Application of Fuzzy Logic: A Review

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Abstract - *Fuzzy Logic is an extremely vital role in the arena of computer science, Artificial Intelligence, control theory and mathematic. Fuzzy logic is the way of organizing belief or idea that cannot be defined precisely but which depends upon their contexts – the human way of thinking, reasoning, and perception. Fuzzy Logic finds widespread use in businesses, medicinal sciences, engineering, behavioral sciences, etc. due to perpetually growing complexities in these systems which have uncertainty, vagueness, imprecision, as its central part. This paper offers the idea of fuzzy logic and its uses in various branches. The proposal of fuzzy set theory especially the Fuzzy Inference System (FIS) has led to an outburst of its application in diversified fields. This review denotes the usage of fuzzy logic approach in soil science, operations research, agriculture, machining, chemical science, medical science, in environmental science, traffic engineering and household.*

*Key Words***:** *Fuzzy Inference System,* fuzzy logic, fuzzy logic application, fuzzy system.

1. Introduction

Employing fuzzy logic has brought in great changes. The introduction of fuzzy logic has made many things simpler and this has helped in saving time, cost and energy. The fuzzy logic is one of these techniques which is broadly used in today's intelligent problem-solving system and applications. Before going to fuzzy logic first we have to know what is fuzzy. Webster's dictionary defines "fuzzy" as not clear, distinct, or precise; blurred. In a wide sense, fuzzy logic denotes fuzzy sets that are sets with blurred boundaries[1]. Fuzzy logic was initiated in 1965 [2] by Lotfi A. Zadeh, professor for computer science at California University in Berkeley and it becomes a mathematical tool for dealing with uncertainty.

Fuzzy is extensively accepted as a subdivision of contemporary mathematics when equated with old-fashioned mathematics although it has its history just over 40 years Zimmermann 2001. Its beginning can be found back when Zadeh 1965 wrote a seminal paper in1965 in which he familiarized fuzzy sets with unsharp boundaries. These sets generally agree better with the human mind because they employ shades of gray and not just white or black. Fuzzy sets classically have the ability to represent linguistic terms, for example, low, high, and hot, warm. Before Zadeh tremendous hard work was done in this domain by most of the researchers like Lukasiewicz, Hegel, Plato, Marx, etc. Some of them introduced three-valued logic and while few of them gave four-valued or five valued logic, which is the extension of Boolean logic, which takes only two values true or false (0 or 1). Fuzzy logic is a method of many-valued logic; in this way, it deals with approximate reasoning instead of being

fixed and exact. Equated to old-style binary sets (in which variables used to adopt true or false values), fuzzy logic variables can adopt a truth value that ranges between 1 and 0. Fuzzy logic is a means to make use of natural language in logic. Expert systems, fuzzy controllers, pattern recognition, databases and information retrieval, decision making are the applications of fuzzy logic. This paper offers the notion of fuzzy logic and a brief assessment of its uses in various fields. This study signifies that how fuzzy logic is useful in various fields and how its application makes concepts easier.

2. Concept of Fuzzy logic

Fuzzy Logic – FL is used for solving uncertainties in a given problem. E.g. consider the condition "drive slowly". When we hear about it, we can understand what it means. But for the computer it does not have knowledge about which is slow speed, 10 km/h or 15 km/h or 25 km/ h. and if we give a limit as the slowest speed e.g. 20km/h is speed limit. More than this speed considered as fast. But if 20km/h is speed limit, is 20.1 km/h is fast or 19.9 is slow. Fuzzy Logic (FL) is used to figure out these uncertainties for the computer system.

Fuzzy inference systems (FIS), which are also called fuzzy models, are the nonlinear black-box models that state the relationship between the output and the inputs of a real-time system by employing a set of fuzzy rules known as IF-THEN rules. The inner operation of FIS requires the use of the inference rules of fuzzy logic[3]. FIS provides flexible solutions. An important advantage of FIS over traditional black-box modeling styles is their capability to infer the behavior of complex systems purely from data, without prior specification of a functional structure.

The functioning of FIS is more transparent. Because the structure of fuzzy rules can be pulled out from the knowledge available about the real system, they can provide a formal representation with a more readily physical interpretation.

3. FOUNDATIONS OF FUZZY LOGIC

3.1 FUZZY SETS

Fuzzy sets, on the other hand, allow elements to be incomplete in a set. Each element is assigned a membership degree in every set. This membership function ranges range from 1 (which means it is a member of a set) or 0 (means that it is not an element of the set). Hence it is sure that if one only allowed the extreme values of 1 and 0, then this would essentially be correspondent to crisp sets. A membership function is stated as the relationship between the membership degree and the values of an element in a set. It has a graphical portrayal that expresses how the transition takes place from one to another. This graphical explanation

is referred to as a membership function. Membership functions are used to describe the situation graphically. Fuzzy logic transacts with a degree of membership and degree of truth. There are various types of membership functions used in fuzzy logic. Most used once are triangle, Gaussian and trapezoid membership functions

3.2 LINGUISTIC VARIABLES:

A fuzzy set can be used to describe the value of the variable. A linguistic variable is "that kind of variable whose value is sentence or word in artificial or natural language". Linguistic variables are used to represent qualities that spread over a distinct spectrum. Each linguistic variable can be assigned one or multiple linguistic values.

