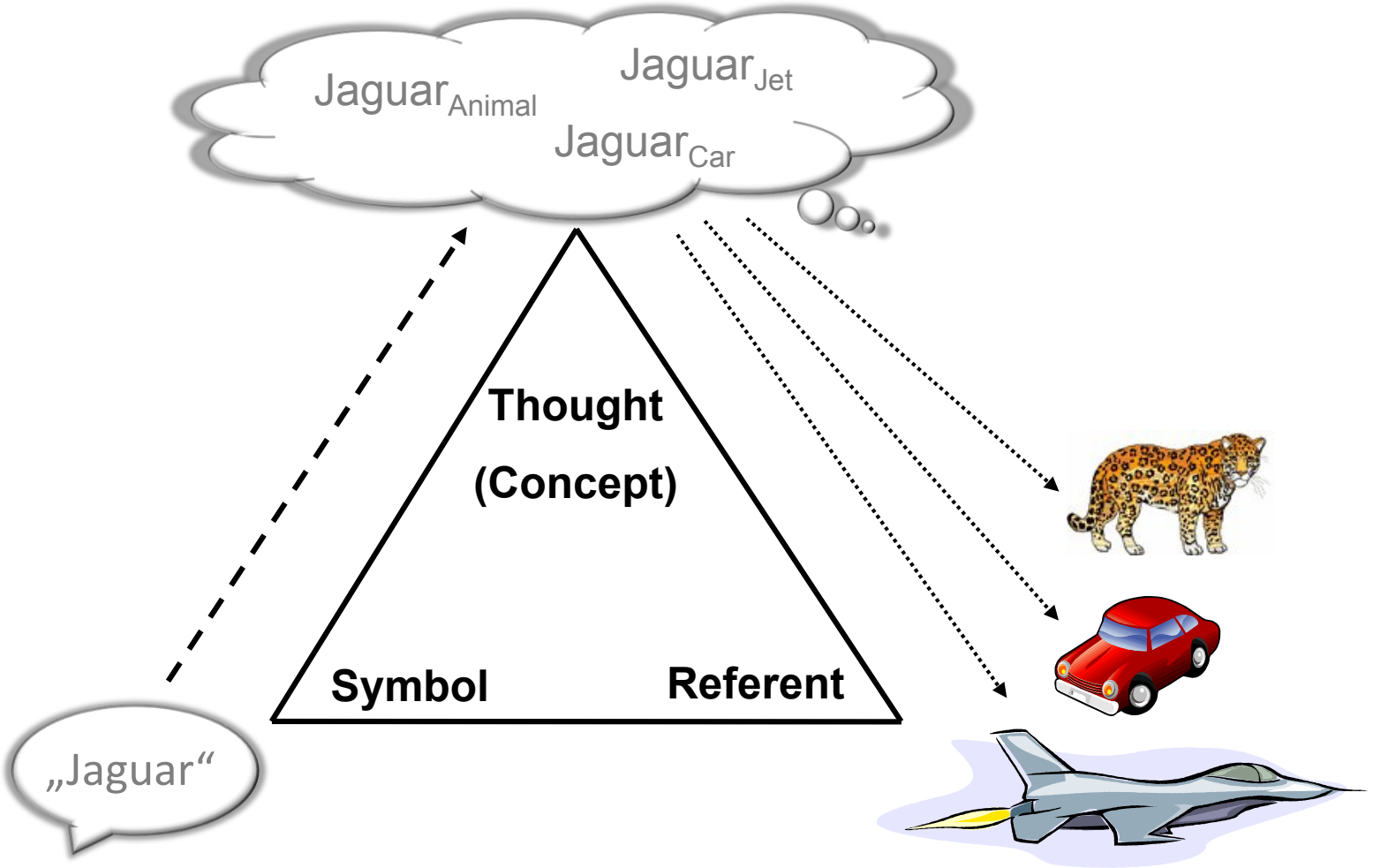
[Noy and McGuinness 2001]

Example: Common Understanding

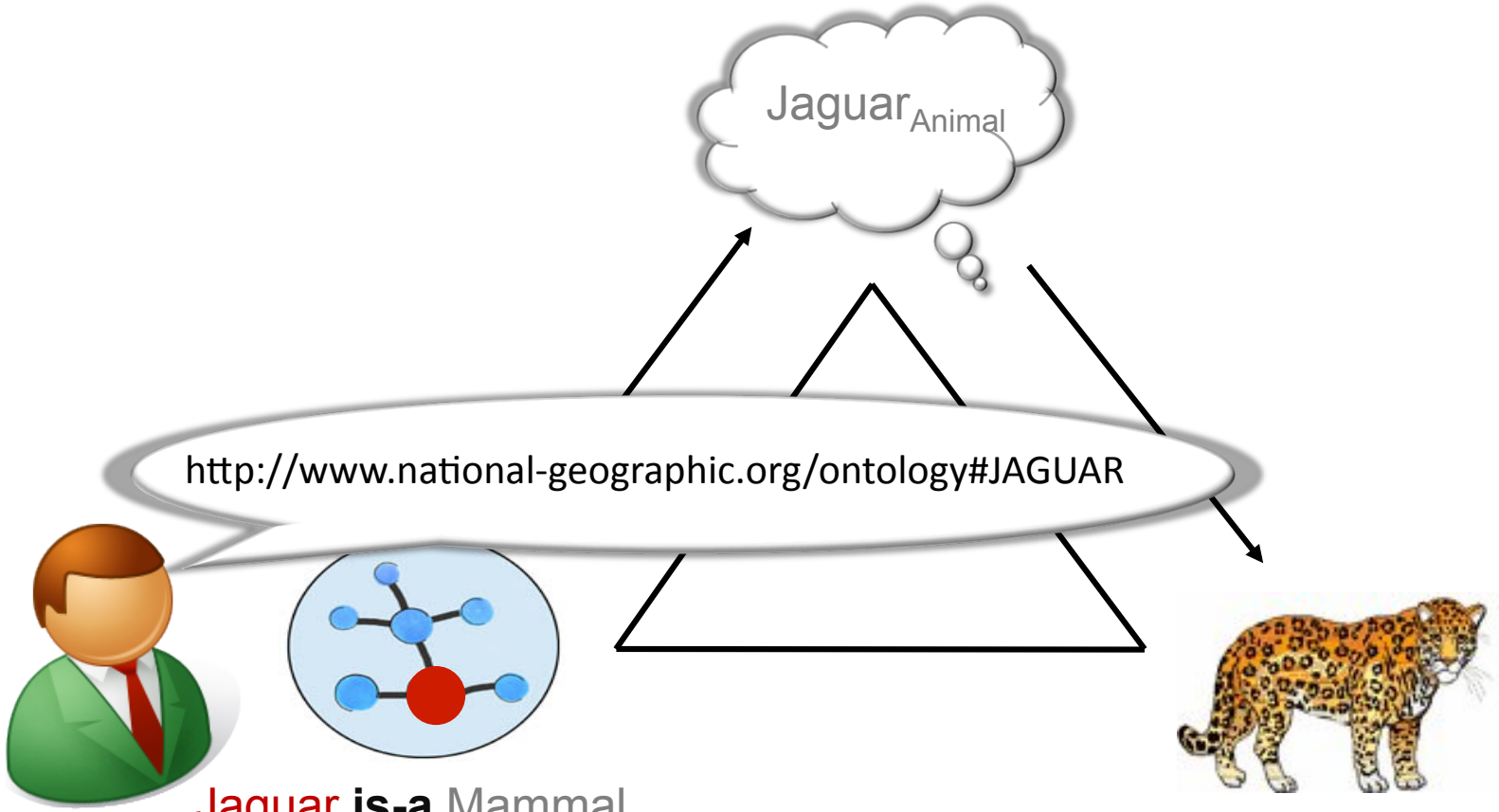


Example: Common Understanding

Semiotic Triangle [Ogden and Richards 1923]

