Grigoris Antoniou
Harold Boley (Eds.)

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Rules and Rule Markup Languages for the Semantic Web

Third International Workshop, RuleML 2004
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Volume Editors

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Preface

The Semantic Web is a worldwide endeavor to advance the Web by enriching its content with semantic metainformation that can be processed by inference-enabled Web applications. Taxonomies and rules, along with their automated reasoning techniques, are the main components of Semantic Web ontologies.

Rule systems are considered to be a major area in the further development of the Semantic Web. On one hand, rules can specify declarative knowledge in ontology languages, expressing constraints or transformations, either in conjunction with, or as an alternative to, description logics. On the other hand, rules can specify behavioral knowledge, enforcing policies or reacting to events/changes.

Finally, rule markup languages such as RuleML allow us to publish rules on the Web, to process rules in general XML environments as well as special rule engines, to exchange rules between different applications and tools via XSLT translators, as well as to embed rules into other XML content and vice versa.

This workshop was dedicated to all aspects of rules and rule markup languages for the Semantic Web. RuleML 2004 was the third in a series of workshops that was initiated with the International Semantic Web Conference. The previous workshops were held on Sardinia, Italy (2002), and on Sanibel Island, USA (2003).

This year we had 25 submissions, of which 11 were accepted as regular papers and another five as short papers describing tools.

We are grateful to our two invited speakers, Mike Dean from BBN and Christine Golbreich from the University of Rennes. Our thanks also go to all submitters and reviewers without whom the workshop and these proceedings could not have succeeded.

September 2004

Grigoris Antoniou and Harold Boley
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Semantic Web Rules: Covering the Use Cases

Mike Dean

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Abstract. Rules represent the next step for the Semantic Web. A number of use cases for Semantic Web Rules have been formally and informally proposed, including ontology extension, ontology translation, data expansion, portable axiomatic semantics, matching, monitoring, and profile and process descriptions for Semantic Web Services. This talk will describe each of these use cases, provide examples, and assess the degree to which each is addressed by the Semantic Web Rule Language (SWRL) and other current alternatives.

1 Introduction

Following the development of the OWL Web Ontology Language [15], rules represent the next step for the Semantic Web. The Semantic Web Rule Language (SWRL) [11] has recently been acknowledged as a Member Submission by the World Wide Web Consortium (W3C), allowing it to be used as an input to a future Semantic Web Rules Working Group. Several groups [3] [18] are working on representations of first-order logic (FOL) for the Semantic Web. The FORUM Working Group [13] seeks to unify Web rule languages based on F-logic. Several existing Semantic Web tools such as cwm [1] and Jena 2 [12] include their own rule languages.

A number of use cases have been formally [7] and informally proposed for a Semantic Web rule language. The following sections describe each of these use cases, provide examples, and assess the degree to which each is addressed by SWRL and other current alternatives.

2 Ontology Extension

Because of its focus on decidability, there are a number of things that cannot be represented in OWL (Lite, DL, or Full). Many of these involve property chaining, e.g. the ability to express the uncle property as the composition of parent and brother. Another example is the inability to define an InternationalFlight as a Flight involving airports in different countries. These can easily be expressed in SWRL, which sacrifices decidability for expressiveness.

OWL is also limited in its ability to define classes based on datatype values. SWRL with builtins allows us to easily define a class Adult as a Person with age >=

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18, and even to compute age based on a Person's birthDate and some representation of the current date.

3 Ontology Translation

We expect that many different ontologies will be used on the Semantic Web. For example, an automotive ontology used by Ford may represent wheelbase in inches, while a similar ontology used by BMW might use centimeters. Structural differences may also occur. An application that needs to make use of data using multiple ontologies will need to translate some or all of the data into another ontology.

OWL provides some basic mapping primitives, including owl:sameClassAs and owl:samePropertyAs, and owl:sameAs. rdfs:subClassOf and rdfs:subPropertyOf can also be used to express relationships between classes in different ontologies. For more complex mappings, rules can provide a portable representation of mappings whether automatically or manually generated.

[6] relates some experience in using SWRL to translate between different ontologies.

The builtins for arithmetic conversions and other calculations added in SWRL 0.6 are a major step forward in supporting ontology translation, accommodating such functions as unit of measure conversion.

[6] also discusses a current limitation of SWRL is dealing with existentials. Data sets sometimes refer implicitly to individuals that are not explicitly named (e.g. the Company corresponding to a given Stock). In translating to another ontology that makes both individuals explicit, it is helpful to be able to refer to that implicit individual through the use of an existential, a free variable, or other means. In more generative applications (e.g. when creating a visualization for a given data set), one may prefer to think of this as creating a new instance. The Jena 2 rule language includes a makeInstance builtin, and cwm allows the use of bNode existentials in rule heads.