3.3 FUZZY INFERENCE SYSTEM

The fuzzy logic system can be referred to as a system that maps an input set of data into scalar output data. Fuzzy inference is the process of mapping a given input into an output using fuzzy.

Fuzzy inference happens to be computer exemplar-based on fuzzy if-then- rules, fuzzy theory, and fuzzy reasoning. Fuzzy logic is executed with three stages: (1)Fuzzifier, (2) Inference(Rule Definition), (3)Defuzzifier

(1)Fuzzifier: It makes use of the membership functions that are stored in the fuzzy knowledge base to transforms the crisp input into a linguistic variable. This process is called fuzzification.

(2) Inference: Uses If-Then type fuzzy rules to convert the input to the fuzzy.

(3)Defuzzifier: Converts the output of the inference engine into crisp by making use of membership functions similar to the ones used by the Fuzzifier.

4. Application of Fuzzy Logic

This paper assesses a few areas which have seen fuzzy logic being implemented positively. The narration of some of them is as follows:

4.1 In chemical science

Fuzzy logic has been applied in chemical science. Hayward and Davidson [4] considered numerous examples which made use of fuzzy logic. Almardy's study made use of a fuzzy control system which helped in applying current to anodes connected in series which was done so that a lengthy buried pipeline gets protected and also minimized power requirements to safeguard the pipeline [4]. The study showed that for this he set up a126 rules fuzzy control system and ensured the output by adjusting the output membership functions. Adroer et al found out the fuzzy error, which was the variance between the actual and desired pH, in the control of flowing discarded waterpH[4]. His techniques found that for acceptable pH control, a little

mixer can be provided which has less residence time. Hence the study showed that fuzzy logic has a huge contribution to chemical science.

4.2 In Healthcare Industry

Fuzzy logic is being used extensively in the healthcare industry. Biomedicine is looked upon as a branch of science but more than science, it is an art. Because it uses human knowledge, experience and skills to treat and diagnose diseases. Biomedical systems are intrinsically nonlinear, time-varying and have a delay in time. In 1980, in the case of open-heart patients, to regulate the blood pressure of patients a real-time drug distribution method controlled with the help of fuzzy logic has been developed. The study of Hayward and Davidson [4] presented again that Warren et al presented a decision support system that automated the use of clinical practice guiding principle that is based on the fuzzy logic method. The study showed that the test results produced likely estimates instead of confirmation of absence or presence of disease and in the fuzzy method, likely guesstimates can be handled with the aid of membership values and used as such in the interpretation model. Hence the study demonstrates that the fuzzy logic has contributed greatly to the health industry.

4.3 In Agriculture

N. Ganesanand Philomine Roseline T [5] studied the uses of fuzzy logic in agriculture. The paper characterizes employing fuzzy logic in weed management, disease management, and pest management and to develop a professional system for several crops and to scrutinize and study soil. The paper "Design and development of Fuzzy Expert System for Integrated Disease management in Finger Millets" identified syndromes as moderately resistant, highly resistant, immune, resistant, highly susceptible and susceptible. The professional system uses defuzzification and fuzzification process which is traditionally done only by experienced farmers or agricultural scholars. The paper "Integrated pest management system using the fuzzy expert system" showed fuzzy logic approach-based on three inputs on pests like damages to pests, dimensions of pests, number of pests. A fuzzy-based system "Development and design of the professional system for potato crop" studied the condition of soil development with fuzzy membership function. Thus the study presented that the fuzzy logic approach had an immense contribution to agriculture.

4.4 In soil science

Many models in soil studies are interdisciplinary, requiring mathematical models that are built in the hard sciences and which are then linked with connections and subjective rule-based models used in the less exact or soft sciences. The resulting complex models are often difficult to interpret and may not possibly reflect the soil or soil processes of the real world. In soil science, the fuzzy set theory is prominently used for classification. The purpose of classification is to ease

a complicated system, represented with the aid of some sets of data, into explicitly defined classes. In soil science, we often hear of classification such as 'very deep soil', 'deep soil' or 'shallow soil'. Thus study shows that soil classification can be done using fuzzy logic.

4.5 In Traffic Engineering

In the-condensed traffic, with the growing number of cars, it requires regularly progressing and more intricate explanation of the traffic situation that includes traffic signal control. The controlling and monitoring of traffic in the city is a crucial task due to the capability to handle control of roads. There have been numerous studies [6, 7] focusing on various approaches to predicting and modeling traffic behavior. The fuzzy logic control system provides an improved solution than conservative traffic-dependent control. For instance, humans would think in the following way to control traffic condition at a junction: "if the traffic is dense on the northern or southern lanes and the traffic on the western or eastern lanes is lesser, then at such a situation the traffic lights must remain green for a longer time for northern and southern lanes." Such necessity can now be simply put up in the fuzzy logic controller.

