International Journal of Advanced Research in Engineering and Applied Sciences ISSN: 2278-6252

FUZZY LOGIC APPLICATIONS AND ITS CHALLENGES

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Abstract: *We have heard many times that the computer follows a logic zero and one. In this logic, anything is true of false, exists or does not exist. But Einstein says: "As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality". Einstein's description is visualization from deficiency of mathematic and classical logic rules, when we're talking about right or wrong phenomena and objects that we are facing with them in a real-world. Therefore we see that idea of relativity is formatted and is developed. In this paper, we briefly want to be familiar with fuzzy logic. a logic that does not see world as zero or one facts but that sees the world as gray spectrum from facts and use of this logic has grown increasingly in artificial intelligence.*

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1- INTRODUCTION

Soft Computing (SC) is an area of artificial intelligence research focused on the design of intelligent systems to process uncertain, imprecise and incomplete information. SC methods applied to real-world problems frequently offer more robust, tractable and less costly solutions than those obtained by more conventional mathematical techniques.

In real world, there exists much fuzzy knowledge. Knowledge that is vague, imprecise, uncertain, ambiguous, inexact, or probabilistic in nature.

Human thinking and reasoning frequently involve fuzzy information, originating from inherently inexact human concepts. Humans can give satisfactory answers, which are probably true [1].

However, our systems are unable to answer many questions. The reason is, most systems are designed based upon classical set theory and two-valued logic which is unable to cope with unreliable and incomplete information and give expert opinions.

We want, our systems should also be able to cope with unreliable and incomplete information and give expert opinions. Fuzzy sets have been able provide solutions to many real world problems. Fuzzy Set theory is an extension of classical set theory where elements have degrees of membership.

Before illustrating the mechanisms which make fuzzy logic machines work, it is important to realize what fuzzy logic actually is. Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth- truth values between "completely true" and "completely false". As its name suggests, it is the logic underlying modes of reasoning which are approximate rather than exact. The importance of fuzzy logic derives from the fact that most modes of human reasoning and especially common sense reasoning are approximate in nature [2].

The essential characteristics of fuzzy logic as founded by Zader Lotfi are as follows.

- In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning.
- In fuzzy logic everything is a matter of degree.
- Any logical system can be fuzzified
- In fuzzy logic, knowledge is interpreted as a collection of elastic or, equivalently , fuzzy constraint on a collection of variables
- Inference is viewed as a process of propagation of elastic constraints.

The third statement hence, defines Boolean logic as a subset of Fuzzy logic.

2- SEVERAL TRUTHS OF FUZZY LOGIC

2-1- There Is Nothing Fuzzy About Fuzzy Logic

The idea that fuzzy logic is fuzzy or intrinsically imprecise is one of the most commonly expressed fables in the fuzzy logic mythos. This wide-spread belief comes in two flavors, the first holds that fuzzy logic violates common sense and the well proven laws of logic, and the second, perhaps inspired by its name, holds that fuzzy systems produce answers that are somehow ad-hoc, fuzzy, or vague. The feeling persist that fuzzy logic systems somehow, through their handling of imprecise and approximate concepts, produce results that are approximations of the answer we would get if we had access to a model that worked on hard facts and crisp information. Nothing could be further from fact.

There is nothing fuzzy about fuzzy logic, Fuzzy Sets differ from classical or crisp sets in that they allow partial or gradual degrees of membership. We can see the difference easily by looking at the difference between a conventional (or "crisp") set and a fuzzy set. Thus someone 34 years, eleven months, and twenty eight days old is not middle aged. In the Fuzzy representation, however, we see that as a person grows older he or she acquires a partial membership in the set of Middle Aged people, with total membership at forty years old.

But there is nothing ambiguous about the fuzzy set itself. If we know a value from the domain, say an age of 35 years old, and then we can find its exact and unambiguous membership In the set, say 82%. This precision at the set level allows us to write fuzzy rules at a rather high level of abstraction. Thus we can say, if age is middle-aged, then weight is usually quite heavy; and means that, to the degree that the individual's age is considered middle aged, their weight should be considered somewhat heavy. A weight estimating function, following this (very simple) rule might infer a weight from age through the following fuzzy implication process.

