

Chapter VI

Rule-Based OWL Reasoning Systems: Implementations, Strengths and Weaknesses

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ABSTRACT

This chapter is focused on the basic principles behind the utilization of rules in order to perform reasoning about the Web Ontology Language (OWL), a Description Logic-based language that is the W3C recommendation for creating and sharing ontologies in the Semantic Web. More precisely, we elaborate on the entailment-based OWL reasoning (EBOR) paradigm, which is based on the utilization of RDF/RDFS and OWL entailment rules that run on a rule engine, applying the formal semantics of the ontology language. To this end, seven EBOR systems are described and compared, analyzing the different approaches. Despite the closed rule environment, which comes in contrast with the open nature of the Semantic Web, and the fact that OWL semantics are partially mapped into rules, the rule-based OWL reasoning paradigm can give great potentials in the Semantic Web, enabling the utilization of rule engines on top of ontology information.

INTRODUCTION

Rule-based systems have been extensively used in several applications and domains, such as e-

commerce, personalization, games, businesses and academia. They offer a simplistic model for knowledge representation for both domain experts and programmers; experts usually find it easier to

express knowledge in a rule-like format and programmers usually find rule-based programming easier to understand and manipulate, decoupling computation from control. The first is performed by the rules whereas the latter is determined by the rule engine itself, that is when and how to apply the rules. In that way, it is more easily to add new rules or data, especially in continuously changing environments.

Nowadays, the Web has been evolved in a large repository of information and has become a useful means of communication and knowledge sharing. However, in order to exploit the Web to its full extent, information should become understandable not only to humans but also to machines. Towards this need, the Semantic Web initiative (W3C, 2008) works on standards, technologies and tools in order to give to the information a well-defined meaning, enabling computers and people to work in better cooperation. It is also worth mentioning the effort to design and build semantic Web services (Paolucci & Sycara, 2003), that are semantically annotated Web services using service description standards based on ontologies (OWL-S, 2004; Roman et al., 2005). Ontologies are considered as a primary key for the Semantic Web since they provide a controlled vocabulary of concepts, each with explicitly defined and machine processable semantics. The Web Ontology Language (OWL) (McGuinness & Harmelen, 2004) is the W3C recommendation for creating and sharing ontologies on the Web. It provides the means for ontology definition and specifies formal semantics on how to derive new information.

There are mainly two modeling paradigms for the Semantic Web. The first paradigm is based on the notion of the Classical Logics, such as the Description Logics (Baader, 2003) on which the OWL is based. In this case, the semantics of OWL ontologies can be handled by DL reasoning systems, such as Pellet (Sirin, Parsia, Grau, Kalyanpur & Katz, 2007), RacerPro (Haarslev & Moller, 2003) and Fact++ (Tsarkov & Horrocks,

2006) that reuse existing DL algorithms, such as tableaux-based algorithms (Baader & Sattler, 2001). The other paradigm is based on the Datalog paradigm. In this case, a subset of the OWL semantics is transformed into rules that are used by a rule engine in order to infer implicit knowledge. There are major differences between these two paradigms, including computational and expressiveness aspects. For example, the DL reasoning engines have a rather inefficient instance reasoning performance, whereas rules are insufficient to model certain situations related to the open nature of the Semantic Web. Obviously, the selection of the most suitable modeling paradigm depends on the domain and the needs of the application.

This chapter is focused mainly on the practical aspects of the implementation of a rule-based OWL reasoning system using OWL entailment rules (Horst, 2005), describing the way a rule engine can be used in order to reason about OWL ontologies. After a short background about the Semantic Web, the OWL language and the basic approaches behind the combination of rules and ontologies, a description of the basic foundations of the EBOR paradigm is given, explaining the way the entailment rules can operate over ontological data in order to apply semantic relationships. Furthermore, the benefits and limitations are discussed between the approach of building a rule-based OWL reasoning system based on a general-purpose rule engine and developing from scratch an OWL-aware rule engine. To this end, seven existing EBOR systems are described and compared that follow different implementation directions.

The chapter presents also the basic arguments of the debate about the suitability of the Classical and the Datalog paradigms for the Semantic Web. Notions such as the open and closed-world semantics, the unique name assumption and the reasoning complexity are addressed for each modeling paradigm, highlighting the basic differences.

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