Fuzzy Logic – Evolution & Relevance in the Hi-Tech Era

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Abstract— Fuzzy logic is a form of multi-valued logic. It is based on imprecise reasoning and perception. Compared to conventional bivalent-logic (where a proposition has exactly one truth value either true or false), fuzzy logic variables may have a truth value that can range in degree between 0 and 1. Fuzzy logic has been applied to conceptualize the notion of partial truth, where the truth value may range between completely true and completely false. There has been difference in opinion amongst the mathematicians on the use of fuzzy logic as the base of probability theory. The article describes in details the origin of fuzzy logic and its growing popularity in the current hi-tech world.

Key words: Fuzzy Logic, Many Valued Logic, Bayesian Logic, Crisp Logic, Fuzzy Associative Map inference (FAM)

I. INTRODUCTION

The word fuzzy is synonymous to indistinct, distorted, obscure or unclear. The term fuzzy logic, therefore, inspires certain cynicism, as how can something that is indefinite or obscure be logical. What's essential to comprehend is that fuzzy logic is logic of fuzziness or uncertainty, not a logic which is fuzzy by itself. The laws of probability are not arbitrary, and the laws of fuzziness are not ambiguous. Fuzzy sets and logic may be viewed as a formal mathematical theory for the representation of uncertainty. Uncertainty is vital part of our everyday life, for example, if you want to reach your office precisely at 8 a.m. daily, it would not be possible. Instead, you work within, say, 5 minute tolerances. The presence of uncertainty is inevitable in any real life complex system. The article describes in details the origin of fuzzy logic and its growing popularity in the current hi-tech world.

II. ORIGIN & EVOLUTION

Fuzzy logic was first proposed by Lotfi Aliasker Zadeh, working in the Computer Science department of the University of California at Berkeley. He published his fundamental work on fuzzy sets in 1965. In 1973 he proposed his philosophy of fuzzy logic. He has been entitled as the father of fuzzy logic.

The word Logic, is derived from the classical Greek λόγος (logos), which literally means the word, or what is spoken, but it actually implies to reason out. Logic is most commonly accepted to be the study of arguments, nevertheless the exact definition of logic debatable among philosophers, with different definitions proposed by different school of philosopers. However the topic is disputed upon, the assignment of the theorist is the same: to suggest an explanation of true and fallacious inference to allow one to distinguish good arguments from bad arguments. Conventionally, logic was considered as a branch of philosophy. Logic has been commonly studied in mathematics, since the mid-1800s, and, more recently, has become an integral part of computer science. As a science, logic examines and categorizes the structure of statements and arguments, both through the study of formal systems of inference and through the study of arguments in natural language. The domain of logic can, therefore, be very extensive, ranging from fundamental topics such as the study of fallacies and paradoxes, to specialist analyses of reasoning.

Modern logic descends from ancient greek tradition. Both Plato and Aristotle conceived of logic as the study of argument. Arisstotle proposed six works in logic collectively known as Oragonon. In his work he espoused the laws of thought, which consisted of three fundamental laws:

– Principle of identity
– Law of the excluded middle
– Law of non-contradiction.

The first law of identity states that "each thing is the same as itself and different from another" or a statement cannot remain the same and change its truth value. The law of the excluded middle states that something either exists or not exists or every statement is either true or false. The law of non-contradiction states that nothing can both exist and not exist at the same time or no statement is both true and false. Aristotle was therefore credited with the establishment of a binary logic that admits only the opposites of true and false, a logic that does not admit degrees of truth in between the two extremes. Therefore, Aristotelian logic does not acknowledge fuzziness in truth. Jan Łukasiewicz was the first to suggest a methodical substitute to the bi-valued logic of Aristotle and described the 3-valued logic, with the third value being Possible. In his model of fuzzy sets, Zadeh, proposed the concept of a membership function effective on the sphere of all possible values. He proposed new operations for the calculus of logic and showed that fuzzy logic was a generalization of classical and Boolean logic. He also suggested fuzzy numbers as a special case of fuzzy sets and the rules for reliable mathematical operations (fuzzy arithmetic).

Despite of strong opposition to the concept of Fuzzy logic by few statisticians and control engineers, other research followed. And the first industrial application, a cement kiln built in Denmark, came on line in 1975. Interest in fuzzy systems was sparked by Seiji Yasunobu and Soji Miyamoto of Hitachi, who in 1985 provided simulations that, demonstrated the superiority of fuzzy control systems for the Sendai railway. Their vision was implemented, and fuzzy systems were used to regulate the accelerating, braking, and stopping functions when the line opened in 1987. The demonstration of the use of fuzzy control by Takeshi Yamakawa, through a set of fuzzy logic chips, in an "inverted pendulum" experiment in the international meeting of fuzzy researchers in Tokyo in 1987, further sparked the interest of researchers in the development and application of fuzzy control systems. Yamakawa finally organized his own fuzzy-systems research lab to help exploit his patents in the field. Eventually, Japanese engineers developed a wide range of fuzzy systems for both engineering and consumer applications. Japan established "Laboratory for International Fuzzy Engineering (LIFE) "an undertaking by a joint collaboration of 48 companies, to pursue fuzzy research. Japanese consumer goods often incorporate fuzzy systems.

Major companies like Hitachi, Canon and Mitsubishi adopted the concept of Fuzzy logic in the advancement of their highly automatized and smart systems. The passion of the Japanese for fuzzy logic is echoed in the wide range of other applications in which they have incorporated the use of fuzzy logic, including character and handwriting recognition; optical fuzzy systems; voice-controlled robot helicopters and robots for making Ikebana – the famous art of Japanese flower arrangements.