4.6 In petroleum exploration, production

Petroleum production and exploration business prosper with in-depth understanding and knowledge of the subsurface. Technological advancement has aided in providing the industry with a lot of information about the petroleum reservoir; though, a lot of uncertainties are still present as of the nature of the subsurface. The industry has attempted to report this problem in diverse ways; unfortunately, the classical methods have failed to provide proper guidance to management decisions in making use of these reservoirs. The application of fuzzy logic comes across various extents of engineering. Decision-makers solve problems on a day-to-day basis with the aid of quantitative information obtained. Therefore, solving real-life and industrial problems requires quantitative information. Fuzzy logic aids to guarantee quality and precision avoids uncertainty and inconsistency. Additional areas where fuzzy logic is being used largely in this domain are simulation treatment, completion, and drilling, and reservoir characterization.

4.7 In Household

These days, a lot of home-use appliances are being upgraded with the aid of fuzzy logic to save money and time. Fuzzy logic is used in a lot of appliances like an air conditioner, vacuum cleaner, washing machine, etc. Tiryaki and Kazan's dishwasher which made used fuzzy logic and Alhanjouri and Alhaddad's optimized wash time of washing machine using fuzzy logic are the important studies that are based on the fuzzy logic. After which many researchers have worked on this so that they can achieve reduced wash time and the reduced consumption of water and time. The paper

"Washing machine using fuzzy logic" [8] shows the use of fuzzy logic for the washing machine. The study represents that four input variables and five output variables are set up together with eighty-one rules to define the relationship among these variables. Some other researchers made use of sensors in washing machines for linguistic inputs that are mass of clothes, dirt type, clothes type, etc. These control the linguistic output that is rinse time, spin time, wash time, etc. The study showed fuzzy logic being used in air coolers and air conditioners also. The paper "Application of Fuzzy Logic in Daily Life" [2] shows that the design of the room cooler might have multiple inputs and output variables. The paper measured dual input variables: humidity and temperature and three output variables: cooler fan speed, exhaust fan speed, and water pump speed. By making use of this, fuzzy logic was employed to get the optimum result. Hence fuzzy logic has a tremendous contribution to the household too.

4.8 In Operations Research

In operations research, we talk about the problems which are related to optimization. Operations research proves helpful in maximizing profit and in minimizing the cost of production or transportation cost etc. Fuzzy logic can be useful in operations research too. By using the fuzzy logic cost of transportation can be minimize. Mamdani and Pappis (1977) [2] have used fuzzy logic in operation research effectively. The study shows fuzzy logic to the governor a juncture of two one way streets. Kalie and Teodorovic(1996) used fuzzy logic to decide the transportation mode so that travel cost and time gets minimized [2]. Thus fuzzy logic has prodigious influence towards operations research.

4.9 In Environment Science

Fuzzy logic finds its application in Environment science too. It has been effectively used in detecting natural tragedies like a flood, earthquakes, etc. A review of the paper "Prediction of flood detection system Fuzzy logic approach" [8] showed that the fuzzy logic model developed with the help of If-Then rules for predicting flood detection based on Mamdani approach is tremendously useful. In this paper water level and climate conditions are used as input and control action is used as output and a total of twenty-five rules are set up for the process of prediction of the flood. Due to fuzzy logic now it is possible to make vehicles safer, better, and efficient to save the climate. Thus fuzzy logic has tremendous inputs in environment science too.

4.10 In Machining

Researchers have attempted to apply methods of the fuzzy system in various areas of application. One of them is to optimize machining by applying a fuzzy system. The execution of the fuzzy system substantiated to be largely useful in case of highly complex or very nonlinear processes, in the absence of any simple mathematical model or which the needed for processing by expert's knowledge. Machining data play a vital role in the effective consumption of machine

tools and thus meaningfully impacts the overall costs of manufacturing. Execution of a fuzzy logic model to be used for the metal cutting operation to advance a computerized database of machining systems that could be a great help to the process planner for the establishment of the strategy for selecting machining data for a specific machining process.

5. Conclusion

Fuzzy logic is a further version of Boolean logic or binary that is two-valued logic. In uses mainly three steps. They are fuzzification, inference system, and defuzzification. It can be easily taught by using fuzzified educational methods. So it is appropriate to use multi-valued fuzzy logic rather than two-valued logic. In General, the employing fuzzy logic may prove to be helpful, for very complex processes, when there does not exist a simple mathematical model. This paper presents a brief outline of fuzzy logic and its applications in different fields. Very less is covered and more are there, which means this paper presents just an overview of fuzzy logic and its applications. But it has a lot of applications that have been discovered and are realized these days. A lot are left that are to be discovered still. The paper reviews the fuzzy logic concept and its application in chemical science, in the healthcare industry, in agriculture, in environmental science. Consequently fuzzy logic has become a helping hand not only in mathematics but in many other branches also.

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