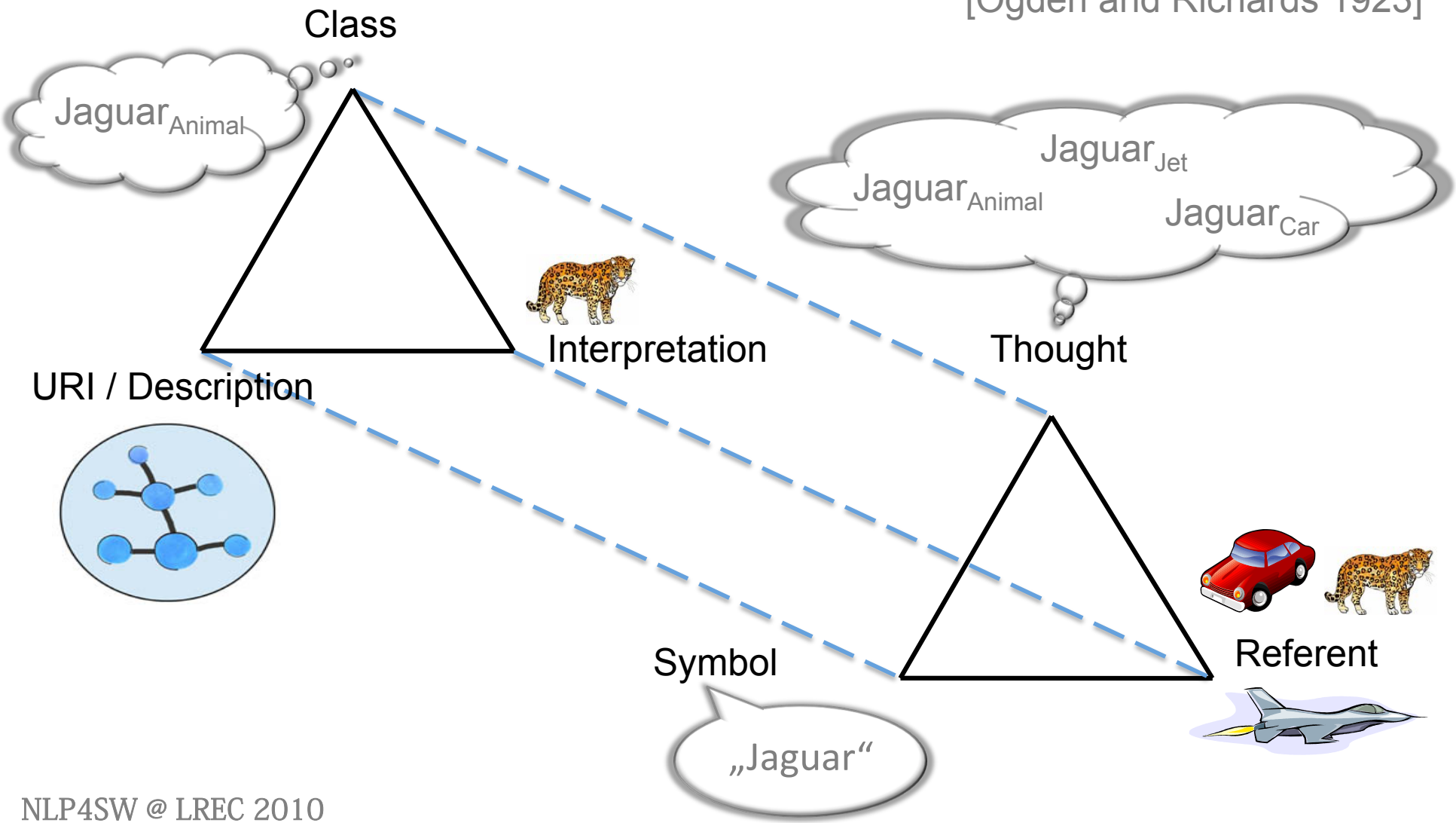


Example: Common Understanding

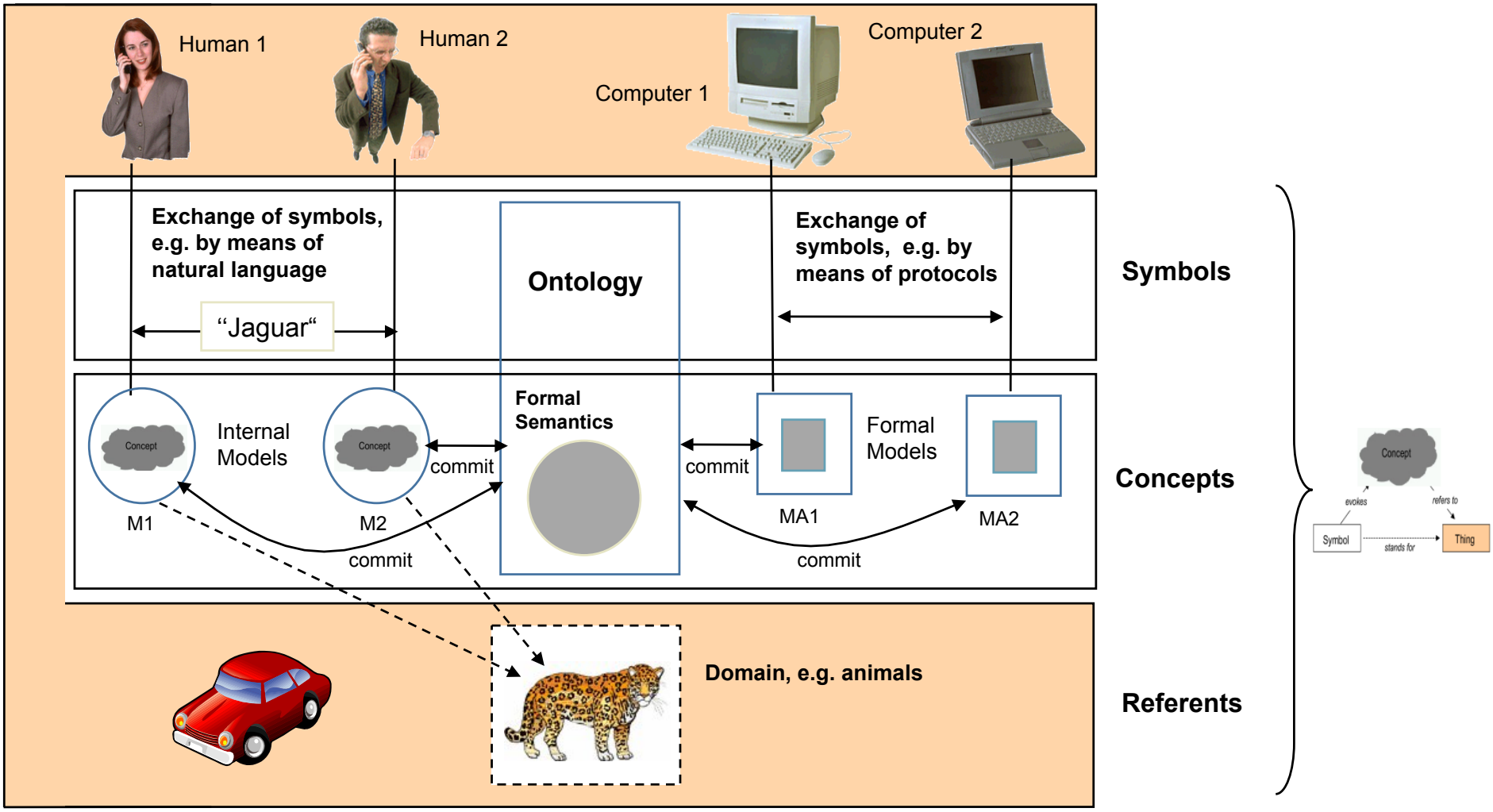


