

Ontology Languages and Engineering

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What is an Ontology?





What is an Ontology?

An explicit specification of a conceptualization





What is an Ontology?

A model of (some aspect of) the world

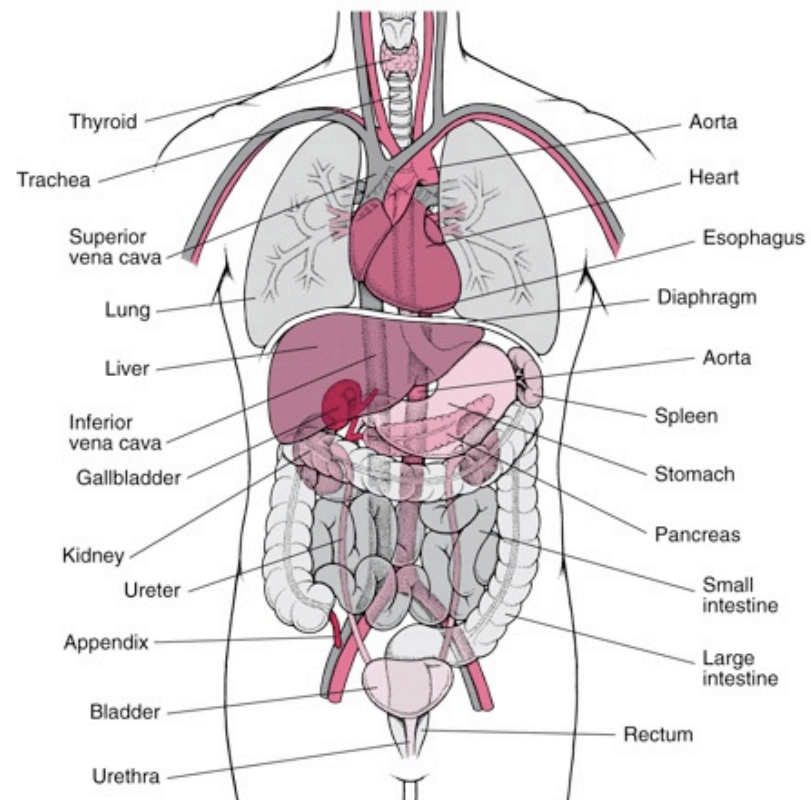




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A model of (some aspect of) the world

- Introduces **vocabulary** relevant to domain, e.g.:
 - Anatomy

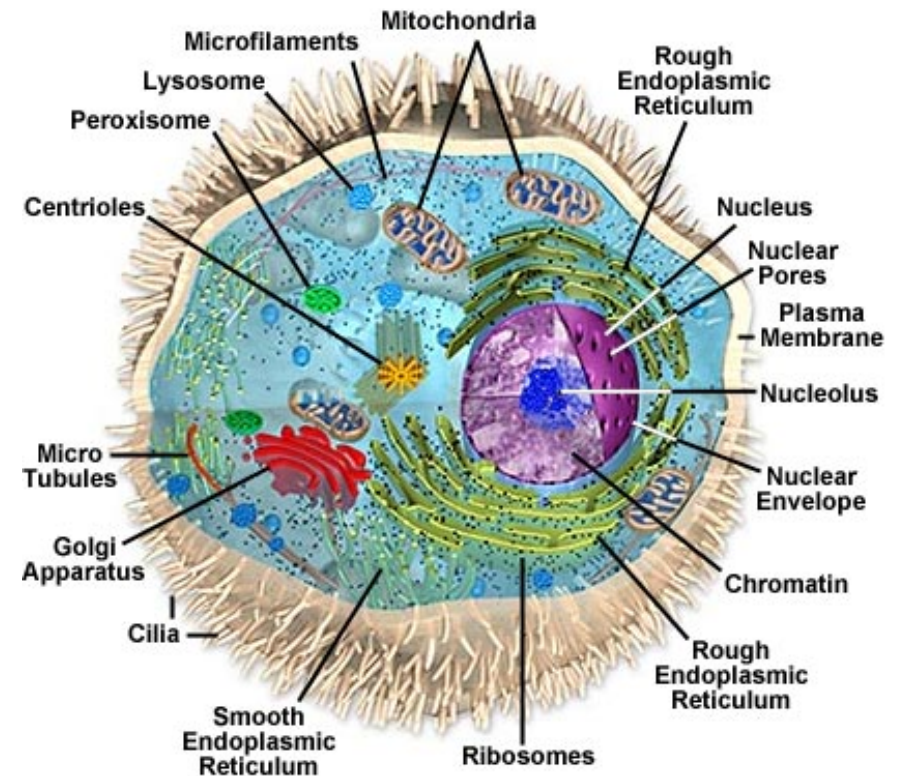




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 - Cellular biology

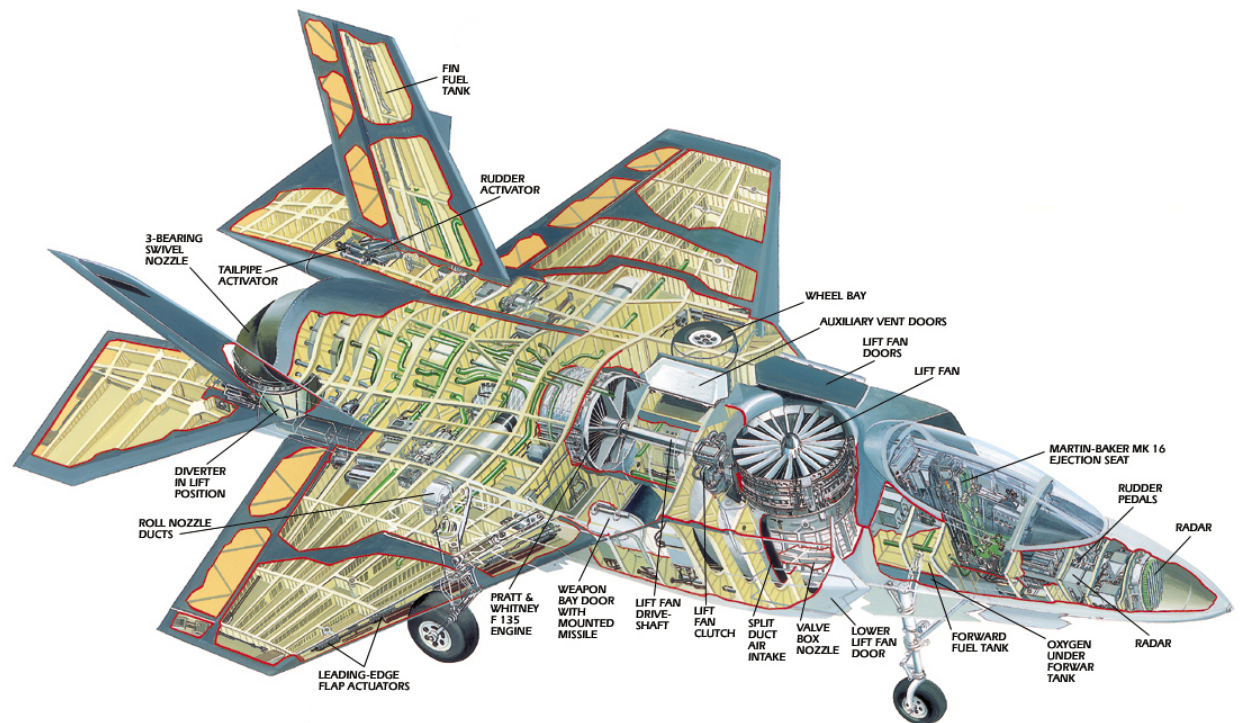




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 - Anatomy
 - Cellular biology
 - Aerospace

