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An Overview of Fuzzy Logic Applications

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Abstract:*Fuzzy logic has become a very promising mathematical approach that is based near the human thinking and natural activities. In a classical logic system an object either is or is not a member of a set but a member in a fuzzy set has degree of membership to a set. It uses very descriptive language to deal with input data more like a human operator that involves all intermediate values 1(YES) and 0(NO). It can be used in software, hardware or in combination of both. It provides an ultimate mechanism of communication between human and computing environment. This paper gives glance of wide range of its applications such as: computers, medicine, ACs, bioinformatics, etc.*

Keywords: *fuzzy logic, fuzzy patches, applications, medicine, ACs, washing machines, ATM Networks, bioinformatics, transportation, computers.*

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I. Introduction

The idea behind fuzzy logic has been around since 1965 which was introduced by Lofti A. Zadeh. Over these years, interest in the field has grown exponentially bringing some new theoretical advances and many practical applications of the fuzzy mathematical tools.

In classical logical system, an object either is or is not a member of a set. It gives the idea that members are not restricted to be true or false definitions. A member in a fuzzy set has a degree of membership to a set. With fuzzy logic, propositions can be represented with degree of truthfulness and falsehood. For example, the statement, today is sunny, might be 100% true if there are no clouds, 80% true if there are a few clouds, 50% true if it's hazy and 0% true if it rains all day. The function that determines this degree is called fuzzy membership function. Number of different membership functions can be used for this purpose. The most common are triangular, Gaussian and sigmoid.

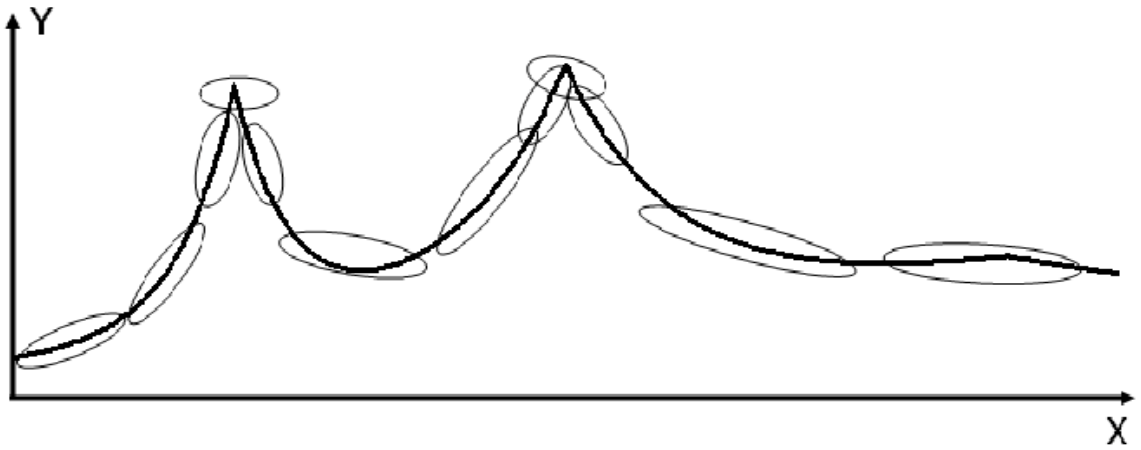
Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, imprecise, partially true or missing input information. It manipulates such vague concepts as 'warm' or 'still dirty' which helps engineers to build air conditioners, washing machines and many other devices that judge how fast they should operate or shift from one setting to another even when criteria for making those changes are hard to define.

HOW FUZZY LOGIC SYSTEM WORKS?

Human beings make decisions based on rules. The decisions humans make are all based on 'if-then' statements. For instance, if the weather is fine, then they may decide to go out. If the forecast says the weather will be bad today, but fine tomorrow, then they make a decision not to go today, and postpone it till tomorrow. Rules associate ideas and relate one event to another.

