
DAML+OIL: a Reason-able Web Ontology Language

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Talk Outline

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The Semantic Web

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Web Ontology Languages

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Summary

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 - **Metadata** annotations that describe content/function
- Coincides with Tim Berners-Lee's vision of a **Semantic Web**

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- ➔ Topics covered at **ISWC** include:

Agents

Database technologies

Digital libraries

e-business

e-science and the Grid

Integration, mediation and storage

Knowledge representation and reasoning

Languages and infrastructure

Metadata (inc. generation and authoring)

Multimedia data

Natural language

Ontologies

Searching and querying

Services and service description

Trust and meaning

User interfaces

Visualisation and modelling

Web mining

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- ➔ Ontologies can be used, e.g.:
 - To facilitate buyer–seller communication in **e-commerce**
 - In semantic based **search**
 - To provide richer **service descriptions** that can be more flexibly interpreted by intelligent agents

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- ➔ Requirements for web ontology language:
 - **Compatible** with existing Web standards (XML, RDF, RDFS)
 - **Easy to understand** and use (based on common KR idioms)
 - **Formally specified** and of “adequate” expressive power
 - Possible to provide **automated reasoning** support

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- ➔ Efforts merged to produce DAML+OIL
 - Development was overseen by **joint EU/US committee**
 - Now **submitted to W3C** as basis for standardisation
 - **WebOnt working group** developing language standard
 - New standard may be called **OWL** (Ontology Web Language)

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 - **Inherits** RDFS ontological primitives (subclass, range, domain)
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 - **Object oriented**: classes (concepts) and properties (roles)
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- ➔ RDF used for class/property membership assertions (**data**)
 - E.g., John is an **instance of** Person; ⟨John, Mary⟩ is an instance of parent

DAML+OIL Language

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- ➔ DAML+OIL benefits from many years of DL research
 - Well defined **semantics**
 - **Formal properties** well understood (complexity, decidability)
 - Known **reasoning algorithms**
 - **Implemented systems** (highly optimised)

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- ➔ **Expressive power** determined by
 - Kinds of constructor provided
 - Kinds of axiom allowed

DAML+OIL Class Constructors

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Constructor	DL Syntax	Example
intersectionOf	$C_1 \sqcap \dots \sqcap C_n$	Human \sqcap Male
unionOf	$C_1 \sqcup \dots \sqcup C_n$	Doctor \sqcup Lawyer
complementOf	$\neg C$	\neg Male
oneOf	$\{x_1 \dots x_n\}$	{john, mary}
toClass	$\forall P.C$	\forall hasChild.Doctor
hasClass	$\exists P.C$	\exists hasChild.Lawyer
hasValue	$\exists P.\{x\}$	\exists citizenOf.{USA}
minCardinalityQ	$\geq n P.C$	≥ 2 hasChild.Lawyer
maxCardinalityQ	$\leq n P.C$	≤ 1 hasChild.Male
cardinalityQ	$= n P.C$	$= 1$ hasParent.Female

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- ➡ XMLS **datatypes** as well as classes
- ➡ Arbitrarily complex **nesting** of constructors
 - E.g., Person $\sqcap \forall$ hasChild.(Doctor $\sqcup \exists$ hasChild.Doctor)

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subClassOf	$C_1 \sqsubseteq C_2$	Human \sqsubseteq Animal \sqcap Biped
sameClassAs	$C_1 \equiv C_2$	Man \equiv Human \sqcap Male
subPropertyOf	$P_1 \sqsubseteq P_2$	hasDaughter \sqsubseteq hasChild
samePropertyAs	$P_1 \equiv P_2$	cost \equiv price
sameIndividualAs	$\{x_1\} \equiv \{x_2\}$	{President_Bush} \equiv {G_W_Bush}
disjointWith	$C_1 \sqsubseteq \neg C_2$	Male $\sqsubseteq \neg$ Female
differentIndividualFrom	$\{x_1\} \sqsubseteq \neg\{x_2\}$	{john} $\sqsubseteq \neg\{peter\}$
inverseOf	$P_1 \equiv P_2^-$	hasChild \equiv hasParent ⁻
transitiveProperty	$P^+ \sqsubseteq P$	ancestor ⁺ \sqsubseteq ancestor
uniqueProperty	$\top \sqsubseteq \leq 1P$	$\top \sqsubseteq \leq 1$ hasMother
unambiguousProperty	$\top \sqsubseteq \leq 1P^-$	$\top \sqsubseteq \leq 1$ isMotherOf ⁻

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➡ Axioms (mostly) **reducible to subClass/PropertyOf**