Much of the discomfort with fuzzy logic stems from the implicit assumption that a single ``right'' logical system exists and to the degree that another system deviates from this right and correct logic it is in error. This ``correct'' logic, of course, is Aristotelian or Boolean logic. But as logic of continuous and partial memberships, Fuzzy Logic has a deep and impressive pedigree. Using the metaphor of the river, Heraclitus aptly points out that a continuous reasoning system more correctly maps nature's logical ambiguities. From his dictum that all is flux, nothing is stationary; he developed a rudimentary multi-valued logic two hundred years before Aristotle. Recently, Bart Kosko, one of the most profound thinkers in fuzzy logic, has shown that Boolean logic is, in fact, a special case of fuzzy logic.

2-2- Fuzzy Logic Is Different from Probability

The difference between probability and fuzzy logic is clear when we consider the underlying concept that each attempts to model. Probability is concerned with the undecidability in the outcome of clearly defined and randomly occurring events, while fuzzy logic is concerned with the ambiguity or undecided ability inherent in the description of the event itself. Fuzziness is often expressed as ambiguity rather than imprecision or uncertainty and remains a characteristic of perception as well as concept.

2-3- Designing the Fuzzy Sets is very easy

Not only are fuzzy sets easy to conceptualize and represent, but they reflect, in a general "one-to-one" mapping, the way experts actually think about a problem. Experts can quickly sketch out the approximate shape of a fuzzy set. Later, after we have run the model or examined the process, the precise characteristics of the fuzzy vocabulary can be adjusted if necessary.

2-4- Fuzzy Systems are Stable, Easily Tuned, and can be conventionally validated

Creating fuzzy sets and building a fuzzy system is faster and quicker than conventional knowledge-based systems using "crisp" constructs. These fuzzy systems routinely show a one or two order of magnitude reduction in rules since fuzzy logic simultaneously handles all the interlocking degrees of freedom. Fuzzy systems are very robust since the over-lapping of the fuzzy regions, representing the continuous domain of each control and solution variable, contributes to a well-behaved and predictable system operation. These systems are validated in the same manner as conventional system. The tuning of fuzzy systems, however, is usually much simpler since there are fewer rules; representation if visually centered around fuzzy sets, and operations act simultaneously on the output areas.

2-5- Fuzzy Systems are Different From and Complementary to Neural Networks

There is a close relationship between fuzzy logic and neural systems. A fuzzy system attempts to find a region that represents the space defined by the intersection, union, or complement of the fuzzy control variables. This has analogies to both neural network classifiers and linear programming models. Yet fuzzy systems approach the problem differently with a deeper and more robust epistemology. In a fuzzy system, the classification and bounding process is much more open to the developer and user with capabilities for explanations, rule and fuzzy set calibration, performance measurements, and controls over the way the solution is ultimately derived.

2-6- Fuzzy logic "is not just process control anymore"

Historically we have come to view fuzzy logic as a process control and signal analysis technique, but fuzzy logic is really a way of logically representing and analyzing information, independent of particular applications. The information management field in particular has, until recently, ignored fuzzy logic, delaying its introduction into expert system and decision support technology. Recently, however, new types of knowledge base construction tools have emerged. Such tools will make it easier for experts who are not computer experts to intuitively represent and manipulate information.

2-7- Fuzzy Logic is a Representation and Reasoning Process

Not the "Magic Bullet" for all AI's current problems – Fuzzy Logic is a tool for representing imprecise, ambiguous, and vague information. Its power lies in its ability to perform meaningful and reasonable operations on concepts that are outside the definitions available in conventional Boolean logic. We have used fuzzy logic in such applications as project management, product pricing models, health care provider fraud detection, sales forecasting, market share demographic analysis, criminal identification, capital budgeting, and company acquisition analysis. Although fuzzy logic is a powerful and versatile tool, it is not a solution to all problems. Nevertheless, it opens the door for the modeling of problems that have generally been extremely difficult or intractable [3].

3- BASIC CONCEPTS

In fuzzy logic, the truth of any statement is a matter of degree. Any statement can be fuzzy. A membership function is the curve that defines how true a given statement is for a given input value. It defines how each point in the input space is mapped to a membership value (or degree of membership) from 0 and 1 .

One of the most commonly used examples of a fuzzy set is the set of tall people. In this case the input space includes all potential heights, say from 3 feet to 9 feet, and the word "tall" would correspond to a curve that defines the degree to which any person is tall. If the set of tall people is given the well-defined (crisp) boundary of a classical (non-fuzzy) set, we might say that all people taller than 6 feet are officially considered tall. But such a distinction doesn't reflect our experience. Just as importantly, the example is not as practical or as accurate as it could be. It may make sense to consider an abstract concept such as the set of all real numbers greater than six, but when we want to talk about real people, it is unreasonable to call one person short and another one tall when the difference in height between them is only the width of a hair.