Fuzzy machines, which always tend to mimic the behavior of man, work the same way. However, the decision and the means of choosing that decision are replaced by fuzzy sets and the rules are replaced by fuzzy rules. Fuzzy rules also operate using a series of if-then statements that convert input to output, one

fuzzy set into another. To build a fuzzy system an engineer might even begin with a set of fuzzy rules from an expert. An engineer might define the degree of membership in various fuzzy input and output sets of curves. The relation between the input and output sets could then be plotted. Given the rule 'if the air feels cool, then set the motor to slow', the input should be listed along one axis of a graph and the output (motor speed) along second axis. The product of these fuzzy sets forms a fuzzy patch; an area that represents the set of all associations that the rule forms between inputs and outputs. So, fuzzy rules define fuzzy patches, which is the key idea in fuzzy logic. A machine is made smarter using a concept designed by Bart Kosko called the Fuzzy Approximation Theorem (FAT). The FAT theorem generally states a finite number of patches can cover a curve as seen in the figure below. If the patches are large, then the rules are sloppy. If the patches are small then the rules are fine.



Fuzzy Patches

APPLICATIONS OF FUZZY LOGIC:

Fuzzy logic in Medicine

One of the areas of greatest concern to humans is certainly their health, thus we are always constantly striving to improve performance in this area and develop and invent new techniques to make the applications of this field even more accurate and more effective. An essential element of the medical profession is making numerous decisions. In this process doctors rely on gained knowledge and experience. When a doctor diagnosis diseases, he has to face several levels of uncertainty and imprecision. A single disease may manifest itself quite differently, depending on the patient and with different intensities. One symptom may correspond to many diseases. One patient may have many diseases and all symptoms taken together can correspond to one of a disease. So, it seems necessary for them to have the ability to think logically, to use reasoning, to infer, to precisely and clearly express their thoughts and justify the assertions made. Even when their actions are based on certain algorithms or standards, they have to logically model the situation. Lack of knowledge concerning the rules of logic can lead to dangerous errors and may result in continuous failures in performance flowing from faulty reasoning processes. To deal with imprecision and uncertainty, we use Fuzzy Logic. Fuzzy logic offers partial truth values between true and false. Classical logic gives two values to a statement true-false, black-white, 1-0. But in real, things are not either black or white. As in most of the cases it is convenient to consider intermediate logical values, so use of fuzzy logic is more appropriate. We consider a simple example. As we know being healthy and ill are mutually exclusive and complement each other.

If h represents degree of being healthy and i represents degree of being ill then h+i=1. If you are totally healthy then h=1, i=0. But in general as we all have some minor health issues so h<1 and i>0. And for a dead person (completely unhealthy person), h=0 and i=1. In some other situations like if person is suffering from some deadly disease like cancer then perhaps h= 0.01 and i=0.99 and for common cold like disease probably h= 0.8 and i= 0.2

Uncertainty is now considered essential to science and fuzzy logic is qualitative computational approach which can be used as tool to deal with uncertainty in many fields of science such as medicine

Development of medical domain application has been one of the most active research areas. The use of FLCs in the medical applications is very diverse; and they cover various types of medical applications like control of injected doses, surgery, physical therapy, in detection system for heart disease, for decision-making in radiation therapy, for controlling hypertension during anesthesia, to visualize nerve fibers in the human brain, to represent quantitative estimates of drug use, etc.

Fuzzy logic in Washing Machines

Washing machine is commonly used household appliances. On using a washing machine, the user manually sets the washing time, based on the type of clothes, type of dirt and amount of clothes. Many people find it very difficult to decide that which cloth what need amount of washing time. So these days fuzzy logic washing machines are gaining popularity. The fuzzy logic checks for the extent of dirt and grease, the amount of soap and water to add, direction of spin, and can sense how heavy a load is and determine the correct amount of water and detergent, speed of agitation, and length of the wash cycles. There is no single standard for the dirty laundry. Fuzzy logic enables the machine's computer to make "in between" decisions. At the beginning of the wash load, the water is clear. As it becomes dirtier, the machine's computer senses the discoloration that doesn't allow light to pass through as easily. The sensors use fuzzy logic to control settings so to get a clean load.