The Semiotic Triangle Revisited

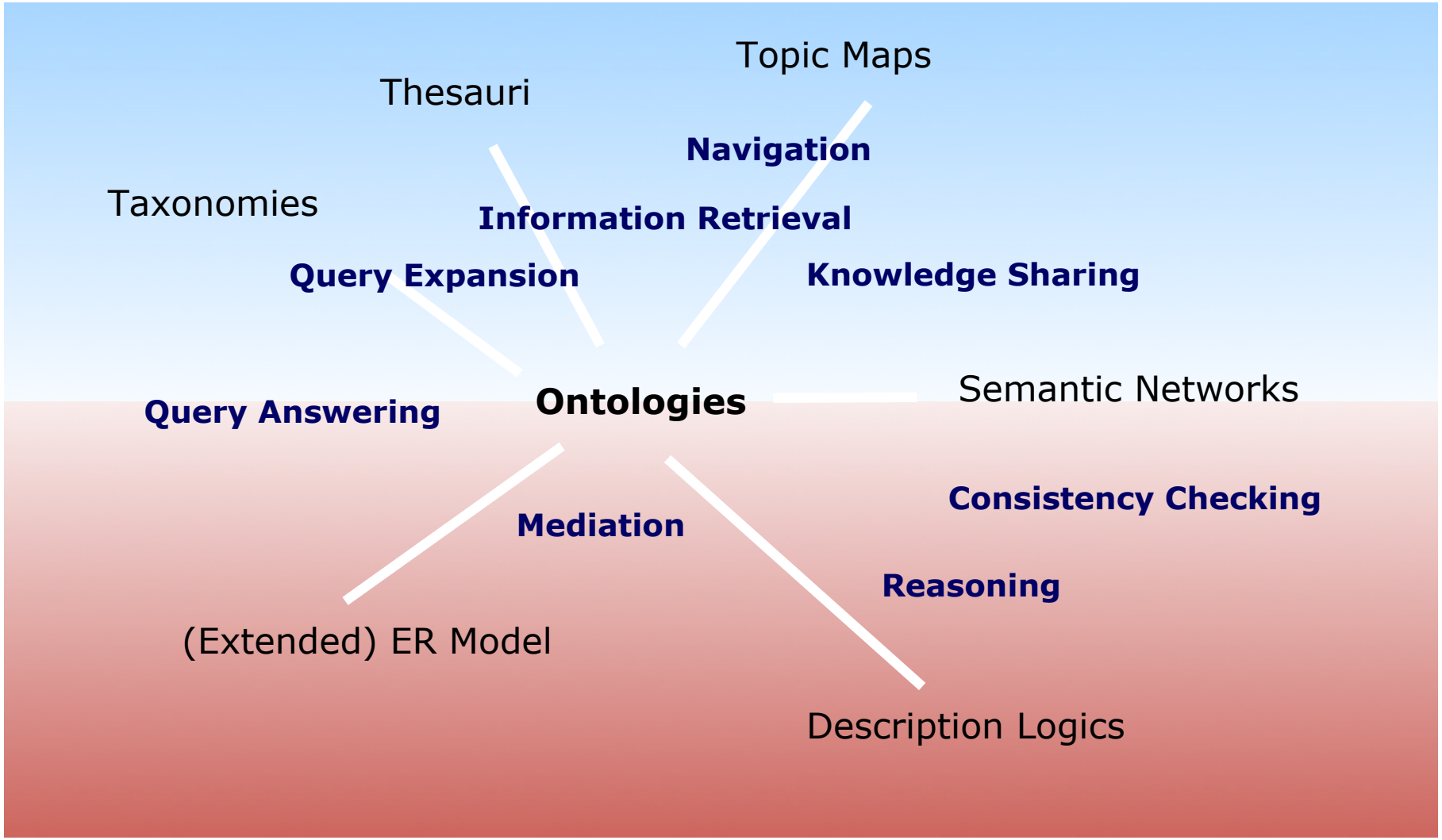
[Ogden and Richards 1923]



