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Reasoning over decomposing fuzzy description logic

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ABSTRACT

A DF-ALC (Decomposing fuzzy ALC) is proposed in this paper to satisfy the need for representing and reasoning with fuzzy ontologies in the context of semantic Web. A DF-ALC is also proposed to satisfy the need for seeing the necessity of decomposing ontology into several sub-ontologies in order to optimize the fuzzy reasoning process.

The main contribution of this work is to decompose the axioms of the ontology into sub-axioms according to a degree of certainty which is assigned to the fuzzy concepts and roles. It is also to define the syntax and semantics and to propose a local reasoning algorithm and a way of using gateways to infer between local TBox.

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1. Introduction

The consideration of semantics is also essential in the research for information and the evaluation of Web queries. Many works from the Semantic Web community were realized to describe the semantic of applications by building ontologies. Indeed, Semantic Web is very important for the Internet users and researchers on which they give hopes in a lot of fields such as; information search, e-business, Competitive Intelligence, etc., Its functions are to give a meaning to the data, to allow the machines to analyze and to understand the circulating information.

Have a semantic, we must first give a description to information (create meta-data), then trying to link them together through inference and deducing rules to construct ontologies. These are so central to the Semantic Web, which on the one hand, seeks to rely on the modeling of Web resources from conceptual representations of the concerned domain, on the other hand aims to enable programs to make inferences above.

"*Toleration of inconsistency can only be done by fuzzy systems. We need a semantic web which will provide guarantees and about which one can reason with logic*" [1], such are the words of Tim Berners-Lee, founder and President of the World Wide Web Consortium. Where he tries to show us that all these metadata are created by humans, and so they should contain many uncertainties and inaccuracies which will affect the construction of ontologies. Because fuzzy logic was conceived to find solutions to the problems of inaccuracies and uncertainties in a flexible way, researchers have had the idea to integrate this logic in the field of the Semantic Web in

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general and to use it in the construction of ontologies by the logic of description in particular.

Description logics are a good model to describe the semantics of the data from the Web by restrictions, which are necessary to obtain reasoning algorithms that pass in the scale to detect inconsistencies or logical correlations between data or data sources, and to compute the set of answers to conjunctive queries on one hand. On the other hand they are very weak when you want to model a domain whose knowledge and information is vague and imprecise [2]. For this reason there were many proposals to extend description logics by mathematical theories which treat the uncertain and the imprecise. As a result the birth of *fuzzy description logic appears*.

To reflect our objectives, and after the exposure of our motivation, this article is organized as follows: Section 3 gives basic concepts onto the ALC DL and preliminary on the fuzzy DL and distributed DL. Section 4 presents our proposed description logic. Section 5 details the method of reasoning on a fuzzy and decomposed DL; and finally the article ends with a conclusion and perspectives.

2. Motivation

The fuzzy description logic does not look for the precision in the assertions; on the contrary, it looks for the answer of the vague proposals, requiring a certain uncertainty (vagueness). For example, in the classical logic, to the question: "is this person taller?" We can answer only by true, if this is the case or false if not. With fuzzy logic, we can represent cases where the person is very small, medium small, normal, not very tall, tall, etc.

However, the reasoning problems considered on ontologies have often taken a secondary position in the fuzzy knowledge bases, in most cases researchers based their efforts on uncertain knowledge representation method focusing on mathematical concepts and fuzzy sets theories, existing work, dealing with the reasoning in Fuzzy knowledge bases, merely small KB and also without giving any importance to the optimization of the reasoning algorithm.

To arrive at an effective treatment for the fuzzy KB,

we shall opt for the Organization of knowledge in categories of axioms according to certain characteristics that specify a sub domain of the ontology's general domain. The specific categories represent subsets of axioms composed by fuzzy concepts (roles) of the ontology. This structuring will be represented by the distributed description logic, while the reasoning will be parallel on these subcategories of axioms, what will reduce the area of research on the one hand and on the other hand will reduce the relative to the reasoning time on the other hand.

In our contribution also, the axioms may be composed of concepts (roles) that belong to two different categories; the fuzziness will be represented by an annotation related to each concept and each role, and will be treated by the notions of fuzzy sets proposed by Zadeh. We shall note then two types of axioms, axioms intra-categories and inter-categories using the concept of bridge.

3. Preliminary

We start with a brief introduction to classical description logic, fuzzy description logic and distributed description logic, which will be useful for defining decomposing fuzzy description logic.

3.1. *Description logic*

Description logics [3–7] forms a family of knowledge representation languages which can be used to represent knowledge in an application domain in a structured and formal way. A fundamental characteristic of these languages is that they have a formal semantics. Description logics are used for numerous applications.

They have a common basis AL enriched with different extensions: the description logic ALC, object of the present work, adds the negation to AL and thus makes a modal propositional logic extension. Other extensions add the transitive closure of roles, restrictions number on roles and the concept of sub-role, etc.

Description logics use the notion of concept, role and individual. Concepts correspond to classes of individuals and roles are relations between these individuals. Both a concept and a role have a structured description defined from a set of constructors.

In description logics there are two levels of processing:

- Terminological level Tbox: the generic level (global) true in all models and for any individual.
- Assertion Level Abox: Provides instances of concepts and roles.

3.1.1. *Syntax*

NC is a set of concept names and NR is a set of role names. The ALC-concept is constructed by induction using the following grammar:

$C; D ::=$

- A: Atomic Concept
- T: Universal concept Top
- $\perp$: Bottom concept
- $\neg$: Atomic negation
- $C \sqcap D$: Conjunction concepts
- $C \sqcup D$: Disjunction de concepts
- $\forall r.C$: Value restriction
- $\exists r$: Limited exist restriction

where $A \in NC$ and $R \in NR$.

3.1.2. *Semantic*

A semantic is an associated description of the concepts and the roles: the concepts are interpreted like subsets of a domain Δ^I and the roles like subsets of a product $\Delta^I \times \Delta^I$.

An interpretation I is essentially a couple $(\Delta_I, .^I)$ where Δ_I is called an interpretation domain and $(.^I)$ an interpretation function that assigns to a concept C, a subset C^I of Δ_I and a role r a subset r^I of $\Delta_I \times \Delta_I$. In mathematical notation, it is defined as follows:

- $T^I = \Delta_I$
- $\perp^I = \emptyset$
- $\neg C = \Delta_I - C_I$
- $(C \sqcap D)^I = C^I \cap D^I$
- $(\forall r.C)^I = \{x \in \Delta_I / \forall y : (x, y) \in r^I \rightarrow y \in C^I\}$
- $(\exists r.C)^I = \{x \in \Delta_I / \exists y : (x, y) \in r^I \bigwedge y \in C^I\}$.

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