One ontology may represent an aggregation of another (e.g. reporting annual sales vs. quarterly sales). Straightforward aggregation (such as applying XQuery [2] sequence expressions over a collection of statements) is limited by the open world assumption of the Semantic Web, although one can explicitly enumerate the component values to be summed. A related example is defining a class of Pilots with more than a specified number of total flight hours. This doesn't require a closed world, but rather identifying a sufficient number of unique flights and summing their durations. It's currently beyond the capabilities of SWRL and most alternatives.

4 Data Expansion

Rules can be used to expand a compact data representation convenient for generation into an alternative representation more suitable for computation. An example is Subway Maps in OWL [5], which represents each subway Line using an ordered list of Stations. Rules are used to expand this compact representation into a representation where each Station is directly associated with one or more Lines and adjacent Stations.

Rules can similarly be used to specify conditions holding across entire data sets, e.g. dinner is served on all flights of a given airline that are over 2 hours long and depart between 1700 and 1900. The only major limitation here is the inability (due to concerns about non-monotonicity) to treat this as a default that can be over-ridden where necessary by specific instances.

5 Portable Axiomatic Semantics

The axiomatic semantics developed for DAML+OIL [9] provided a valuable resource for tool developers. Without an axiomatic semantics for OWL, developers of tools such as Jena 2 [12] and OWLJessKB [14] have had to develop their own sets of axioms based on the OWL Semantics and Abstract Syntax [16]. A Semantic Web rule language could potentially be used to express an axiomatic semantics for OWL in a machine processible form.

SWRL is limited for this purpose in that it does not allow variables in the predicate position. This would preclude, for example, an axiomatic definition of owl:TransitiveProperty.

On-going proposals for a FOL language would allow the definition of such axiomatic semantics.

6 Matching

Rules can be very effective in identifying matches between different data sets, such as reconciling credit card transactions, expense reports, and reimbursements in [4]. A key requirement here is being able to easily express that an individual has not already been matched, which touches on negation and open world assumptions. SWRL is limited in this regard.

Equivalence in the absence of a unique names assumption is a key issue for Semantic Web rules particularly relevant for matching. Two individuals may in fact be the same (e.g. duplicate credit card transactions). SWRL provides explicit atoms for sameAs and differentFrom, but one would like for this to be handled more automatically.

Matching also motivates the need for user-defined builtin functions. [6] cites the use of a great circle distance calculation as well as functions for parsing textual representations of latitude and longitude.

7 Monitoring

Rules can be very effectively used to watch for conditions in stream of data, alerting a user or triggering some automated response when specified conditions are met.

SWRL currently includes only non-side effecting builtins, which limits the range of response within the standard language. Actions might be performed using user-defined builtins or other mechanisms such as those under development by the reaction rules technical group within the RuleML Initiative [17].

8 Profile and Process Descriptions for Semantic Web Services

Perhaps the most demanding use case for Semantic Web rules has been in the area of Semantic Web Services. This is currently a very active topic of discussion in the Language Committee of the Semantic Web Services Initiative [19].

Simple uses of rules such as ensuring that the credit cards accepted by a service include one held by the client can be handled by SWRL. More complex examples involving non-monotonic defaults and negotiation go beyond SWRL.

Description of service process models to allow automated service composition has been a major motivation for the recent development of FOL RuleML [3].

9 Conclusions

The need for rules in the Semantic Web is well motivated. SWRL represents a significant first step, layered on top of the existing W3C Semantic Web Recommendations, but is currently insufficient to address the full range of use cases. Some have opposed SWRL because its computational complexity is not provably less than first order [8], but a growing number of implementers [6] [10] [20] have found it useful.

Ultimately, we may see several Semantic Web rule languages with different computational and usage characteristics in widespread use. Such proliferation comes at a cost in terms of interoperability and redundancy, and should be justified by real needs.

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Combining Rule and Ontology Reasoners for the Semantic Web

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Abstract. Using rules in conjunction with ontologies is a major challenge for the Semantic Web. We propose a pragmatic approach for reasoning with ontologies and rules, based on the Semantic Web standards and tools currently available. We first achieved an implementation of SWRL, the emerging OWL/RuleML-combining rule standard, using the Protégé OWL plugin. We then developed a Protégé plugin, SWRLJessTab, which enables to compute inferences with the Racer classifier and the Jess inference engine, in order to reason with rules and ontologies, both represented in OWL. A small example, including an OWL ontology and a SWRL rule base, shows that *all* the domain knowledge, i.e. the SWRL rule base *and* the OWL ontology, is required to obtain complete inferences. It illustrates that some reasoning support must be provided to interoperate between SWRL and OWL, not only syntactically and semantically, but also *inferentially*.

