Description Logics:
a nice family of logics
Introduction Part 2: OWL & DLs

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Ontology Language - a Motivation

What's the Problem?

- Typical web page markup consists of:
  - Rendering information (e.g., font size and colour)
  - Hyper-links to related content
- Content is accessible to humans but not (easily) to computers…

Information we can see

- University of Manchester
  - The Business School
- Consultancy
  - Gain a broader perspective and solve complex business problems
- Commercialisation
  - From idea to marketplace -- bringing our ground-breaking inventions into the commercial world
- Manchester Business School
  - MBS is redefiing business education to meet the challenges of a fast-evolving global landscape
- Recruit our graduates
  - Attend careers fairs or arrange your own dedicated event on campus
- Contact the Business Engagement Support Team
  - +44 161 275 2227
  - business@manchester.ac.uk
- ….

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Information a computer can see…

…

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Solution: XML markup with "meaningful" tags?

<university> </university>
<school> </school>
<address> </address>
<topic> </topic>
<topic>
<details> </details>… </topic>
<topic>
<details> </details>… </topic>
<contact> <contact>

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But what about....?

<university> </university>
<department> </department>
<address> </address>
<activity> </activity>
<activity>
<details> </details>… </activity>
<activity>
<details> </details>… </activity>
<contact> <contact>

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Still the Machine only sees…

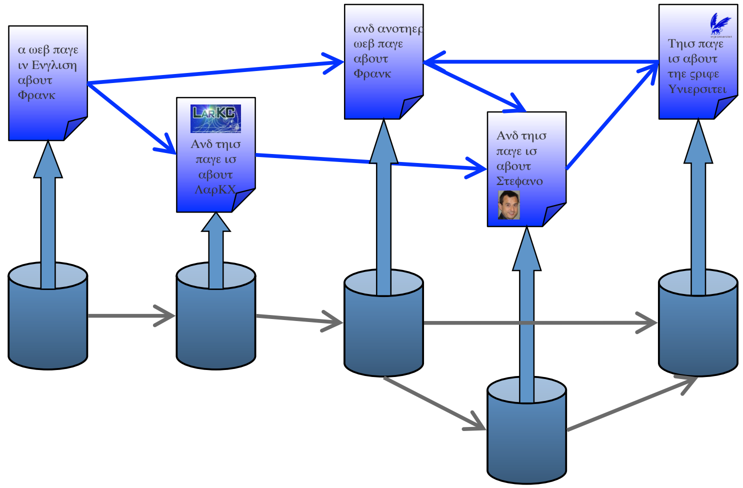
…

Need to Add "Semantics"

shoulder_catches_during_movement
shoulder_feels_like_it_will_slip_out_of_place
shoulder_joint_feels_like_it_may_slip_out_of_place
shoulder_joint_pain_better_after_rest
shoulder_joint_ ... affected_side
shoulder_joint_
shoulder_joint_
shoulder_joint_ ... movement
shoulder_joint_pain_first_appears_at_night
shoulder_joint_pain_improved_by_medication
shoulder_joint_pain_improves_during_exercise__returns_later
shoulder_joint_pain_incr_by_raising_arm_above_shoulder_level
shoulder_joint_pain_increased_by
shoulder_joint_pain_increased_by_lifting
shoulder_joint_pain_increased_by_moving_arm_across_chest

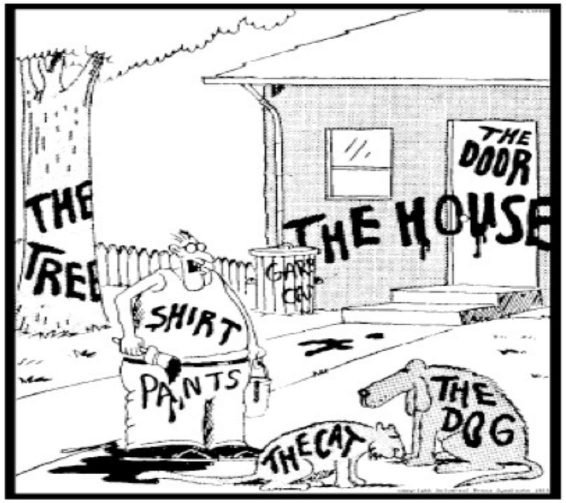
Machine Processable
not
Machine Understandable

