Description Logics and OWL

Based on slides from
Ian Horrocks
University of Manchester (now in Oxford)
Where are we?

- XML
- RDF(S)/SPARQL
- PL/FOL
- OWL
- OWL Reasoning
- OWL in practice
- DL Extensions
- Scalability
- Practical Topics

Combining the strengths of UMIST and The Victoria University of Manchester
Task

Translate the following inclusion axioms in the language of First order logic

- \( \text{Female} \subseteq \text{Human} \)
- \( \text{Child} \subseteq \text{Human} \)
- \( \text{StudiesAtUni} \subseteq \text{Human} \)
- \( \text{SuccessfulMan} \equiv \text{Man} \)
  - \( \text{InBusiness} \sqsubseteq \exists \text{married}. \text{Lawyer} \)
  - \( \exists \text{hasChild}. (\text{StudiesAtUni}) \)
- \( \neg \text{Female}(\text{Pedro}) \)
- \( \text{InBusiness}(\text{Pedro}) \)
- \( \text{Lawyer}(\text{Mary}) \)
- \( \text{married}(\text{Pedro}, \text{Mary}) \)
- \( \text{child}(\text{Pedro}, \text{John}) \)
Task

• Write down one interpretation for the previous knowledge base.
Task

Show that $\models C \subseteq D$ implies $\models \exists R. C \subseteq \exists R. D$
Note on DL Naming

• Basic description logic is $\mathcal{ALC}$ (equiv modal $K_{(m)}$)
  – Concepts constructed using $\cap, \cup, \neg, \exists$ and $\forall$

• $S$ often used for $\mathcal{ALC}$ with transitive roles

• Additional letters indicate other extension, e.g.:
  – $\mathcal{H}$ for role inclusion axioms (role hierarchy)
  – $\mathcal{O}$ for nominals (singleton classes, written $\{x\}$)
  – $\mathcal{I}$ for inverse roles
  – $\mathcal{N}$ for number restrictions (of form $\leq n \ R$, $\geq n \ R$)
  – $\mathcal{Q}$ for qualified number restrictions (of form $\leq n \ R.C$, $\geq n \ R.C$)
  – ...
Basic Inference Tasks

• Ontology $\mathcal{O}$: Tbox + ABox

• Knowledge is correct (captures intuitions)
  – Does C subsume D w.r.t. ontology $\mathcal{O}$? ($C^I \subseteq D^I$ in every model $I$ of $\mathcal{O}$)

• Knowledge is minimally redundant (no unintended synonyms)
  – Is C equivalent to D w.r.t. $\mathcal{O}$? ($C^I = D^I$ in every model $I$ of $\mathcal{O}$)

• Knowledge is meaningful (classes can have instances)
  – Is C is satisfiable w.r.t. $\mathcal{O}$? ($C^I \neq \emptyset$ in some model $I$ of $\mathcal{O}$)

• Querying knowledge
  – Is $x$ an instance of C w.r.t. $\mathcal{O}$? ($x^I \in C^I$ in every model $I$ of $\mathcal{O}$)
  – Is $\langle x, y \rangle$ an instance of R w.r.t. $\mathcal{O}$? ($\langle x^I, y^I \rangle \in R^I$ in every model $I$ of $\mathcal{O}$)

• Above problems can be solved using highly optimised DL reasoners
Short History of Description Logics

Phase 1:
- **Incomplete** systems (Back, Classic, Loom, . . . )
- Based on **structural algorithms**

Phase 2:
- Development of **tableau algorithms** and complexity results
- Tableau-based systems for **Pspace** logics (e.g., Kris, Crack)
- Investigation of **optimisation techniques**

Phase 3:
- Tableau algorithms for **very expressive** DLs
- **Highly optimised** tableau systems for **ExpTime** logics (e.g., FaCT, DLP, Racer)

Phase 4:
- Mainstream applications and tools
Why Ontology Reasoning?

• Given key role of ontologies in many applications, it is essential to provide tools and services to help users:
  – Design and maintain high quality ontologies, e.g.:
    • **Meaningful** — all named classes can have instances
    • **Correct** — captured intuitions of domain experts
    • **Minimally redundant** — no unintended synonyms
    • **Richly axiomatised** — (sufficiently) detailed descriptions
  – Answer queries over ontology classes and instances, e.g.:
    • Find more general/specific classes
    • Retrieve individuals/tuples matching a given query
  – **Integrate** and align multiple ontologies
Why Correct Reasoning?

- Need to have high level of confidence in reasoner
  - Most interesting/useful inferences are those that were unexpected
  - Likely to be ignored/dismissed if reasoner known to be unreliable
- Many realistic web applications will be agent ↔ agent
  - No human intervention to spot glitches in reasoning
Why Decidable Reasoning?

- OWL is an W3C standard DL based ontology language
  - OWL constructors/axioms restricted so reasoning is decidable
- Consistent with Semantic Web's layered architecture
  - XML provides syntax transport layer
  - RDF(S) provides basic relational language and simple ontological primitives
  - OWL provides powerful but still decidable ontology language
  - Further layers (e.g. SWRL) will extend OWL
    - Will almost certainly be undecidable
- W3C requirement for “implementation experience”
  - “Practical” decision procedures
  - Several implemented systems
  - Evidence of empirical tractability
Task

• Design a correct reasoning algorithm for any description logic knowledge base, deciding entailment.
Summary

• DLs are a family of logic based Knowledge Representation formalisms
  – Describe domain in terms of concepts, roles and individuals

• DLs are (usually) decidable subsets of FOL

• An Ontology is an engineering artefact consisting of:
  – A vocabulary of terms
  – An explicit specification of their intended meaning