DLP

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DLP (for Description Logic Prover) is a description logic system that contains a sound and complete reasoner for an expressive description logic. DLP is an experimental system, in that it does not contain all the support facilities that one might like in a full description logic system. However, DLP does have an interface that allows the creation and examination of taxonomies of concepts.

DLP employs a heavily-optimised decision procedure for description logic satisfiability to determine subsumption relationships. This decision procedure has excellent performance on a wide variety of test suites, including several propositional modal logic test suites.

Language

DLP implements the description logic shown in Figure 1. In the syntax chart A is a concept name; C and D are arbitrary concepts; P is a role name; R and S are arbitrary roles. Concept and role names are given meaning via operations that define them. DLP requires that concepts be defined before they are used in descriptions.

The semantics for DLP is a normal semantics for description logics, with a domain $\Delta^{\mathcal{I}}$, disjoint from the integers, and an interpretation function $^{\mathcal{I}}$ for concepts and roles.

DLP's reasoner is sound and complete for this logic, modulo bugs in the implementation. It uses the now-standard method for subsumption testing in description logics, namely translating subsumption tests into satisfiability tests and checking for satisfiability using an optimised tableaux method.

DLP accepts a subset of the KRSS specification [Patel-Schneider and Swartout, 1993]. It implements the following operators:

(DEFINE-CONCEPT <name> <dscription>)
(DEFINE-PRIMITIVE-CONCEPT <name> [<concept>])
(DEFINE-PRIMITIVE-ROLE <name>)
(DEFINE-PRIMITIVE-ATTRIBUTE <name>)
(DEFINE-PRIMITIVE-TRANSITIVE-ROLE <name>)
(CONCEPT-SUBSUMES? <concept> <concept>)

	Syntax	Semantics
Concepts	A	$\mathsf{A}^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$
	$\top$	$\Delta^{\mathcal{I}}$
	$\bot$	$\emptyset$
	$\neg C$	$\Delta^{\mathcal{I}} - C^{\mathcal{I}}$
	$C \sqcap D$	$C^{\mathcal{I}} \cap D^{\mathcal{I}}$
	$C \sqcup D$	$C^{\mathcal{I}} \cup D^{\mathcal{I}}$
	$\exists R.C$	$\{d \in \Delta^{\mathcal{I}} : R^{\mathcal{I}}(d) \cap C^{\mathcal{I}} \neq \emptyset\}$
	$\forall R.C$	$\{d \in \Delta^{\mathcal{I}} : R^{\mathcal{I}}(d) \subseteq C^{\mathcal{I}}\}$
	$\geqslant$nP	$\{d \in \Delta^{\mathcal{I}} : \mid P^{\mathcal{I}}(d) \mid\ \geq n\}$
	$\leqslant$nP	$\{d \in \Delta^{\mathcal{I}} : \mid P^{\mathcal{I}}(d) \mid\ \leq n\}$
	P:n	$\{d \in \Delta^{\mathcal{I}} : P^{\mathcal{I}}(d) \cap \ni n^{\mathcal{I}} \neq \emptyset\}$
Roles	P	$\mathsf{P}^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}}$
	$R \sqcup S$	$R^{\mathcal{I}} \cup S^{\mathcal{I}}$
	R/C	$R^{\mathcal{I}} \cap (\Delta^{\mathcal{I}} \times C^{\mathcal{I}})$
	$R \circ S$	$R^{\mathcal{I}} \circ S^{\mathcal{I}}$
	R^+	$\bigcup_{n \geq 1} R^{\mathcal{I}^n}$

Figure 1: Description Logic for DLP

The prover in DLP has facilities for handling global axioms, but there is no description logic input facility for global axioms.

DLP thus accepts a very expressive description logic. However, DLP cannot represent individuals, nor does it incorporate any domain extensions, aside from allowing integers as role fillers. Nor does DLP have any facilities for explanation or query answering.

Other Features

Because of the correspondence between description logics and propositional modal logics, the description logic reasoner in DLP can serve as a reasoner for several propositional modal logics. As well as propositional dynamic logic, the logic underlying DLP contains fragments that are in direct correspondence to the propositional modal logics $\mathbf{K_{(m)}}$ and $\mathbf{K4_{(m)}}$.

DLP provides an interface that allows direct satisfiability checking of formulae in $\mathbf{K_{(m)}}$ and $\mathbf{K4_{(m)}}$ plus global axioms. Using a standard encoding, the interface also allows satisfiability checking of formulae in $\mathbf{KT_{(m)}}$

and $\mathbf{S4_{(m)}}$.

Implementation

DLP is implemented in Standard ML of New Jersey. It is written in a mostly-functional programming style. The only side effects in the satisfiability engine have to do with unique storage of formulae and caching of formulae.

DLP incorporates a number of optimisations for description logic provers. A number of these optimisations have appeared in various description logic systems [Baader *et al.*, 1992; Bresciani *et al.*, 1995; Horrocks, 1997]. In fact, much of DLP is a reimplementation of the ideas underlying FaCT [Horrocks, 1997].

The basic algorithm in DLP is a simple tableau algorithm that searches for a model that demonstrates the satisfiability of a description logic description or, equivalently, a propositional modal logic formula. The algorithm incorporates the usual control mechanism to guarantee termination, including a check for equality of nodes to guarantee termination for transitive roles (modalities). The optimisations in DLP include lexical normalisation, semantic branching, boolean constraint propagation, dependency-directed backtracking, caching, and heuristic guidance search.

Most of these optimisations can be turned on or off or modified through various compile-time switches. Through these switches the effectiveness of the various optimisations in DLP has been analysed for test suites.

Performance

DLP has been used to classify the Galen medical knowledge base [Rector *et al.*, 1997] with the portions it cannot represent removed. DLP performed capably on this knowledge base, creating the subsumption partial order in 210 seconds on a Sparc Ultra 1-class machine. FaCT also takes about 200 seconds for this task on a comparable machine.

DLP has also been tested on two sets of benchmarks of propositional modal formulae, the Tableaux'98 comparison benchmarks [Heuerding and Schwendimann, 1996] and a collection of hard random modal formulae due to Hustadt and Schmidt [Hustadt and Schmidt, 1997]. DLP outperformed the existing description logic systems on the Tableaux'98 benchmarks and was competitive with KSatC, the fastest description logic system on the random formulae. More detail on DLP's performance is available in a paper discussing the performance of the various optimisations in DLP [Horrocks and Patel-Schneider, 1998].

Availability

DLP is available for research purposes via the WWW at http://www.bell-labs.com/user/pfps. Standard ML of New Jersey is available free via the WWW at http://cm.bell-labs.com/cm/cs/what/smlnj.

Future Plans

DLP is probably close to its final state. The implementation philosophy of DLP cannot easily be extended to build models that are not tree structures with loops. This is not to say that DLP is not a useful tool, it is a very fast decision procedure for propositional modal logics, and can effectively compute taxonomies of concepts.

I am at the beginnings of building a successor to DLP, provisionally called BAROC, which will be able to reason with individuals.

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