Communication of Humans and Machines



1.3 Ontologies on the Web

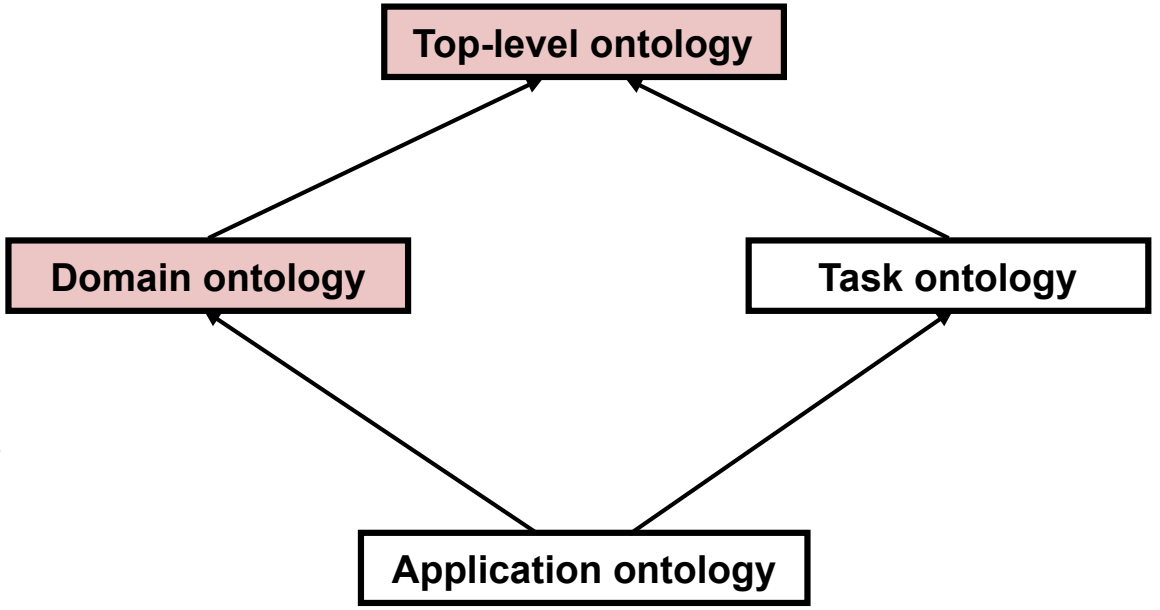


[Guarino, 1998]

Types of Ontologies

Describe **very general concepts** like space, time, event, which are independent of a particular problem or domain. It seems reasonable to have unified top-level ontologies for large communities of users.

Describe the vocabulary related to a **generic domain** by specializing the concepts introduced in the top-level ontology.

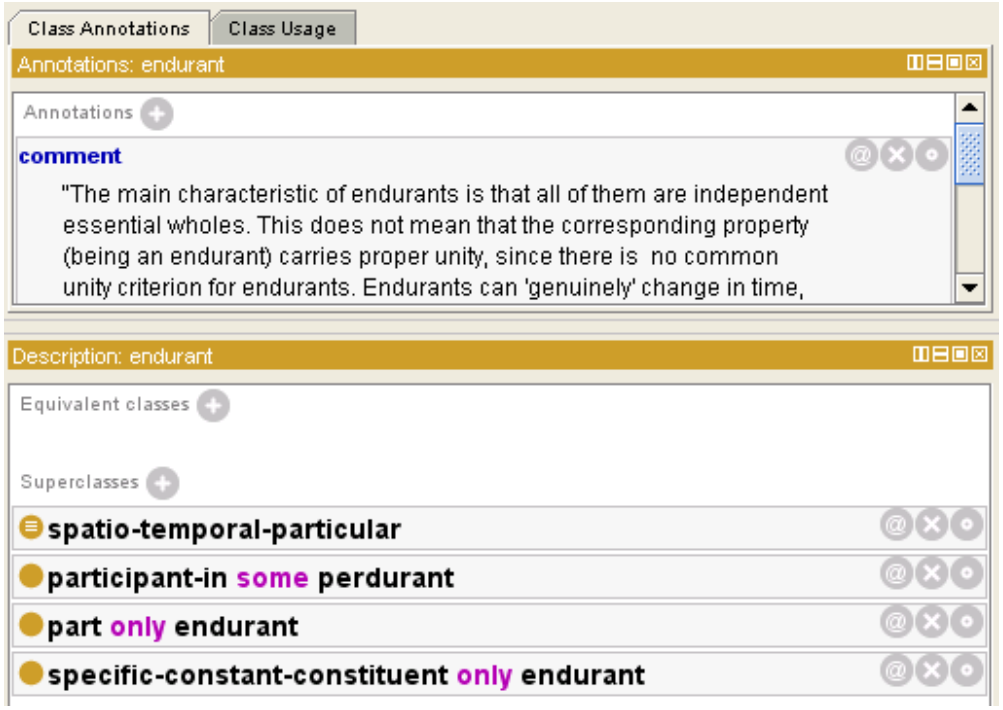


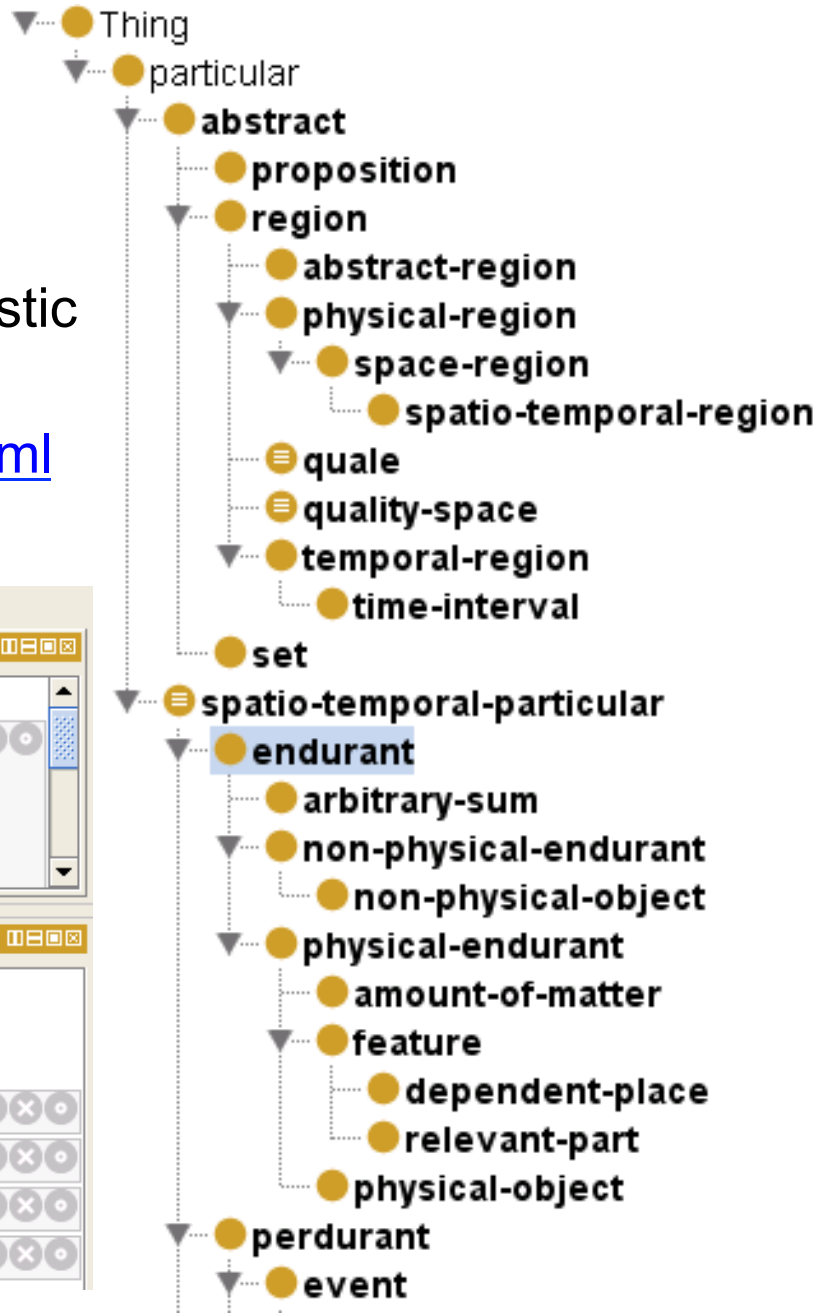
Describe the vocabulary related to a **generic task or activity** by specializing the top-level ontologies.