1 Introduction

The present challenge for the Web is to evolve towards a Semantic Web (SW) that can provide readable information for both human and machines, and an easier access to heterogeneous data distributed in multiple sites. Ontologies can be considered as playing a key part in the Semantic Web since they provide the vocabulary needed for semantic mark-up. But rules are also required for the Web, and most people now agree that a Web rule language is needed. According to the Semantic Web stack, rules are on the top of ontologies. But in many cases, ontologies alone (resp. rules) are not enough. Using rules *in conjunction* with ontologies is a major challenge for the Semantic Web.
A main motivation of this work is issued from our experience with ontologies in the biomedical domain. Indeed, it turned out that a Web rule language might be very helpful for biomedical ontologies in various situations [9]. For example (1) "standard-rules" are needed for chaining ontologies properties, such as the transfer of properties from parts to wholes, or the dependencies in the brain-cortex [2, 9], (2) "bridging-rules" for reasoning across several domains such as Genomics, Proteonomics, Pathology, when searching for correlations between diseases and the abnormality of a function of a protein coded by a human gene (3) "mapping rules" for mapping Web ontologies in data integration, e.g. for accessing patient data scattered in many

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Hospital Information Systems [12, 11], (4) "querying-rules" for expressing complex queries upon the Web in an ontology vocabulary [11], (5) "meta-rules" for facilitating ontology engineering (acquisition, validation, maintenance) [9, 4] etc.

There are presently two important trends of Semantic Web languages, corresponding respectively to description logic and rule paradigms: the Ontology Web languages OWL and the Rule Markup Language RuleML.

OWL, the Web Ontology Language [1], is the current W3C recommended standard for ontologies. OWL borrows its formal semantics from description logics (DL), a family of knowledge representation formalisms issued from frames and semantic networks. DL use an object oriented modeling paradigm, describing a domain in terms of individuals, concepts, roles. OWL is well suited for the "terminological" part of knowledge, and for representing "structured" knowledge by classes and properties, organized in taxonomies.

RuleML, the Rule Markup Language, is developed by the "Rule Markup Initiative", an international initiative for standardizing inference rules, forward and backward, on the basis of XML, so as to fulfill the various encountered needs of rules: diagnosis rules for engineering, business rules, marked up for e-Commerce, rules for intelligent agents, Web services, etc.

Description Logics and rules, thus OWL and RuleML, are *both* required for the Semantic Web [9]. Indeed, although some knowledge may be represented by either paradigm, and even though DL extensions are possible to overcome some expressiveness limitations, e.g. "role inclusion axioms" for expressing the transfer of properties along another property [17], it should be noted that (1) DL and rules expressiveness are generally different, (2) each paradigm better fits some particular type of knowledge and supports specific reasoning services. On one side, DL are really suited to the "terminological" part of a domain. Most of them, e.g. OWL DL, provide efficient means to reason on it, such as ontology checking, classification, and class recognition of instances. Such services are particularly essential in the biomedical domain where the ontologies are often *huge* (e.g. The Digital Anatomist Foundational Model contains approximately 70,000 concepts and over 110,000 terms; over 1.5 million relations from 168 relationships). But on the other side, rules are useful to represent the "deductive" part of the knowledge. For example, they allow to express the transfer of biomedical properties from parts to wholes, in a more natural way than in introducing inclusions axiom [17] or a specific "AnatomicalLocation" class dedicated to represent spatial anatomical locations in a *subsumption* hierarchy so as to get the desired inferences [11]. Besides, although OWL DL may be well suited to represent and reason with ontologies, and RuleML Datalog to express rules, some applications furthermore need a close integration of the two languages. Several medical examples [9] illustrate that an OWL sublanguage extended by a Web rule language is required.

The recent draft proposal [15] for a Semantic Web Rule Language SWRL[1] combining OWL DL and OWL Lite [1] with the Unary/Binary Datalog RuleML [2] sublanguages, is a first important step in that direction. At the moment, this proposal provides a syntactical and semantical specification of SWRL that extends OWL.

[1] http://www.daml.org/rules/proposal/

Obviously it is not enough; a step further is needed for interoperating between SWRL and OWL, not only syntactically and semantically, but also *inferentially*. In other words, a language for SWRL rules that can make use of the vocabulary of an OWL ontology, is not sufficient. A crucial point is to provide some support to reason in a consistent way with them, that is, a tool that exploits all the knowledge, both of the ontology and of the rule base, to get inferences. But the current draft proposal of the SWRL rule language extending OWL DL axioms so as to include Horn-like rules is not yet completely finished, and at that time no effective implemented reasoner enabling to interoperate between SWRL rules and OWL ontologies, is available. The difficulty is that OWL DL becomes undecidable when extended in this way, as rules can be used to simulate role value maps [18]. Thus, providing reasoning support for a SW rule language still raises theoretical and practical questions. For example, in the DLP approach, a combined logical formalism has been proposed [13], and a prototypical implementation of Description Horn Logic achieved based on a Datalog engine. But as noticed in [16] "DLP is less expressive than either the description logic or the rule language from which it is formed". How reasoning support might be provided for an OWL rules language is still an open issue, and several strategies are possible for it [16]. Some current initiatives, such as HOOLET[2], KAON EXT[3], ROWL[4] are discussed section 6.

