A Brief History of Fuzzy Logic

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Motto : "Everything is vague to a degree which you do not realize until they tried to specify" (Bertrand Russell, *Vagueness* [1]).

Abstract

The problems of uncertainty, imprecision and vagueness have been discussed for many years. These problems have been major topics in philosophical circles with much debate, in particular, about the nature of vagueness and the ability of traditional Boolean logic to cope with concepts and perceptions that are imprecise or vague. The Fuzzy Logic (which is usually translated into Castilian by "Lógica Borrosa", or "Lógica Difusa", but also by "Lógica Heurística") can be considered a bypass-valued logics (Multi-valued Logic, MVL, its acronym in English). It is founded on, and is closely related to-Fuzzy Sets Theory, and successfully applied on Fuzzy Systems. You might think that fuzzy logic is quite recent and what has worked for a short time, but its origins date back at least to the Greek philosophers and especially Plato (428-347 B.C.). It even seems plausible to trace their origins in China and India. Because it seems that they were the first to consider that all things need not be of a certain type or quit, but there are a stopover between. That is, be the pioneers in considering that there may be varying degrees of truth and falsehood. In case of colors, for example, between white and black there is a whole infinite scale: the shades of gray. Some recent theorems show that in principle fuzzy logic can be used to model any continuous system, be it based in AI, or physics, or biology, or economics, etc. Investigators in many fields may find that fuzzy, commonsense models are more useful, and many more accurate than are standard mathematical ones. We analyze here the history and development of this problem: Fuzziness, or "Borrosidad" (in Castilian), essential to work with Uncertainty.

Keywords: Mathematical Logic, Non-Classical Logics, Fuzzy Logic, Uncertainty, Philosophical aspects of Fuzzy Logic.

1. Introduction

As we know, logic is the study of the structure and principles of correct reasoning, and more specifically, attempts to establish the principles that guarantee the validity of deductive arguments. The central concept of validity is for logic, because when we affirm the validity of an argument are saying that it is impossible that its conclusion is false if its premises are true.

Propositions are descriptions of the world, that is, are affirmations or denials of events in various possible worlds, of which the "real world" is just one of them. There is a long philosophical tradition of distinguishing between truth necessary (a priori or "logical") and facts "contingent" (a posteriori or "factual").

Both have really led the two concepts of logical truth, without being opposed to each other, are quite different: the conception of truth as coherence, and the conception of truth as correspondence. According to the point of view of consistency, a proposition is true or false depending on their relationship with respect to a given set of propositions, because they have been consistently applied the rules of that system. Under the terms of correspondence, a proposition is true or false, if it agrees with reality, that is, the fact referred to.

Other views have tried to be overcome such dichotomy. Among them may be mentioned the semantic point of view, raised by Polish mathematician and philosopher Alfred Tarski (1902-1983).

2. Truth or Falsity

To further enhance the complexity of the problem, one should bear in mind that not only told the truth or falsity of propositions, but also of theories, ideas and models. And so, we allow new and different conception of truth.

The basic idea underlying all these approaches is that of an intrinsic dichotomy between true and false. This opposition implies the validity of two fundamental laws of classical logic:
- Principle of excluded middle: Every proposition is true or false, and there is another possibility.
- Principle of non-contradiction: No statement is true and false simultaneously.

This basic idea generates a series of paradoxes and dissatisfaction that is based on the need to overcome this strict truth-bivalence of classical logic.

Accept that a proposition about a future event is true or false becomes necessary or impossible, respectively, the event expressed by the proposition. The solution proposed by Jan Lukasiewicz himself in his classic 1920, is the acceptance of a logic with three truth values (or three-valued), also called trivalent), which in addition to true and false, accepts a value of indeterminate truth, which is ascribed a truth value or grade of membership of 0.5.

In the eighteenth century, David Hume (1711-1776) and Immanuel Kant (1724-1804) were inquiring about such concepts. They concluded that the reasoning is acquired through experiences throughout our lives.

