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Approximate Resolution for OWL ABox Reasoning

Pascal Hitzler
AIFB, Universität Karlsruhe

Boris Motik
FZI Karlsruhe

Problem Description

Terminology: TBox+RBox

Annotations: ABox

To date: approx. 25 million active websites.

Consequence:

Scalability is an ABox size problem.

ABox reasoning is worst-case exponential even without nominals.

We propose a polynomial complete but unsound approximate reasoning algorithm.

Idea

We facilitate recent results due to

Hustadt, Motik, Sattler, Studer 2003/2004

on casting OWL-DL into disjunctive Datalog.
(currently being implemented in KAON2)

We approximate ABox reasoning by
regarding disjunctive heads of rules as conjunctions.

We can use standard SLD-resolution.

Resulting data complexity polynomial instead of NP-hard.

Prolog

$$\text{Human} \sqsubseteq \text{Male} \sqcup \text{Female}$$

$$\rightsquigarrow \text{Male}(x) \vee \text{Female}(x) \leftarrow \text{Human}(x)$$

$$\rightsquigarrow \text{Male}(x) \wedge \text{Female}(x) \leftarrow \text{Human}(x)$$

Reduction to Disjunctive Datalog

Start with OWL-DL ontology.

$D \equiv \{o_1,o_2\} \rightsquigarrow \{o_1,o_2\} \sqsubseteq D$

1. Get rid of nominals. $\rightsquigarrow \mathcal{SHIQ}(D)$ (language weakening)
2. OWL-DL is subset of first-order logic.
   So translate into clausal form.
3. Saturate TBox+RBox by taking all consequences. [Exponential]
4. Eliminate function symbols. [No modification of semantics!]

Result: Function- and negation-free disjunctive logic program.

$\text{Human} \sqsubseteq \exists \text{Parent.Human}$

$\rightsquigarrow \forall x\, \exists y\, (\text{Human}(x) \rightarrow \text{Parent}(x,y) \wedge \text{Human}(y))$

$\rightsquigarrow \text{Parent}(x,f(x)) \wedge \text{Human}(f(x)) \leftarrow \text{Human}(x)$

$\rightsquigarrow \text{Parent}(x,fx)) \wedge \text{Human}(fx) \leftarrow \text{Human}(x)$

TBox reasoning

ABox reasoning with disjunctive datalog is exponential.

We speed it up by changing the inference.

Disjunctive heads become conjunctive.
Use standard SLD-resolution.

Prolog

Complexity becomes polynomial.

New inference can be described semantically using standard NMR terminology.

NonMonotonic Reasoning

Approximate SLD-Resolution

Answering of conjunctive (non-ground) queries.

Human $\sqsubseteq$ Male $\sqcup$ Female.
Human(Rudi).

Human $\sqsubseteq$ Male $\sqcap$ Female.
Human(Rudi).

?- Male(X).
X=Rudi

?- Female(X).
X=Rudi

Complete (no nominals!) but unsound.

Semantic effect of nominal elimination unclear.

Semantic description

NMR: Associate set of models $\mathcal{M}$ with program P.

***A* is a *brave consequence* of P if it is true with respect to *at least one* model in $\mathcal{M}$.**

For approximate SLD-resolution $\mathcal{M}$ is the set of all *well-supported models* of P.

Variant of standard notion for non-disjunctive programs. Shown by Fages (1994) to be equivalent to stable models.

Reiter's Default Logic

Answer Set Programming

Performance forecast

Trade-off between performance gain and correctness of answers.

Many disjunctions in ontology:

- **Higher** speed-up. 
- **More** incorrect answers. 

Few disjunctions in ontology:

- Only **little** speed-up. 
- **Few** incorrect answers. 

Currently, disjunctions are rarely being used in applications.

References

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2. Hustadt, Motik, Sattler. Reasoning in Description Logic with a Concrete Domain in the Framework of Resolution. ECAI2004.

3. Hustadt, Motik, Sattler. Reasoning for Description Logics around $\mathcal{SHIQ}$ in a Resolution Framework. FZI Technical Report 3-8-04/04, 2004.

4. Motik, Sattler, Studer. Query Answering for OWL-DL with Rules. ISWC 2004.

5. New results forthcoming in Hitzler, Motik, Vrandecic. Approximate Resolution for OWL ABox reasoning (tentative title).