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Soft computing - Fuzzy Logic: An overview

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Abstract. Soft computing is an emerging field of computational intelligence, which deals with approximate models & seeks solution to complex problems. It replaces the traditional time-consuming and complex techniques of hard computing with more intelligent processing techniques. Soft Computing is an umbrella term for a collection of computing techniques comprises Fuzzy logic, Artificial Intelligence and Genetic algorithm. Fuzzy logic is the building blocks of soft computing, can deal with information which is, uncertain, imprecise, vague, or partially true.
The broad objective of this paper is to discuss the concept of soft computing by means of Fuzzy logic and to revisit some of its notable applications in the areas like image processing, medical diagnosis and education field.

Keywords: Soft computing, Fuzzy logic, Fuzzy expert system

AMS Mathematics Subject Classification (2010): 03B52

1. Introduction

In real life situations, we come across many problems which we have to solve logically or theoretically. In practice, due to the requirements of huge resources & computational time we failed to address such problems by using traditional way of computation. To deal with such problems, methods motivated by nature, work efficiently & effectively. Although the solutions obtained by these methods are not always mathematically strict solutions rather near optimal solutions is enough in most of the cases. So these types of practical situations can be handled by biologically inspired methods called soft computing. The two major problem-solving techniques include hard computing & soft computing. Hard computing is basically a conventional way of computing with precise models where accurate solutions are obtained quickly, whereas soft computing deals with approximation in models & gives solution to complex problems. Inductive reasoning plays a larger role in soft computing than in hard computing. Soft computing is based on knowledge, common sense, and reasoning and on natural as well as artificial ideas. The

term “Soft computing” was first coined by Zadeh [10], who developed the concept of Fuzzy logic. Soft Computing is the big motivation behind the idea of conceptual intelligence in machines. Soft computing deals with a tolerance of uncertainty, unpredictability, fuzziness approximation, low solution cost and has better rapport with reality. In this paper, we have presented a review on the role of soft computing approach over traditional approach. We have made an attempt to explore the concept of soft computing and revisit its applications of soft computing technique by means of Fuzzy logic. The paper is organized as follows: Section 2, deals with basic concepts of soft computing. In Section 3, we will discuss the aspects of Fuzzy logic & finally in section 4, revisit the Fuzzy logic applications in the areas like image processing, medical diagnosis and education.

2. Soft computing

Soft computing deals with approximate models. The approximate models are categorized into approximate reasoning and functional optimization as well as random search method. The term soft computing was introduced by Zadeh in 1993 [10]. According to Zadeh [10], the guiding principle of soft computing is as follows: “To exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve robustness, low solution cost and better rapport with reality.” The primary goal of soft computing is to follow the human mind or match up the reasoning and thinking behavior of human mind as closely as possible. Soft computing is viewed as a foundation component for the emerging field of computational intelligence. In general, soft computing is a good option for complex systems where: the required information is not available, the behavior is not completely known, and the existence of measure of variable is noisy. Soft computing has been comprised by four technical disciplines. The first two, probabilistic reasoning and fuzzy logic which are based on knowledge-driven reasoning. the other two, neural network and evolutionary computing are data-driven search, is shown in the following Fig. 1.

