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FUZZY DESCRIPTION LOGIC AND ITS APPLICATIONS

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Abstract. In this paper we will show how Fuzzy logic, has proven its existence and its effective influence in different life areas because of its flexibility, which based on "degrees of truth" rather than the usual "true or false". Then we will shed light on how the Description Logic (DL) can be extended to the Fuzzy Logic. Although Description Logic is suitable for managing structured knowledge, but at the same time the Description Logic is limited in dealing with certain kinds of concepts which they do not have precisely defined criteria of membership, they are vague concepts like (height, weight, illness, happiness,etc.). Fuzzy logic can deal with such kind of vague concepts, besides that the fuzzy logic has been used for many important technologies in life.

Keywords and phrases: Fuzzy logic, description logic.

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1 Introduction. Artificial intelligence has become a fundamental and integral part of our daily lives, and through continuous development by scientists and researchers for the artificial intelligence in an attempt to simulate the human mentality, and thus to think about all the data and concepts in life and try to bring it closer to the computer mindset so that it can be dealt with. And during the trial of the Artificial intelligence community in an attempt to extend existing knowledge representation in this way, they faced many concepts that carry uncertainty and fuzziness [2, 6, 4, 8, 12]. In the last decade a substantial amount of work has been carried out in the context of Description Logics (DLs), provide a logical reconstruction of the so-called frame-based knowledge representation languages.

Description Logic which is suitable for managing structured knowledge. They allow reasoning about individuals and well-defined concepts, i.e. set of individuals with common properties [1]. But Description Logic is limited in dealing with certain kinds of concepts which they do not have precisely defined criteria of membership, they are vague concepts like (height, weight, illness, happiness,etc.).

Fuzzy Logic which based on "degrees of truth" rather than the usual "true or false", can deal with such kind of vague concept, fuzzy logic has been used for many types of services around the world like the most significant application area of fuzzy logic has in control field, Fuzzy control includes (Aerospace, complex aircraft engines, and control surface, fuzzy set modeling of NATO decision making, traffic control, Control of automatic exposure in video cameras, humidity in a clean room, air conditioning systems, washing machine, etc.) as well as in other types like Financial (Banknote transfer control, fund management, etc.), industrial processes (Cement kiln controls heat exchanger control, activated sludge wastewater treatment process control, etc.), Chemical Industry (Control of pH, drying, chemical distillation, etc.), and so on.

The aim of this work is to present a general fuzzyDL, which combines fuzzy logic with Description logic (DL).

In the next lines we will give a brief overview of the preliminaries of Fuzzy logic, then we will extend the Description logic(DL) to the Fuzzy Logic to obtain fuzzyDL. Thereafter we will give a brief overview of the scientists's work through the years for extending the FuzzyDL, then we will give examples of some applications that use fuzzy logic in real life.

2 Preliminaries of fuzzy logic. Fuzzy set theory and fuzzy logic were proposed by Zadeh [17] to manage imprecise and vague knowledge. While in classical set theory elements either belong to a set or not, in fuzzy set theory elements can belong to some degree. More formally, let X be a set of elements. A fuzzy subset A of X, is defined by a membership function $\mu A(x)$, or simply $A(x)$ [5]. This function assigns any $x \in X$ to a value between 0 and 1 that represents the degree in which this element belongs to X. In this new framework the classical set theoretic and logical operations are performed by special mathematical functions. More precisely, fuzzy complement is a unary operation of the form $c\colon [0,1] \to [0,1]$, fuzzy intersection and union are performed by two binary functions of the form $t\colon [0,1] \times [0,1] \to [0,1]$ and $u : [0,1] \times [0,1] \to [0,1]$, called t-norm and t-conorm operations [5], respectively, and fuzzy implication also by a binary function, $J\colon [0,1] \times [0,1] \to [0,1]$. In order to produce meaningfull fuzzy complements, conjunctions, disjunctions and implications, these functions must satisfy certain mathematical properties. For example, the operators must satisfy the following boundary properties, $c(0) = 1$, $c(1) = 0$, $t(1,a) = a$ and $u(0,a) = a$. Due to space limitations we cannot present all the properties that these functions should satisfy [5].

