CENTRE FOR ARTIFICIAL INTELLIGENCE RESEARCH

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Contextual Defeasible Ontologies

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Knowledge Representation

- Explicit domain representation
- Formal semantics
- Reasoning tasks – search guided by domain knowledge
  - instance checking / retrieval
  - classification
  - entailment / implications
  - consistency checking
  - justification / diagnosis
  - ...
- Subfields of KR
  - SAT
  - Constraint Satisfaction
  - Conceptual Graphs
  - Description Logics
  - Answer Set Programming
  - ...

Web Ontology Language

- Build formal ontologies
- Attach formal meaning to data and structured domains
- W3C open standards
  - RDF(S) data standard,
  - SPARQL query language,
  - OWL2 web ontology language, including OWL2 DL

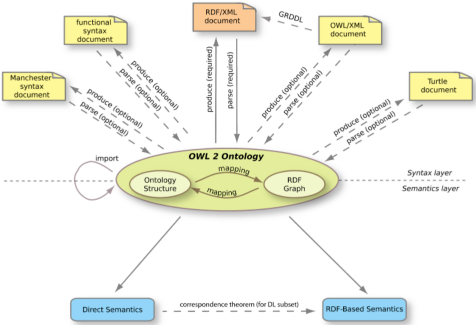


Figure 1. The Structure of OWL 2

Description Logics

- The satisfiability problem for first-order logic is undecidable (Church 1936, Turing 1937)
- 2-variable fragment of FOL is decidable:
  - unary predicates $C(x)$ — concept expressions
  - binary predicates $r(x, y)$ — roles
- Guarded fragment – closed under boolean composition and limited guarded quantification:
  - $\forall y[r(x, y) \to C(y)]$
  - $\exists y[r(x, y) \land C(y)]$
  - $\forall x[C(x) \to D(x)]$

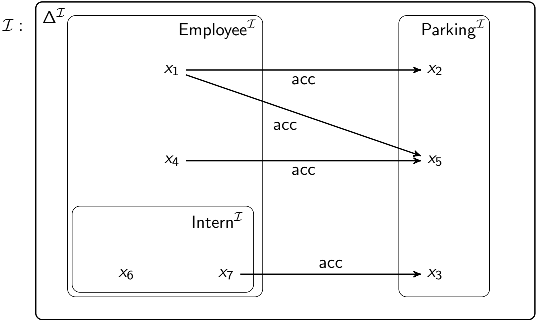
Description Logic Concepts

Concept Language – $\mathcal{ALC}$

$$C ::= \top \mid \bot \mid A \mid \neg C \mid C \sqcap C \mid C \sqcup C \mid \forall r.C \mid \exists r.C$$

Example

Intern $\sqcap$ Employee; $\exists$acc.Parking; $\neg\exists$acc.Parking



Description Logic Axioms

- Subsumption statements: $C \sqsubseteq D$
- Read: 'C is subsumed by D'
- FOL translation: $\forall x[C(x) \rightarrow D(x)]$

Example

$$\mathcal{KB} = \left\{ \begin{array}{c} \text{Intern} \sqsubseteq \text{Employee}, \\ \text{Employee} \sqsubseteq \exists \text{acc.Parking}, \\ \text{Intern} \sqsubseteq \neg \exists \text{acc.Parking}, \\ \text{Intern} \sqcap \text{Technician} \sqsubseteq \exists \text{acc.Parking} \end{array} \right\}$$

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- There can be no interns

- Classical logic is explosive and monotonic
- Requires prior knowledge of exceptions
- Even with prior knowledge, entailment remains monotonic

Commonsense Reasoning

- Semantic representation
  - mental states – desire, beliefs, intentions
  - exceptions, contradictions
  - preference, subjectivity, context
- Inference
  - non-monotonic reasoning, belief revision
  - abductive and inductive reasoning
- Applications
  - domains – legal, medical, biological, etc.
  - semantic web; internet of things
  - image understanding
  - cognitive robotics

Defeasible Description Logic Axioms

- Defeasible subsumption statements: $C \sqsubsetsim D$; $C \sqsubsetsim_r D$
- Read: 'C is normally subsumed by D (in the context r)'
- FOL translation: can be done

Example

$$\mathcal{KB} = \left\{ \begin{array}{c} \text{Intern} \sqsubseteq \text{Employee}, \\ \text{Employee} \sqsubsetsim \exists \text{acc.Parking}, \\ \text{Intern} \sqsubsetsim \neg\exists \text{acc.Parking}, \\ \text{Intern} \sqcap \text{Technician} \sqsubsetsim \exists \text{acc.Parking} \end{array} \right\}$$

Defeasible Description Logic Axioms

- Defeasible subsumption statements: $C \precsim D$; $C \precsim_r D$
- Read: 'C is normally subsumed by D (in the context r)'
- FOL translation: can be done

Example

$$\mathcal{KB} = \left\{ \begin{array}{c} \text{Intern} \sqsubseteq \text{Employee}, \\ \text{Employee} \precsim \exists \text{acc.Parking}, \\ \text{Intern} \precsim \neg\exists \text{acc.Parking}, \\ \text{Intern} \sqcap \text{Technician} \precsim \exists \text{acc.Parking} \end{array} \right\}$$

- Defeasible DLs are non-explosive
- Defeasible subsumption is non-monotonic
- Preferential semantics
- Entailment remains monotonic
- Cannot build reasoner using classical DL reasoner as black box

Postulates

(Cons) $\top \not\sqsubsim_r \bot$ (Ref) $C \sqsubsim_r C$ (LLE) $\dfrac{C \equiv D, \quad C \sqsubsim_r E}{D \sqsubsim_r E}$

(And) $\dfrac{C \sqsubsim_r D, \quad C \sqsubsim_r E}{C \sqsubsim_r D \sqcap E}$ (Or) $\dfrac{C \sqsubsim_r E, \quad D \sqsubsim_r E}{C \sqcup D \sqsubsim_r E}$ (RW) $\dfrac{C \sqsubsim_r D, \quad D \sqsubseteq E}{C \sqsubsim_r E}$

(CM) $\dfrac{C \sqsubsim_r D, \quad C \sqsubsim_r E}{C \sqcap D \sqsubsim_r E}$ (RM) $\dfrac{C \sqsubsim_r D, \quad C \not\sqsubsim_r \neg E}{C \sqcap E \sqsubsim_r D}$

- $\sqsubsim_r$ is preferential if it satisfies Cons, Ref, LLE, And, Or, RW, CM
- $\sqsubsim_r$ is rational if it is preferential and satisfies RM

Rational Closure

- Modular semantics
- Presumption of typicality
- Non-monotonic entailment
- Defeasible entailment checking reduced to iterated classical entailment checks
- Complexity as for classical DL entailment

Theorem

Let $\mathcal{KB}$ be a knowledge base having a modular model. $C \sqsubseteq\!\!\!\sim_r D$ is in the rational closure of $\mathcal{KB}$ iff $\mathcal{KB} \models_{\mathsf{rat}} C \sqsubseteq\!\!\!\sim_r D$.

Work in progress

- implementation
- modelling, application, integration

1. Britz, K and Varzinczak, I. Rationality and context in defeasible subsumption. In: Proceedings of the 10th International Symposium on Foundations of Information and Knowledge Systems, Budapest, Hungary, May 14-18, 2018. To appear.

Thank you!