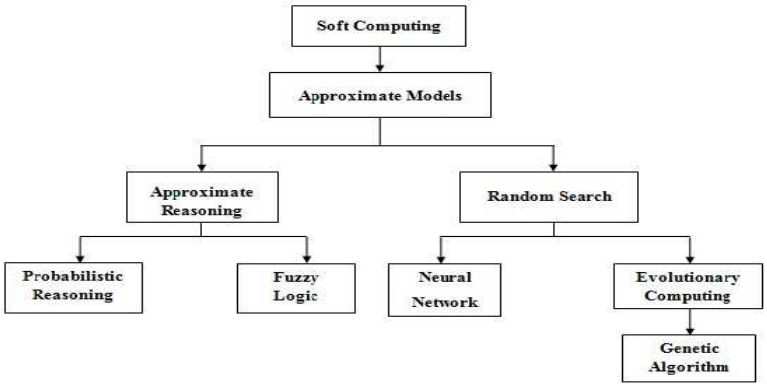

Figure 1: Soft computing

Soft computing is a consortium of computing methodologies that provides a foundation for the conception, design, and deployment of intelligent systems to provide feasible solutions with reduced complexity. Different combinations of techniques from such consortium have provided excellent results for designing intelligent systems; e.g. Fuzzy Logic (FL), Neural Network (NN), Evolutionary Computations (EC) and Probabilistic Reasoning (PR). Each of these techniques has their own strengths and limitations. Integration of two or more techniques can provide significant advantages for intelligent system design. Soft computing plays various roles in the broader perspective in our day to day life like automobile, wireless communication, agriculture and many more. Intelligent vehicle, an upcoming challenging field in the automobile engineering, where soft computing provides the platform for synchronization between the driver and machines. In wireless communication soft computing are used for optimizing network signals with minimum power consumption. With the help of soft computing technique (artificial neural network), it is also possible to distribute different bandwidths and at the same time security is also maintained, which will prevent from cyber attacks. In agricultural field, data management (data mining) and prediction of crops based on soil, fertilizer, and weather condition are more easily dealt with the help of soft computing. For more literature, one can refer to [20, 21, 22]. Fuzzy logic plays a significant role in soft computing, used to mimic the reasoning and decision making of a human. The next section describes the concept of Fuzzy logic & Fuzzy systems, which is used in many applications.

3. Fuzzy logic

Fuzzy logic is an organized method for dealing with imprecise data, generated by fuzzy sets. In a narrow sense, Fuzzy logic refers to a logical system that generalizes classical two- valued logic (or Boolean logic) for reasoning under uncertainty. In a broader perspective, Fuzzy logic refers to all of the theories and technologies that employ Fuzzy sets, which are classes with un sharp boundaries. Fuzzy logic allows intermediate values to be defined between the two aforementioned conventional evaluations. Fuzzy expert systems are based on Fuzzy Logic; a generalization of conventional (Boolean) logic that has been extended to handle the concept of partial truth - truth values between “completely true” and “completely false”. Fuzzy expert system has four components namely, Fuzzifier (or Fuzzification), Inference, Knowledge base and Defuzzifier (or Defuzzification). Fuzzy logic has an appealing way to deal with real world, rather than trying to define how things “really are”. The following Fig.2 represents Block diagram of Fuzzy logic system.

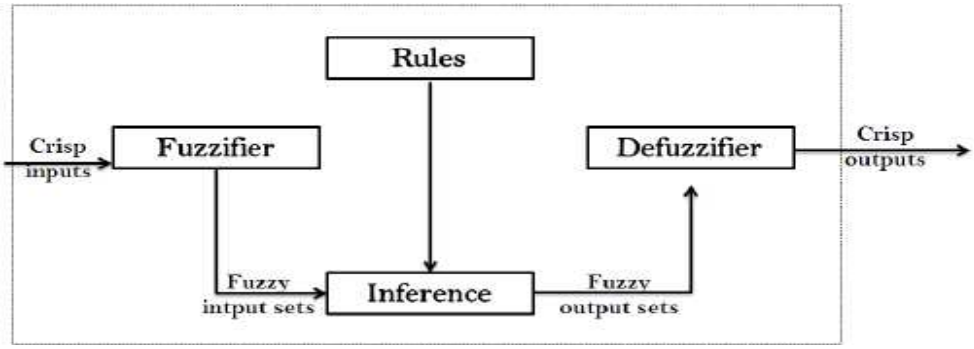

Figure 2: Fuzzy logic

Bart Kosko [1] starts his book, "Fuzzy thinking: the new science of Fuzzy logic" as follows: *"Hold an apple in your hand. Is it an apple? Yes. The object in your hand belongs to the clumps of space-time we call the set of apples – all apples anywhere, ever. Now take a bit, chew it and swallow it. Let your digestive tract take apart the apple's molecules. Is the object in your hand still an apple? Yes or no? Take another bite. Is the new object still an apple? Take another bite, and so on down to void."* Initially the apple is clearly an apple. But as the number of pieces bitten off increases it gradually looses the property of "apple-ness". At the end, when the apple has been completely eaten, it is no longer a member of the class of apples. The basic idea of fuzzy logic is to associate a number with each object indicating the degree to which it belongs to a particular class of objects. Initially, for our apple, this number will be 1 or close to 1. At the end it will be zero, since the apple ceases to exist. In between it will be slowly decreasing. The function that associates a number with the object is called the membership function. In classical set theory, this function is either 1(the objects belongs to the set) or 0 (the object does not belong to the set); it is also called the "characteristic" function. Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based.