United States of America is not behind in incorporating fuzzy logic. The US Environmental Protection Agency has investigated fuzzy control for energy-efficient motors, and NASA has studied fuzzy control for automated space docking. Firms such as Boeing, General Motors, Allen-Bradley, Chrysler, Eaton, and Whirlpool have adopted fuzzy control systems in their machines and automated systems. There have been widespread investigations on fuzzy applications in software including fuzzy expert systems and integration of fuzzy logic with neural-network, with the ultimate goal of building "self-learning" fuzzy control systems.

III. Logical Interpretation of Fuzzy Logic

Fuzzy control aims to solve the general mathematical problem using the approach of interpolation, in which the argument-value pairs of a particular fuzzy function are defined by a set of fuzzy input-output data generally provided by a set of linguistic control rules. However, contrary to the usual understanding of interpolation, in the actual approaches this interpolation problem is considered as a global one: one uniformly and globally defined function should realize all the fuzzy input-output data. In standard classes of functions thus this interpolation problem often becomes unsolvable. Hence it becomes intertwined with an approximation problem which allows that the given fuzzy input-output data are realized only approximately by argument-value pairs. Fuzzy controls can fuzzy logic programming to solve mathematical problems. It has been observed that the class of fuzzy Herbrand interpretations provides semantics for fuzzy programs. The fuzzy function related to a fuzzy system of IF-THEN rules is the fuzzy Herbrand interpretation associated with a suitable fuzzy program (Gerla, 2005). However, there are several difficulties in providing a rigorous logical interpretation of the IF-THEN rules. Undoubtedly, if we consider systems of rules in which the class antecedent define a partition such a contradictory phenomenon does not arise. Gerla (2005) proposes a logical approach to fuzzy control based on the following idea. Let f represent the fuzzy function associated with the fuzzy control system, i.e., given the input r, s(y) = f(r,y) is the fuzzy set of possible outputs. Then given a possible output “t”, we interpret f(r,t) as the truth degree of the claim "t is a good answer given r". This implies, any system of IF-THEN rules can be translated into a fuzzy program in such a way that the fuzzy function f is the interpretation of a vague predicate Good(x,y) in the associated least fuzzy Herbrand model. In such a way fuzzy control becomes a chapter of fuzzy logic programming. The learning process becomes a question belonging to inductive logic theory. Possibilistic logic is a weighted logic introduced and developed since the mid-1980s, in the setting of artificial intelligence, with a view to develop a simple and rigorous approach to automated reasoning from uncertain or prioritized incomplete information. Standard possibilistic logic expressions are classical logic formulas associated with weights, interpreted in the framework of possibility theory as lower bounds of necessity degrees. Possibilistic logic handles partial inconsistency since an inconsistency level can be computed for each possibilistic logic base. Logical formulas with a load greater than this level are invulnerable to inconsistency and can be precisely employed in deductive reasoning. (Hajek, 1998) recalls the basic features of possibilistic logic, including information fusion operations. Then, several extensions that mainly deal with the nature and the handling of the weights attached to formulas are suggested or surveyed: the leximin-based comparison of proofs, the use of partially ordered scales for the weights, or the management of fuzzily restricted variables. Inference principles that are more powerful than the basic possibilistic inference in case of inconsistency are also briefly considered. The interest of companion logic, based on the notion of guaranteed possibility functions, and working in a way opposite to the one of usual logic, is also emphasized. Its joint use with standard possibilistic logic is briefly discussed. This position paper stresses the main ideas only and refers to previous published literature for technical details. (Kevin, 1998) mentions concerns like stability analysis, systematic design, and performance analysis, are vital to the rationality and applicability of fuzzy control methodology. Fuzzy Control Systems Design and Analysis attempts to resolve these concerns with the help of of parallel distributed compensation, a controller structure devised in accordance with the fuzzy model. If there are complex applications, one can simply cause confusing rules using different operators, a chaos of parentheses and complicated "if-then-else" statements. Such paradigms destroy the actual benefits of fuzzy logic systems, like clarity and easy expansion. A different approach by providing normalized rule sets and graphical structure editors may be used to handle complex fuzzy logic tools. Applying normalized rule sets has the additional advantage that the rules can be transformed automatically and developed easily in matrix form, which is often more readable than text or table form in the case of huge and complex systems. Fuzzy Associative Map inference (FAM) is an advancement of fuzzy inference and combines f neural technology and fuzzy logic to solve complex problems. It allows more accurate tuning of the rule bases according to the prerequisites, and as a result, it reduces the often necessary selection procedures of the rules.

IV. Conclusion

Fuzzy logic has proved it pedantically successful for automated systems and is being widely used in many day-to-day appliances, as it permits more rational analysis and reasoning comparable to human brain. Fuzzy washing machines decide the washing cycle required to wash the laundry depending upon its degree of dirtiness. Fuzzy Smart Air-conditioners use fuzzy logic to regulate air flow depending on the degree of hotness or coldness. Smart TVs adjust the color and contrast modes. In future, more and more systems can be built using Fuzzy Logic which incorporate human thinking, experience and reasoning instead of limiting it to only true/false values. Recent research in Fuzzy logic has made Fuzzy logic applicable in industrial automation, modeling, data analysis, diagnostics, decision making in areas of Engineering, Technology, Managerial and Biomedical Sciences. Klun and Virant (1999) present how fuzzy logic can be used as a substitute or enhancement to statistics in biomedical analysis. Hooshang and James propose a framework for the application of fuzzy logic to employee performance appraisal. Novak (2012) proposes an extension called fuzzy logic in broader sense (FLb). The paradigm of FLb is to be the logic of natural human reasoning, whose most essential characteristic is the use of natural language. Therefore we may conclude fuzzy logic and the fuzzy control system hold a promising future towards the building of a smart hi-tech world.

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