A Conformance Test Suite for the OWL 2 RL/RDF Rules Language and the OWL 2 RDF-Based Semantics

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Abstract. We present the first version of a comprehensive conformance test suite for reasoners implementing the OWL 2 RL/RDF rules language and compliant super languages, up to the scale of the OWL 2 RDF-based semantics. The OWL 2 RL/RDF rules language is one of the new specifications of the W3C OWL Working Group, and it is a promising candidate to foster a larger spread of practical reasoning on the Semantic Web. Several groups have now announced to develop reasoners for the language. The test suite consists of more than 700 test cases that have been carefully constructed to check reasoners for valid conclusions. It is meant to indirectly contribute to a wide adoption of the language by supporting reasoner creators to better assure the quality of their product.

1 Introduction

This paper gives an overview of a conformance test suite that we have developed for the OWL 2 RDF-based semantics [1] and several of its sub languages, including the new OWL 2 RL/RDF rules language [2].

The OWL 2 RDF-based semantics is a fully compatible extension of the semantics of RDFS [3] and is applicable to arbitrary RDF graphs [4]. The OWL 2 RL/RDF rules language can handle unrestricted RDF as well, but has a much less complex specification, which is expressed in terms of a set of simple RDF entailment rules. However, implementations are allowed to go beyond the original OWL 2 RL/RDF rules specification and will still be compliant OWL 2 RL reasoners, as long as they are sound w.r.t. the OWL 2 RDF-based semantics [5]. We believe that the simplicity of the basic rule-based language specification on the one hand and the flexibility given by the option to build significantly extended reasoners on the other hand make the OWL 2 RL/RDF rules languages a promising candidate to foster a larger spread of practical reasoning on the Semantic Web. In fact, several groups have now announced to develop reasoners for the language.

Our test suite is intended to help reasoner implementers to ensure the correctness of their reasoning systems. It contains a well defined subset of test cases dedicated to the original OWL 2 RL/RDF rules language. We expect this part

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of the test suite to be particularly useful for reasoners that follow different implementation approaches not being based on the RDF rules, while still wanting to be compliant with the semantics specified by the original rule set. But since the test suite has been constructed for the OWL 2 RDF-based semantics as a whole, it will also be applicable to arbitrarily extended OWL 2 RL reasoners.

There have been conformance test suites for ontology languages in the past, for example the test suite of the original W3C OWL Web Ontology Language [6]. The main contribution of the test suite presented here is that it provides systematic and comprehensive coverage for both the OWL 2 RDF-based semantics and the OWL 2 RL/RDF rules language. Our test suite provides significantly more comprehensive treatment for these two languages than the official W3C OWL 2 test suite [7], in particular regarding datatype support and the part of the OWL 2 RDF-based semantics that goes beyond the OWL 2 RL/RDF rules language.

2 Test Suite Design

The test suite has been designed for reasoners for the following languages: the *OWL 2 RDF-based semantics* [1], the *OWL 2 RL/RDF rules language* [2], the original *OWL RDF-compatible semantics* [8], and all the entailment regimes defined by the RDF semantics specification [3], namely *Simple Entailment*, *RDF*, *RDFS* and *D-Entailment*. Each test case in the test suite indicates all the languages it applies to.

Since the OWL 2 RDF-based semantics is a super language for most [1] of the other languages, the basic design idea has been to closely follow the structure of the OWL 2 RDF-based semantics. A main aspect here are the so called *"semantic conditions"* (see Section 5 of [1]), which include all the normative semantic conditions given in the RDF semantics specification [3]. The general idea has been to have one test case per semantic condition in the test suite.

