# Semantic Web Technologies

## Lecture 5: Ontology engineering methodologies

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# Outline

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## The landscape

- Difference between *method* and *methodology*
- Difference between writing down what you did (to make it a 'guideline') vs. experimentally validating a methodology
- Isn't ontology development just like conceptual data model development?
  - yes: e.g., interaction with the domain expert, data analysis
  - no: e.g., logic, automated reasoning, using (parts of) other ontologies, different scopes/purposes, specific isolated application scenario vs. general knowledge
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# Advances and questions

- Multiple modelling issues in ontology development for the applied life sciences (e.g., part-of, uncertainty, prototypes, multilingual), methodological issues, highly specialised knowledge
- W3C's incubator group on modelling uncertainty, mushrooming of bio-ontologies, ontology design patterns, W3C standard OWL, etc.
- Solving the early-adopter issues moves the goal-posts
  - Which ontologies are reusable for one's own ontology?
  - What are the consequences choosing one ontology over the other?
  - The successor of OWL, OWL 2, has 5 languages: which one should be used for what and when?

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- Ontologies are application-independent, hence sole purpose of representing reality. But...
- Ontology engineers do take it into account
- A real caveat with choosing explicitly for a specific goal is that a few years after initial development of the ontology, it may get its own life and be used for other purposes than the original scope
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# Possible purposes (1/2)

A. Ontology-based data access through linking data to ontologies

B. Data(base) integration, most notably the strand of applications initiated by the Gene Ontology Consortium and a successor, the OBO Foundry

C. Structured controlled vocabulary to link database records and navigate across databases on the Internet, also known as 'linked data';

D. Using it as part of scientific discourse and advancing research at a faster pace, including experimental ontologies in a scientific discipline and usage in computing and engineering to build prototype software;

# Possible purposes (2/2)

E. As full-fledged discipline “Ontology (Science)”, where an ontology is a formal, logic-based, representation of a scientific theory, or: representation of reality;

F. Coordination and integration of Web Services;

G. Tutorial ontologies to learn modelling in the ontology development environment (e.g., the wine and pizza ontologies).

# Outline

# Which ontologies to reuse and how? (1/2)

a. Foundational ontologies that provide generic top-level categorisations;
⇒ give a head-start by providing a basic structure, such as endurants being disjoint from perdurants, types of processes, attributes, and basic relations; e.g., GFO, DOLCE, BFO, RO; Marine Microbial Loops reusing DOLCE

b. 'Reference ontologies' that contain the main concepts of a subject domain;
⇒ Restricted in scope of the content, such as an ontology of measurements, and 'top-level' ontologies for a domain, such as BioTop, OBI

# Which ontologies to reuse and how? (2/2)

c. Domain ontologies that have a (partial) overlap with the new ontology;
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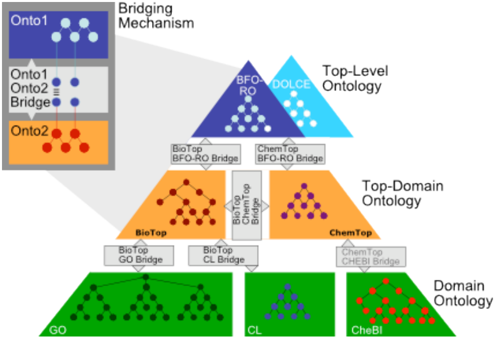
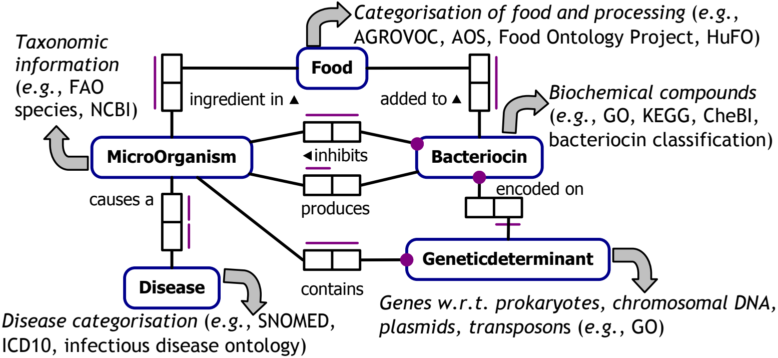