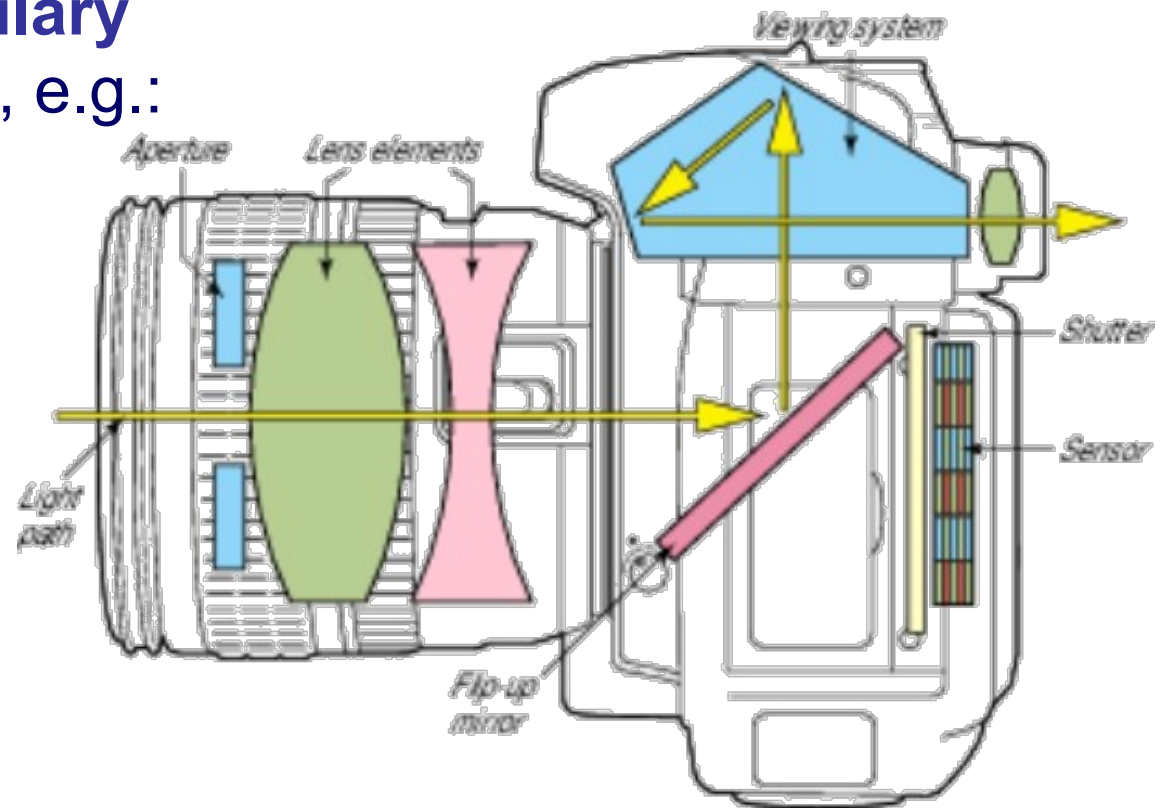




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 - Cellular biology
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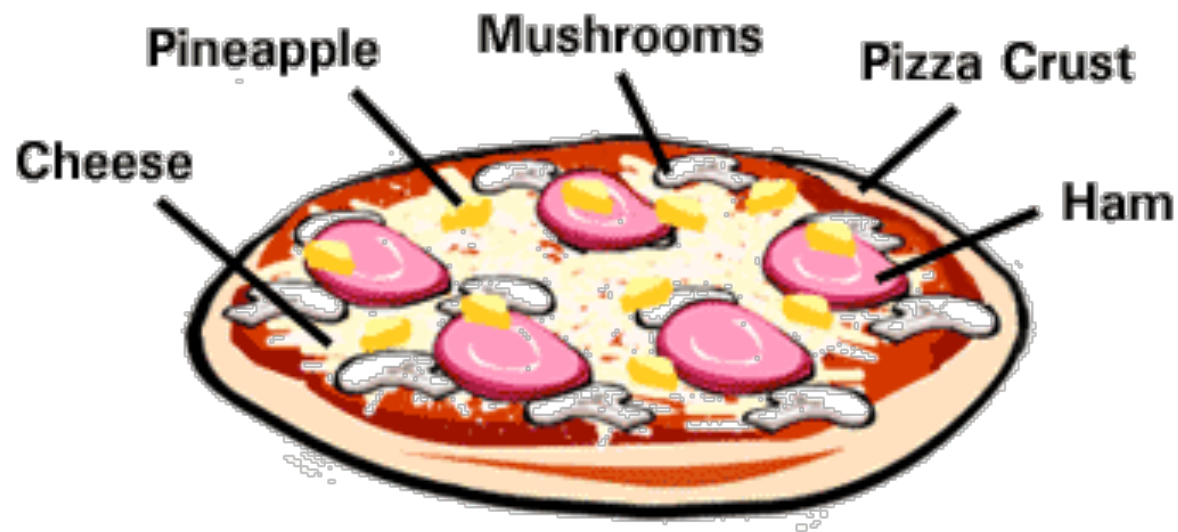




What is an Ontology?

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- Introduces **vocabulary** relevant to domain, e.g.:
 - Anatomy
 - Cellular biology
 - Aerospace
 - Photography
 - Pizzas
 - ...



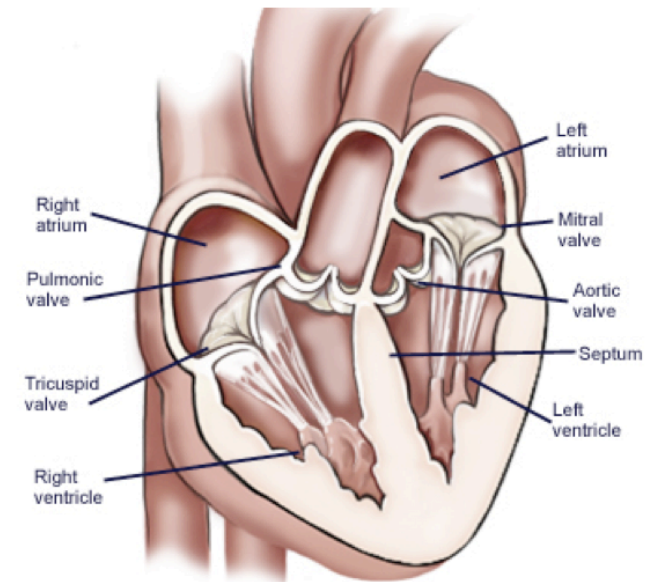


What is an Ontology?

A model of (some aspect of) the world

- Introduces **vocabulary** relevant to domain
- Specifies *relative meaning* (aka semantics) of terms

Heart **is** a muscular organ that **is part of** the circulatory system





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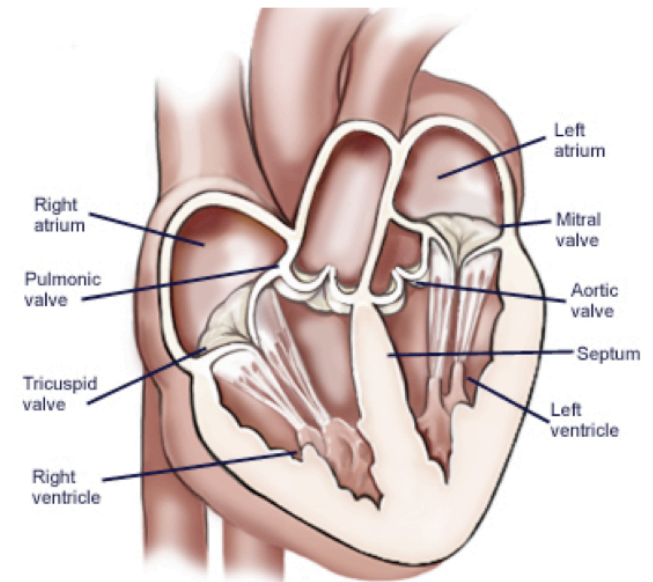
A model of (some aspect of) the world

- Introduces **vocabulary** relevant to domain
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Heart **is** a muscular organ that **is part of** the circulatory system

- **Formalised** e.g. using suitable logic

Heart \sqsubseteq MuscularOrgan \sqcap
 \exists isPartOf.CirculatorySystem





What are Ontologies Used For?

- Coherent **shared view** of domain
 - Help identify and resolve disagreements
- Ontology-based **Information Systems**
 - User-centric view of data that is independent of logical/physical schema
 - Answers reflect knowledge & data, e.g.:



Now... *that* should clear up a few things around here



What are Ontologies Used For?

$Q(x) \leftarrow \text{Patient}(x) \wedge \text{suffersFrom}(x, y) \wedge \text{VascularDisease}(y)$

i.e., "Patients suffering from Vascular Disease"





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John : Patient \sqcap
 $\exists \text{suffersFrom} . \text{HeartDisease}$





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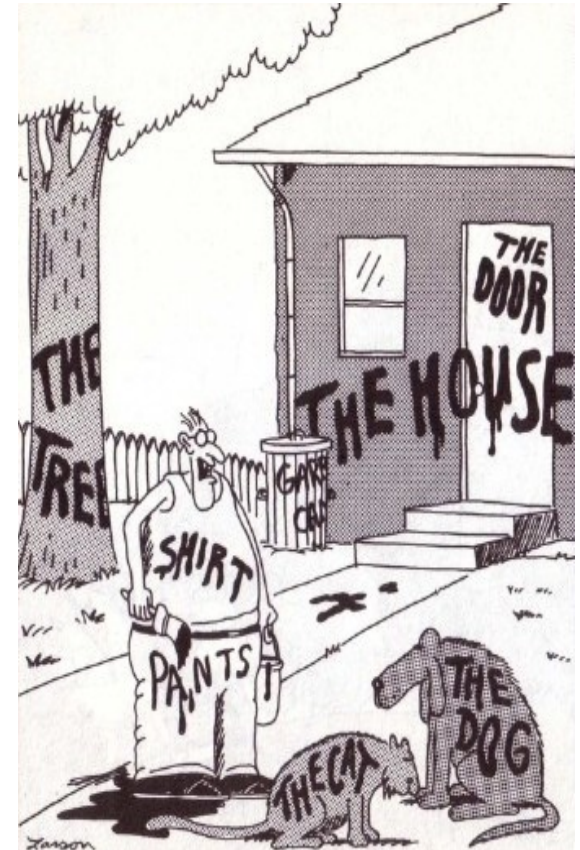
Heart \sqsubseteq MuscularOrgan \sqcap
 $\exists \text{isPartOf}.\text{CirculatorySystem}$
HeartDisease \equiv Disease \sqcap
 $\exists \text{affects}.\text{Heart}$
VascularDisease \equiv Disease \sqcap
 $\exists \text{affects}.\left(\exists \text{isPartOf}.\text{CirculatorySystem}\right)$



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 - Answers reflect knowledge & data, e.g.:
 - “Patients suffering from Vascular Disease”
 - Query expansion/navigation/refinement
 - Incomplete and semi-structured data
 - ...

