OWL Rules, OK?

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Abstract

Although the OWL Web Ontology Language adds considerable expressive power to the Semantic Web it does have expressive limitations, particularly with respect to what can be said about properties. One possible solution to this problem is to extend OWL with some form of "rules" language. Several different integration frameworks have already been proposed, each having different features and limitations. Regardless of which framework is eventually chosen, it is essential that the integrated language has a clear declarative semantics that is independent of any particular implementation technique.

Background

The OWL Web Ontology Language [16] adds considerable expressive power to the Semantic Web. However, for a variety of reasons (see `http://lists.w3.org/Archives/Public/www-webont-wg/`), including retaining the decidability of key inference problems in OWL DL and OWL Lite, OWL has expressive limitations. These restrictions can be onerous in some application domains, for example in describing web services, where it may be necessary to relate inputs and outputs of composite processes to the inputs and outputs of their component processes [17], or in medical informatics, where it may be necessary to transfer characteristics across partitive properties [14].

Many of the limitations of OWL stem from the fact that, while the language includes a relatively rich set of class constructors, the language provided for talking about properties is much weaker. In particular, there is no composition constructor, so it is impossible to capture relationships between a composite property and another (possibly composite) property. The standard example here is the obvious relationship between the composition of the "parent" and "brother" properties and the "uncle" property.

One way to address this problem would be to extend OWL with a more powerful language for describing properties. For example, a decidable extension of the description logics underlying OWL DL to include the use of composition in subproperty axioms has already been investigated [7]. In order to maintain decidability, however, the usage of the constructor is limited to axioms of the form $P \circ Q \sqsubseteq P$, i.e., axioms asserting that the composition of two properties is a subproperty of one of the composed properties. This means that complex relationships between composed properties cannot be captured—in fact even the relatively simple "uncle" example cannot not be captured (because "uncle" is not one of "parent" or "brother").

An alternative way to overcome some of the expressive restrictions of OWL would be to extend it with some form of "rules language". In fact adding rules to description logic based knowledge representation languages is far from being a new idea. Several early description logic systems, e.g., Classic [13, 1], included a rule language component. In these systems, however, rules were given a weaker semantic treatment than axioms asserting sub- and super-class relationships; they were only applied to individuals, and did not affect class based inferences such as the computation of the class hierarchy. More recently, the CARIN system integrated rules with a description logic in such a way that sound and complete reasoning was still possible [10]. This was achieved, however, by using a rather weak description logic (*much* weaker than OWL), and by placing severe syntactic restrictions on the occurrence of description logic terms in the (heads of) rules. Similarly, the DLP language proposed in [3] is based on the intersection of a description logic with horn clause rules; the result is obviously a decidable language, but one that is necessarily less expressive than either the description logic or rules language from which it is formed.

More recent work suggests, however, that it may be possible to integrate Description Logic based ontology languages (such as OWL DL) with rules languages so as to combine the best features of the two frameworks, and in particular to retain decidability for key inference problems (such as subsumption, satisfiability and query answering). Techniques that have been proposed include reductions of Description Logic ontologies to Disjunctive Datalog Programs [9], the integration of Description Logics and Answer Set Programs [2], and an extended CARIN style framework that can deal with very expressive Description Logics [15].

All of the above techniques involve some restriction, however, on either the syntactic form of rules or on the degree of semantic integration between the rules and the ontology. An alternative approach proposed in [4] is to extend OWL DL with Horn-style rules, with such roles simply being treated as a new kind of axiom. The advantage of this approach is that ontology axioms and rules is full integrated, with both having a standard first order semantics; the disadvantage is that the extended language is no longer decidable. In spite of this, early implementation efforts have been surprisingly successful [18], but it remains to be seen if it will be possible to provide reasoning support that will meet the requirements of real applications.

Important Features for an OWL Rules Language

The above mentioned research and experience gained in the development of ontology languages such as OIL, DAML+OIL and OWL [6], as well as work on the recent SWRL proposal [4, 5], suggests the following list of requirements and desiderata for a rules language extension of OWL.

- An essential feature of any language extension is that it has a clear declarative semantics that is compatible with the semantics of OWL DL and is independent of any particular implementation technique.

- There are several reasons why a rules language should be layered on top of OWL DL rather than on top of OWL Full:

  – Given that future extensions up to and including full First Order Predicate Calculus are already being considered, it would be an advantage if the integrated language were given a standard First Order style semantics.

  - The complex semantics necessitated by "same-name" extensions of RDF [6], and the impossibility of developing such a semantics for a full First-Order language [12], makes it undesirable to layer more expressive languages on top of OWL Full.
  - There is already a wide range of tools available for OWL DL, and few if any tools available for OWL Full (unless we believe that supporting RDF is the same thing as supporting OWL Full). Moreover, it is likely that OWL DL tools can easily be extended to support an integrated language layered on top of OWL DL (e.g., the Hoolet reasoner has already been extended to support SWRL [18], and work has begun on adding SWRL support to the Protégé OWL plugin[1]).

- In order to maximise interoperability, and avoid (further) fragmentation of Semantic Web languages into a partially ordered set (with possibly incompatible semantics), it is highly desirable that the integrated language *not* be layered on top of some sub-language of OWL DL.

- Any extension should be based on established research, both with respect to the semantics and algorithms/implementation techniques that could be used to provide reasoning support.

- Possible future extensions to OWL, e.g., to support qualified cardinality constraints [8], more expressive datatypes [11] or complex property inclusion axioms [7] should be taken into consideration when designing a rules language extension.

- Finally, such an extension should be conservative and not try to incorporate too many advanced features.

I believe that adherence to the above requirements would facilitate the rapid development and widespread adoption of a rule language extension to OWL.

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