*image from http://www.imbi.uni-freiburg.de/ontology/biotop/*

# Which ontologies to reuse and how? (2/2)

d. Legacy representations of information systems and ontology-like artefacts: conceptual data models of database and application software (sometimes called ‘application ontologies’), terminologies, and thesauri;
$\Rightarrow$ ‘ontologise’ a conceptual data model and possibly extend the contents; e.g. the conceptual data model for the bacteriocins

# Examples


*Categorisation of food and processing* (*e.g.*, AGROVOC, AOS, Food Ontology Project, HuFO)
*Taxonomic information* (*e.g.*, FAO species, NCBI)
Food
ingredient in ▲
added to ▲
*Biochemical compounds* (*e.g.*, GO, KEGG, CheBI, bacteriocin classification)
MicroOrganism
◀inhibits
Bacteriocin
encoded on
causes a
produces
Geneticdeterminant
Disease
contains
*Genes w.r.t. prokaryotes, chromosomal DNA, plasmids, transposons* (*e.g.*, GO)
*Disease categorisation* (*e.g.*, SNOMED, ICD10, infectious disease ontology)

# Outline

# Extracting in a semi-automatic way the subject domain semantics

I. Extraction of types from data in database and object-oriented software applications, including database reverse engineering and clustering;

II. Abstractions from models in textbooks and diagram-based software;

III. Text mining of documents, including scientific articles and other Digital Libraries, to find candidate terms for concepts and relations;

VI. Wisdom of the crowds and usage of those tagging techniques;

V. Other (semi-)structured data, such as excel sheets and company product catalogs.

# Outline

# Preliminary considerations

- Depending on the purpose(s)—and, in practice, available resources, such as time, money, domain experts, and available baseline material—one ends up with either
  (a) a large but simple ontology, i.e., mostly just a taxonomy without, or very few, properties (relations) linked to the concepts, where 'large' is, roughly, $>$ 10000 concepts, so that a simple representation language suffices;
  (b) a 'medium size' and elaborate ontology, which includes rich usage of properties, defined concepts, and, roughly, requiring OWL-DL; or
  (c) a small and very complex ontology, where 'small' is, roughly, $<$ 250 concepts, and requiring at least OWL 2 DL
- Certain choices for reusing ontologies or legacy material, or goal, may lock one a language
- $\Rightarrow$ Separate dimension that interferes with the previous parameters: the choice for a representation language

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# Languages

- "OWL": OWL-Lite, OWL-DL, OWL full
- "OWL 2" with 4 languages to tailor the choice of ontology language to fit best with the usage scope in the context of a *scalable* and *multi-purpose* SW:
  - OWL 2 DL is most expressive and based on the DL language $\mathcal{SROIQ}$
  - OWL 2 EL fragment to achieve better performance with larger ontologies (e.g., for use with SNOMED-CT)
  - OWL 2 QL fragment to achieve better performance with ontologies linked to large amounts of data in secondary storage (databases); e.g. DIG-QuOnto
  - OWL 2 RL has special features to handle rules
- Differences between expressiveness of the ontology languages and their trade-offs

# Reasoning services

- The current main reasoning services fall into three categories:
  i. The 'standard' reasoning services for ontology usage: satisfiability and consistency checking, taxonomic classification, instance classification, and querying functionalities including epistemic and (unions of) conjunctive queries;
  ii. Additional 'non-standard' reasoning services to facilitate ontology development: explanation/justification, glass-box reasoning, pin-pointing errors;
  iii. Further requirements for reasoning services identified by users, such as hypothesis testing, reasoning over role hierarchies, and discovering type-level relations from ABox instance data.

# On trade-offs and choices

- OWL 2 DL, but not OWL 2 QL, has: role concatenation, qualified number restrictions, enumerated classes, covering constraint over concepts, and reflexivity, irreflexivity, and transitivity on simple roles.
- With OWL 2 QL, but not OWL 2 DL: UCQ and one can obtain similar performance as with relational databases
- Use parameters in a software-supported selection procedure:
  - select the desired purpose and reasoning services to find the appropriate language
  - decide on purpose of usage of the ontology and one's language, and obtain which reasoning services are available.
- Purpose A or B goes well together with OWL 2 QL and query functionalities
- For purposes D and E, OWL 2 DL and the non-standard reasoning services will be more useful