More “intelligent” applications



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What are Ontologies Used For?

- Coherent **user-centric view** of domain



- Help identify and resolve disagreements

- **Principally-based Information Systems**

– View of data that is independent of logical/

– Any other

– Answer reflects the & a, e.g.:

– “Patient was in a house”

– Query engine for information refinement

– Incomplete and semi-structured

More “intelligent” applications

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What is the Semantic Web?





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- According to **TBL** circa 1998:

“... a **consistent logical web of data** ...” in which
“... information is given **well-defined meaning** ...”





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 - **OWL** provides machine readable schemas (**ontologies**)





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 - **RDF** provides uniform syntactic structure for data
 - **OWL** provides machine readable schemas (**ontologies**)

i.e., a large distributed ontology based information system





A Brief History of OWL

- RDF standard first published 1999; revised 2004
- RDF extended to **RDFS**, a primitive ontology language
 - classes and properties; sub/super-classes (and properties); range and domain (of properties)
- But RDFS **lacks** important **features**, e.g.:
 - existence/cardinality constraints; transitive/inverse properties; localised range and domain constraints, ...
- And RDF(S) has “higher order flavour” with no (later **non-standard**) **formal semantics**
 - difficult to understand or to provide reasoning support





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- Efforts soon merged to produce **DAML+OIL**
 - Further development carried out by “Joint EU/US Committee”





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- DAML+OIL submitted to **W3C** as basis for standardisation
 - **WebOnt** WG developed OWL (2004)
 - **OWL** WG developed OWL 2 (2009)
- OWL (2) based on *SHOIN (SROIQ)* Description Logics!?





What are Description Logics (DLs)?

- Fragments of **first order logic** designed for KR
- Useful computational properties
 - **Decidable** (essential)
 - Low complexity (desirable)
- Succinct and **variable free syntax**

Heart \sqsubseteq MuscularOrgan \sqcap
 \exists isPartOf.CirculatorySystem

$\forall x. [\text{Heart}(x) \rightarrow \text{MuscularOrgan}(x) \wedge$
 $\exists y. [\text{isPartOf}(x, y) \wedge$
 $\text{CirculatorySystem}(y)]]$



Why base OWL on a (Description) Logic?

Can exploit the results of 20+ years of DL research

- Well defined (model theoretic) **semantics**

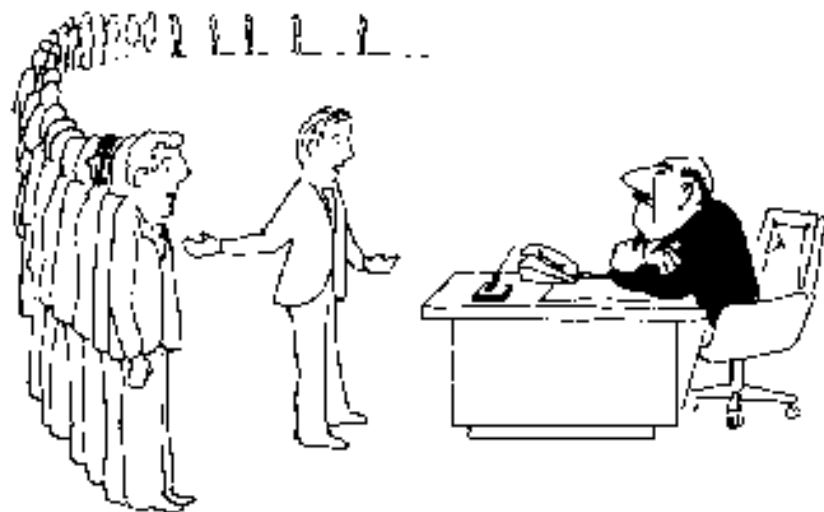
Constructor	DL Syntax	Example	FOL Syntax
intersectionOf	$C_1 \sqcap \dots \sqcap C_n$	Human \sqcap Male	$C_1(x) \wedge \dots \wedge C_n(x)$
unionOf	$C_1 \sqcup \dots \sqcup C_n$	Doctor \sqcup Lawyer	$C_1(x) \vee \dots \vee C_n(x)$
complementOf	$\neg C$	\neg Male	$\neg C(x)$
oneOf	$\{x_1\} \sqcup \dots \sqcup \{x_n\}$	{john} \sqcup {mary}	$x = x_1 \vee \dots \vee x = x_n$
allValuesFrom	$\forall P.C$	\forall hasChild.Doctor	$\forall y.P(x, y) \rightarrow C(y)$
someValuesFrom	$\exists P.C$	\exists hasChild.Lawyer	$\exists y.P(x, y) \wedge C(y)$
maxCardinality	$\leq_n P$	≤ 1 hasChild	$\exists^{\leq n} y.P(x, y)$
minCardinality	$\geq_n P$	≥ 2 hasChild	$\exists^{\geq n} y.P(x, y)$



Why base OWL on a (Description) Logic?

Can exploit the results of 20+ years of DL research

- Well defined (model theoretic) **semantics**
- **Formal properties** well understood (complexity, decidability)



I can't find an efficient algorithm, but neither can all these famous people.

[Garey & Johnson. Computers and Intractability]





Why base OWL on a (Description) Logic?

Can exploit the results of 20+ years of DL research

- Well defined (model theoretic) **semantics**
- **Formal properties** well understood (complexity, decidability)
- Practical **reasoning algorithms**

\sqcap -rule	if 1. $(C_1 \sqcap C_2) \in \mathcal{L}(v)$, v is not indirectly blocked, and 2. $\{C_1, C_2\} \not\subseteq \mathcal{L}(v)$ then $\mathcal{L}(v) \rightarrow \mathcal{L}(v) \cup \{C_1, C_2\}$.
\sqcup -rule	if 1. $(C_1 \sqcup C_2) \in \mathcal{L}(v)$, v is not indirectly blocked, and 2. $\{C_1, C_2\} \cap \mathcal{L}(v) = \emptyset$ then $\mathcal{L}(v) \rightarrow \mathcal{L}(v) \cup \{E\}$ for some $E \in \{C_1, C_2\}$
\exists -rule	if 1. $\exists r.C \in \mathcal{L}(v_1)$, v_1 is not blocked, and 2. v_1 has no safe r -neighbour v_2 with $C \in \mathcal{L}(v_2)$, then create a new node v_2 and an edge $\langle v_1, v_2 \rangle$ with $\mathcal{L}(v_2) = \{C\}$ and $\mathcal{L}(\langle v_1, v_2 \rangle) = \{r\}$.
\forall -rule	if 1. $\forall r.C \in \mathcal{L}(v_1)$, v_1 is not indirectly blocked, and 2. there is an r -neighbour v_2 of v_1 with $C \notin \mathcal{L}(v_2)$ then $\mathcal{L}(v_1) \rightarrow \mathcal{L}(v_1) \cup \{C\}$.
\forall_+ -rule	if 1. $\forall r.C \in \mathcal{L}(v_1)$, v_1 is not indirectly blocked, and 2. there is some role r' with $\text{Trans}(r')$ and $r' \sqsubseteq r$ 3. there is an r' -neighbour v_2 of v_1 with $\forall r'.C \notin \mathcal{L}(v_2)$ then $\mathcal{L}(v_1) \rightarrow \mathcal{L}(v_1) \cup \{\forall r'.C\}$.
choose-rule	if 1. $\leq n r.C \in \mathcal{L}(v_1)$, v_1 is not indirectly blocked, and 2. there is an r -neighbour v_2 of v_1 with $\{C, \dot{C}\} \cap \mathcal{L}(v_2) = \emptyset$ then $\mathcal{L}(v_1) \rightarrow \mathcal{L}(v_1) \cup \{E\}$ for some $E \in \{C, \dot{C}\}$.
\geq -rule	if 1. $\geq n r.C \in \mathcal{L}(v)$, v is not blocked, and 2. there are not n safe r -neighbours v_1, \dots, v_n of v with $C \in \mathcal{L}(v_i)$ and $v_i \neq v_j$ for $1 \leq i < j \leq n$



Why base OWL on a (Description) Logic?

Can exploit the results of 20+ years of DL research

- Well defined (model theoretic) **semantics**
- **Formal properties** well understood (complexity, decidability)
- Practical **reasoning algorithms**
- Effective **implemented systems**

 **Hermit**

FaCT++

ORACLE

Racer

pellet

 **uOnto**
Querying ONTOlogies

 **KAON2**

 **CEL**

 **Jena**
semantic web
framework

TrOWL
www.trowl.eu



What did OWL ever do for us?





What did OWL ever do for us?

