f-SWRL: A Fuzzy Extension of SWRL

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Abstract. In an attempt to extend existing knowledge representation systems to deal with the imperfect nature of real world information involved in several applications like multimedia analysis and understanding, the AI community has devoted considerable attention to the representation and management of uncertainty, imprecision and vague knowledge. Moreover, a lot of work has been carried out on the development of reasoning engines that can interpret imprecise knowledge. The need to deal with imperfect and imprecise information is likely to be common in the context of multimedia and the (Semantic) Web. In anticipation of such requirements, this paper presents a proposal for fuzzy extensions of SWRL, which is a rule extension to OWL DL.

1 Introduction

According to widely known proposals for a Semantic Web architecture, Description Logics (DLs)-based ontologies will play a key role in the Semantic Web [5]. This has led to considerable efforts to developing a suitable ontology language, culminating in the design of the OWL Web Ontology Language [2], which is now a W3C recommendation. SWRL (Semantic Web Rule Language) [3] is proposed as a well known Horn clause rules extension to OWL DL.[1]

Experience in using ontologies and rules in applications has shown that in many cases we would like to extend their representational and reasoning capabilities to deal with vague or imprecise knowledge. For example, multimedia applications have highlighted the need to extend representation languages with capabilities which allow for the treatment of the inherent imprecision in multimedia object representation, matching, detection and retrieval. Unfortunately, neither OWL nor SWRL provides such capabilities.

In order to capture imprecision in rules, we propose a fuzzy extension of SWRL, called f-SWRL. In f-SWRL, fuzzy individual axioms can include a specification of the "degree" (a truth value between 0 and 1) of confidence with which one can assert that an individual (resp. pair of individuals) is an instance of a given class (resp. property); and atoms in f-SWRL rules can include a "weight" (a truth value between 0 and 1) that represents the "importance" of the atom in

[1] OWL DL is a key sub-language of OWL.

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a rule. For example, the following fuzzy rule asserts that being healthy is more important than being rich to determine if one is happy:

$$\mathsf{Rich}(?p) * 0.5 \wedge \mathsf{Healthy}(?p) * 0.9 \rightarrow \mathsf{Happy}(?p),$$

where Rich, Healthy and Happy are classes, and 0.5 and 0.9 are the weights for the atoms Rich(?p) and Healthy(?p), respectively. A detailed motivating use case for fuzzy rules can be found in [11].

In this paper, we will present the syntax and semantics of f-SWRL. We will use standard Description Logics [1] notations in the syntax of f-SWRL, while the model-theoretic semantics of f-SWRL is based on the theory of fuzzy sets [14]. To the best of our knowledge, this is the first paper describing a fuzzy extension of the SWRL language.

2 Preliminaries

2.1 SWRL

SWRL is proposed by the Joint US/EU ad hoc Agent Markup Language Committee.[2] It extends OWL DL by introducing *rule axioms*, or simply *rules*, which have the form:

$$\mathsf{antecedent} \rightarrow \mathsf{consequent},$$

where both antecedent and consequent are conjunctions of atoms written $a_1 \wedge \ldots \wedge a_n$. Atoms in rules can be of the form C(x), P(x,y), Q(x,z), sameAs(x,y) or differentFrom(x,y), where C is an OWL DL description, P is an OWL DL *individual-valued* property, Q is an OWL DL *data-valued* property, x,y are either *individual-valued* variables or OWL individuals, and z is either a *data-valued* variable or an OWL data literal. An OWL data literal is either a typed literal or a plain literal; see [2,6] for details. Variables are indicated using the standard convention of prefixing them with a question mark (e.g., $?x$). For example, the following rule asserts that one's parents' brothers are one's uncles:

$$parent(?x, ?p) \wedge brother(?p, ?u) \rightarrow uncle(?x, ?u), \quad (1)$$

where $parent, brother$ and $uncle$ are all *individual-valued* properties.

The reader is referred to [3] for full details of the model-theoretic semantics and abstract syntax of SWRL.

2.2 Fuzzy Sets

While in classical set theory any element belongs or not to a set, in fuzzy set theory [14] this is a matter of degree. More formally, let X be a collection of elements (the universe of discourse) with cardinality m, i.e $X = \{x_1, x_2, \ldots, x_m\}$. A fuzzy subset A of X, is defined by a membership function $\mu_A(x)$, or simply $A(x)$, $x \in X$. This membership function assigns any $x \in X$ to a value between 0

[2] See `http://www.daml.org/committee/` for the members of the Joint Committee.