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# Recap

- Four influential factors to enhance the efficiency and effectiveness of developing ontologies:
    - seven types of purpose(s) of the ontology;
    - what and how to reuse existing ontologies and ontology-like artefacts;
    - five different types of approaches for bottom-up ontology development from other legacy sources;
    - the interaction with choice of representation language and reasoning services
- Future works pertain to setting up a software-mediated guidance system; hence, to structure and make accessible more easily the ‘soft’ knowledge about ontology development, which then could feed into design methodologies such as methontology

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# OntoClean overview

- Problem: messy taxonomies on what subsumes what
- How to put them in the right order?
- OntoClean provides guidelines for this (refer to Guarino & Welty, 2004 for an extended example)
- Based on philosophical principles, such as identity and rigidity (see Guarino & Welty's EKAW'00 and ECAI'00 papers for more information on the basics)

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# Basics

- A property of an entity is *essential* to that entity if it must be true of it in every possible world, i.e. if it necessarily holds for that entity.
- Special form of essentiality is *rigidity*

## Definition (+R)

A *rigid* property $\phi$ is a property that is essential to *all* its instances, i.e., $\forall x \phi(x) \rightarrow \Box \phi(x)$.

## Definition (-R)

A *non-rigid* property $\phi$ is a property that is not essential to *some* of its instances, i.e., $\exists x \phi(x) \wedge \neg \Box \phi(x)$.

# Basics

**Definition (∼R)**

An *anti-rigid* property $\phi$ is a property that is not essential to *all* its instances, i.e., $\forall x \phi(x) \rightarrow \neg \Box \phi(x)$.

**Definition (¬R)**

A *semi-rigid* property $\phi$ is a property that is non-rigid but not anti-rigid.

- Anti-rigid properties cannot subsume rigid properties

# Basics

- *Identity*: being able to recognize individual entities in the world as being the same (or different)
- *Unity*: being able to recognize all the parts that form an individual entity; e.g., ocean carries unity (+U), legal agent carries no unity (-U), and amount of water carries anti-unity ("not necessarily wholes", ∼U)
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# Basics

**Definition**

A non-rigid property carries an IC $\Gamma$ iff it is subsumed by a rigid property carrying $\Gamma$.

**Definition**

A property $\phi$ supplies an IC $\Gamma$ iff i) it is rigid; ii) it carries $\Gamma$; and iii) $\Gamma$ is not carried by all the properties subsuming $\phi$. This means that, if $\phi$ inherits different (but compatible) ICs from multiple properties, it still counts as supplying an IC.

- Any property carrying an IC: +I (-I otherwise).
- Any property supplying an IC: +O (-O otherwise); "O" is a mnemonic for "own identity"
- +O implies +I and +R

# Formal ontological property classifications

<table>
<tr><td rowspan="2">+O</td><td rowspan="2">+I</td><td rowspan="2">+R</td><td>+D</td><td rowspan="2">Type</td><td rowspan="8">Sortal</td></tr>
<tr><td>-D</td></tr>
<tr><td rowspan="2">-O</td><td rowspan="2">+I</td><td rowspan="2">+R</td><td>+D</td><td rowspan="2">Quasi-Type</td></tr>
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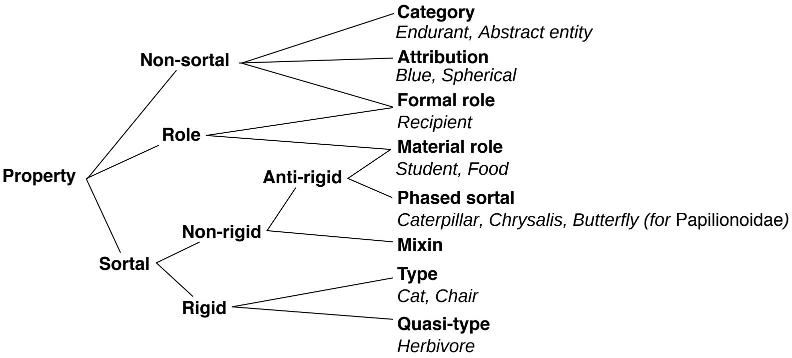
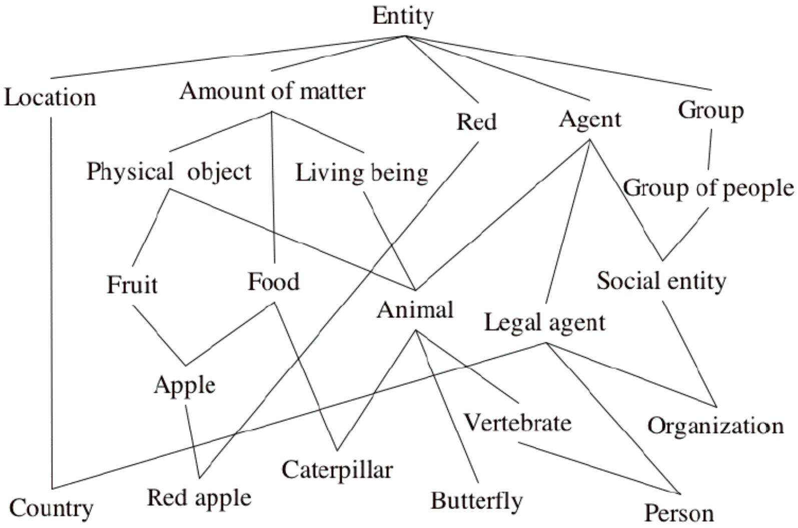