Ontologies before:

Name	Original Language	de- fined	primi- tive	arti- ficial	Σ	de- fined	primi- tive
		concepts				roles	
CKB	SB-ONE	23	57	58	138	2	46
Companies	BACK	70	45	81	196	1	39
FSS	SB-ONE	34	98	75	207	0	47
Espresso	SB-ONE	0	145	79	224	11	41
Wisber	TURQ	50	81	152	283	6	18
Wines	CLASSIC	50	148	237	435	0	10





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Ontologies after:





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Ontologies after:

Welcome to the Protege Ontology Library!

OWL ontologies

- [AIM@SHAPE Ontologies](#): Ontologies pertaining to digital shapes. Source: [AIM@SHAPE NoE](#) - Advanced and Innovative Models And Tools for the development of Semantic-based systems for Handling, Acquiring, and Processing knowledge Embedded in multidimensional digital objects.
- [amino-acid.owl](#): A small OWL ontology of amino acids and their properties. Source: [Amino Acid Ontology Web site](#).
- [Basic Formal Ontology \(BFO\)](#)
- [bhakti.owl](#): An OWL ontology for the transcendental states of consciousness experienced by practitioners of bhakti-yoga, a form of Vedic consciousness engineering.
- [Biochemical Ontologies](#): Over 30 ontologies for knowledge representation and reasoning across scientific domains. Ontologies are normalized into non-disjoint primitive skeletons and

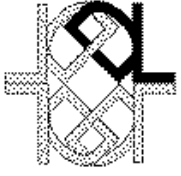


What did OWL ever do for us?

“**Profile**” before:

DL2000 (2000 International Workshop on Description Logics)

http://dl.kr.org/dl2000/

 **2000 International Workshop on Description Logics - DL2000**

RWTH Aachen, Germany

August 17 - August 19, 2000

A copy of the proceedings [Proceedings](#) is [available for free](#).

Call for Participation

The 2000 International Workshop on Description Logics continues the tradition of [international workshops](#) devoted to discussing developments and applications of knowledge representation formalisms based on [Description Logics](#). Demonstrations of systems and DL-based applications will be possible and people interested are encouraged to get in touch with the organizers.

DL2000 will precede [ECAI2000](#) (14th European Conference on Artificial Intelligence) which will be held in Berlin, Germany, August 20-25, 2000. DL2000 overlaps with [ICCS2000](#) which will be held in Darmstadt, Germany, August 13-18, 2000. There is an agreement with the ICCS organizers that DL-related sessions at the ICCS conference will be scheduled on non-overlapping days.

DL2000 is supported by the [Graduiertenkolleg Informatik und Technik](#) of the [University of Technology in Aachen \(RWTH\)](#).



What did OWL ever do for us?

“Profile” after:

WILSHIRE *conferences*

Designing and Building Business Ontologies

An Intensive 4-DAY SEMINAR with Workshops and Demonstrations, Semantically Enabling the Enterprise led by Dave McComb and Simon Robe

Seminar Objectives

Participants will:

- Gain an understanding of what an ontology is and what it can be used for.
- Understand how representing information in an ontology goes beyond a conceptual model or a simple taxonomy
- Understand the difference between frame based/ declarative classes and description logic based/ derivable classes.
- Understand the difference between open world and closed world models.
- Understand the basic principles for designing Ontologies for corporate applications.

Tuition Fee: \$2,450



What did OWL ever do for us?

Applications before:





What did OWL ever do for us?

Applications after:

- eScience, eCommerce, geography, engineering, defence, ...
- Major impact in healthcare and life sciences
- Mainstream technology supported by, e.g., **ORACLE** 11g
- Increasing impact in business applications





What did OWL ever do for us?

Peter and Ian before:





What did OWL ever do for us?

Peter and Ian after:





What did OWL ever do for us?

Tools before:

```
> (load-tkb "demo.kb" :verbose T)
.....
.....
> (classify-tkb :mode :stars)
ppppppppppppppppppppccpcppcccpccppcpcppcccpccpcp
pccccppcpcppcccp
T
> (direct-supers 'MAN)
(c[HUMAN] c[MALE])
>
```





What did OWL ever do for us?

Tools after:

The image displays a collage of screenshots from several OWL-related software tools:

- OntoTrack**: A web-based ontology editor showing a search for 'Oncogene' and a list of classes including Antigen_Gene, Apoptosis_Regulation_Gene, Cancer_Gene, etc.
- Protégé**: A desktop ontology editor showing a class hierarchy for 'Symptom' with subclasses like 'Hallucination' and 'Anxiety'.
- NeOn Toolkit**: A desktop ontology editor showing a class hierarchy for 'Drug' with subclasses like 'Antibiotic' and 'Chemotherapy'.
- OWL - NeOn Toolkit**: A desktop ontology editor showing a class hierarchy for 'Symptom' with subclasses like 'Hallucination' and 'Anxiety'.
- OWL - NeOn Toolkit**: A desktop ontology editor showing a class hierarchy for 'Symptom' with subclasses like 'Hallucination' and 'Anxiety'.



Tools, Tools, Tools

Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:





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Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

- Editors/development environments

The image displays three overlapping screenshots of OWL development environments:

- OntoTrack (left):** Shows a hierarchical class diagram for 'cyc.owl'. The root class is 'Thing', which branches into 'Individual' and 'Relation'. 'Individual' further branches into 'TemporalThing', 'SpatialThing', 'SolidTangible', and 'PartiallyIntangible'. 'SpatialThing' branches into 'SomethingExisting' and 'SpatialThingLocalized'. 'SomethingExisting' branches into 'Agent-Generic' and 'Place'. 'SpatialThingLocalized' branches into 'Place' and 'PartiallyTangible'. 'PartiallyIntangible' branches into 'PartiallyIntangible' and 'Intangible'. 'Intangible' branches into 'MyClass'. 'Relation' branches into 'TruthValue' and 'Mass'. 'Mass' branches into 'Temperature'. A 'Classes' list on the left includes 'man', 'sheep', 'tree', 'truck', 'van', 'van driver', 'vegetarian', 'vehicle', 'white van man', and 'woman'. A 'Restrictions' table shows 'has-class' with property 'drives' and value '(has color)'. The bottom status bar shows the path '/home/horrocks/systems/OllEd/ontologies/mad_cows.dam'.
- SWOLP v2.2b (top right):** Shows the 'Intersection of' dialog box. The 'OWL-Class' is 'space.DistanceCategory'. The 'Intersection of' is 'space.SpatialReferenceCategory (Date)' and '(! 1 space.hasDirection) (Date)'. The 'Disjoint with' is 'space.DistanceCategory (Date)'. The 'Subclass of' is '(! 1 space.hasDirection) (Date)'. The 'Superclass of' is 'space.DistanceCategory (Date)'. The 'Changes' panel shows 'Ontology Change Logging: enabled (Press link to disable)'. The 'Recommended Changes' panel shows 'REMOVE SUPER_CLASS (space.DistanceCategory) (Undo)', 'ADD DISJOINT_CLASSES (space.DistanceCategory, space.DistanceCategory) (Undo)', and 'SUPERCLASS_OF (space.DistanceCategory) (Undo)'.
- Protégé (bottom right):** Shows the 'Class Hierarchy' panel. The 'Class Hierarchy' is 'Phenomenon'. The 'Subclasses' are 'Hallucination', 'Anxiety', 'SensoryDeprivation', and 'WeightLoss'. The 'Datatype Properties' are 'Symptom'. The 'Associations' are 'Symptom'. The 'Properties' panel shows 'hasSymptom', 'isMedicationFor', 'causes', 'alleviates', and 'compensate'. The 'Instances' panel shows 'Disease' and 'Drug'.



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- Reasoners





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Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

- Editors/development environments
- Reasoners
- Explanation, justification and pinpointing

The screenshot shows the SWOOP v2.3 beta 3.1 (Jan 2006) interface. The main window displays the 'OWL Ontology: tambis-full.owl' with 'Annotations' and 'Root/Derived Debugging Information'. The debugging information includes 144 unsatisfiable classes, categorized into root and derived unsatisfiable classes.

root unsat. classes (3)	parent dependencies
metal (141)	
metalloid (140)	
nonmetal (140)	

derived unsat. classes (141)	parent dependencies
acetylation-site	modification-site , protein-part ,
active-site	macromolecule-part , protein , site , protein-part ,
alkali-metal	nonmetal , ? , metal , metalloid ,
alpha-helix	protein-structure , protein-secondary-structure , macromolecular-compound ,
amidation-site	modification-site , protein-part ,
amino-acid	organic-molecular-compound , small-organic-molecular-compound ,
anti-codon	rna-part , macromolecule-part , rna ,
astatine	nonmetal , ? , metal , metalloid ,
atom	nonmetal , metal , metalloid ,
beta-sheet	protein-structure , protein-secondary-structure , macromolecular-compound ,



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- Developing and using ontologies is *hard*





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- Reasoning enabled tools allow K-Eng to check if, e.g.:
 - classes are consistent (no “obvious” errors)

The screenshot shows a software interface with a window titled "Explanation". At the top right of the interface are buttons for "Concise Format" and "Abstract Syntax". Below these is a label "OWL-Class: mad+cow". The "Explanation" window contains the following text:

Axioms causing the inference
mad+cow = owl:Nothing:

