DAML+OIL: a Reason-able Ontology Language for the Semantic Web

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Talk Outline

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The Semantic Web

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- The Semantic Web
- Web Ontology Languages

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- DAML+OIL Language

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- Reasoning with DAML+OIL
    - OilEd Demo

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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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  - **Object oriented**: classes (concepts) and properties (roles)
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  - E.g., Person is **kind of** Animal whose parents are Persons

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- RDF used for class/property membership assertions (**data**)
  - E.g., John is an **instance of** Person; $\langle \text{John}, \text{Mary} \rangle$ is an instance of parent

DAML+OIL Language

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  - **Formal properties** well understood (complexity, decidability)
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  - Various **constructors** provided for building class expressions
- **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	$C_1 \sqcap \ldots \sqcap C_n$	Human $\sqcap$ Male
unionOf	$C_1 \sqcup \ldots \sqcup C_n$	Doctor $\sqcup$ Lawyer
complementOf	$\neg C$	$\neg$Male
oneOf	$\{x_1 \ldots x_n\}$	$\{$john, mary$\}$
toClass	$\forall P.C$	$\forall$hasChild.Doctor
hasClass	$\exists P.C$	$\exists$hasChild.Lawyer
hasValue	$\exists P.\{x\}$	$\exists$citizenOf.$\{$USA$\}$
minCardinalityQ	$\geqslant n P.C$	$\geqslant 2$hasChild.Lawyer
maxCardinalityQ	$\leqslant n P.C$	$\leqslant 1$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)

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

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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 **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**
  - RDF(S) provides basic **relational language** and simple ontological primitives
  - DAML+OIL provides powerful but still decidable **ontology language**
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- Understanding dependent on **reliable & consistent** reasoning

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- Problems all **recucible** to consistency (satisfiability):
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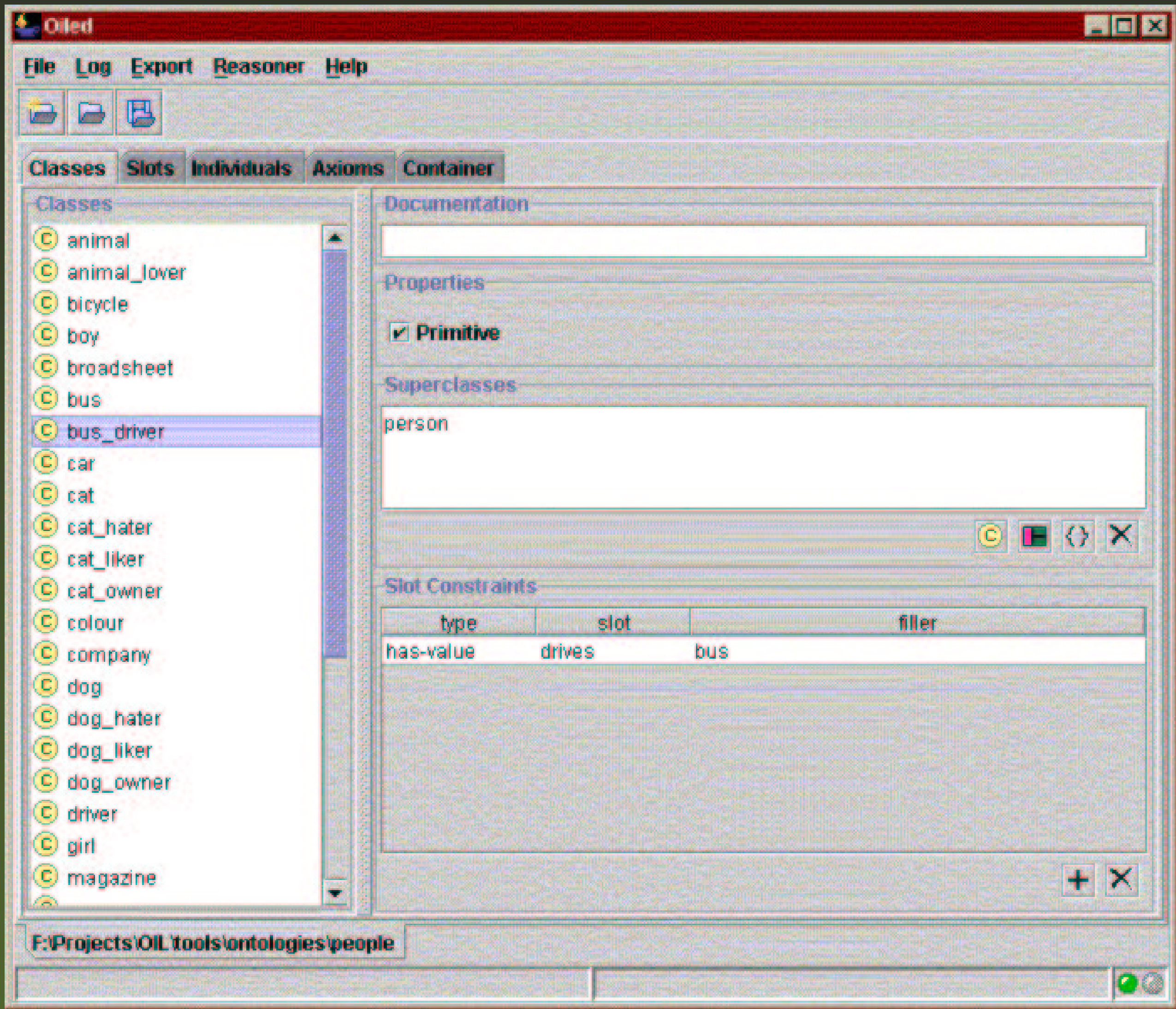
  - $i \in_{\mathcal{O}} C$ iff $\mathcal{O} \cup \{i \in \neg C\}$ is **not** consistent

Reasoning Support for Ontology Design: OilEd



Description Logic Reasoning

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- Optimised **subsumption** testing (search for models)
  - 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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  - Promising research on **automata** based algorithms
- **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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- ☞ 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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- **Querying**
  - Retrieval and instantiation wont be sufficient
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- **LCS** and/or **matching** [Baader, Küsters & Molitor]
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  - To support “bottom up” design of ontologies

Tools and Infrastructure

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- Ontology **design and maintenance**
  - Several **editors** available, e.g, OilEd (Manchester), OntoEdit (Karlsruhe), Protégé (Stanford)
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- **Popular** combination of features—already being widely adopted
- **Challenges** remain
  - Reasoning with full language
  - Demonstration of scalability
  - Development of (high quality) tools and infrastructure

Acknowledgements

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- Members of the Information Management, Medical Informatics, Formal Methods and Artificial Intelligence Groups at the University of Manchester

Resources

Slides from this talk

`http://www.cs.man.ac.uk/~horrocks/Slides/aisb02.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/`

I.COM (CASE tool with reasoning support)

`www.cs.man.ac.uk/~franconi/icom/`

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