# Basics

- Given two properties, $p$ and $q$, when $q$ subsumes $p$ the following constraints hold:
  1. If $q$ is anti-rigid, then $p$ must be anti-rigid
  2. If $q$ carries an identity criterion, then $p$ must carry the same criterion
  3. If $q$ carries a unity criterion, then $p$ must carry the same criterion
  4. If $q$ has anti-unity, then $p$ must also have anti-unity

# Example: before



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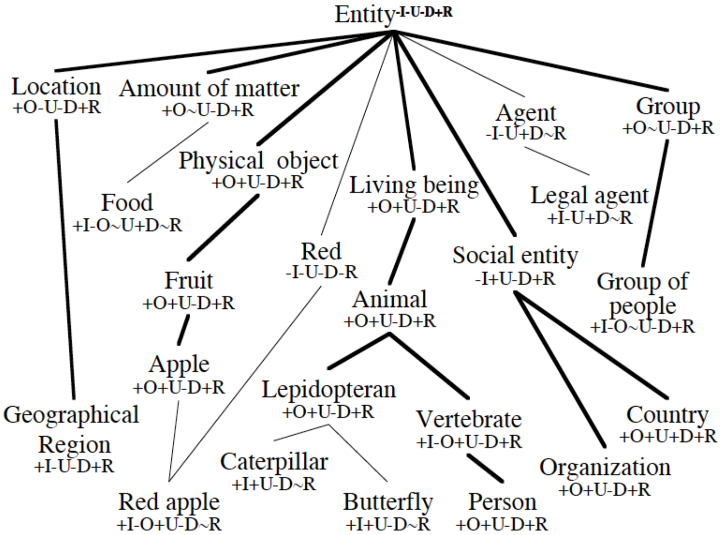

# Outline

# Overview

- Domain experts are expert in their subject domain, which is not logic
- Modellers often do not understand the subject domain well
- The more expressive the language, the easier it is to make errors or bump into unintended entailments
- Simple languages can represent more than it initially may seem (by some more elaborate encoding), which clutters the ontology and affects comprehension
- In short: people make errors (w.r.t. their intentions) in the modelling task, and automated reasoners can help fix that

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# Overview

- Using automated reasoners for ‘debugging’ ontologies, requires one to know about reasoning services
- Using standard reasoning services (recollect slide 22)
- New reasoning services tailored to pinpointing the errors and explaining the entailments (slide 22)
- Details in KR & onto course next semester (and the two papers in the ‘recommended readings’ of this lecture), here a general overview

# Common errors

- Unsatisfiable classes
  - In the tools: the unsatisfiable classes end up as direct subclass of `owl:Nothing`
  - Sometimes one little error generates a whole cascade of unsatisfiable classes
- Satisfiability checking can cause rearrangement of the class tree and any inferred relationships to be associated with a class definition: 'desirable' vs. 'undesireable' inferred subsumptions
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  - Atomic: An individual belongs to a class and its complement
  - Cardinality: An individual has a max cardinality restriction but is related to more distinct individuals
  - Datatype: A literal value violates the (global or local) range restrictions on a datatype property
- Basic set of clashes for KBs (ontology + instances) are:
  - Inconsistency of Assertions about Individuals, e.g., an individual is asserted to belong to disjoint classes or has a cardinality restriction but related to more individuals
  - Individuals Related to Unsatisfiable Classes
  - Defects in Class Axioms Involving Nominals (`owl:oneOf`, if present in the language)

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# Where are we?

