FUZZY LOGIC AND ITS APPLICATION: A BRIEF REVIEW

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Abstract: The goal of this work is to make a brief review on Fuzzy Logic along with its usefulness in several areas such as pattern recognition, control systems, knowledge-based systems, and medical diagnosis. Fuzzy Logic provides support in addressing imprecision, uncertainty, and vagueness etc, to make formalization of human reasoning. Because of its nature, it is widely accepted as a method of imitating the way of decision making in human thinking and natural language.

Keywords: fuzzy set theory; membership functions; fuzzy inference systems; control systems.

1. INTRODUCTION:

Fuzzy set theory was introduced by Lotfi A. Zadeh in the year 1965 and it is an extension of the classical crisp logic (also known as Boolean Logic) into multivariate form. In the conventional logic system, each value is either True or False usually denoted by 1 and 0 [1]. Zadeh first realised the incapability of computer logic to manipulate data representing unclear human ideas [2]. Accordingly in the 1960s, based on based on earlier work on fuzzyset theory he introduced the term Fuzzy Logic incorporating an intermediate valuerepresenting partially true and partially false. Henceforth, the fuzzy logic has been commonly applied in almost all the areas of human knowledge. The paper is structured as follows. In section-2, an outline of fuzzy set theory and associated results are specified. In section-3, the membership functions are discussed concisely and, fuzzy inference systems and fuzzy logic control systems are extended in section-4 and 5. Finally, we wind-up our paper with a brief conclusion in section-6.

2. THE FUZZY SET THEORY

The fuzziness of any given set is described by Fuzzy Logic and this fuzziness is characterized by a membership function that represents the degree of truth (also means the degree of belongingness) in fuzzy logic.

The mathematical notation of a fuzzy set $\bar{A}$ in the universe of discourse X is a set of ordered pairs represented as-

$$\bar{A} = \{(x, \mu_{\bar{A}}(x) \mid x \in X\},$$

Where $\mu_{\bar{A}}(x)$ is the membership function of $\bar{A}$ and the values ranges in the interval [0,1]. [3]

3. TYPES OF MEMBERSHIP FUNCTIONS

Different types of fuzzy sets will be obtained depending on the type of membership functions (MFs).
•Triangular MFs
•Trapezoidal MFs
•Gaussian MFs
•Generalized Bell MFs
•Sigmoidal MFs
Based on the studied literature, the two membership functions commonly used are triangular and gaussian membership functions [4].

The triangular MF is defined by three parameters $\{a, b, c\}$ as follows:

$$\text{triangle}(x; a, b, c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 0, & c \le x \end{cases}$$

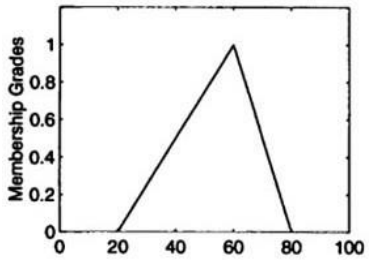

Figure 1. Triangular MF defined by triangle (x; 20, 60, 80)

A Gaussian MF is specified by two parameters :

$$\text{gaussian}\,(x; c, \sigma) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2}$$

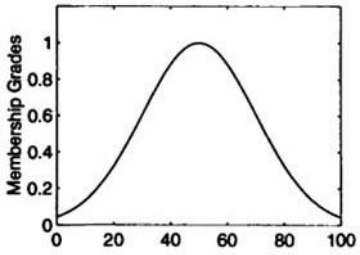

Figure 2. A graph of a Gaussian MF defined by gaussian(x; 50, 20)

4. FUZZY INFERENCE SYSTEM

A system that uses membership function to make a decision is known as FuzzyInference System (FIS)and it is the keyunit of fuzzy logic. It is the process that formulates the output from the mappingof the given input using fuzzy logic [5]. Based on the study, the two main types offuzzy systems implemented are Mamdani-type(1977) and Sugeno-type(1985) [6]. The performance of the four steps of the Mamdani-style fuzzy inference process is as follows :

- Fuzzification of the given input variables
- Rule evaluation
- Aggregation of the rule outputs
- Defuzzification
- **Fuzzification** – the first step takes the inputs and determines the degree of belongingness to each of the appropriate fuzz sets via membership functions.
- **Rule evaluation**- after the inputs are fuzzified, the fuzzy operator (AND or OR) is applied to obtain one number that represents the result of the rule antecedent. The output should be a single truth value.
- **Aggregation of the rule outputs**- here in this process, the outputs of each rules are combined into a single fuzzy set known as the unification process which means that the single output value represents all the inputs.
- **Defuzzification**-this is the last step of the fuzzy inference process and this process is the representation of a fuzzy set with a crisp number. The defuzzification is realized by a decision-making algorithm that selects the best crisp value based on a fuzzy set. One of the forms of defuzzification is the centre of gravity (COG), mathematically represented as:

$$COG=\frac{\int_a^b \mu_A(x)\,.\;x\,dx}{\int_a^b \mu_A(x)\,dx} \quad [7].$$

5. FUZZY LOGIC CONRTOL SYSTEMS

Fuzzy logic is widely used in fuzzy logic control (FLC) and in today's fast-paced world of increasing with innovative new technology. FLC is the most active research area in the application of fuzzy set theory, fuzzy reasoning, and fuzzy logic. Its application extends from industrial control systems to bioinstrumentations and in cyber security systems [8]. In air conditioners, FLC controls the compressor motor speed, fan speed and fin direction [9]. Fuzzy logic air- conditioning control can also be utilized in a living environment especially in houses and workplaces [10]. Using fuzzy logic controls in air conditioners ultimately results in saving energy for efficient energy operation and maintains the room temperature to provide human comfort [11]. Fuzzy logic in washing machines controls the complete washing process. It determines the amount of time for washing, the quantity of water, water temperature and the required amount of detergent to use for washing [12]. The procedures and the rules to materialize this study is made using Fuzzy Logic Toolbox in MATLAB. Carefully implementing the design of the fuzzy logic controller of the inputs has saved a lot of time, electricity, and water for washing clothes [13]. One of the techniques in image processing to identify the boundaries of an object within the image is the edge detection method detection [14]. Most of the traditional edge-detection algorithm results is a considerable loss in edge detection. Nonetheless, there is no such loss in the fuzzy logic-based method according to the studies. Since fuzzy logic helps in dealing with problems which has imprecision and vagueness, it helps in achieving high performance along with simplicity in the resulting model of the digital image processing [15]. Creating a knowledge-based systems, in medicines has been generated using fuzzy logic and fuzzy set theory [16]. One of the applications in the medical area is the diagnosis of renal cancer using fuzzy logic systems. The system is built using the fuzzy inference system where the patient's data is collected for the input (they have used Gaussian membership functions) and then obtain required results and the model has been developed using MATLAB software [17]. Diagnosis of leukemia (a type of cancer in the blood cells) has also been developed by providing a rule-based system which provides accuracy of about 97% [18].

6. CONCLUSION

Fuzzy logic has been proven to be an effective technique in various areas of the real-life situations and problems. In this context, the paper provides the understanding of some of the applications. Fuzzy logic control systems have shown to be useful in consumer products due to its ability to control the machines efficiently. The complexity and high uncertainty in the systems is modeled using fuzzy logic. In an image with so many discontinued points that is too complex and ill-defined to recognize the edge using traditional methods, fuzzy logic provides to be a suitable method to detect the edge (boundary) of the image. Thus, we conclude that fuzzy logic can be a powerful tool to mimic human-like thinking which provides an acceptable reasoning from the list of given decisions and much research is needed in the future as it has portrayed to be an important concept in several applications.

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