4. Review of fuzzy logic applications

Fuzzy logic provides the way to solve complex and non-linear problems easily and effectively. Fuzzy logic has a wide range of applications in the areas such as decision making, control theory, pattern recognition, image processing, health care and so on. We will restrict ourselves to applications of Fuzzy logic pertaining to image processing, medical diagnosis & educational field.

4.1. Image processing

An image refers to a 2D light intensity function $f(X,Y)$ denote spatial coordinates. A digital image is a representation of a two dimensional image as a finite set of digital values called picture elements or pixels. Image processing is a set of computational techniques for analyzing, enhancing, compressing and reconstructing image. Fuzzy

techniques can manage the vagueness and ambiguity efficiently in complex systems. In recent years, the concept of Fuzzy logic has been extended to image processing by Hamid Tizhoosh [7]. The following **Fig.3** represents general structure of Fuzzy Image processing.

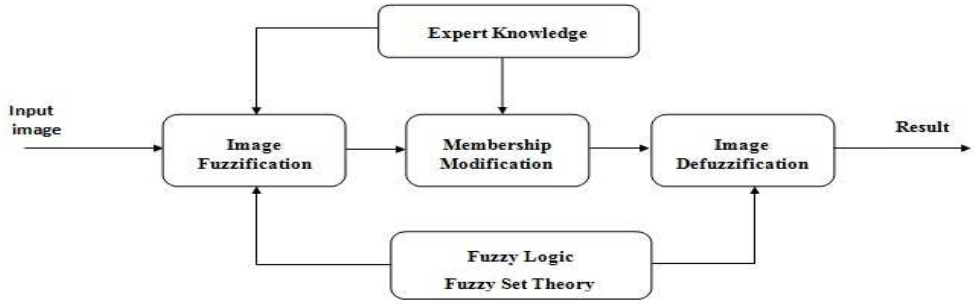

Figure 3: Fuzzy Image processing

Nowadays, the researchers always try to find out the best solutions by using the fuzzy logic to extract the useful information from the given input as an image. In 2011 Bhatia, et al.[4] has introduced one new face detection technique by using two different models. Bhattacharya and Islam[13] proposed image enhancing method based on Fuzzy Image Intensification Operator (FIO). In 2016, Bhagavathi and Niba [12] have discussed the fuzzy logic system which will help in the detection of RBC (Red blood cell count) and WBC (White blood cell count) from blood samples. They used the blood smear image to process it in the MATLAB for further digital processing. In 2018, Pragalath, et al.[8] has used the fuzzy logic-decision making tool with image processing algorithm, which is used for identifying the damaged plane and measure the deterioration for scaling the civil grounds.

4.2. Medical diagnosis

Fuzzy logic is a simple and yet effective technique used for medical diagnosis for a wide range of diseases. It resembles the human decision making which deals with vague and imprecise information. Medical diagnosis is basically a pattern classification phenomena, based on some input (or information) provided by a patient, an expert gives a conclusion on the basis of its knowledge, which is normally stored in a binary form, and finally the result is calculated i.e. either the patient suffering from a certain disease or not. Recently, computational intelligence has been used in several complicated medical issues by developing intelligent systems and fuzzy logic is a strong system for decision making programs. Medical data has ample of imprecision and ambiguity due to which it is difficult to predict the consequences of symptoms at the personal level. Fuzzy logic expert systems used in medical examination are of great importance, providing an exact evaluation report of medical data provided to the system. This type of system provide

an instant and simple method of medical examination and this is also helpful where professional or medical practitioners are not present. Numerous medical diagnosis systems, based on Fuzzy set model have already been developed and applied in treatments and diagnosis. Let us consider the diagnosis of heart disease of the expert physician, which is interpreted in a fuzzy table. We consider three stages (Fuzzy sets) Yes, May be and No as shown in Fig. 4 to represent the certainty level for the presence of disease