Hume believed in the logic of common sense, and Kant thought that only mathematicians could provide clear and precise definitions, both accepting that there were conflicting principles that had no solution. In conclusion, both were detecting conflicting principles within the so-called classical logic.

Then in the early twentieth century, the British philosopher and mathematician Bertrand Russell reported the idea that classical logic inevitably leads to contradictions. A study on the "vagaries" of language [1], concluding that the vagueness is precisely one degree.

Also Charles Sanders Peirce (1839-1914) somewhat anticipated this, but there are many who, like Bart Kosko, Bertrand Russell considered the father of Fuzzy Logic. Because in the early twentieth century, the British philosopher and mathematician Bertrand Russell (1872-1970) reported the idea that classical logic inevitably leads to contradictions, making a study on the vagaries of language [10], and concluding that the vagueness is precisely one degree.

3. The origins of Fuzzy Logic

According to this theory, we have a transfer function derived from the characteristic function usually called the "membership function", which runs from the universe of discourse, U, until the unit closed interval of reals, which is [0, 1]. Not so in the sets "classic" or "crisp sets", where the range of the function is reduced to a set consisting of only two elements, namely was the {0, 1}. Therefore, fuzzy set theory is a generalization of classical set theory.

The thesis then proposed emerged from the study of various thinkers from many different disciplines, who, like him, had a different vision of the problems of traditional logic. The paradox of all sets that do not contain themselves, that is very famous and was proposed by Bertrand Russell. Or the uncertainty principle of quantum physics by Werner Heisenberg.

The theory of "vague sets" (today, so-called Fuzzy Sets) proceeds from the quantum physicist and German philosopher Max Black (1937), which also analyzes the problem of modeling "vagueness". He differs from Russell in that he proposes that traditional logic can be used by representing vagueness at an appropriate level of detail and suggests that Russell's definition of vagueness confuses vagueness with generality. He discusses vagueness of terms or symbols by using borderline cases where it is unclear whether the term can be used to describe the case. When discussing scientific measurement he points out "the indeterminacy which is characteristic in vagueness is present also in all scientific measurement". An idea put forward by Black is the idea of a consistency profile or curve to enable some analysis of the ambiguity of a word or symbol. To the fuzzy logic researcher of today these curves bear a strong resemblance to the membership functions of (type-1)-fuzzy sets. And also may be considered the subsequent contribution of the Polish Jan Lukasiewiz (1878-1956). So, they must be greatly influenced Lofti A. Zadeh (b. 1921) to publish that article [2] in the journal Information and Control, and three years later (since 1968), the so-called "Fuzzy Algorithm".

At the beginning of its brainstorm, the papers published by Lotfi A. Zadeh was not well received in the West, even in many cases were bitterly dismissed by the more conservative elements of the scientific community. However, over time began to gain enough supporters, which led to these theories were being extended again and again, settling firmly among the most innovative scientists, and especially among the best professionals, more than anywhere else, initially in Japan and then South Korea, China and India. Europe and the States have been incorporated into this new math, but more slowly.

As a matter picturesque, if you will, but true, we can tell that the now recognized by many as "the father of Fuzzy Logic", Lotfi A. Zadeh, in his time met with executives from IBM, which told him that his "discovery" had no interest or no utility. Of course, it will be considered a very clear model of intelligence and vision. Were it not so, you probably have developed the United States and other Western countries many of the remarkable technological advances arising from the new science.

Zadeh's intention was to create a formalism to handle more efficiently the imprecision of human reasoning. It was in 1971 when he published his "Quantitative Fuzzy Semantics", in which appeared the formal elements that led to the methodology of fuzzy logic and its applications, as known today.