These are the most specific ontologies. Concepts in application ontologies often correspond to **roles played by domain entities while performing a certain activity**.

DOLCE

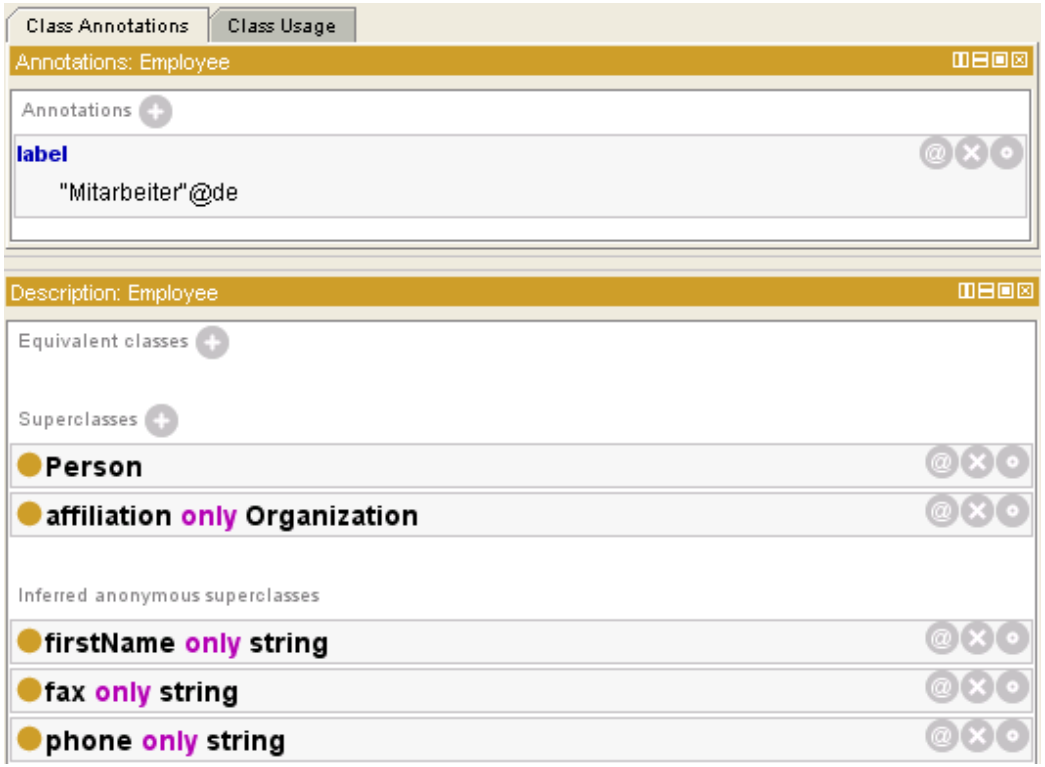
- Descriptive Ontology for Linguistic and Cognitive Engineering
- http://www.loa-cnr.it/DOLCE.html





SWRC

- Semantic Web for Research Communities
- http://ontoware.org/projects/swrc/



Other Ontologies

- SUMO: http://www.ontologyportal.org
- CYC: http://www.cyc.com
- Proton: http://proton.semanticweb.org
- WordNet: http://wordnet.princeton.edu
- Dublin Core: http://dublincore.org
- Pizza: http://www.co-ode.org/ontologies/pizza/2007/02/12/
- Time: http://www.w3.org/TR/2006/WD-owl-time-20060927/
- Gene Ontology: http://www.geneontology.org
- GALEN: http://www.openclinical.org/prj_galen.html
- NCI Thesaurus: http://nciterms.nci.nih.gov
- …

Repositories and Search Engines

- Watson
  - http://watson.kmi.open.ac.uk
- Swoogle
  - http://swoogle.umbc.edu
- TONES Ontology Repository
  - http://owl.cs.manchester.ac.uk/repository/
- Open Biomedical Ontologies
  - http://www.obofoundry.org
- OntoSelect
  - http://olp.dfki.de/ontoselect/

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  1.2 Why do We Need Ontologies?
  1.3 Ontologies on the Web
2 Semantic Web
3 Web Ontology Language

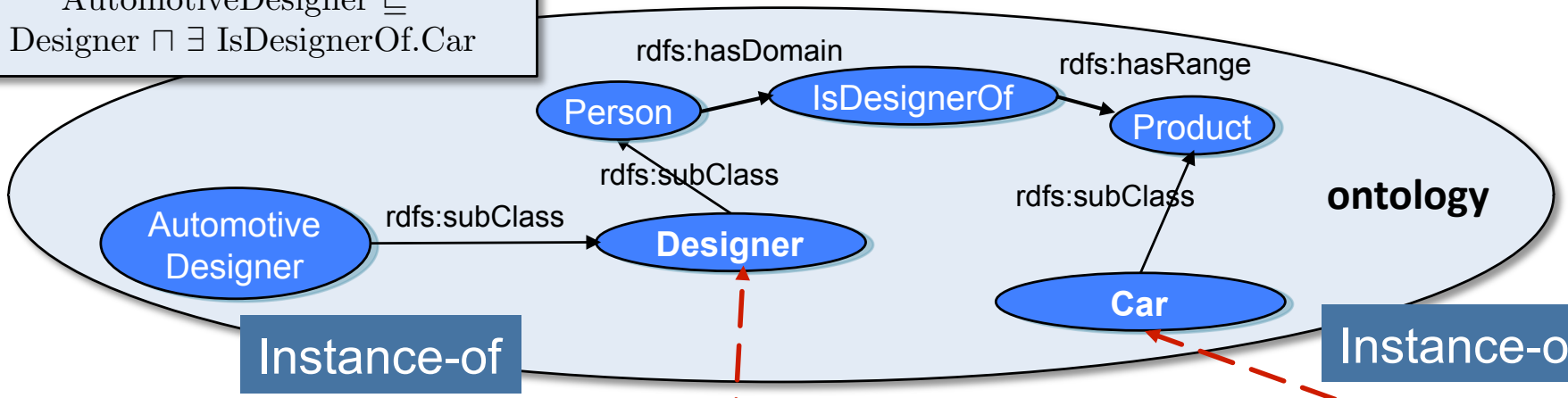
2 Semantic Web

- “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 2001]

$$\text{AutomotiveDesigner} \sqsubseteq \text{Designer} \sqcap \exists\, \text{IsDesignerOf}.\text{Car}$$

xmlns:onto="http://www.co-ode.org/ontologies/design.owl#"