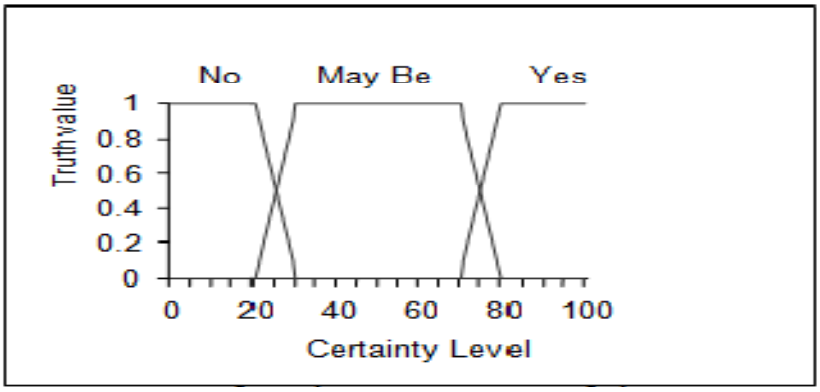

Figure 4: Fuzzy sets for the certainty of disease presence

In 2015, Gayathri, et. al [6] has introduced one Fuzzy expert system to detect the risk of breast cancer. In 2018, Soltani, et al.[15] has introduced one new fuzzy expert system to diagnose the glaucoma disease which can affect the eyes and damage them very badly. A fuzzy logic based classification algorithm, is recommended to govern the patient's conditions like age, race, family history etc. On the basis of these conditions the doctors can take decision about the cause of glaucoma and take some necessary steps for treating the same. The more on applications of medical diagnosis by using Fuzzy matrices and intuitionistic Fuzzy sets can seen in [20, 21].

4.3. Education

The use of Fuzzy logic techniques is very popular to find out the new ways to evaluate the performance and to find out the reasons of low performance of the student as well as faculty member. Students' evaluation is the process of determining the performance levels of individual student in learning objectives which certifies, supports and improves individual achievement. In order to ensure fair evaluation, the system should regularly be reviewed and improved for fair, impartial and beneficial to all students. During the last two decades, Fuzzy logic has been successfully used in working with numerous practical applications. The most well known and popular work is the combination of Fuzzy logic and expert systems. Biswas (1995) [2] presented two methods for evaluating students' answer script by using Fuzzy sets & a matching function; a Fuzzy evaluation method and a generalized Fuzzy evaluation method. Chen and Lee (1999) [5] suggested two methods

for applying Fuzzy sets to overcome the problem of rewarding two different Fuzzy marks for the same total score which could result from Biswas' method. Law (1996) [11] proposed a Fuzzy structure model for an educational grading system with its algorithm aimed at aggregating different test scores in order to produce a single score for an individual student. He also suggested a method to build the Membership functions of several linguistic values with different weights. Wang and Chen (2008) [17] presented a method for evaluating students' answer script by using Fuzzy numbers associated with degrees of confidence of the evaluator. Ibrahim and Kim (2009) [16] proposed a three node Fuzzy logic approach based on Mamdani's Fuzzy inference engine and centre of gravity (COG) defuzzification technique.

Performance appraisal system is used by most of the institutions (or organizations) to evaluate the teacher's performance, which involves crisp and uncertain data. To evaluate the teacher's performance in educational institutions, there are several sub criterions which can contribute on performance evaluation in the form of linguistic terms. Fuzzy expert system on the basis on multi inputs, plays a vital role in performance evaluation [16]. The complexity in deciding the best teacher on the basis of his overall performance considering multi input variables in uncertain situations, the fuzzy logic model can provide the realistic results.

5. Conclusion

Soft computing, as opposed to traditional computing, deals with approximate models and gives optimal solutions to complex real-life problems. Fuzzy logic, the Principal component of a soft computing, is a useful tool to implement key concepts such as control regulation, adaptation, communication and organization. Fuzzy expert systems have recognized to be useful in the medical diagnosis as well as image processing for the quantitative and qualitative analysis. Students' and teachers' academic performance can be evaluated fairly with the help of Fuzzy expert system, dealing with linguistic variables.

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