RDFS Syntax

```
<daml:Class>
  <daml:intersectionOf rdf:parseType="daml:collection">
    <daml:Class rdf:about="#Person" />
    <daml:Restriction>
      <daml:onProperty rdf:resource="#hasChild" />
      <daml:toClass>
        <daml:unionOf rdf:parseType="daml:collection">
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- In practice, DAML+OIL implementations can choose to support **subset** of XML Schema datatypes.

Reasoning with DAML+OIL

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- ➔ Ontology **integration**
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- ➔ Ontology **deployment**
 - Determine if set of facts are consistent w.r.t. ontology
 - Determine if individuals are instances of ontology classes

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 - XML provides syntax **transport layer**
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- ➔ Understanding dependent on **reliable & consistent** reasoning

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- Is \mathcal{O} consistent? There exists some model \mathcal{I} of \mathcal{O}
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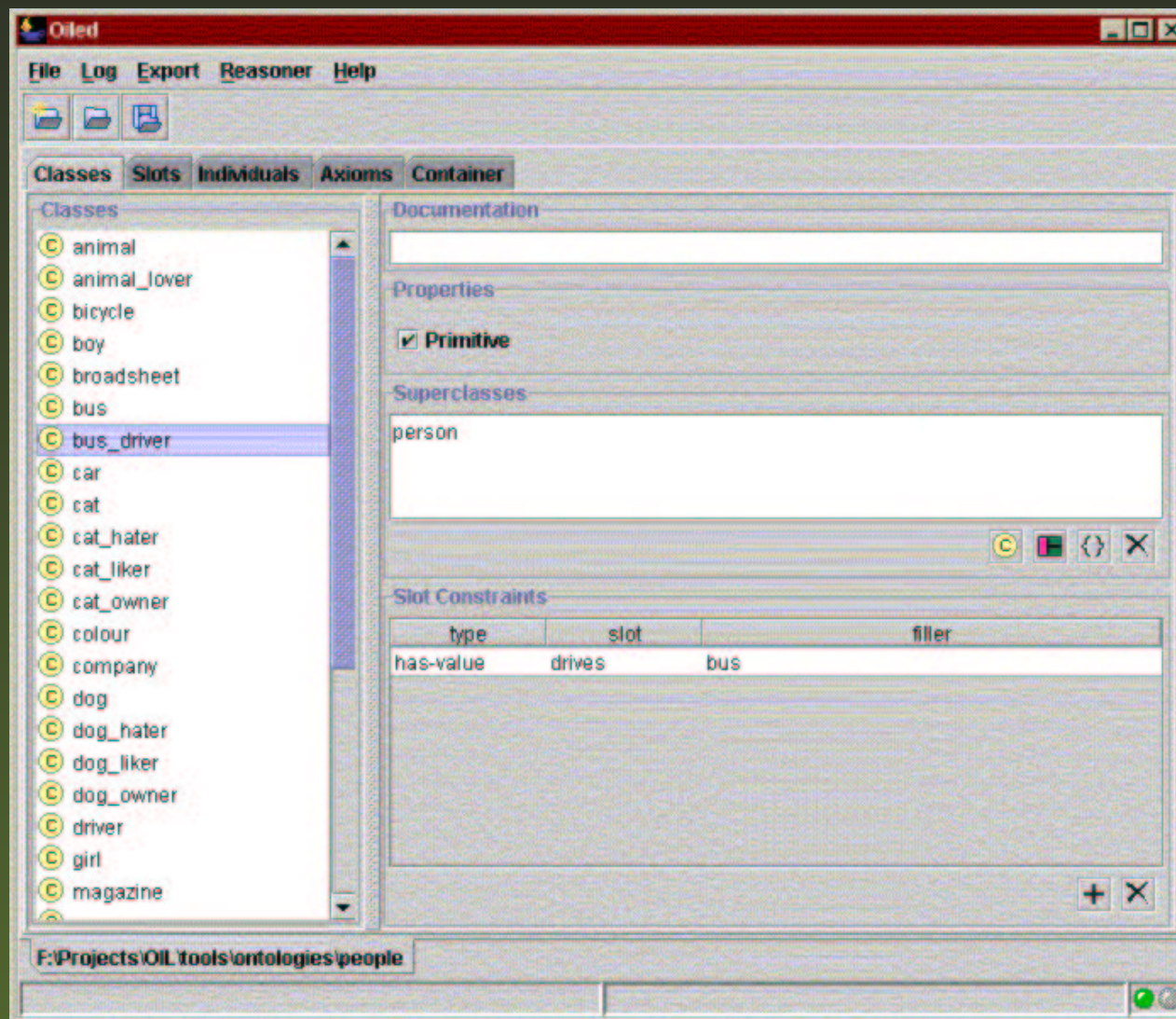
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➔ Problems all **reducible** to consistency (satisfiability):

- $C \sqsubseteq_{\mathcal{O}} D$ iff $D \sqcap \neg C$ not consistent w.r.t. \mathcal{O}
- $i \in_{\mathcal{O}} C$ iff $\mathcal{O} \cup \{i \in \neg C\}$ is **not** consistent

Reasoning Support for Ontology Design: OilEd



Description Logic Reasoning

Highly Optimised Implementation

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- ➔ Optimised **subsumption** testing
 - Normalisation and simplification of concepts
 - Absorption (simplification) of general axioms
 - Davis-Putnam style semantic branching search
 - Dependency directed backtracking
 - Caching of satisfiability results and (partial) models
 - Heuristic ordering of propositional and modal expansion
 - ...

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- ➔ Already seeing some (partial) **implementations**
 - Cerebra system (Network Inference), Racer system (Hamburg)

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- ➔ **Standard solution** is weaker semantics for nominals
 - Treat nominals as (disjoint) primitive classes
 - Loose some inferential power, e.g., w.r.t. max cardinality

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 - Important **optimisations** no longer (fully) work
- ➔ Reasoning with **individuals**
 - **Deployment** of web ontologies will mean reasoning with (possibly very large numbers of) individuals/tuples
 - Unlikely that standard **Abox** techniques will be able to cope
 - Necessary to employ **database** technology

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👉 LCS and/or matching [Baader, Küsters & Molitor]

- To support ontology integration
- To support “bottom up” design of ontologies

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- ➔ **Challenges** remain
 - Reasoning with full language
 - Demonstration of scalability

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- ➔ Carole Goble and other members of the Information Management Group (University of Manchester)

Resources

Slides from this talk

<http://www.cs.man.ac.uk/~horrocks/Slides/edbt02.pdf>

FaCT system (open source)

<http://www.cs.man.ac.uk/FaCT/>

OilEd (open source)

<http://oiled.man.ac.uk/>

OIL

<http://www.ontoknowledge.org/oil/>

DAML+OIL

<http://www.w3c.org/Submission/2001/12/>