FiRE: A Fuzzy Reasoning Engine for Imprecise Knowledge

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Abstract

Imprecise and vague information is part of our lives. Concepts like "tall", "clever", "fat" and others are imprecise since they can be used with slightly different meaning. Hence, we might use the concept tall to say that Paul is tall and Frank is tall. In this case someone could consider that Paul and Frank have the same height, fact that is not necessarily true. Similar problems occur in many areas such as Semantic Web, multimedia processing, medical informatics, databases and many more. In this paper FiRE -a Fuzzy Reasoning Engine- based on the fuzzy extension of DL language SHIN is presented. Contrary to the existing reasoners, FiRE can deal with imprecise information providing useful inference services.

1 Introduction

The management of imprecise and vague information has gained great attention in knowledge representation and reasoning in the last decade. This interest originated from the several applications of different research domains that include uncertain information which has to be managed appropriately. One example is multimedia processing [6] where concepts like circular, big, small, and others are vague. Many kinds of logical formalism have been extended with uncertainty and imprecise handling frameworks.

Description Logics are a family of class-based (concept-based) knowledge representation formalism, equipped with well defined model theoretic semantics [1]. Their decidability as well as the high performance of the implemented reasoning systems attracted the attention of many research communities. Today DLs are used in numerous applications like the Semantic Web [7], multimedia applications [6], medical applications [4] and many more.

DL languages are considerably expressive but they are limited in their representation of uncertainty and imprecision. For that purpose researchers have proposed possibilistic [3], and fuzzy extensions [9], among others. In this paper FiRE (Fig 1) which is a prototype JAVA implementation of a fuzzy algorithm for an expressive fuzzy DL language f_{KD}-$\mathcal{SHIN}$ [8] is presented. (FiRE can be found at http://www.image.ece.ntua.gr/∼nsimou together with installation instructions and examples). Despite the fact that there are other implementations of many-valued tableaux algorithms [2] , this is the first tableaux implementation for fuzzy logics, i.e. logics where truth values are taken from the interval [0,1]. FiRE allows the user to create a fuzzy knowledge base, based on the description logic Knowledge Representation System Specification (KRSS) which was extended to accommodate the fuzzy element. Furthermore, despite entailment and subsumption, it provides the user with enriched, by the fuzzy element, inferencing procedures .

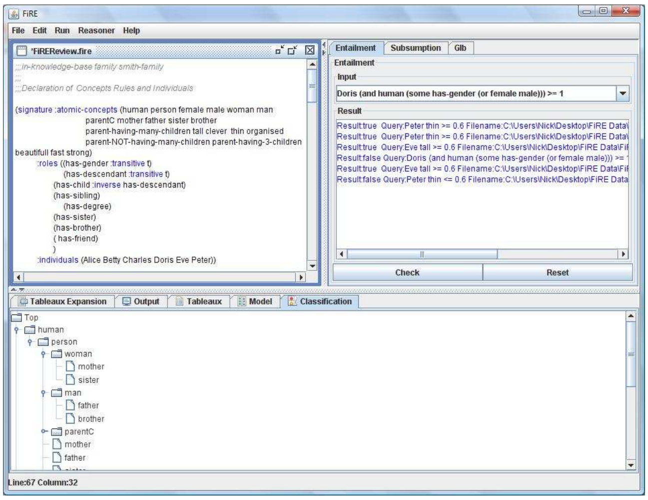

Figure 1. The FiRE user interface

2 f-$\mathcal{SHIN}$ and Reasoning Services

f-$\mathcal{SHIN}$ is a fuzzy extension of DL $\mathcal{SHIN}$ [5]. As pointed out in the fuzzy DL literature [9, 8], fuzzy extensions of DLs involve only the *assertion* of individuals to concepts and the semantics of the new language. Hence, as usual we have an alphabet of distinct concept names ($\mathbf{C}$), role names ($\mathbf{R}$) and individual names ($\mathbf{I}$). Then, f-$\mathcal{SHIN}$-concepts are inductively defined as follows,

1. If $C \in \mathbf{C}$, then C is a f-$\mathcal{SHIN}$-concept,

2. If C and D are concepts, R is a role and $n \in \mathbb{N}$, then $(\neg C)$, $(C \sqcup D)$, $(C \sqcap D)$, $(\forall R.C)$, $(\exists R.C)$, $(\geq nR)$ and $(\leq nR)$ are also f-$\mathcal{SHIN}$-concepts.

Moreover, if R is a role then R^- is also a role, namely the inverse of R. Furthermore, DL concept axioms are of the form $C \equiv D$ or $C \sqsubseteq D$, where C, D are concepts, saying that C is equivalent or a sub-concept of D, respectively. A set of such axioms defines a $TBox$ ($\mathcal{T}$). Additionally, we can have role axioms of the form $\mathsf{Trans}(R)$ saying that R is transitive or $R \sqsubseteq S$ saying that R is a sub-role of S. A set of role axioms defines an $RBox$ ($\mathcal{R}$)

The semantics of fuzzy DLs are provided by a *fuzzy interpretation* [9, 8]. A fuzzy interpretation is a pair $\mathcal{I} = \langle \Delta^{\mathcal{I}}, \cdot^{\mathcal{I}} \rangle$ where the domain $\Delta^{\mathcal{I}}$ is a non-empty set of objects and $\cdot^{\mathcal{I}}$ is a fuzzy interpretation function, which maps an individual name $\mathtt{a}$ to elements of $\mathtt{a}^{\mathcal{I}} \in \Delta^{\mathcal{I}}$ and a concept name A (role name R) to a membership function $\mathsf{A}^{\mathcal{I}} : \Delta^{\mathcal{I}} \rightarrow [0, 1]$

Hence a fuzzy knowledge base Σ is a triple $\langle \mathcal{T}, \mathcal{R}, \mathcal{A} \rangle$, where $\mathcal{T}$ is a fuzzy $TBox$, $\mathcal{R}$ is a fuzzy $RBox$ and $\mathcal{A}$ is a fuzzy $ABox$. $TBox$ and $RBox$ introduce the terminology i.e the vocabulary of the application domain while $ABox$ contains the assertions about named individuals in terms of this vocabulary.

The main reasoning services provided by crisp reasoners are entailment and subsumption. These services are also available by FiRE together with greatest lower bound queries which take the advantage of the fuzzy element. Fuzzy entailment queries ask whether an individual participates in a concept in a specific degree. Subsumption queries on the other hand ask whether a concept is sub-concept of another concept i.e $Head \sqsubseteq PartOfHuman$. Finally, since a fuzzy $ABox$ $\mathcal{A}$ might contain many positive assertions for the same individual (pair of individuals), without forming a contradiction, it is in our interest to compute what is the best lower and upper truth-value bounds of a fuzzy assertion. The concept of *greatest lower bound* of a fuzzy assertion w.r.t. Σ was defined in [9]. Greatest lower bound ask for the degree of participation of an individual in a concept.

3 Future extensions

FiRE is a research software based on the f$_{KD}$-$\mathcal{SHIN}$. Currently support on general concepts inclusion for fuzzy description logics is implemented, to extend its expressiveness. The major disadvantage of FiRE, compared to crisp reasoners, is the lack of performance, due to the increased complexity of f$_{KD}$-$\mathcal{SHIN}$. For that purpose research is being done on optimizations of f$_{KD}$-$\mathcal{SHIN}$ that will improve it's performance and will make it competitive to crisp reasoning engines. Further extensions on FiRE include support of rules and data types.

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