Instance-of

Instance-of

semantic annotation

```
<onto:Designer rdf:ID="sergio">
  <onto:name>Sergio Pininfarina
            </onto:name>
  <onto:isDesignerOf
  rdf:resource = "testarossa"/>
...
</onto:Designer>
```

IsDesignerOf

```
<onto:Car rdf:ID="testarossa">
   <onto:name>Ferrari Testarossa
   </onto:name>
...
</onto:car>
```

webpage


Sergio Pininfarina's biographical Notes

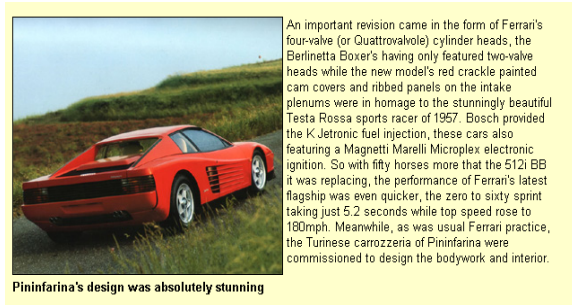
- Pininfarina Sergio
- parents: late Pininfarina Battista and late Rosa Copasso
- born: Turin, Italy, September 8, 1926
- married: 1951, with Giorgia Gianolio
- children: Lorenza, Andrea, Paolo

Graduated in mechanical engineering from the Polytechnic of Torino in 1950, he began his career in the family firm, "Carrozzeria Pinin Farina"; in 1960, he undertook the responsibility of General Manager of the firm; in 1961 he became also Managing Director and in 1966, at his father's death, he took over the Chairmanship of the Company

In 1961, the President of the Italian Republic, Giovanni Gronchi, changed by decree the name Farina in Pininfarina.

From 1974 to 1977 he has been professor of "Car Body Design" at the Polytechnic of Torino.

http://www.pininfarina.it/bio_s_pininfarina2.html

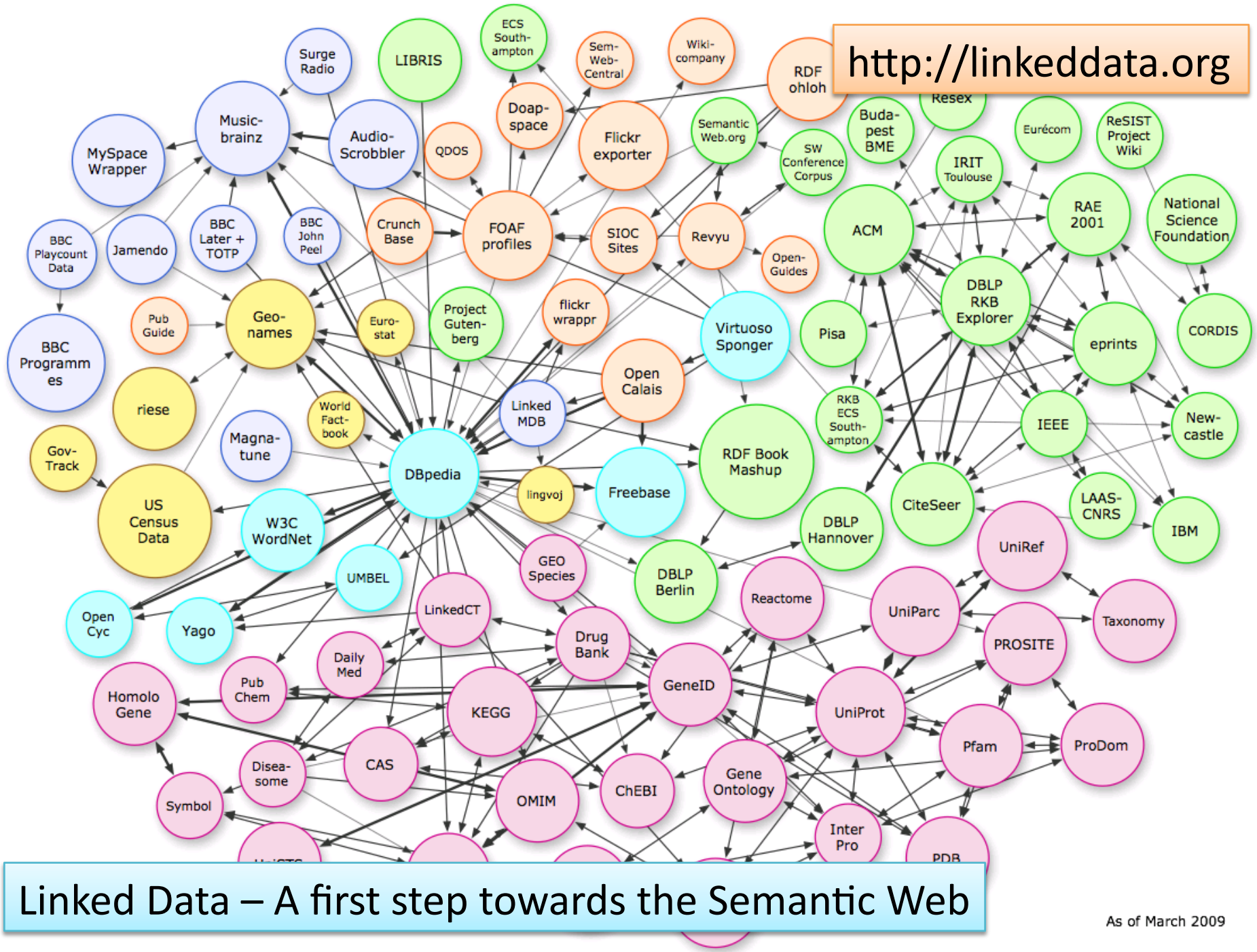

An important revision came in the form of Ferrari's four-valve (or Quattrovalvole) cylinder heads, the Berlinetta Boxer's having only featured two-valve heads while the new model's red crackle painted cam covers and ribbed panels on the intake plenums were in homage to the stunningly beautiful Testa Rossa sports racer of 1957. Bosch provided the K Jetronic fuel injection, these cars also featuring a Magnetti Marelli Microplex electronic ignition. So with fifty horses more that the 512i BB it was replacing, the performance of Ferrari's latest flagship was even quicker, the zero to sixty sprint taking just 5.2 seconds while top speed rose to 180mph. Meanwhile, as was usual Ferrari practice, the Turinese carrozzeria of Pininfarina were commissioned to design the bodywork and interior.

Pininfarina's design was absolutely stunning

http://www.pininfarina.it/ferrari1.html

Show me all automotive designers!