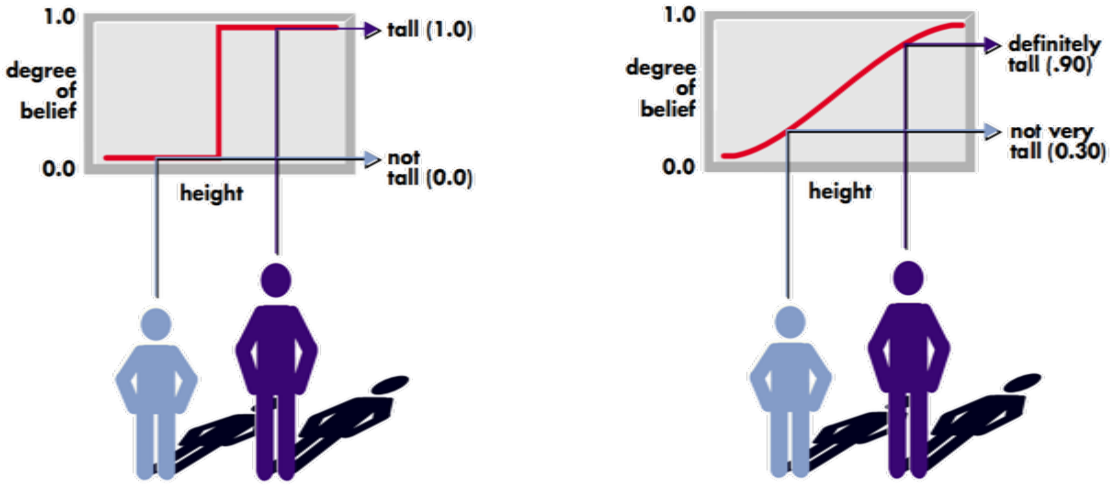

Figure 1. Left: sharp-edged (non-fuzzy). Right: smooth-edged (fuzzy) membership functions

But if the kind of distinction shown in the left diagram of figure 1 is unworkable, then what is the correct way to define the set of tall people? The right diagram shows a smoothly varying curve that passes from not tall to tall. The output-axis indicates the degree of membership in the set of tall people, which is a value from 0 and 1. The curve is known as a membership function and the degree of membership it defines is often given the designation of μ. The curve defines the transition from not tall to tall. Both people are tall to some degree, but one is significantly taller than the other. Subjective interpretations and appropriate units are built into fuzzy sets. If I say "She's tall," the membership function "tall" should already take into account whether I'm referring to a six-year-old girl or a grown woman. Similarly, the units are included in the curve. Certainly it makes no sense to say "Is she tall in inches or in meters?" [4].

4- APPLICATION OF FUZZY RULES

The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of "if-then" statements called rules. All rules are evaluated in parallel, so the order of the rules is unimportant. Before we can build a system that interprets rules, we have to define all the terms we plan on using and the adjectives that describe them. If we want to talk about how hot the water in a boiler is, we need to define the range over which the water's temperature can be expected to vary as well as what we mean by the word hot. The diagram in figure 2 is a road map for the fuzzy inference process. It shows the general description of a fuzzy inference process on the left, and a specific fuzzy system (a thermostat problem) on the right [4].

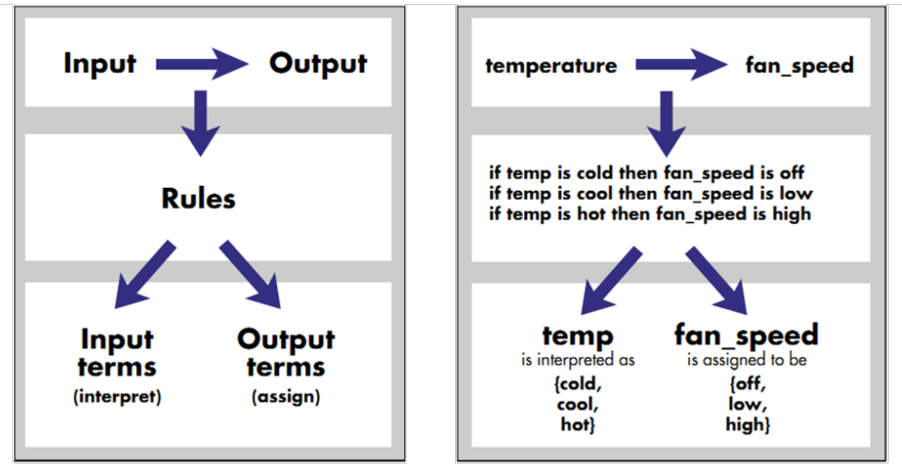

Figure 2: Fuzzy inference process (left), specific fuzzy system (right)