From the above it follows that you may need a radical rethink of our classical concepts of truth and falsehood, replacing the concept of fuzziness (vagueness or fuzziness) as a result of which the truth or falsity are only extreme cases. By fuzziness understand the fact that a proposition may be partially true and partially false simultaneously. A person is not just high or low, but partially may participate in both features, so that only above and below certain heights necessarily called it higher or lower bound, while in the intermediate zone of both heights exist as a graduation which is ceasing to be high. It seems intuitively clear that the concept of fuzziness is rooted in most of our ways of thinking and speaking. Another separate issue is the valuation that each individual granted such a fuzzy character (the glass half full or half empty), which depend on subjective psychological issues and difficult to evaluate.

The fuzzy principle states that everything is a matter of degree. It will be its more famous "leitmotiv". All propositions acquire a truth value between one (true) and zero (false), inclusive. The allocation of these extreme values will only be given in the case of logical truths or falsehoods or strong inductions: "All men are mortal" can be an example of strong induction, since there is no counterexample.

The arguments for introducing the concept of fuzziness in logic have already been exposed, but it will be necessary to examine in detail some key aspects:

a) The historical background and methodological concept.

b) The possibility of building an infinite-valued formal language, and if so, try to define their properties and laws.

c) The philosophical and practical consequences stemming from such introduction.

4. Eastern vs. Western perspective

The well-known American Professor Bart Kosko [3] highlighted the differences between Eastern and Western philosophies regarding the concept of truth, summing up in opposition against Aristotle Buddha. In fact, Kosko said that Western philosophy, Aristotle's successor, has accepted uncritically the bivalent as the system that is useful, but overly simplifying complex reality. Put simply: what has won in simplicity is lost in accuracy. By contrast, Eastern philosophies: Buddha, Lao Tse, Confucius, etc. Always have accepted the strict unity of opposites, of what they call (as we know) the yin and yang.

On the other hand, if it is true that Aristotle was the great introducer of bivalence absolute, we should not ignore that he was not spent entirely overlooked aspects could be fuzzy propositions, as when he commented that: "In any case, what is said according to these (qualities) supports arguably the most and least", or when we talk about that we can come to knowledge, but without the certainty of it. If Aristotle did not study this concept, it may have been lacking the necessary

mathematical knowledge for development. It was not until the appearance of a Calculus increasingly systematic and operational, combinatorial and probability theory, or the new theory, now known as 'Crisp', or Classic, Sets, initiated by Cantor, as well as modern statistics and matrix calculations.
As mentioned earlier, Aristotle did not have the mathematical apparatus for developing a fuzzy logic. The gestation of this construct starts with Newton and Leibniz, who developed calculus in the seventeenth century. Despite the obsession with accuracy in mathematics has made them perfectly applicable sentence Einstein: “To the extent that mathematics refer to reality, not true. And to the extent they are true, not refer to reality”. But does not say Einstein is undoubtedly the deductive apparatus developed by mathematics facilitates the understanding of reality. The explanation given by Aristotle movement is replaced by the most innovative in Newton, but thanks to a sharp appoggiatura in calculus, without which it would not have been possible. However, the infinitesimal calculus in depth was only used for the study of physics in the following centuries, experiencing spectacular growth with Euler, Laplace, Lagrange, Fourier, and so on. Today permeates all sciences, both social and human and natural. This Calculus Mathematics introduced the question of degree: to what degree is modified by changing seamlessly B, where A is a dependent variable B?
Classical Aristotelian logic has been shown, therefore, and for a long time, quite effective in science so-called “hard”, such as math or physics. But it is insufficient when the predicates contain imprecision, uncertainty or vagueness, on the other hand, is how the brain actually works and human reasoning, and in general, is how systems behave around us. Fuzzy logic has also helped that the software can interpret judgments of this kind.