The Vision of the Semantic Web


http://linkeddata.org
Linked Data – A first step towards the Semantic Web
As of March 2009
Surge Radio
LIBRIS
ECS South-ampton
Sem-Web-Central
Wiki-company
RDF ohloh
Music-brainz
Audio-Scrobbler
Doap-space
Flickr exporter
Semantic Web.org
Buda-pest BME
Resex
Eurécom
ReSIST Project Wiki
MySpace Wrapper
QDOS
SW Conference Corpus
IRIT Toulouse
BBC Playcount Data
Jamendo
BBC Later + TOTP
BBC John Peel
Crunch Base
FOAF profiles
SIOC Sites
Revyu
Open-Guides
ACM
RAE 2001
National Science Foundation
Pub Guide
Geo-names
Euro-stat
Project Guten-berg
flickr wrappr
Virtuoso Sponger
Pisa
DBLP RKB Explorer
CORDIS
BBC Programmes
riese
Open Calais
eprints
World Fact-book
Linked MDB
RKB ECS South-ampton
IEEE
New-castle
Gov-Track
Magna-tune
DBpedia
lingvoj
Freebase
RDF Book Mashup
US Census Data
W3C WordNet
CiteSeer
LAAS-CNRS
IBM
DBLP Hannover
UniRef
UMBEL
GEO Species
DBLP Berlin
Reactome
UniParc
Taxonomy
Open Cyc
Yago
LinkedCT
Drug Bank
PROSITE
Daily Med
Pub Chem
GeneID
Homolo Gene
KEGG
UniProt
Pfam
ProDom
Disea-some
CAS
Gene Ontology
Symbol
OMIM
ChEBI
Inter Pro
PDB

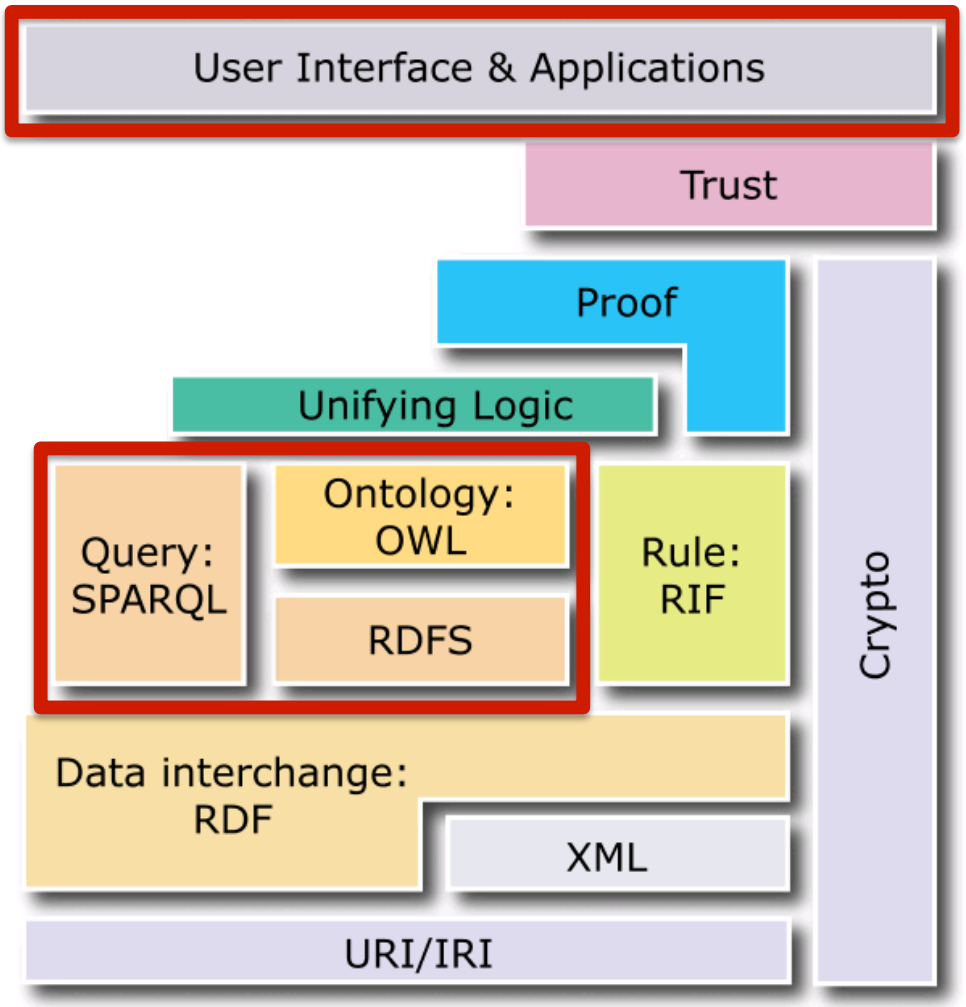

```
PREFIX dbo: <http://dbpedia.org/ontology/>

SELECT ?description WHE
    ?person dbo:birthpla  /dbpedia.org/resource/Mannheim> .
    ?person skos:subject  pedia.org/resource/Category:German_footballers> .
    ?person foaf:name ?
    ?person rdfs:comme  tion .
    FILTER (LANG(?desc  ') .
}
ORDER BY ?name
```

http://dbpedia.org/snorql/

description
"Christian Wörns (born on May 10, 1972 in Mannheim) is a retired German footballer who played at both Full-back and Centre-back."@en
"Jochen Kientz (born September 17 1972 in Mannheim) is a former German professional football defender."@en
"Josef "Sepp" Herberger (March 28, 1897 in Mannheim, Germany — April 20, 1977 in Weinheim-Hohensachsen, Germany) was a German football player and manager."@en
"Sergio Peter (born 12 October 1986 in Mannheim, Baden-Württemberg) is a German footballer who plays for Sparta Prague in the Czech Gambrinus liga. Peter came through the Youth Academy at Blackburn Rovers and joined Belgian side Cercle Brugge on loan from January 2005 until the end of the season."@en
"Uwe Rahn (born May 21, 1962 in Mannheim) is a former German football player."@en
"Christian Wörns (born on May 10, 1972 in Mannheim) is a retired German footballer who played at both Full-back and Centre-back."@en
"Christopher Gäng (born May 10, 1988 in Mannheim) is a German football player. As of January 2009, he plays for Hertha BSC Berlin."@en
Sepp Herberger, Gernot Rohr, Karl-Heinz Emig, Oskar Rohr, Heiko Herrlich, Jochen Kientz, Marco Terrazzino, Reinhold Fanz, Christian Wörns, Christopher Gäng, Dietmar Danner, Fritz Walter, Oliver Kreuzer, Thomas Schaaf, Sergio Peter, Uwe Rahn
"Karl-Heinz Emig (born July 29, 1962 in Mannheim) is a German football coach and a former player. As of February 2009, he is managing the under-17 youth team of 1. FC Kaiserslautern."@en
"Marco Terrazzino (born 15 April 1991 in Mannheim) is a German footballer who plays for 1899 Hoffenheim. Terrazzino made his debut during the 2008–09 season, in January 2009."@en
"Oliver Kreuzer (born 13 November 1965) is a German former footballer who played as a defender for Karlsruher SC, FC Bayern Munich and FC Basel."@en
"Oskar Rohr (April 24, 1912 – November 8, 1988) was a German footballer and one of the first footballers to play abroad in a foreign league."@en
"Reinhold Fanz (born January 16, 1954 in Mannheim) is a German former professional footballer and formerly manager of the Cuba national football team."@en
"Sergio Peter (born 12 October 1986 in Mannheim, Baden-Württemberg) is a German footballer who plays for Sparta Prague in the Czech Gambrinus liga. Peter came through the Youth Academy at Blackburn Rovers and joined Belgian side Cercle Brugge on loan from January 2005 until the end of the season."@en
"Thomas Schaaf (born April 30, 1961 in Mannheim) is a German former footballer (defender) and current manager."@en
"Uwe Rahn (born May 21, 1962 in Mannheim) is a former German football player."@en

