

Chapter 1.5

A Review of Fuzzy Models for the Semantic Web

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ABSTRACT

In the Semantic Web context, information would be retrieved, processed, shared, reused and aligned in the maximum automatic way possible. Our experience with such applications in the Semantic Web has shown that these are rarely a matter of true or false but rather procedures that require degrees of relatedness, similarity, or ranking. Apart from the wealth of applications that are inherently imprecise, information itself is many times imprecise or vague. In order to be able to represent and reason with such type of information in the Semantic Web, different general approaches for extending semantic web languages with the ability to represent imprecision and uncertainty has been explored. In this chapter, we focus our attention on fuzzy extension approaches which are based on fuzzy set theory. We review

the existing proposals for extending the theoretical counterpart of the semantic web languages, description logics (DLs), and the languages themselves. The following statements will include the expressive power of the fuzzy DLs formalism and its syntax and semantic, knowledge base, the decidability of the tableaux algorithm and its computational complexity etc. Also the fuzzy extension to OWL is discussed in this chapter.

INTRODUCTION

The Semantic Web is an extension of the current web in which the web information can be given well-defined semantic meaning, and thus enabling better cooperation between computers and people. From this point of view, we should find some methods which can describe the semantic mean-

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ing of the web. Fortunately, “ontology” can do this. The core of the Semantic Web is “ontology” which refers to a set of vocabulary to describe the conceptualization of a particular domain. Over the past few years, several ontology definition languages for the Semantic Web have emerged, including RDF(S), OIL, DAML, DAML+OIL, and OWL. Among them, OWL is the newly released standard recommended by W3C. As the Semantic Web expects, OWL has the reasoning nature because description logics (*DLs*) (Baader, 2003) are essentially the theoretical counterpart of OWL and play a crucial role in this context. *DLs* provide a logical reconstruction of object-centric and frame-based knowledge representation languages. It is a subset of first-order logic that provides sound and decidable reasoning support (Baader, 2003).

It is clear that *DLs* play a key role in the Semantic Web. As with traditional crisp logic, any sentence in OWL, being asserted facts, domain knowledge, or reasoning results, must be either true or false and nothing in between. However, most real world domains contain uncertainty knowledge and incomplete or imprecise information that is true only to a certain degree. Ontologies defined by these languages thus cannot quantify the degree of the overlap or inclusion between two concepts, and cannot support reasoning in which only partial information about a concept or individual in the domain can be obtained. Uncertainty becomes more prevalent when more than on ontologies are involved where it is often the case that a concept defined in on ontology can only find partial matches to one or more concepts in another ontology. To overcome the difficulty arising from the crisp logics, existing ontology languages need to be extended to be able to capture uncertainty knowledge about the concepts, properties and instances in the domain and to support reasoning with partial, imprecise information. Along this direction, researchers in the past have attempted to apply different formalisms such as Fuzzy logic (Zadeh, 1965), Rough set theory and

Bayesian probability as well as ad hoc heuristics into ontology definition and reasoning.

In this paper, we review existing proposals to extend semantic web languages with the capability to handle uncertain information to better deal with the situations mentioned above. There are many ways of representing and dealing with uncertainty. In this paper, we restrict our attention to approaches that use fuzzy methods for representing uncertain information. In particular, we will not cover recent proposals for probabilistic extensions of semantic web languages. We will also not discuss non-monotonic and non-standard logics for representing uncertainty. As described above, existing Semantic Web languages are mainly based on logic and do not support representing imprecise and uncertain information. In this paper, we therefore review a number of proposals for extending logical languages with fuzzy extensions in more details. We focused on:

1. Approaches that extend description logics which play as the theoretical counterpart of the semantic web languages.
2. Approaches that directly extend semantic web languages, in particular OWL.

In the first category, we cover fuzzy extensions of description logics which are commonly accepted as being the formal basis of OWL. Even though most approaches only cover logics that are much weaker than OWL, the methods proposed can directly be applied to the corresponding subset of OWL without changes because the description logics play as the theory counterpart of the OWL. When talking about the different approaches, we will survey them according to the expressive power from weaker to stronger. And in the following survey, we should discuss the following issues of the different approaches:

- Expressiveness of the logical language
- The syntax and semantic of the fuzzy extension to description logics

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