- Parameters that affect ontology development, such as purpose, base material, language
- Methods, such as reverse engineering text mining to start, OntoClean to improve
- Tools to model, to reason, to debug, to integrate, to link to data
- Methodologies that are coarse-grained: they do not (yet) contain all the permutations at each step, i.e. *what* and *how* to do each step, given the recent developments;
- e.g. step $x$ is "knowledge acquisition", but what are it component-steps?

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# Example methodology: METHONTOLOGY

- Basic methodology:
  - specification: why, what are its intended uses, who are the prospective users
  - conceptualization, with intermediate representations
  - formalization (transforms the domain-expert understandable 'conceptual model' into a formal or semi-computable model)
  - implementation (represent it in an ontology language)
  - maintenance (corrections, updates, etc)
- Additional tasks (as identified by METHONTOLOGY)
  - Management activities (schedule, control, and quality assurance)
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# MOdelling wiKI

- MoKi is based on a **SemanticWiki**, which is used for collaborative and cooperative ontology development
- It enables actors with different expertise to develop an "enterprise model" not only using structural (formal) descriptions but also adopting more informal and semi-formal descriptions of knowledge[1]
- access to the enterprise model **at different levels of formality**: informal, semi-formal and formal
- more info at http://moki.fbk.eu

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# Extending the methodologies

- METHONTOLOGY, MoKi, and others (e.g., On-To-Knowledge, KACTUS approach) are for developing one *single* ontology
- Changing landscape in ontology development towards building "ontology networks"
- Characteristics: dynamics, context, collaborative, distributed
- E.g. the emerging NeOn methodology (more info at http://www.neon-project.org/web-content/images/Publications/neon_2008_d5.4.1.pdf)

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- NeOn's "Glossary of Activities" identifies and defines 55 activities when ontology networks are collaboratively built
- Among others: ontology localization, -alignment, -formalization, -diagnosis, -enrichment etc.
- Divided into a matrix with "required" and "if applicable"
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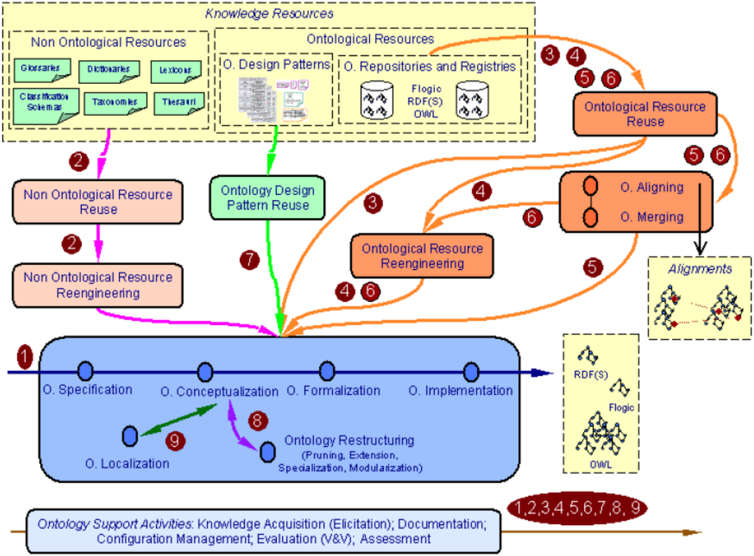
# Scenarios for Building Ontology Networks



# Tools

- Thus far, no tool gives you everything
  - WebODE to support METHONTOLOGY with a software application
  - Protégé with its plugins. a.o.: ontology visualisation, querying, OBDA, etc.
  - NeOn toolkit aims to be a "open source multi-platform ontology engineering environment, which aims to provide comprehensive support for all activities in the ontology engineering life-cycle"; 45 plugins
  - RacerPro, RacerPorter. a.o.: sophisticated querying
  - KAON, SWOOP, etc.
  - Specialised tools for specific task, such as ontology integration and evaluation (e.g. Protégé-PROMPT, ODEClean)
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# Summary

## Methodologies overview

## A collection of parameters

- Purposes of the ontologies
- Reusing ontologies
- Bottom-up development of ontologies
- Representation languages and reasoning services

## Methods

- Guidance for modelling: OntoClean
- Debugging ontologies

## Methodologies and tools