WSML2Reasoner - A Comprehensive Reasoning Framework for the Semantic Web

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1 Introduction

The amount of data on the Internet is rapidly growing. Formal languages are used to annotate such data in order to make it machine-understandable; i.e., allow machines to reason about it, to check consistency, to answer queries, or to infer new facts. Essential for this are formalisms that allow for tractable and efficient reasoning algorithms. Particular care is demanded in efficiently responding to the trade-off between expressivity and usefulness.

The updated Web Ontology Language (OWL 2) provides dialects that are restricted in their semantic expressivity for optimizing the reasoning behavior; e.g., the OWL 2 EL or OWL 2 RL profiles. Such dialects are very important to respond to the aforementioned trade-off. Profiles reflect particular requirements and yield purposeful balance between expressivity and computational complexity. The support for dialects is not only given in OWL 2, but also in the Rule Interchange Format (RIF) standards. RIF specifies formalisms for the knowledge exchange between different rule systems. The same applies for the WSML language that provides variants for Description Logics and rule-based reasoning. The goal remains the same, formalisms that are expressive enough to be useful, while exhibiting reasoning characteristics that can scale to the size of the Web. Leveraging this is exactly the objective of the WSML2Reasoner framework.

In Section 2 we present WSML2Reasoner and our reasoners IRIS and Elly. We show how the Datalog engine IRIS is used as reasoner for RIF-BLD, and how the ELP reasoner Elly supports the OWL 2 EL and RL profiles. In Section 3 we provide a short example of what shall be shown, amongst other things, during the demo session, and we conclude with Section 4.[1]

2 Reasoners for the Semantic Web

The WSML2Reasoner framework serves as entry point for all the supported OWL, RIF and WSML reasoning.[2] It is based on a highly modular architecture and combines validation, normalization and transformation algorithms for working with ontology descriptions in WSML. The framework includes two default reasoning engines termed IRIS and Elly, and two libraries, namely RIF4J and

[1] This work is supported by the EU FP7 IPs SOA4All and LarKC.

[2] http://tools.sti2.at/wsml2reasoner/

WSMO4J,[3] that provide the object models for RIF-BLD and WSML, respectively. The third-party OWL API yields the data model for the manipulation of OWL ontologies.[4] It adds the reasoner interface that is implemented by ELLY for supporting OWL 2 EL and RL. Figure 1 depicts the relevant software components of the WSML2Reasoner framework.

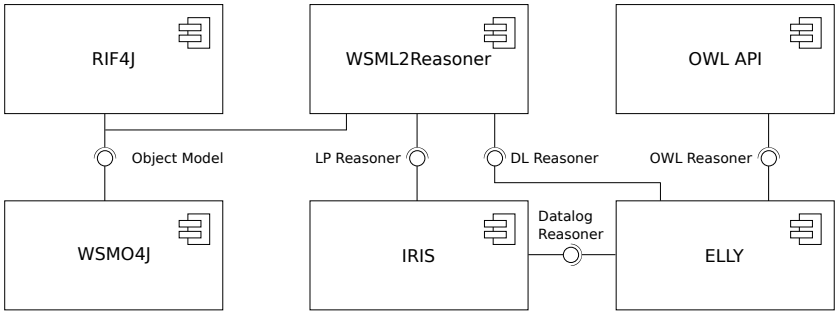

Fig. 1. Reasoner architecture and data model components

2.1 WSML2Reasoner and WSML

WSML is a formal language for the specification of ontologies and the description of Semantic Web services [2]. The latest version WSMLv2.0 provides an alignment of the Logic Programming-based variants WSML-Rule/Flight with RIF, and an updated semantics for the WSML-DL dialect.

Although WSML2Reasoner is designed to support various reasoners, the default release is shipped with IRIS (Section 2.2) and ELLY (Section 2.3). These reasoners offer the most complete support for the semantics of WSML, and include the built-ins defined by RIF-DTB. All together, WSML2Reasoner provides a comprehensive reasoning infrastructure for the WSML language family.

2.2 IRIS and RIF Dialects

The Datalog engine IRIS provides the core for both WSML2Reasoner and ELLY.[5] In fact, IRIS was initially developed with the WSML stack in mind. The integration of RIF4J and WSML2Reasoner — including the translation modules from RIF rule bases to WSML logical expressions — on top of IRIS realizes the targeted RIF reasoner.

The RIF Datatypes and Built-Ins document specifies a list of datatypes, built-in functions and built-in predicates that are expected to be supported by all RIF dialects [7]. IRIS has been updated to support the full range of built-ins with the exception of the list-related ones.