The idea behind fuzzy inference is to interpret the values in the input vector (like temperature) and, based on some set of rules, to assign values to the output vector (like fan speed). That's really all there is to it. For our thermostat problem, one of the fuzzy "if-then" rules is:

If temperature is hot then fan_speed is high

The "*if*" part of the rule temperature is hot is called the antecedent or premise, while the "*then*" part of the rule *fan_speed* is high is called the consequent or conclusion. Interpreting an "*if-then*" rule involves two distinct steps: evaluating the antecedent (which involves fuzzifying the input), and applying that result to the consequent (known as implication). In the case of classical binary logic, "*if-then*" rules don't present much difficulty. If the premise is true, then the conclusion is true. But if we relax the restrictions of binary logic and interpret the antecedent using fuzzy logic, how does this affect the conclusion? The answer is simple: if the antecedent is true to some degree, then the consequent is also true to that same degree. In other words

In binary logic: *p => q (p and q are either both true or both false)*

In fuzzy logic: *0.5 p => 0.5 q (partially true antecedents imply the same degree of truth in the consequent)*

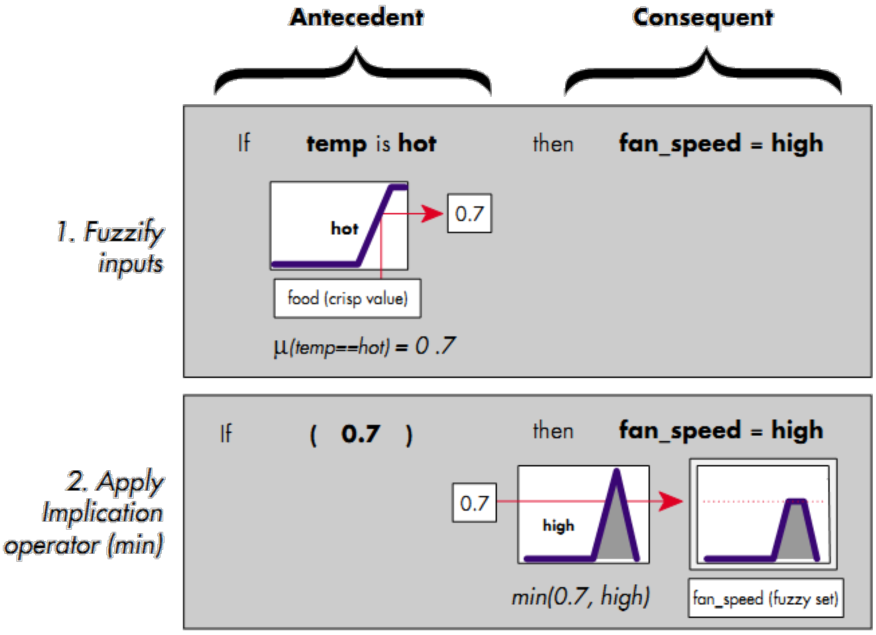

Figure 3. Implementation of a fuzzy rule

In the example shown in figure 3, we see only one rule—but real-world fuzzy systems may have many. The outputs of each rule are combined and defuzzified to return the final output of the sys-tem. In fuzzy logic, multiple rules can be active for the same input value. This means that a few rules can interpolatively cover a wide operating space, just as a few poles can support a large tent. As a result, simple fuzzy systems can solve quite complex problems [4].

5- KEY POINTS FOR A FUZZY SET

- The members of a fuzzy set are members to some degree, known as a ***membership grade*** or ***degree of membership***
- A fuzzy set is fully determined by the membership function
- The membership grade is the degree of belonging to the fuzzy set. The larger the number (in [0,1]) the more the degree of belonging.
- The translation from x to $\mu A(x)$ is known as ***fuzzification***
- A fuzzy set is either continuous or discrete.
- Fuzzy sets are NOT probabilities

Graphical representation of membership functions is very useful.