5. Applications of Fuzzy Logic

In fuzzy logic, statements are not absolutely true or absolutely false [4]. One thing can be true to 5% (technically, its “degree of truth” is 0.05). And the variables (or categories) are no longer numbers but no names or borders linguistically accurate (high or low, rich or poor, are fat or thin, is healthy or sick, old or young, hot, or cold, or conversely, “is normal”, and with what degree this occurs, etc.), operators that modify them are of the “lot”, “pretty”, “too”, “almost” or “not too much”. These are called fuzzy modifiers (“hedges” or even “fuzzy modifiers”). This is attributed a value to each of these features diffuse, and that value is accentuated or diluted according, for example, the various powers or roots of the initial values or with polynomial expressions that depend on these functions. They are called modifiers “Intensification” or “Expansion” (Dilation), respectively, with gradual effects and variation. The feature of working with border regions is not fully defined itself in this area of mathematics [6].

In 1973, with the basic theory of Zadeh fuzzy controllers, other researchers began to apply fuzzy logic to various mechanical and industrial processes, improving existing hitherto.
Established several research groups at universities fuzzy Japanese. Thus, Professors Terano and Shibata in Tokyo, with Professors Tanaka and Asai in Osaka, made major contributions both to the development of fuzzy logic theory and its applications [7, 8].

In 1980 Professor Ebrahim Mandani in the United Kingdom [9-11], designed the first fuzzy controller for a steam engine, which would be applied to control a cement plant in Denmark, and did-of course-with great success.

In 1987 Hitachi used a fuzzy controller for the Sendai train control, which used an innovative system created by man. Since then, the controller has been doing his job very efficiently. It was also during this year of 1987 when the company Omron developed the first commercial fuzzy controllers. So the year 1987 is considered the “fuzzy boom” due to the large number of products based on fuzzy logic to be traded. In 1993, Fuji Fuzzy Logic applied to control chemical injection water treatment plants for the first time in Japan. It was right there in the country Nippon and South Korea, where more height Fuzzy Logic has been, creating close partnerships between government, universities and industries [12, 13].

Parallel to the study of the applications of fuzzy logic, Professors Takagi and Sugeno developed the first approach to construct fuzzy rules (Fuzzy Rules), from training data or training

(Fuzzy Learning). The applications of fuzzy logic in everyday life since then grow rapidly. In fact, already part of it. For example, some brands of washing machine using fuzzy logic are Electrolux, AEG and Miele, and use these computational methods to moderate the program if the clothes washing "is not very dirty", which is a vague concept. The technique also is widespread in the ABS, braking cars, auto focus cameras, or control of the elevators, spam filters, also called "spam", and the now ubiquitous video games. Manufacturers do not want to give much publicity to the fuzziness implicit in these developments for an obvious reason. To say that their cars' brake controlled by fuzzy logic does not belong to the class of messages that can sell more cars.

To build a fuzzy system, an engineer might begin with a set of fuzzy rules from an expert. An engineer might define the degrees of membership in various fuzzy input and output sets with sets of curves.

The Fuzzy Rules, or rules of a fuzzy system, define a set of overlapping patches that relate a full range of inputs to a full range of outputs. In that sense, the fuzzy system approximates some mathematical function or equation of cause and effect.

A very important result says that fuzzy systems can approximate any continuous math function. Bart Kosko [3] proved this uniform convergence theorem by showing that enough small fuzzy patches can sufficiently cover the graph of any function or input/output relation. The theorem also shows that we can pick in advance the maximum error of the approximation and be sure there exists a finite number of fuzzy rules that achieve it.

And recent advances in Neural Networks, or Neural Nets (in terms of programs that learn from experience), and Genetic Algorithms (as programs evolve over time) are certainly a fitting complement to fuzzy logic. Another key reason for increased research in this field would be the interest in Neural Networks and Fuzzy Systems resemblance. Wanted relations between the two techniques, thereby obtaining Neuro-Fuzzy Systems, which use learning methods based on neural networks to identify and optimize its parameters [8]. Then, as we say, appeared genetic algorithms, which together with neural networks and "Fuzzy Systems" are powerful and therefore are of great interest for future research, both current and mathematics for the most new, it is already here, quickly taking shape [13].

Neural networks are collections of "neurons" and "synapses" that change their values in response to inputs from surrounding neurons and synapses. The neural network acts like a computer, because it maps inputs to outputs. The neurons and synapses may be silicon components, or equations in software, that simulate their behavior.