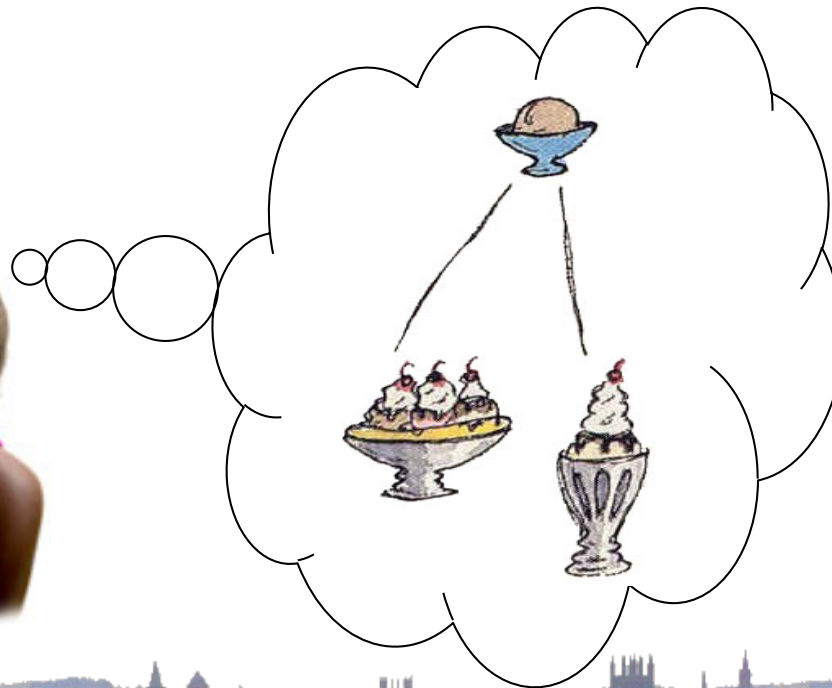
- 1) (mad+cow = ((∃eats . ((∃part+of . sheep) ∩ brain)) ∩ cow))
- 2) |_(sheep ⊆ animal)
- 3) |_(cow ⊆ vegetarian)
- 4) |_(vegetarian = (animal ∩ (∃eats . (¬ animal)) ∩ (∃eats . (¬ (∃part+of . animal)))))

Below the list is a checkbox labeled "Strike out irrelevant parts of axioms". At the bottom of the explanation window, there is a yellow highlighted area containing the text "owl:Nothing (Why?)".



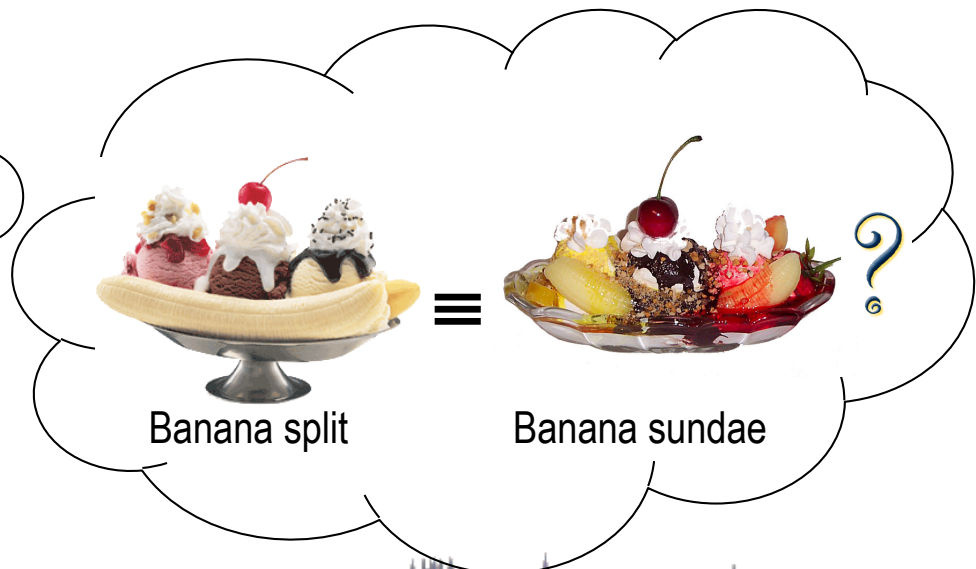
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- Reasoning enabled tools allow K-Eng to check if, e.g.:
 - classes are consistent (no “obvious” errors)
 - expected subsumptions hold (consistent with intuitions)
 - unexpected equivalences hold (unintended synonyms)





Case Study: HCLS

- **OBO foundry** includes more than 100 biological and biomedical ontologies
- **Siemens** “actively building OWL based clinical solutions”
- OWL tools used to find and repair critical errors in ontology used at **Columbia Presbyterian**
- **SNOMED-CT** (Clinical Terms) ontology
 - used in healthcare systems of more than 15 countries, including Australia, Canada, Denmark, Spain, Sweden and the UK
 - also used by major US providers, e.g., Kaiser Permanente
 - ontology provides common vocabulary for recording clinical data



Case Study: HCLS

SNOMED is **BIG** – over **400,000** concepts





Case Study: HCLS

SNOMED is **BIG** – over 400,000 concepts

The screenshot shows the ClniClue 2006: SNOMED CT interface. The main window displays the concept 'TB - Pulmonary tuberculosis' with Concept Id 154283005 and Description Id 1784750013. The interface is divided into several panes:

- Search Results:** A list of search results for 'pulmonary tuber', with 'TB - Pulmonary tuberculosis' highlighted.
- Hierarchy:** A tree view showing the concept's position within the hierarchy, with 'pulmonary tuberculosis' selected.
- Definition:** A detailed view of the concept's definition, including its status (Current), descriptions, and relationships.

Annotations with callout boxes highlight specific terms and relationships:

- Pulmonary Tuberculosis:** Points to the main concept name.
- pneumonitis:** Points to the 'pneumonitis' relationship in the definition pane.
- inflammatory disorder of lower respiratory tract:** Points to the 'inflammatory disorder of lower respiratory tract' relationship in the definition pane.
- Pulmonary disease due to Mycobacteria:** Points to the 'pulmonary disease due to Mycobacteria' relationship in the definition pane.
- found in lung structure:** Points to the 'lung structure' relationship in the definition pane.



Case Study: HCLS

- **Kaiser Permanente** extending SNOMED to express, e.g.:
 - *non-viral pneumonia* (negation)
 - *infectious pneumonia* is caused by a *virus* or a *bacterium* (disjunction)
 - *double pneumonia* occurs in *two lungs* (cardinalities)
- This is easy in **SNOMED-OWL**
 - but reasoner failed to find expected subsumptions, e.g., that *bacterial pneumonia* is a kind of *non-viral pneumonia*
- Ontology highly **under-constrained**: need to add disjointness axioms (at least)
 - *virus* and *bacterium* must be disjoint



Case Study: HCLS

- Adding disjointness led to **surprising results**
 - many classes become inconsistent, e.g., *percutaneous embolization of hepatic artery using fluoroscopy guidance*
- Cause of **inconsistencies** identified as class *groin*
 - *groin* asserted to be subclass of both *abdomen* and *leg*
 - *abdomen* and *leg* are disjoint
 - modelling of *groin* (and other similar “junction” regions) identified as incorrect





Case Study: HCLS

- Correct modelling of groin is quite complex, e.g.:
 - groin has a part that is part of the abdomen, and has a part that is part of the leg (*inverse properties*)

$\text{Groin} \sqsubseteq \exists \text{hasPart} . (\exists \text{isPartOf} . \text{Abdomen})$

$\text{Groin} \sqsubseteq \exists \text{hasPart} . (\exists \text{isPartOf} . \text{Leg})$

$\text{hasPart} \equiv \text{isPartOf}^{-}$

- all parts of the groin are part of the abdomen or the leg (*disjunction*)

$\text{Groin} \sqsubseteq \forall \text{hasPart} . (\exists \text{isPartOf} . (\text{Abdomen} \sqcup \text{Leg}))$

- ...