Four principles towards a *Semantic Web of Data**



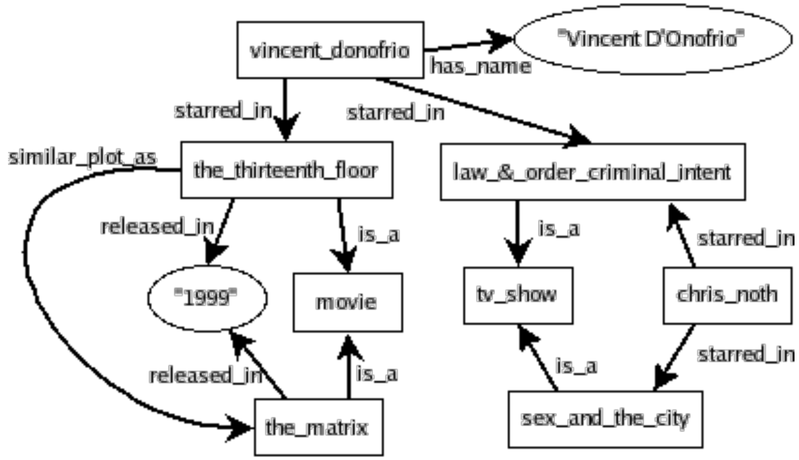
* With thanks to Frank van Harmelen

Principle 1: Give all things a name

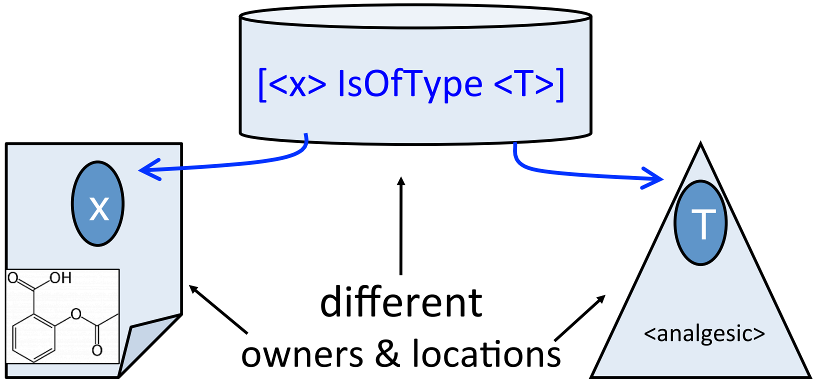


"Now! *That* should clear up a few things around here!"

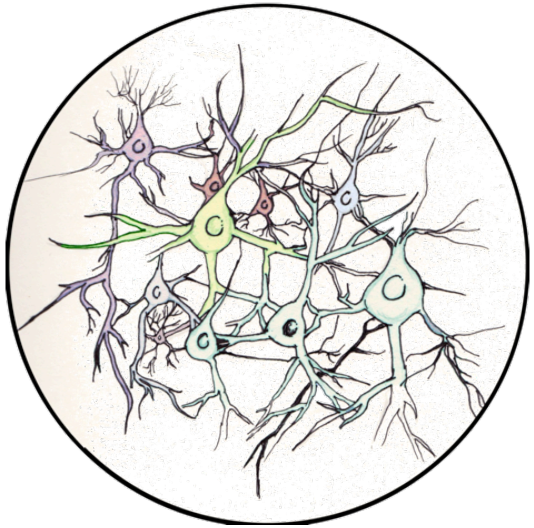
Principle 2: Relationships form a graph between things



Principle 3: The names are addresses on the Web



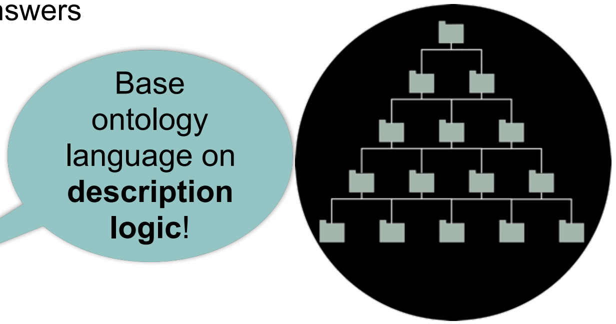
P1 + P2 + P3 = Giant Global Graph



Principle 4: Explicit, Formal *Semantics*

So we all agree on

- meaning of statements in this graph/*ontology*
- entailments of statements
  - hierarchies
  - query answers
  - …



Introduction to OWL

E. Shepard,
Winnie-the-Pooh [A. A. Milne]

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OWL is based on *Description Logics*

- precise semantics
- OWL is based on an extension of $\mathcal{ALC}$
  - later more
- decades of research on
  - *automated reasoning* techniques
    - to base tool support on
    - to help domain expert with design, maintenance,...
  - *computational complexity* to understand trade-offs
  - *model theory*

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OWL is a *Web* Ontology Language

- entity names are IRIs
  eg http://www.cs.man.ac.uk/~sattler/ontologies/WebST2016/RunningExample#Endocardium
- various web friendly syntaxes
  - RDF/XML
  - OWL/XML
  - …
  - Manchester syntax
- import mechanism
- version mechanism
- annotations of
  - entities
  - axioms
- …

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OWL Axioms - an Example

Inflammation	*SubClassOf*	Disease
HeartDisease	*EquivalentClass*	Disease *and* hasLoc *some* Heart
Endocarditis	*EquivalentClass*	Inflammation *and* hasLoc *some* Endocardium

