Fuzzy Ontologies for the Semantic Web

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Abstract. It is presented several connections between Fuzzy Logic, the Semantic Web, and its components (Ontologies, Description Logics). It is then introduced and illustrated by an example ("Ontology of Art") a Fuzzy Ontology structure, Lexicon and Knowledge Base.

1 Introduction: Fuzzy Logic, Semantic Web and Ontologies

The field of Fuzzy Logic has been maturing for forty years. These years have witnessed a tremendous growth in the number and variety of applications, with a real-world impact across a wide variety of domains with humanlike behavior and reasoning. Fuzzy logic is now confronted with a new challenge, namely the vision of the Semantic Web. During recent years, important initiatives have led to reports of connections between Fuzzy Logic and the Internet [11,12]. Scattered papers were published on Fuzzy Logic and the Semantic Web, and a special session was organized during the previous IPMU conference [8]. Then, the first workshop on Fuzzy Logic and the Semantic Web (FLSW) [5] at Marseille was attended by European experts in the field. During BISC-SE 2005 at Berkeley, a panel [4, pp.27-30] discussed recent advances in these combined fields. A recently published volume [13] has shown the positive role Fuzzy Logic, and more generally Soft Computing, can play in the development of the Semantic Web. Finally, the Second Workshop on Fuzzy Logic and the Semantic Web (FLSW-II) will take place during IPMU 2006 at Paris. These are healthy symptoms that indicate, as we believe, that in the coming years, the Semantic Web will be a major field of applications of Fuzzy Logic.

The Semantic Web allows relational knowledge to be embedded as metadata in web pages enabling machines to use ontologies and inference rules in retrieving and manipulating data. *Ontologies* are a key component of the Semantic Web. There are several ways to describe the meaning of concepts (or classes of individuals or categories or types) and relationships between them. Ontologies facilitate a machine processable representation of information. They bridge an effective communication gap between users and machines.

There are many (descriptive) definitions of ontologies, depending also on communities. Basically, they are executable, formal conceptualizations with shared agreement

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between members of a community of interest. They can be viewed as "collections of statements written in a language such as RDF that define the relations between concepts and specify logical rules for reasoning about them. Computers *can understand* the meaning of semantic data on a web page by following links to specified ontologies" [3].

The most typical kind of ontology has a *taxonomy* and a *set of inference rules*. Note that besides the Semantic Web, ontologies have been studied in various domains, for ex. in knowledge engineering, natural language processing, knowledge management, information retrieval, digital libraries, electronic commerce, etc.

There are several types of ontologies, and one may consider, among others:

- *Upper-level (or generic or reference) ontologies.* They describe general concepts, like structure, space, time, state, substance, which are independent of a particular domain.

- *Domain ontologies*. They cover concepts in particular domains and in a *specific way* (for ex. human anatomy or E. coli) or in a *general way* (for ex. organs or gene function). They are the most common and agreed-upon types of ontologies.

- *Task (or application) ontologies.* They express conceptualizations relative to task models (for ex. reasoning processes for medical diagnosis).

Note that in biology, most ontologies are formed by a mixture of these three types.

The construction of an ontology implies the parallel construction of a vocabulary for it. As T. Gruber pointed out in [6], "pragmatically, a common ontology defines the vocabulary with which queries and assertions are exchanged among agents." But most of the information which relates to world knowledge is ill-structured, uncertain and imprecise. What is then needed is a collection of tools drawn from fuzzy logic, for example Zadeh's *PNL* (Precisiated Natural Language) [19,20]. Usually in the Semantic Web, knowledge is assumed to be crisply defined and no uncertainty or imprecision is allowed in the description of objects. The Semantic Web, as presented under *W3C* recommendations [17], deals with hard semantics in the description and manipulation of crisp data, like in "the Huveaune is a river." RDF based languages do not have the ability to represent soft semantics as in "the Huveaune is a *very_small* river." To process this type of information, fuzzy logic concepts and techniques are needed: "the Huveaune is a *very_small* river" can be translated into "length(Huveaune) is *very_ small*." It can then be encoded in RDF format with a triple

< Huveaune , length , very_small >,

where the term "very_small" is assumed to be the label of a fuzzy set *[note: the Huveaune is a 51 km long river that flows into the Mediterranean sea at Marseille]*. It can be considered as a typed literal and an XML schema [18] can be defined to describe its membership function.

2 Fuzzy Ontologies

There has been different approaches to characterize or define *fuzzy ontologies*. In [16] the query refinement *PASS* System (Personalized Abstract Search Services) uses a fuzzy ontology of term associations to suggest alternative queries for searching for