The theoretical issue is outside the scope of this paper. Motivated by concrete needs for biomedical ontologies, we investigated a pragmatic approach for reasoning both with ontologies and rules, based on the current or emerging Semantic Web standards OWL, RuleML, and SWRL, and on the tools currently available, Protégé-OWL for editing, RACER and Jess engines for reasoning. Since at that time, the swrl.owl ontology given in the proposal could neither be loaded in Protégé with the OWL plugin[5], nor a fortiori inferentially processed, we first achieved a draft implementation of SWRL in Protégé-OWL. We then developed a prototypical plugin, SWRLJessTab, to bridge between Protégé OWL, RACER [14], and Jess [6] so as to allow reasoning with SWRL rules combined with OWL ontologies. A small example including an OWL ontology representing the usual family relationships, and a SWRL rule base representing their dependencies, has been prepared to illustrate that some reasoning support shall obviously be provided to interoperate between SWRL and OWL, not only syntactically and semantically, but also *inferentially*.

Section 2 briefly introduces the current SW standards, and section 3 the tools we use. Section 4 is devoted to our approach for reasoning with OWL ontologies combined with SWRL rules, based on the available tools. It describes the proposed implementation of SWRL in Protégé OWL and SWRLJessTab, a plugin achieved to bridge between Protégé OWL, RACER, and Jess. Section 5 presents the results of the inferences derived respectively (i) by RACER from the OWL ontology, (ii) next by Jess from the SWRL rules, and (iii) in combining both. Finally, we situate the work among other initiatives and discuss its limitations and perspectives in section 6.

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[2] http://owl.man.ac.uk/hoolet/

[3] http://kaon.semanticweb.org/owl/.

[4] http://mycampus.sadehlab.cs.cmu.edu/public_pages/ROWL/ROWL.html

[5] http://protege.stanford.edu/plugins/owl/

2 SW Current or Emerging Standards

The Web Ontology Language OWL, is the current W3C recommended standard for ontologies. For rules, several languages and standards are proposed, among which SWRL, the RuleML-oriented extension of OWL.

2.1 OWL and RuleML

OWL[6], is a semantic markup language for publishing and sharing ontologies on the World Wide Web. OWL has been developed as a vocabulary extension of RDF (the Resource Description Framework) and is derived from the DAML+OIL Web Ontology Language. The OWL language provides three increasingly expressive sublanguages. OWL Lite is less expressive, OWL DL provides completeness and decidability[7], while OWL Full offers the maximal expressiveness and syntax freedom of RDF, but no computational guarantees. OWL DL semantics enables automatic deduction processes, in particular powerful automatic reasoning, such as ontology checking, classification, and instances retrieval, which are based on basic reasoning tasks including satisfiability, subsumption, instantiation. Powerful reasoning systems were developed for ontologies constrained by the restrictions required for OWL DL, such as RACER (§3).

For rules, several languages and standards have been proposed, corresponding to different needs and efforts. Some of the most popular are the RuleML Rule Markup Language[8] the Java Expert System Shell Jess [6] (§3), and now the emerging standard SWRL [15] (§2.2). The RuleML Initiative[8], initially created as a standards effort for delivering markup language for rules in XML, is more generally concerned with all issues for Rules and Rule Markup Languages for the Semantic Web. Started in 2000, a first public version of XML DTD's was released for several rule flavors in January 2001. Current work on the design of RuleML includes First-Order-Logic (FOL[9]) RuleML, Semantic Web Rule Language (SWRL[1]) RuleML, and OO RuleML[10]. There are now many participating institutions in the RuleML Initiative that are listed on the Website, and over a dozen prototype RuleML tools. Some of the most recent developments about languages, tools and applications for rules on the Web were presented at the Rules on the Web track[11] of the 2004 World Wide Web Conference, such as cwmr rules, a new N3 rules subset, Sweetrules[12], OO jDREW[13], the newest implementation of F-Logic/Flora 3 etc.

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6 http://www.w3.org/TR/owl-ref

7 the OWL DL restrictions are the maximal subset of OWL Full against which current research can assure that a decidable reasoning procedure can exist for an OWL reasoner

8 http://www.ruleml.org/

9 http://www.ruleml.org/fol/

10 http://www.ruleml.org/indoo/indoo.html

11 cf. www2004-devday-report.pdf

12 http://ebusiness.mit.edu/bgrosof/paps/home.html#SweetRules

13 http://www.jdrew.org/jDREWebsite/jDREW.html