Fuzzy logic in ACs

An air conditioner (often referred to as AC) is a home appliance, system, or mechanism designed to dehumidify and extract heat from an area .Old air conditioners used simple on-off mechanism as they were used to be set to a minimum and maximum room temperature. When that lower number was reached, the unit turned off. When the temperature hit the higher point, the air conditioner turned back on. There was a slight gap between the two preset values to avoid high frequency on-off cycling. Example would be "When the temperature rises above 25º C, turn on the unit, and when temperature falls below 20º C, turn off the unit". In today's AC systems, fuzzy logic doesn't rely on the two "extremes". It manages the temperature to remain steady. By sensing slight fluctuations and making adjustments, the air conditioning system is more energy-efficient.

Fuzzy logic in ATM Networks

Due to the unpredictable behavior of the traffic and various traffic characteristics, it has become a great challenge for ATM networks to effectively control traffic and congestion while at the same time provide the desired quality of service. If any delay has been occurred when one deposit processing, the other deposits are processed very late. Because of that, ATM networks must not have a bottleneck. Switches must be updated continuously and then switches orient the packets on the network for optimization of flow rate

Fuzzy logic appears a promising approach to address many important aspects of networks, particularly the traffic control in ATM (Asynchronous Transfer Mode) network. But Conventional fuzzy logic methods cannot provide updating and adapting systems because of setting input mf functions only one time at the beginning. To find the most adapting function to an ATM network is an expert job and very expensive. At the other hand ANFIS (adaptive Network Fuzzy Inference System) methods can update the switches according to network. Also, ANFIS updates input-functions according to flow rate of any switches. Therefore our NFIS controller adapting to online ATM networks very cheap and without an expert.

Fuzzy logic in Bioinformatics

Bioinformatics is commanding much interest from a variety of disciplines because it presents many problems needing solutions, one of which is the general need to convert massive amounts of biological data into valuable knowledge. Each discipline wants to contribute its techniques to tackling the challenges facing biomedical and biological researchers, i.e., to help them understand the correlations, structures, and patterns in their data. Some examples are specific to biological research such as identifying useful gene structures from biological sequences, but others such as deriving diagnostic knowledge from experimental data or extracting scientific knowledge from the research literature are applicable across a variety of scientific disciplines. One aspect, however, that makes the field of bioinformatics more challenging is the sheer complexity and volume of biological data. Part of its complexity arises from the heterogeneity and variety present in biological data. Traditional computational methods and algorithms often are limited in their capability of solving the real world problems facing biological and biomedical researchers.

Fuzzy set theory and fuzzy logic are not part of traditional computational models but belong to the field of computational intelligence which consists of a variety of approaches such as neural networks and evolutionary computing that were inspired by biological properties and characteristics of animal and human intelligence. Although many computational intelligence techniques are being used in bioinformatics, more recently the value of fuzzy set theory and fuzzy logic for modeling biological systems and objects is being recognized. Bioinformatics integrates biology, physical principles, and chemical principles with computer science and analysis and modeling tools to utilize on vast collections of biological data. An important aspect in the analysis and modeling tasks is the ability to manage and reason with uncertainty. While probability theory plays a key role in modeling uncertainty in science where the source of uncertainty is randomness, fuzzy set theory provides another tool for modeling other kinds of uncertainty such as vagueness and ambiguity and is a complementary approach to probability theory. It can be used to model biological objects that can exist simultaneously in multiple classes and to model classes that lack clear boundaries based on extracted object features. Fuzzy set theory and fuzzy logic provide the researcher with additional computational tools to model uncertainty in bioinformatics.

The following are some examples where Fuzzy logic and fuzzy technologies are now frequently used in bioinformatics:

1. It is used to increase the flexibility of protein motifs.
2. It is used to study differences between polynucleotide.
3. It is used to analyze experimental expression data using fuzzy adaptive resonance theory.
4. It is used to align sequences based on a fuzzy recast of a dynamic programming algorithm.
5. It is used in DNA sequencing using genetic fuzzy systems.
6. It is used to cluster genes from microarray data.
7. It is used to simulate complex traits influenced by genes with fuzzy-valued effects in pedigreed populations.
8. It is used to analyze gene expression data.