Case Study: HCLS

What we learned:

- Ontology engineering is **error prone**
 - errors of omission (e.g., disjointness) and commission (e.g., modelling of groin)
- **Expressive features** of OWL are sometimes needed
- Sophisticated tool support is **essential**
 - handling ontologies of this size is challenging
 - domain experts (and logicians!) often need help to understand the (root) cause of both inconsistencies and non-subsumptions
 - surprising and unexplained (non-) inferences are frustrating for users and may cause them to lose faith in the reasoner



Case Study: BBC

Text only | Help

BBC Home News Sport Weather iPlayer TV Radio More... Search

SPORT WORLD CUP 2010

SPORT FOOTBALL WORLD CUP 2010 GROUPS & TEAMS FIXTURES & RESULTS VIDEO BBC COVERAGE

Latest matches

NED 2-1 BRA

▶ Highlights & report

URU 1-1 GHA

▶ Highlights & report

ARG 0-4 GER

▶ Highlights & report

PAR 0-1 ESP

England

▶ England 1-1 United States Saturday, 12 June Match report

▶ England 0-0 Algeria Friday, 18 June Match report

▶ Slovenia 0-1 England Wednesday, 23 June Match report

▶ Germany 4-1 England Sunday, 27 June Match report

	A	B	C	D	E	F	G	H
Group C Teams								
USA				W	D	L	GD	PTS
England				1	2	0	1	5
Slovenia				1	1	1	0	4
Algeria				0	1	2	-2	1

Latest stories

Gerrard commits future to England **NEW**

- ▶ England sponsorship likely to end
- ▶ Capello to remain England manager
- ▶ Mueller blames England imbalance
- ▶ Capello receives Gartside backing

Pressure got to Rooney - Ferguson

- ▶ FA unfit for purpose says Caborn
- ▶ England's fear of crossing borders
- ▶ England duo bypass London event
- ▶ Barwick baffled by dismal England

Features

German lessons
Jurgen Klinsmann on how to revolutionise England

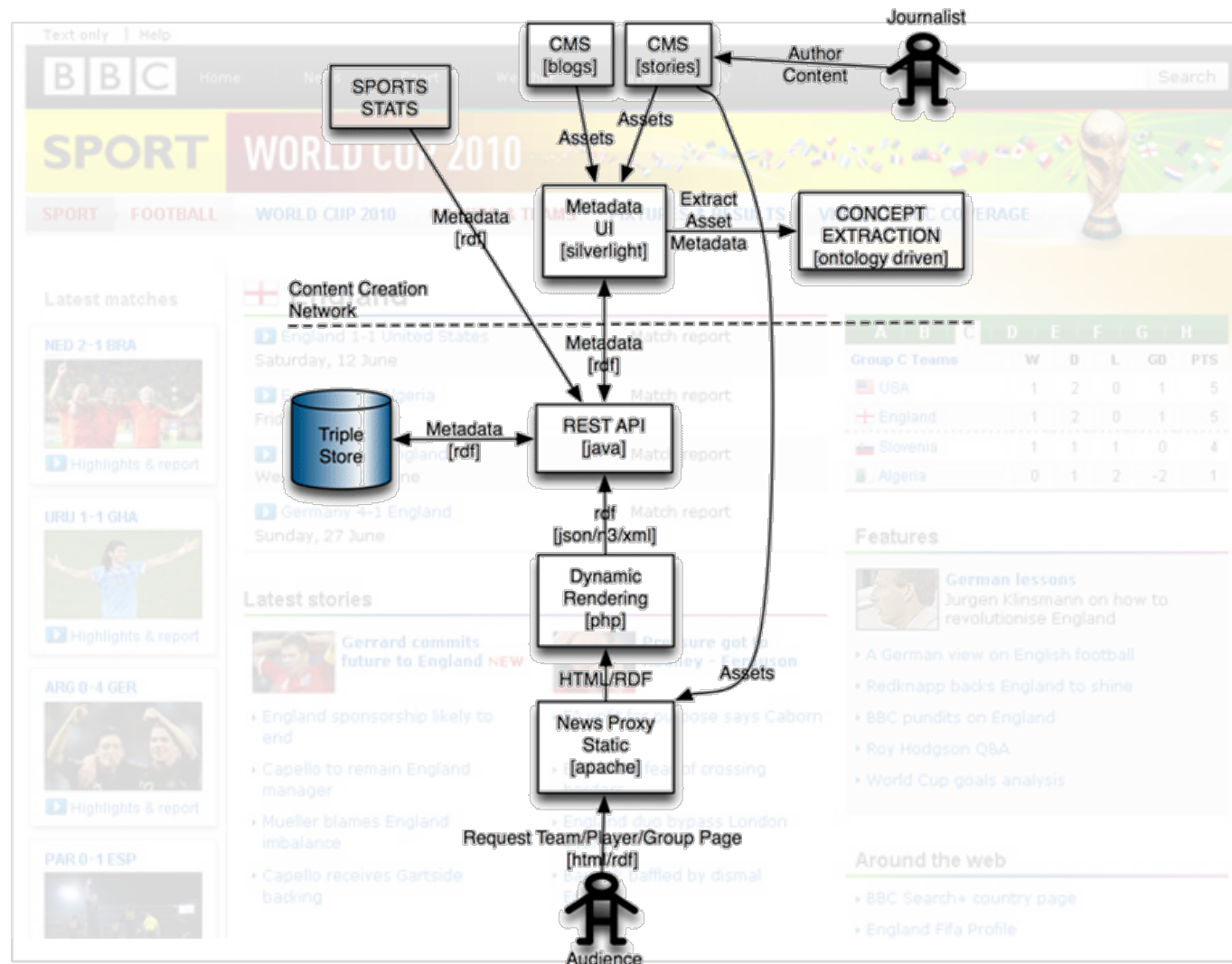
- ▶ A German view on English football
- ▶ Redknapp backs England to shine
- ▶ BBC pundits on England
- ▶ Roy Hodgson Q&A
- ▶ World Cup goals analysis

Around the web

- ▶ BBC Search+ country page
- ▶ England Fifa Profile

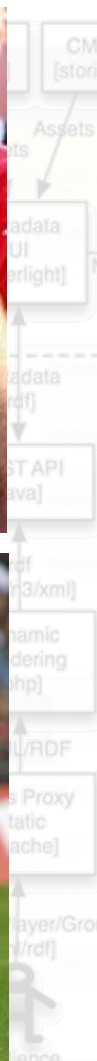


Case Study: BBC





Case Study: BBC





Why Ontology Reasoning?





Why Ontology Reasoning?

$Q(x) \leftarrow \text{Patient}(x) \wedge \text{suffersFrom}(x, y) \wedge \text{VascularDisease}(y)$

i.e., “Patients suffering from Vascular Disease”

John : Patient \sqcap
 $\exists \text{suffersFrom}.\text{HeartDisease}$

+

Heart \sqsubseteq MuscularOrgan \sqcap
 $\exists \text{isPartOf}.\text{CirculatorySystem}$
HeartDisease \equiv Disease \sqcap
 $\exists \text{affects}.\text{Heart}$
VascularDisease \equiv Disease \sqcap
 $\exists \text{affects}.\left(\exists \text{isPartOf}.\text{CirculatorySystem}\right)$

$\models Q(\text{John})$?

