Fuzzy Probabilistic Ontology Approach: A Hybrid Model for Handling Uncertain Knowledge in Ontologies

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ABSTRACT

In spite of the undeniable success of the ontologies, where they have been widely applied successfully to represent the knowledge in lots of real-world problems, they cannot represent and reason with uncertain knowledge which inherently appears in most domains. To cope with this issue, this article presents a new approach for dealing with rich-uncertainty domains. In fact, it is mainly based on integrating hybrid models which combine both fuzzy logic and Bayesian networks. On the other hand, the Fuzzy multi-entity Bayesian network (FzMEBN) proposed as a hybrid model which enhances the classical multi-entity Bayesian network using fuzzy logic, it can be used to represent and reason with probabilistic and vague knowledge simultaneously. Thus, as a language belongs to the proposed approach, this study proposes a promising solution to overcome the weakness of the Probabilistic Ontology Web Language (PR-OWL) based on FzMEBN to allow dealing with vague and probabilistic knowledge in ontologies. The proposed extension is evaluated with a case study in the medical field (diabetes diseases).

KEYWORDS
Fuzzy Logic, FzMEBN, MEBN, Probabilistic Ontology, PR-OWL 2, Semantic Web, Uncertainty

1. INTRODUCTION

The Semantic Web aims to structure the information on the web allowing agents to handle and use it in a more intelligent way. This can be achieved by representing the web content as a semantically structured knowledge in a way that is understandable and process-able by machine. In this context, ontologies provide the key to machine-processable data on the Semantic Web; they have been successfully applied to wide variety domains in order to represent the knowledge, share it and ensure the interoperability between different systems. Nevertheless, a mean limitation of the classical ontologies is that they don’t provide adequate support for handling uncertain knowledge, which characterizes most of the real-world applications. Furthermore, the authors (Fisher et al., 2006; De Runz et al., 2008; Caglioni et al., 2014) mentioned that in ontologies, the uncertainty of information may be attached to two categories of concepts: the category of well-defined concepts which can be handled by the probabilistic approaches (probabilistic knowledge), the second category is about the ill-defined concepts; the uncertainty attached to this class is due to the vagueness or approximation. Thus, fuzzy logic is the appropriate model to deal with vagueness.

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During these recent years, considerable attention has been paid for good representing and reasoning with uncertainty in the Semantic Web area. In addition to that, the World Wide Web Consortium (W3C) created the Uncertainty Reasoning for the World Wide Web Incubator Group (URW3-XG\(^2\)), and defined a top-level ontology (Laskey et al., 2006) that encodes the classes and properties for handling uncertain knowledge in ontologies. It indicates that uncertainty may have several types such as ambiguity, randomness, vagueness, inconsistency, and incompleteness. Also, it represents the mathematical models that can be used to deal with uncertainty in the Semantic Web including Bayesian networks (BNs), Fuzzy logic, hybrid models, etc.

On one hand, probabilistic ontology web language (PR-OWL) was introduced as a candidate solution that belongs to the probabilistic ontologies approach to represent uncertain knowledge based on probabilistic framework. It is one of the most developed work in this area based on multi entity Bayesian networks (MEBNs) to deal with uncertainty due to incompleteness and randomness in the ontology web language (OWL). This model is useful when the concepts are well-defined, but it is unable to deal with vague concepts that may appear in the ontology.

On the other hand, fuzzy multi-entity Bayesian network (Riali et al., 2017) is an enhanced extension that enables classical Multi Entity Bayesian Networks to deal with vagueness based on fuzzy logic. This model is useful to deal with uncertainty due to incompleteness, randomness and takes into account the vague and imprecise knowledge. In other words, it can be used to handle both the ill-defined and the well-defined concepts.

Up to our knowledge, there is currently no formal model to handle the uncertainty that is standardized by the W3C. Nonetheless, based on the ontology proposed by W3C, several extensions have been proposed in the literature in order to deal with uncertainty in ontologies. To this end, most of them are based on mathematical foundations notably BNs and their extensions, fuzzy logic and belief functions. On the other hand, the combination of fuzzy logic and BNs have proved their effectiveness in several domains such as fuzzy Bayesian classification (Moura et al., 2015), risk analytics (Zhang et al., 2016; Ren et al., 2009), recommendation systems (Park et al., 2006), etc. Nevertheless, there is no attention paid to use hybrids models to face the uncertainty in the Semantic Web.

Besides, in most of time, these real-world’s problems involve several kinds of uncertainty at the same time, where the ill-defined concepts and the well-defined concepts appear simultaneously and the probability of an event depends on a fuzzy value (Baldwin et al., 1996). For instance, it is probable that a patient X is cardiac if its blood pressure is high. In this example, the blood pressure is a vague variable and the value high refers to a vague knowledge, the term probable refers to a probabilistic knowledge.

The most important challenges in such situations is to develop models that can take into account the richness of these problems in terms of uncertain knowledge (i.e., take into account the well-defined and the ill-defined concepts). Indeed, to face this real-world problems’ rich-uncertainty, the authors believe strongly that hybrids models must be developed and integrated within the Semantic Web languages. These models should allow going beyond a simple representing and reasoning over uncertainty. To cope with this challenge, this paper presents a promising solution as an extension of PR-OWL 2 (a recent version of PR-OWL) named FUZZy-PR-OWL 2 to deal with vague and imprecise part of knowledge in the probabilistic ontology. The extension proposed in this article is mainly based on the Fuzzy Multi Entity Bayesian Networks, which is a hybrid model that combines the classical MEBN with fuzzy logic. Also, the underlying key of FUZZy-PR-OWL 2 is that it can handle both the ill-defined and the well-defined concepts of the ontology at the same time. Hence it gives the applications of the Semantic Web more flexibility and expressivity for representing and reasoning with the uncertainty and make decisions in their environments.

The main contributions in this paper are summarized as follows:

1. Introducing a novel approach in order to deal with the uncertainty in the Semantic Web that we named Fuzzy probabilistic ontologies (FPO);
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