Typically, an RDF rule in the OWL 2 RL/RDF rules language is closely related to one of the semantic conditions of the OWL 2 RDF-based semantics, which has lead to a pretty seamless integration of the sub suite for the OWL 2 RL/RDF rules language into the whole test suite. For example, the OWL 2 RL/RDF rule that treats property range axioms in RDF graphs is defined in the following way:

if T(?p, `rdfs:range`, ?c) T(?x, ?p, ?y) **then** T(?y, `rdf:type`, ?c) ,

This rule closely corresponds to the RDFS semantic condition for the term `rdfs:range`, as specified in Section 4.1 of the RDF semantics specification [3]. Consequently, the test suite includes only a single test case to cover both the RDFS semantic condition and the OWL 2 RL/RDF rule for `rdfs:range`. This test case has the following form:

[1] Technically, only a (large) fraction of the original OWL RDF-compatible semantics is a proper sub language of the OWL 2 RDF-based semantics; see Section 9 of [1] for a description of the differences between the two languages.

Premise Graph:

```
ex:p rdfs:range ex:c .
ex:x ex:p ex:y .
```

Conclusion Graph:

```
ex:y rdf:type ex:c .
```

The structure of this test case is very similar to the structure of the OWL 2 RL/RDF rule above and the corresponding RDFS semantic condition. For both languages, the "Conclusion Graph" is an entailment of the "Premise Graph" and thus, a reasoner for these languages will be expected to infer the conclusion graph from the premise graph.

A strong similarity between a test case and its corresponding semantic specification is very typical for the test cases of the OWL 2 RL/RDF rules language. However, the semantic conditions of the OWL 2 RDF-based semantics often have the form of *"if-and-only-if"* assertions instead of weaker "if-then" assertions. This is generally reflected by two test cases instead of only one, where the second test case has often been more difficult to construct having a less obvious relationship to its corresponding semantic specification.

Each test case in the test suite has a *test type*, which is exactly one of a *"positive entailment check"*, *"negative entailment check"*, *"consistency check"* and an *"inconsistency check"*. The test case in the above example is a positive entailment check and, indeed, most test cases in the test suite are positive entailment checks or inconsistency checks. There is only a small number of consistency or non-entailment checks, but this situation may change in future versions of the test suite.

A large part of the test suite is dedicated to the *datatypes* and *facets* of OWL 2 [9]. For all datatypes there is a similar set of test cases, such as tests for valid and ill-typed literals, or whether two different literals represent the same or different data values. However, the current test suite only provides rather coarse checking for valid literals, since more detailed checking would have had a strong impact on the size of the test suite. Again, this situation may change in the future.

The test suite further contains a small number of test cases that make sure that reasoners are able to handle arbitrary RDF graphs [4] and internationalized resource identifiers (IRI) [10].

There is also a sub suite of *optional* test cases for language features that have been declared nonnormative in the OWL 2 RDF-based semantics specification. An example is the support for *generalized RDF*, i.e. literals and blank nodes may occur in any position of an RDF triple. Compliant reasoners are not required to succeed on any of these test cases, but the test cases may still be useful to systems that want to implement some of the optional functionality.

In addition, an "extra" sub suite has been created to probe reasoners for typical ramifications of the OWL 2 RDF-based semantics, often resulting from the complex interplay of several language features. For example, there are test cases that demonstrate the meta modeling capabilities of the RDFS semantics and the OWL 2 RL/RDF rules language.

3 Discussion and Outlook

Our conformance test suite consists of 733 test cases, almost 300 of them for the OWL 2 RL/RDF rules language. The test suite can be downloaded freely from [11]. Additional technical information is provided that complements the information presented in this paper.

Manually creating such a large number of conformance test cases has turned out to be a non-trivial and error prone task, forcing us to carefully follow a time-consuming creation and validation process. Nevertheless, we are now pretty confident that at least all the test cases for the OWL 2 RL/RDF rules language are correct, since two independent reasoner implementations have been reported to succeed on all of these tests.

The test suite has already proved its usefulness by detecting several errors in at least one reasoner implementation under development. Also, a fraction of these test cases has been approved by the W3C OWL Working Group as part of its official OWL 2 test suite [7].

Possible extensions of the current test suite include more detailed checking for valid and invalid literals of all the datatypes in OWL 2, and additional test cases for consistency and non-entailment checking. It also seems to be valuable to have more fine-grained testing for those semantic conditions of the OWL 2 RDF-based semantics that extend the OWL 2 RL/RDF rules.

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