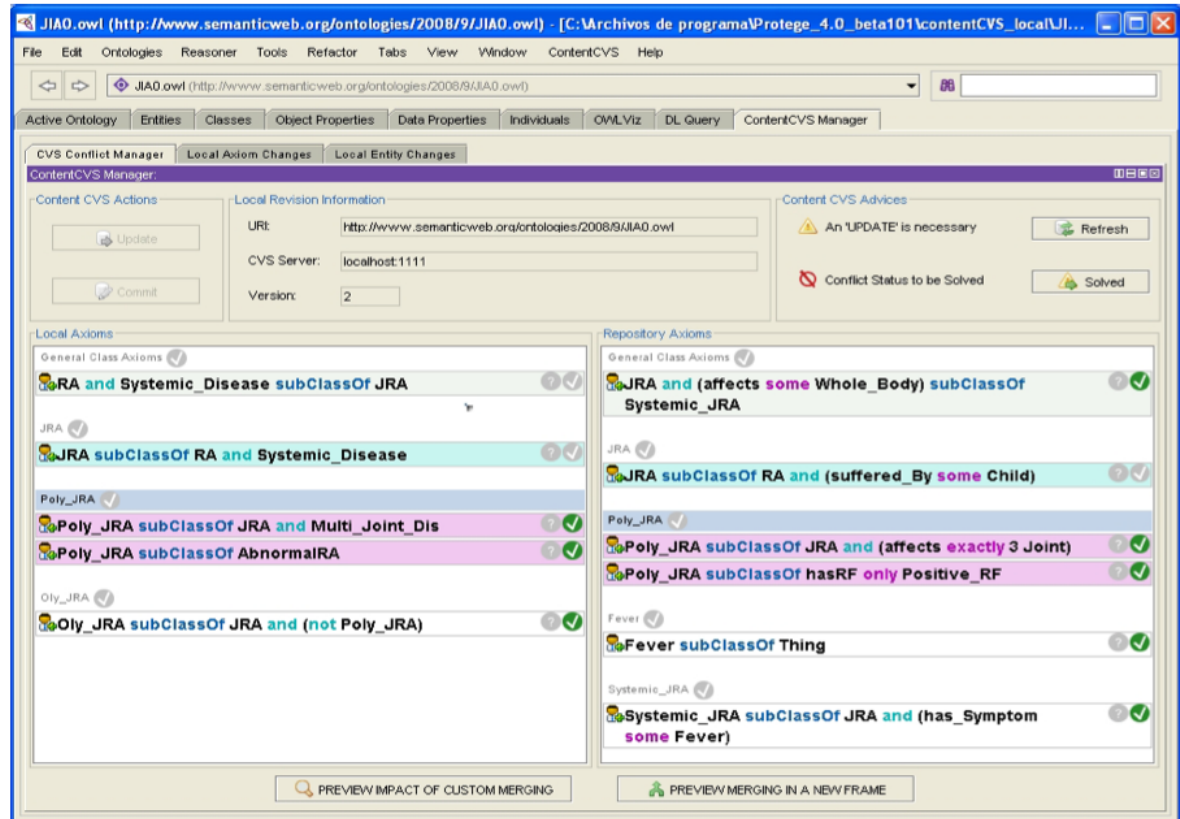




More Tools

Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

- Integration and modularisation

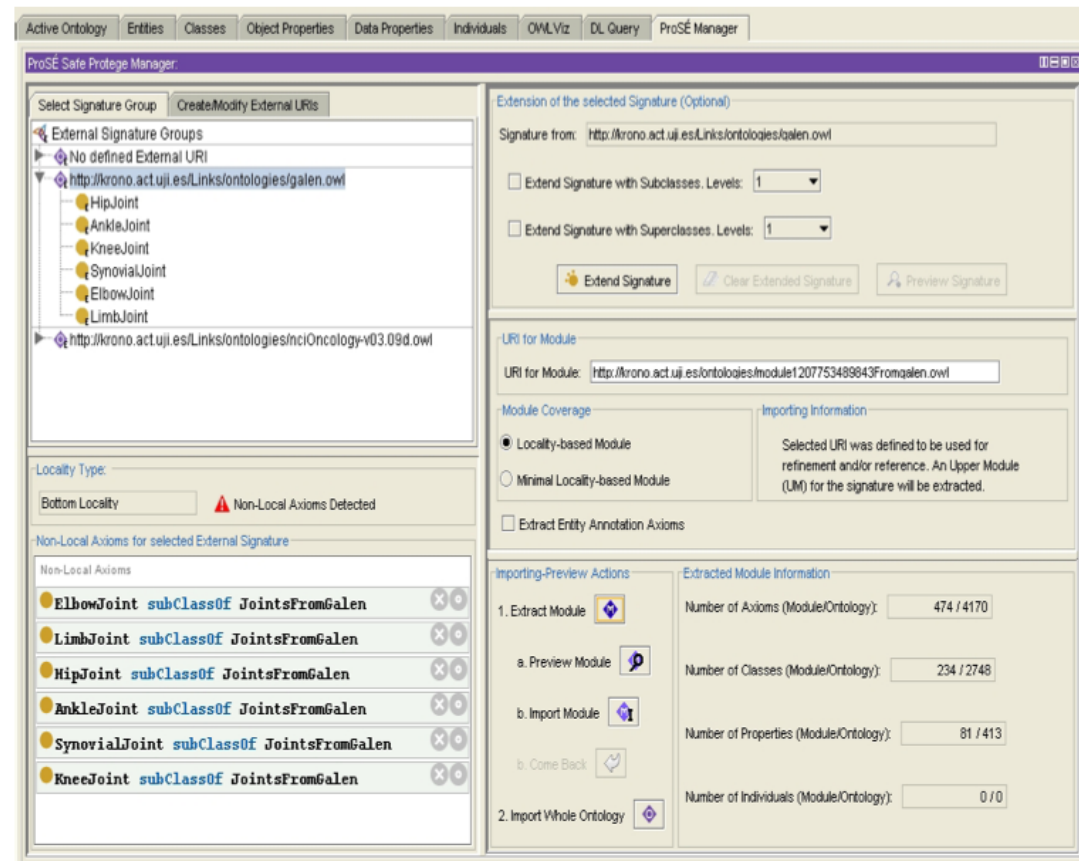




More Tools

Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

- Integration and modularisation
- Extraction

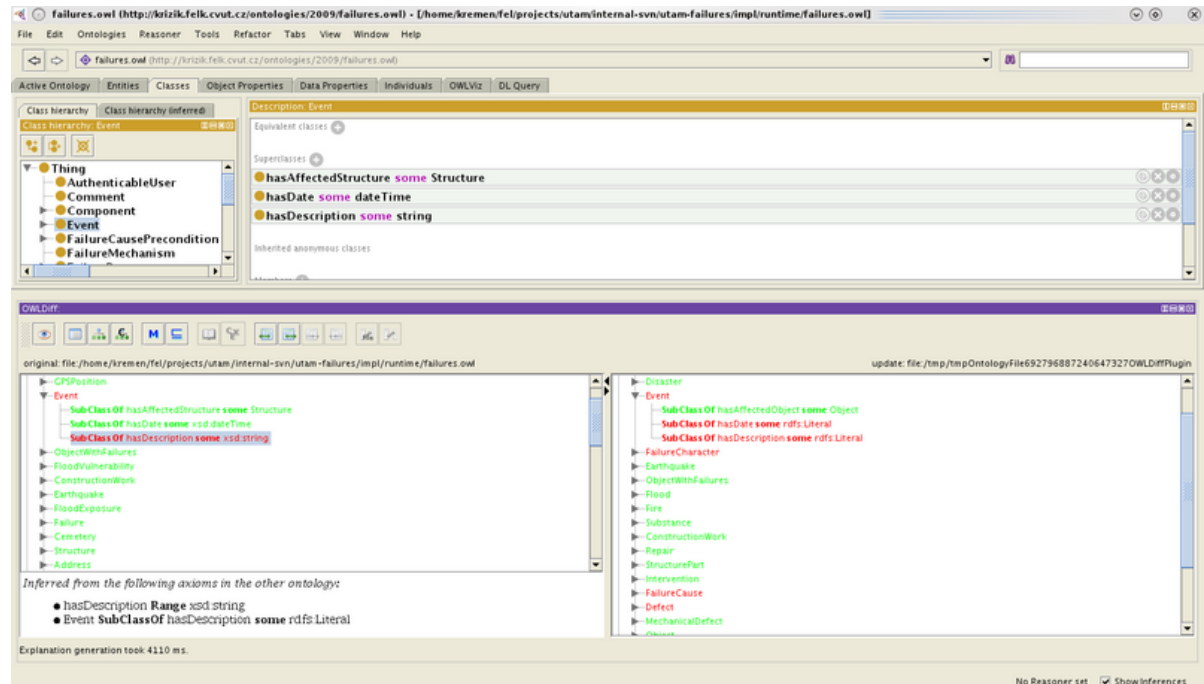




More Tools

Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

- Integration and modularisation
- Extraction
- Comparison

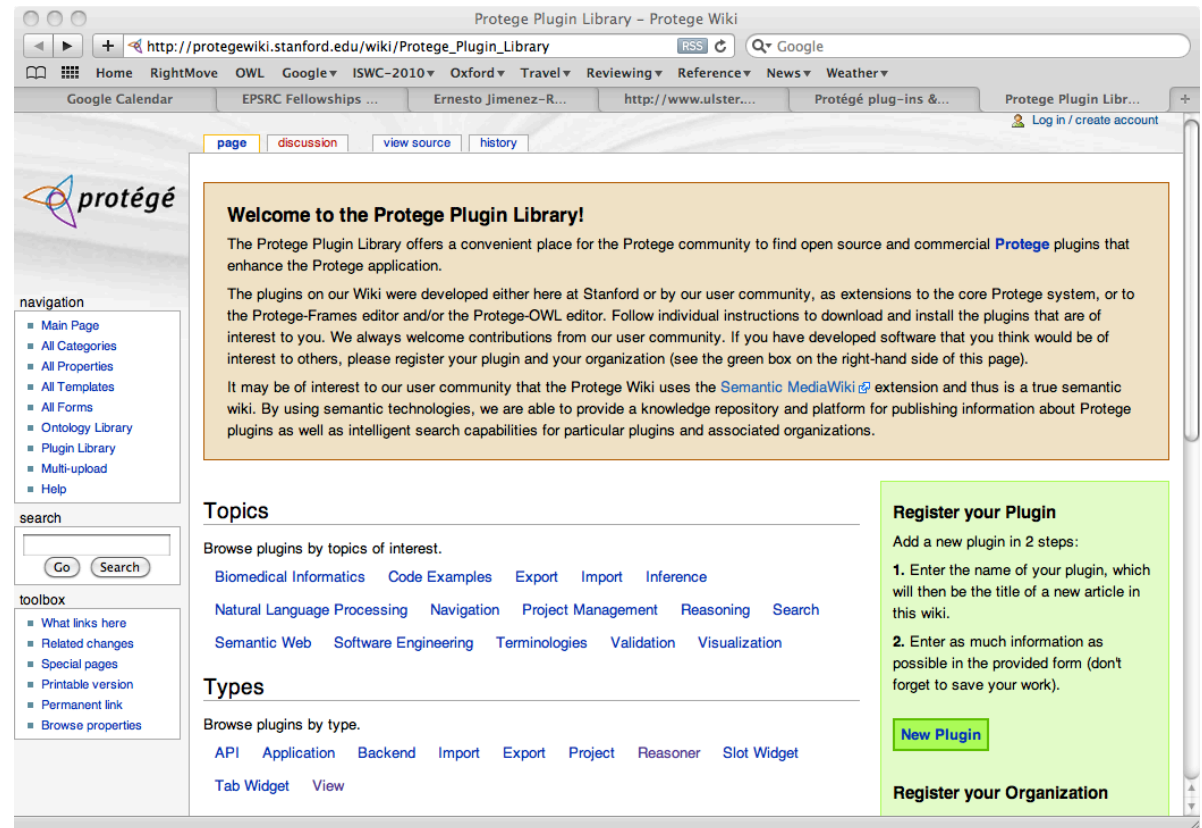




More Tools

Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

- Integration and modularisation
- Extraction
- Comparison
- Protege plugins



The screenshot shows the Protege Plugin Library website. The browser address bar displays the URL http://protegewiki.stanford.edu/wiki/Protege_Plugin_Library. The page features a navigation menu on the left with links such as 'Main Page', 'All Categories', and 'Plugin Library'. The main content area includes a 'Welcome to the Protege Plugin Library!' message, a 'Topics' section for browsing plugins by interest, and a 'Types' section for browsing by type. A green box on the right side contains a 'Register your Plugin' form with instructions and a 'New Plugin' button.