9. It is used to analyze the relationships between genes and decipher a genetic network.
10. It is used to classify amino acid sequences into different super families.

Fuzzy logic in Transportation

Transportation planning is a wide human-oriented field with diverse and challenging problems waiting to be solved. Characteristics and performances of transport systems – services, costs, infrastructures, vehicles and control systems are usually defined on the basis of quantitative evaluation of their main effects. Most of the transport decisions take place under imprecision, uncertainty and partial truth. Some objectives and constraints are often difficult to be measured by crisp values. Traditional analytical techniques were found to be non-effective when dealing with problems in which the dependencies between variables are too complex or ill-defined. Moreover, hard computing models cannot deal effectively with the transport decision-makers' ambiguities and uncertainties. Over the past few decades, there are a variety of mathematical models using various formulations and equations (objective knowledge) to settle such kinds. Actually, in real problems they used approximated number instead of crisp one for input parameter because it is impossible to use fixed value to describe complicated traffic and transportation. For example, when estimating the speed and costing time between two nodes, we will express in term that "around 10 minutes for 20 kilometers". We cannot be able to process to answer exactly that: "9 minutes 10seconds for 18.27 kilometers". To solve these problems we have to record over the long period of time with various values and cannot ignore the linguistic information to evaluate all of options and fulfill as much as possible of real conditions. So that, we do need a technique to present the linguistic information and crucial thing is using a suitable solution to link objective knowledge and subjective knowledge (linguistic information). Fuzzy logic is an absolutely corresponding concept with this case.

Fuzzy logic in Computers

In spite of the fact that human beings do not have sufficient capacity to deal accurately with large amounts of numerical information and data, they are extremely skilful at making complex decisions. The opposite is true of computers, which can carry out highly complex calculations in a fraction of a second, while being totally unable to recognize the most basic activities of humans unless they are numerically represented. This evident mismatch between the abilities of human beings and of numerical systems led to the development the theory of fuzzy logic. . The theory of fuzzy logic has managed to fill some significant gaps in the existing classical logic, because the latter relies on quantitative approaches to system analysis or decision making.

Due to modern information technology powerful computers are produced. It is possible today to collect, store, transfer and compile huge amounts of data at very low costs. Thus an ever-increasing number of companies and scientific and governmental institutions can afford to build up large archives of documents and other data like numbers, tables, images and sounds. Exploiting the information contained in these archives in an intelligent way turns out to be fairly difficult. There is a lack of tools that can transfer their data into useful information and knowledge. Thus new area of research has emerged which has been named as "knowledge discovery in data base (KDD) or Data Mining.

Fuzzy set theory produces excellent means to model the "fuzzy" boundaries of linguistics terms by introducing gradual memberships. In contrast to classical set theory in which an object or a case either belongs to a set or not, fuzzy set theory makes it possible that an object or a case belongs to a set only to a certain degree.

Moreover due to the growing reliance that corporations and government agencies place on their computer networks, the significance of defending these systems from attack cannot be underestimated. A single malicious encroachment into a computer network can cause a great deal of damage to an organization. Computer Security concerns the protection of information and property from misuse by unauthorized people. Computer forensics provides methods for the preservation, collection, validation, identification, analysis, interpretation, documentation and presentation of digital evidence derived from digital sources for the reconstruction of criminal activities or policy violation. Fuzzy logic can properly be used to help deal with issues associated with computer security and computer forensics.

II. Conclusion

We have discussed various applications which were found to be very difficult to solve with traditional analytical techniques. Even hard computing models cannot deal effectively with these problems. In this situation fuzzy logic theory proved itself very beneficial and fruitful. There are so many other problems like power system fault diagnosis, decision making behavior, crime investigation etc which can be handled by fuzzy logic.

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