- NCI Thesaurus
  - ~300K terms/classes
  - since 2000
  - since 2003 in OWL, monthly version, +800 terms/month
- …in OWL, published both
  - as a thesaurus ~ inferred concept hierarchy
  - in OWL, including underlying logical axioms, see BioPortal

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OWL & DL via our Example

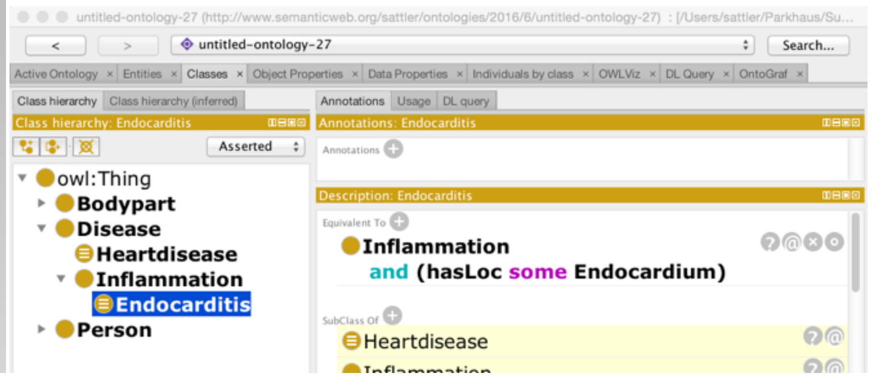
Inflammation	*SubClassOf*	Disease
Inflammation	$\sqsubseteq$	Disease
HeartDisease	*EquivalentClass*	Disease *and* hasLoc *some* Heart
HeartDisease	$\equiv$	Disease $\sqcap$ $\exists$hasLoc.Heart
Endocarditis	*EquivalentClass*	Inflammation *and* hasLoc *some* Endocardium
Endocarditis	$\equiv$	Inflammation $\sqcap$ $\exists$hasLoc.Endocardium

OWL Manchester Syntax for $\mathcal{ALC}$

OWL	DL
Class	Concept
Property	Role
A SubClassOf B	$A \sqsubseteq B$
A EquivalentTo B	$A \equiv B$
Thing	$\top$
Nothing	$\bot$
not A	$\neg A$
A and B	$A \sqcap B$
A or B	$A \sqcup B$
R some A	$\exists R.A$
R only A	$\forall R.A$

Example Axioms in Protégé:

Inflammation	$\sqsubseteq$	Disease
HeartDisease	$\equiv$	Disease $\sqcap$ $\exists$hasLoc.Heart
Endocarditis	$\equiv$	Inflammation $\sqcap$ $\exists$hasLoc.Endocardium



Protégé

Inflammation	*SubClassOf*	Disease
HeartDisease	*EquivalentClass*	Disease *and* hasLoc *some* Heart
Endocarditis	*EquivalentClass*	Inflammation *and* hasLoc *some* Endocardium

Protégé is an OWL editor

- in its 5th version
- built on the OWL API
- with direct access to OWL reasoners
- see http://protege.stanford.edu/products.php

I.e., DL reasoners

OWL/DL reasoning

Semantics reminder: Entailments etc. (3)

Let O be an ontology, α an axiom, A, B concepts, b an individual name:

- O is **consistent** if there exists some model I of O
- O **entails** α (written $O \models \alpha$) if α is satisfied in **all** models of O
- A is **satisfiable** w.r.t. O if $O \not\models A \sqsubseteq \bot$
- b is an **instance of** A w.r.t. O (written $O \models b{:}A$) if $b^I \in A^I$ in every model I of O

Classifying O is a *reasoning service* consisting of

1. testing whether O is consistent; if yes, then
2. checking, for each pair A,B of concept names in $O \cup \{\top,\bot\}$ whether $O \models A \sqsubseteq B$
3. checking, for each individual name b and concept name A in O, whether $O \models b{:}A$

…returning the result in a suitable form: O's **inferred class hierarchy**

…let's see that in action: Protégé

OWL Reasoners and Protégé

- OWL **reasoners**
  - implement **decision procedures** for consistency/entailments, and classify ontologies
  - we will learn more about these this week
- **Protégé**
  - interacts with reasoners via the OWL API
  - shows results as
    - inferred class hierarchy where
    - unsatisfiable classes are red and you get a
    - warning (red triangle) if O is inconsistent
  - very helpful to work through example ontologies
  - download from http://protege.stanford.edu/

Complete details about OWL

- here, we have concentrated on OWL for $\mathcal{ALC}$, e.g., no
  - domain, range axioms
  - SubPropertyOf, InverseOf
  - datatype properties
  - …

look others up:

- OWL is defined via a **Structural Specification**
  - http://www.w3.org/TR/owl2-syntax/
- also check out the OWL Primer
  - https://www.w3.org/TR/owl2-primer/


Thank You!