Semantic Web Layer Cake



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3 Web Ontology Language

- W3C Recommendations
  - RDF Schema (Feb 10, 2004)
    - Simple ontology language
  - OWL (Feb 10, 2004)
    - Based on Description Logics (DL)
  - OWL 2 (Oct 27, 2009)
    - Extension of OWL (e.g. disjoint properties)
- Languages differ in
  - Syntactic serializations
  - Expressivity (complexity of reasoning problems!)
  - Formal semantics (e.g. open-world assumption)

OWL (RDF/XML Syntax)

```
<owl:Class rdf:ID="Woman">
    <rdfs:subClassOf rdf:resource="Person"/>
</owl:Class>
<owl:ObjectProperty rdf:ID=„hasChild">
    <rdfs:range rdf:resource="Person"/>
</owl:ObjectProperty>
```

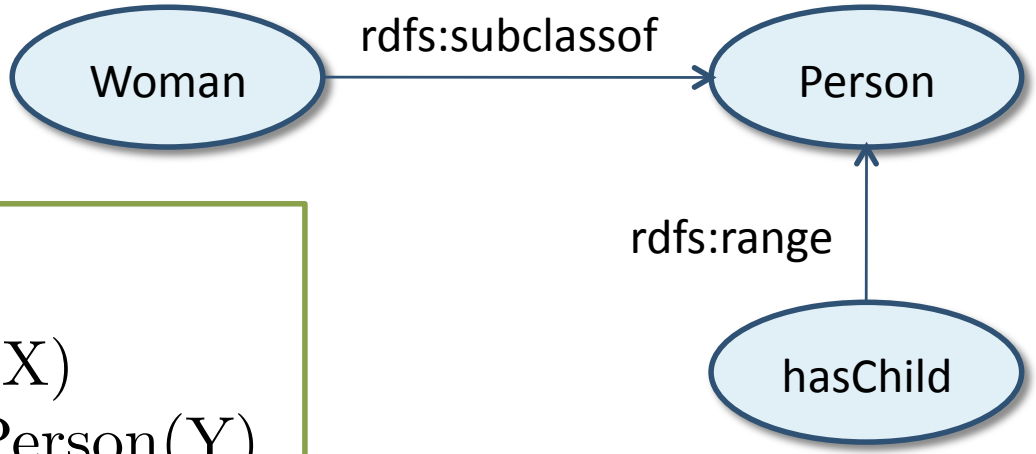
OWL (Manchester Syntax)

```
Class: Woman
    SubClassOf: Person
ObjectProperty: hasChild
    Range: Person
```

Description Logic

$\text{Woman} \sqsubseteq \text{Person}$

$\top \sqsubseteq \forall\ \text{hasChild.Person}$



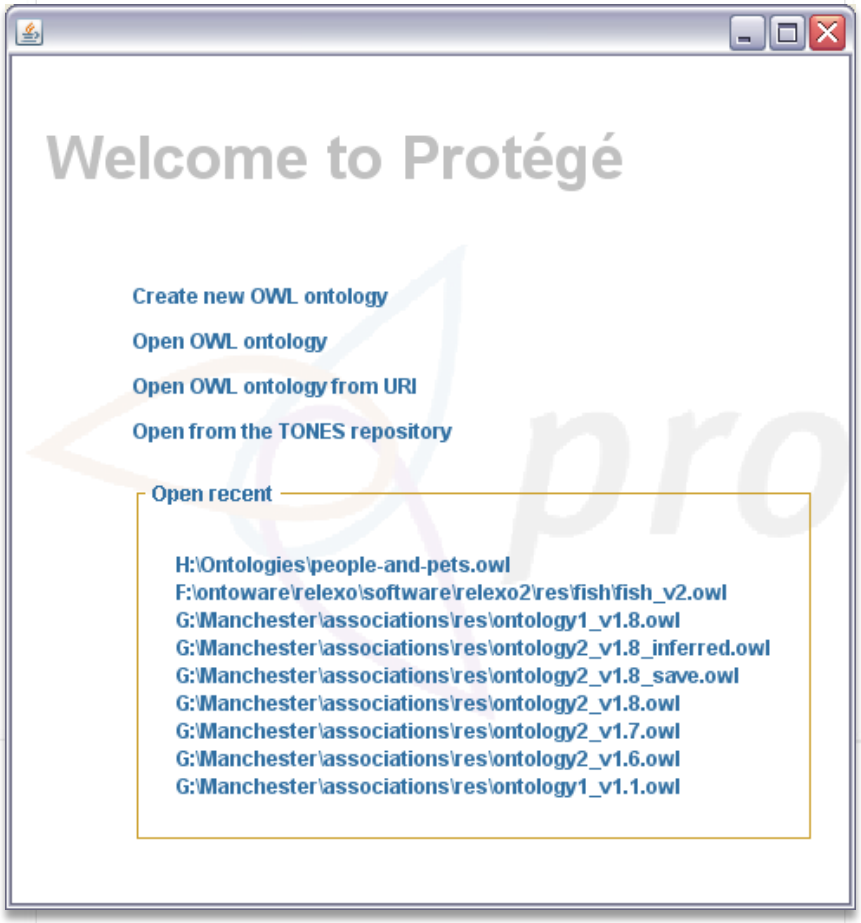
First-order Logic

$\forall\ X \quad \text{Woman}(X) \rightarrow \text{Person}(X)$

$\forall\ X,Y \quad \text{hasChild}(X,Y) \rightarrow \text{Person}(Y)$

OWL Editors

- Protégé-OWL
  - http://protege.stanford.edu
- NeOn Toolkit
  - http://neon-toolkit.org
- Swoop
  - http://www.mindswap.org/2004/SWOOP/
- TopBraid Composer (commercial)
  - http://topquadrant.com/products/TB_Suite.html



Demo: Protégé-OWL

Summary

- In Artificial Intelligence, an ontology is a formal explicit specification of a shared conceptualization.
- Semantic Web (or „Web 3.0“): extension of today‘s Web with machine-interpretable content
- Ontology languages: RDFS, F-Logic, OWL