More Tools

Major benefit of OWL has been huge increase in range and sophistication of tools and infrastructure:

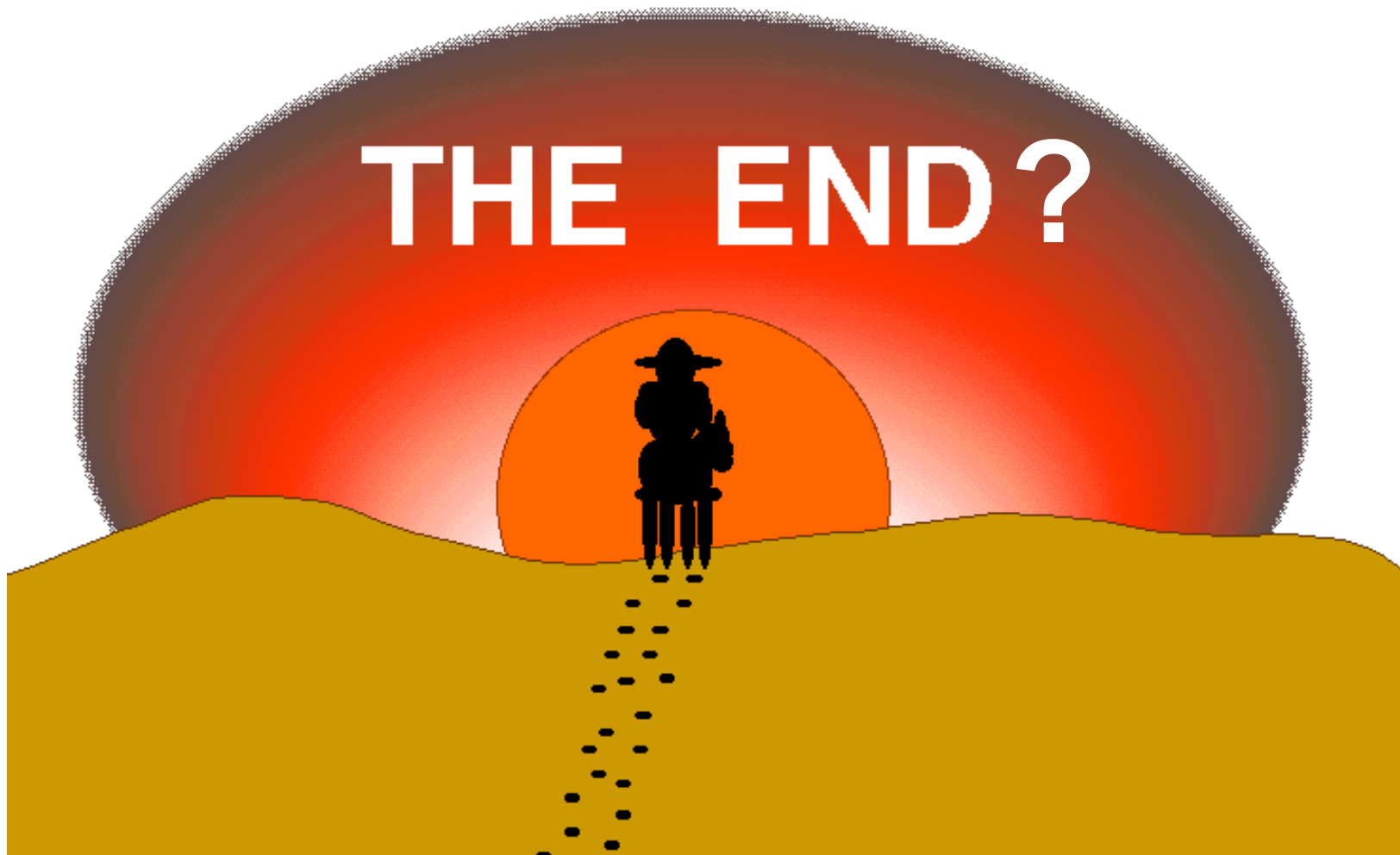
- Integration and modularisation
- Extraction
- Comparison
- Protege plugins
- APIs, in particular the [OWL API](#)

```
Revision 1403 - (download) (annotate)  
Fri Dec 18 17:14:37 2009 UTC (4 months, 2 weeks ago) by matthewhorridge  
File size: 4711 byte(s)  
1 package org.coode.owlapi.examples;  
2  
3 import org.semanticweb.owlapi.apibinding.OWLManager;  
4 import org.semanticweb.owlapi.model.*;  
5 import org.semanticweb.owlapi.util.DefaultPrefixManager;  
6 /*  
7  * Copyright (C) 2009, University of Manchester  
8  *  
9  * Modifications to the initial code base are copyright of their  
10 * respective authors, or their employers as appropriate. Authorship  
11 * of the modifications may be determined from the ChangeLog placed at  
12 * the end of this file.  
13 *  
14 * This library is free software; you can redistribute it and/or  
15 * modify it under the terms of the GNU Lesser General Public  
16 * License as published by the Free Software Foundation; either  
17 * version 2.1 of the License, or (at your option) any later version.  
18 *  
19 * This library is distributed in the hope that it will be useful,  
20 * but WITHOUT ANY WARRANTY; without even the implied warranty of  
21 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU  
22 * Lesser General Public License for more details.  
23
```





THE END?





Ongoing Research

- Query answering
 - [Kontchakov et al], [Konev et al], [Baader et al]
- Diagnosis and repair
 - [Horridge et al], [Peñaloza et al]
- Extensions
 - [Motik et al], [Artale et al]
- Optimisation/Profiles
 - [Kazakov], [Glimm et al], [Faddoul et al], [Savo et al]
- ...





Ongoing Standardisation Efforts

- Standardised query language
 - SPARQL standard for RDF
 - Currently being extended for OWL, see <http://www.w3.org/TR/sparql11-entailment/>
- RDF
 - Revision currently being considered, see <http://www.w3.org/2009/12/rdf-ws/>



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<http://iswc2010.semanticweb.org>

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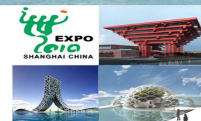
Gui-Rong Xue

Haofen Wang

Lei Zhang



Stunning Venue



Great Time



Fascinating City



Excellent Food

SWSA
Semantic Web Science Association

上海交通大学
SHANGHAI JIAO TONG UNIVERSITY

IBM
Research

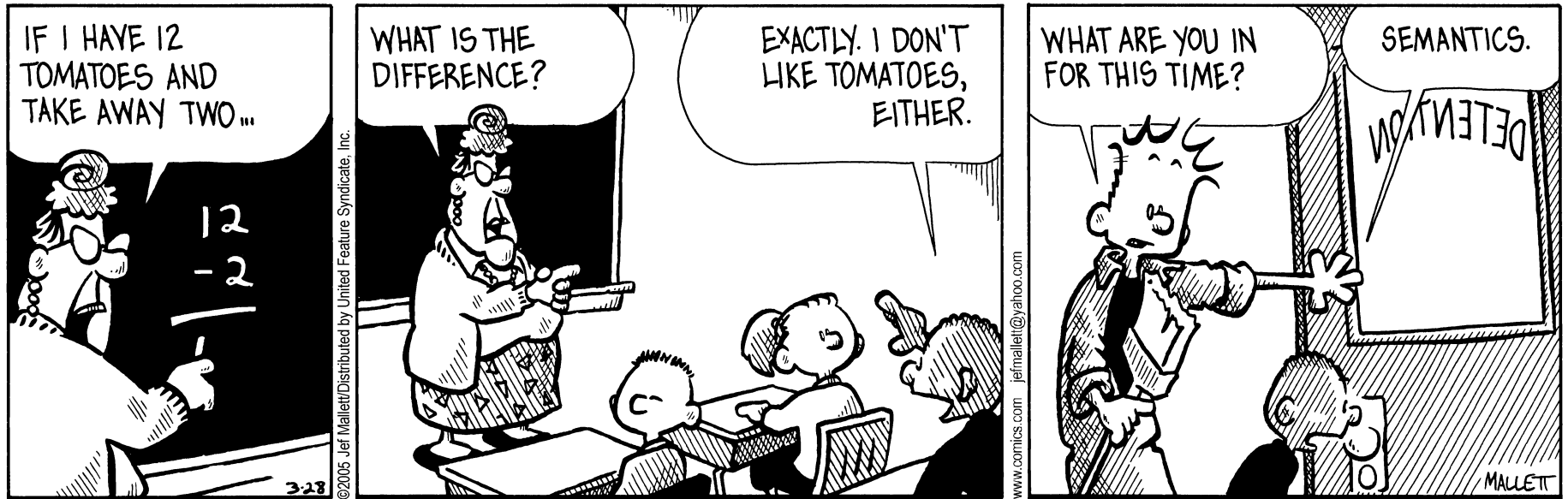


Thank you for listening





Thank you for listening



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Any questions?