6- BASIC PROPERTIES AND REPRESENTATIONS OF FUZZY SETS

6-1- Fuzzy sets

Let's examine ordinary set theory. We have a domain *X*. Now examine a set *A* with objects $x_i \in X$. The membership function $\mu_A(x)$ is defined as

$$\mu_A(x) = \begin{cases} 1 & iff \quad x \in A_i \\ 0 & iff \quad x \in A_i \end{cases}$$

So, an object x is either fully part of A or not at all part of A. We call such a set *A* a crisp set. However, in fuzzy logic, things are different. Now an object x can also be partially in A. In other words, $\mu_A(x)$ can take value s between 0 and 1 as well. We call such a set *A* a fuzzy set. Also, the value of $\mu_A(x)$ is called the membership degree or membership grade [5].

6-2- Properties of fuzzy sets

We can define various properties for fuzzy sets. The height of a fuzzy set hgt(A) is the supremum (maximum) of the membership grades of *A*. So,

$$hgt(A) = \sup_{x \in X} \mu_A(x)$$

A fuzzy set *A* is normal if *hgt*(*A*) = 1. In other words, there is an *x* for which $\mu_A(x) = 1$. Any set that is not normal is called subnormal. Such a set *A* can be normalized using the normalization function norm(*A*). It is defined such that, for all $x_i \in X$, we have

$$B = norm\ (A) \quad \rightarrow \quad \mu_B(x) = \mu_A(x)/hgt(A)$$

The support of a set *A* is the crisp subset of *A* with nonzero membership grade s. Similarly, the core of

a set *A* is the crisp subset of *A* with membership grade equal to one . So,

$$supp(A) = \{x/\ \mu A(x) > 0\} \text{ and } core(A) = \{x/\ \mu A(x) = 1\}.$$

The α-cut A_α of a set *A* is the crisp subset of *A* with membership grades of at least α. So,

$$A\alpha = \alpha\text{-}cut(A) = \{x/\ \mu A(x) \geq \alpha\}$$

Note that core(*A*) = 1-cut(*A*). However, supp (*A*) = 0-cut (*A*) is not always true. Let's examine a set *A*. Its membership function $\mu_A(x)$ is called unimodal if it only has one global/local maximum. The corresponding set *A* is then called convex. If however $\mu_A(x)$ is multimodel (has several local maxima), then *A* is non-convex. Finally, the cardinality card(*A*) = |*A*| of a finite discrete set *A* is the sum of the membership grades. Thus,

$$card(A) = |A| = \sum_{i=1}^{n} \mu_A(x_i)$$

7- PROBLEMS FOR MATHEMATICAL FUZZY LOGIC

Even having in mind that it is almost impossible to make predictions because they are related to the future, we intended to single out some problem areas which appear, from the theoretical point of view, to indicate core op en problems which should b e considered seriously in the future development of (formalized) fuzzy logic.

Our first problem, higher order logic and fuzzy set theory, is expected to offer a general framework for a much deeper understanding of the relationship of fuzzy sets to vagueness phenomena in general.

Our second problem of the relationship between a graded and a crisp under-standing of the identity predicate is mainly of a philosophical nature, however it may b e speculated that its solution may also have consequences for fuzzy modelling.

Our third problem of suitable fuzzifications of areas of philosophical logic is immediately directed toward a deeper understanding of commonsense reasoning, but it is also of deeper philosophical significance, as explained in.

And our fourth problem of relationships between fuzzy and quantum logic aims to support the-partly rather old-efforts to understand the importance of the notion of fuzziness for quantum physics, and thus perhaps also for a future quantum computing. And this is already an old problem which has seen a series of approaches, however, up to now all of them without decisive success, as explained e.g. in [6].

8- CONCLUSION

Fuzzy logic provides a different way for the things that they need to control. This approach focuses on what the system should do, not on how to do things. Using fuzzy logic is easy. Fuzzy logic is capable of complex issues that are not solved by mathematical methods, easily and in less time to solve. The logic acts as well as expert knowledge. Fuzzy set theory was designed to act in situations of uncertainty and this is done using linguistic variables and daily routine. Fuzzy logic can evaluate the issues and transform the qualitative variables to quantity variables. Therefore, fuzzy logic is a suitable logic for management science, which often deals with qualitative variables. Using fuzzy logic, we will go away generalizations and absolute knock and issues will move more toward a more correct answer. Fuzzy logic can be a suitable answer, in the current era of rapid changes that combined with the complexities involved.

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