[3] `http://rif4j.sourceforge.net/`; `http://wsmo4j.sourceforge.net/`
[4] `http://owlapi.sourceforge.net`
[5] `http://www.iris-reasoner.org/`

The expressivity of RIF Core corresponds to Datalog, and due to the very nature of IRIS, RIF Core is fully captured. The RIF-BLD profile matches, in terms of expressivity, the language of definite Horn rules with equality and a standard first-order semantics [1]. IRIS was extended to support the full range of language constructs in RIF-BLD, including equality in rule conclusions. RIF Core and RIF-BLD are at the basis of the W3C recommendation on how to interpret combinations of RIF documents and RDF data, as well as RDFS and OWL ontologies [3]. Consequently, IRIS fulfills the main prerequisites for serving as fully-fledged rule-based reasoner for the (Semantic) Web.

2.3 ELLY and the OWL 2 EL and RL Profiles

ELP is a hybrid between Logic Programming and Description Logics (DL) that combines the tractable DLs $\mathcal{EL}^{++}$ and DLP [4]. These two formalisms yield the logical foundation for the OWL 2 profiles EL and RL, which are thus fully captured by the semantics of ELP [5]. Since ELP does not only define the semantics of the language, but also a tractable reasoning algorithm that translates ELP rule bases into Datalog, a corresponding extension to IRIS could be implemented.

ELLY is a reasoner for entailment and satisfiability checking of ELP rule bases.[6] It includes an object model for ELP and a reasoner based on the translation to Datalog [8]; as such, ELLY is implemented on top of IRIS. As ELP subsumes the semantics of OWL 2 EL and RL, ELLY, in integration with the parsers, object models and reasoning interfaces of the OWL API, becomes a fully-fledged OWL 2 EL and RL reasoner.[7]

3 RIF-BLD Application Scenario

To illustrate how the framework can be leveraged to reason with RIF-BLD rules, we present a scenario based on one of the use cases discussed in [6]. The aim of the chosen example "Publishing Rules for Interlinked Metadata" is to enrich Semantic Web data by application of RIF encoded rules. Table 1 extends the scenario, such that it uses movie metadata that is published on DBPedia[8] and combines it with RIF rules to capture implicit knowledge; e.g., categorizing black and white (B/W) movies depending on their release date.

The RIF-BLD reasoner can then be used for entailment checking against or querying over the specified rule base. For the purpose of this demo, there is a user interface made public at `http://iris.sti2.at/reasoners/rif-reasoner/`. For the modeled scenario, the reasoner returns a variable binding to the movies "Primer" and "The Gold Rush" when querying for low-budget movies (`?- ?Movie#ex:LowBudgetMovie`); the latter is also computed to be a B/W movie. Note that the example uses an abridged RIF presentation syntax and omits namespace declarations; the reasoner solely supports RIF-BLD XML Serialization Syntax, a corresponding example is linked from the Web interface.

[6] `http://elly.sourceforge.net/`
[7] ELLY is listed on `http://www.w3.org/2007/OWL/wiki/Implementations`.
[8] see `http://dbpedia.org`

Table 1. Demo Example: Rules for Interlinked Metadata

```
?Movie#ex:BlackWhiteMovie :-
  ?Movie#dbo:Film
  ?Movie[dbp:released -> ?Date]
  External(pred:date-less-than(?Date "1930-01-01"^^xs:date))
?Movie#ex:LowBudgetMovie :-
  ?Movie#dbo:Film
  ?Movie[dbp:budget -> ?Budget]
  External(pred:numeric-less-than(?Budget "5000000"^^xs:float))
ex:pr#dbo:Film ex:pr[
  rdfs:label -> "Primer"^^xs:string
  dbp:released -> "2004-10-08"^^xs:date
  dbp:budget -> "7000.0"^^xs:float]
ex:gr#dbo:Film ex:gr[
  rdfs:label -> "The Gold Rush"^^xs:string
  dbp:released -> "1925-06-26"^^xs:date
  dbp:budget -> "923000.0"^^xs:float]
```

4 Conclusions

WSML2Reasoner, together with the other presented software components, evolved to a comprehensive reasoning framework for the (Semantic) Web. Emphasized in this respect is a strict conformance to existing Web standards, such as RIF, OWL and in our context WSML too.

With this demonstration, we present the current status of WSML2Reasoner, and emphasize on the application of IRIS as RIF-BLD reasoner; not excluding other examples and online demonstrators for Elly and WSML2Reasoner:

- WSML-DL v2.0, `http://iris.sti2.at/reasoners/wsml-dl-reasoner/`
- WSML-Rule v2.0, `http://iris.sti2.at/reasoners/wsml-rule-reasoner/`
- Datalog, `http://www.iris-reasoner.org/demo`

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