Supervised learning, reached through supervised networks, tune the rules of a fuzzy system as if they were synapses. The user provides the first set of rules, which the neural net refines by running through hundreds of thousands of inputs, slightly varying the fuzzy sets each time to see how well the system performs. The network tends to keep the changes that improve performance and to ignore the others.

Unsupervised learning, reached through unsupervised neural networks, blindly cluster data into groups (by a procedure so-called clustering), the members of which resemble one another. There may be no given right or wrong response or way to organize the data. It is in advance.
Fuzzy Modeling is many times used to transform the knowledge of an expert into a mathematical model. The emphasis is on constructing a fuzzy expert system that replaces the human expert. Also as a tool that can assist human observers in the difficult task of transforming their observations into a mathematical model. In many fields of science, human observers have provided linguistic descriptions and explanations of various systems. However, to study these phenomena, there is a need to construct a suitable mathematical model, a process that usually requires a very subtle mathematical understanding. Fuzzy modeling is a many more direct and natural approach for transforming the linguistic description into such model.

A fuzzy model represents the real system in a form that corresponds closely to the way humans perceive it. Thus, the model is easily understandable, and each parameter has a readily perceivable meaning. The model can be easily altered to incorporate new phenomena, and if its behavior is different than expected, it is usually easy to find which rule should be modified, and how. Furthermore, the mathematical procedures used in fuzzy modeling have been tried and tested many times, and their techniques are relatively well documented.

The possible “bad reputation”, or the bitter controversy over fuzzy logic, apart from prejudice, will be possibly wrong with a name chosen, as noted at the outset. What is fuzzy logic is not in itself, which has a precise mathematical definition, but the world over which it applies, including our perception of its boundaries and categories [14, 15].

6. Conclusions

The Fuzzy Logic research continues to advance in the leading countries [17-19], if we talk in terms of economic and technical progress, even-though with a slower walk-in countries with more traditional scientific culture and static, as may well be the Spanish country. But groups that have formed at least attempt to advance our science always precarious in different “grades” -following that direction. Also on deep (on mathematical foundations and philosophical) theoretical consequences, which influences the future challenges [6, 20].

There are two major barriers that prevent full dissemination and absorption of this new way of dealing with science, at least some of their fields. These are the traditional view of mathematical topics, repeated ad nauseam until even when they have long since lost interest and effectiveness. Hence, there are those who ignore even this new science has emerged, partly ignorance and partly is contempt. Another major difficulty is that it looks like a useful tool around, but not very consistent from the theoretical point of view, looking with disdain, and often are often technical issues from the ivory tower in which entrenched than a few mathematicians. And it is a very pernicious and absurd position where they exist. Science and technology are lost or saved together. Both have a common origin and are two approaches, often converging to the same reality, which has many facets. Logically if a thing is useful it will be the better. Account not only the beauty. The real world is not precise and the notions of vagueness, looseness, uncertainty, imprecision, concepts and perceptions are central to the way human beings solve problem.

It must be stated that some progress, such as the Aggregation Operators (T-Norms, T-conorms, and so on) as well as in Fuzzy Modeling, are crucial. And alongside all this development, new generalizations of mathematical theories which allow them to be applied in the treatment of uncertainty still waiting, in some states more or less forward, to create a new mathematics, more down to reality.

It is also important to note that fields apparently far enough outside and out of the treatment of fuzziness, such as the symmetry and the entropy, have entered into new avenues of research by Fuzzy Symmetry, the Fuzzy Entropy, the Fuzzy Graphs, and so on.

About my country, for instance, we must to mention the group working at the Department of Artificial Intelligence at the University of Granada, or the Center for Artificial Intelligence Research at Mieres, created by the Government of Asturias. There is also a remarkable group of researchers that works in Barcelona and in Madrid, on diverse Fuzzy Logic topics.

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