Examples of fuzzy operators are the Lukasiewicz negation, $cL(a) = 1 - a$, t-norm, $tL(a,b) = max(0, a+b-1)$, t-conorm $uL(a,b) = min(1, a+b)$, and implication, $JL(a,b) = min(1, 1-a+b)$, the Gödel norms $tG(a,b) = min(a,b)$, $uG(a,b) = max(a,b)$, and implication $JG(a,b) = b$ if $a > b$, 1 otherwise, and the Kleene-Dienes implication, $JKD(a,b) = max(1-a, b)$.

3 Fuzzy description logic. The main ingredients of DLs are concepts, which denote unary predicates, and roles, which denote binary predicates. Then there are connectives which allow to construct complex concepts. For instance, if we use the concept `Human` to denote the set of humans, and the concept `Male` to denote the set of male objects, the complex concept (conjunction) $\texttt{Human} \sqcap \texttt{Male}$ will denote the set of male humans. On the other hand, if `hasChild` denotes a role then the concept $\texttt{Human} \sqcap \exists\texttt{hasChild}.\texttt{Male}$ will denote the set of humans having a male child [12, 14, 16].

FuzzyDL supports concrete data types such as reals, integers, strings and allows the definition of concepts with explicit representation of fuzzy membership functions. This is implemented by relying on so-called fuzzy data type theory. A fuzzy data type theory $D = (\Delta D, D)$ is such that D assigns to every n-ary data type predicate D an n-ary fuzzy relation over ΔD [7]. For instance, the predicate ≤ 18 may be a unary crisp predicate over the natural numbers denoting the set of integers smaller or equal to 18. Concerning non-crisp fuzzy domain predicates, we recall that in fuzzy set theory and practice, there are many functions for specifying fuzzy set membership degrees.like the trapezoidal function, the triangular function, the L-function (left-shoulder function), and the R-function (right-shoulder function), are simple, but most frequently used to specify membership degrees.

4 Fuzzy logic applications. The most signicant application area of fuzzy logic has been in control eld. A rough guess has been made that 90% of applications are in control.

Aerospace – Altitude control of spacecraft, satellite altitude control, flow and mixture. regulation in aircraft deicing vehicles.

Automotive – Trainable fuzzy systems for idle speed control, shift scheduling method for automatic transmission, intelligent highway systems, traffic control, improving efficiency of automatic transmissions.

Business – Decision-making support systems, personnel evaluation in a large company.

Defense – Underwater target recognition, automatic target recognition of thermal infrared images, naval decision support aids, control of a hypervelocity interceptor, fuzzy set modeling of NATO decision making.

Electronics – Control of automatic exposure in video cameras, humidity in a clean room, air conditioning systems, washing machine timing, microwave ovens, and vacuum cleaners.

Marine – Autopilot for ships, optimal route selection, control of autonomous underwater vehicles, ship steering.

Medical – Diagnostic support system, control of arterial pressure during anesthesia, multivariable control of anesthesia, modeling of neuropathological findings in Alzheimer's patients, radiology diagnoses, fuzzy inference diagnosis of diabetes and prostate cancer.

Mining and Metal Processing – Sinter plant control, decision making in metal forming.

Robotics – Fuzzy control for flexible-link manipulators, robot arm control.

Signal Processing and Telecommunications – Adaptive filter for nonlinear channel equalization control of broadband noise.

Transportation – Automatic underground train operation, train schedule control, railway acceleration, braking, and stopping.

The most famous controller is the subway train controller in Sengai, Japan. Fuzzy system performs better (uses less fuel, drives smoother) when compared with a conventional PID controller. Companies that have fuzzy research are General Electric, Siemens, Nissan, Mitsubishi, Honda, Sharp, Hitachi, Canon, Samsung, Omron, Fuji, McDonnell Douglas, Rockwell, etc.

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