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Fuzzy logic—a personal perspective

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Abstract

This paper marks the 50th anniversary of the publication of my first paper on fuzzy sets, "Fuzzy sets," Information and Control, 1965. What is of historical interest is that initially—and for some time thereafter—my paper was an object of indifference, skepticism and derision. A prominent school of thought claimed that fuzzy set theory is probability theory in disguise. Positive comments were few and far between. In contrast, my ideas were welcomed with open arms in Japan. In the seventies and eighties of last century, fuzzy set theory and fuzzy logic began to gain acceptance in Europe and, more particularly, in Eastern Europe and the Soviet Union. In part, many negative reactions to my papers reflected the fact that the word "fuzzy" has pejorative connotations. In large measure, science is based on the classical, Aristotelian, bivalent logic. Binarization—drawing a sharply defined boundary between two classes—is a deeply entrenched Cartesian tradition. What is not widely recognized is that this tradition has outlived its usefulness. One of the principal contributions of fuzzy logic is providing a basis for a progression from binarization to graduation, from binarism to pluralism, from black and white to shades of gray. Graduation involves association of a class which has unsharp (fuzzy) boundaries with degrees/grades of membership. Classes with unsharp boundaries are pervasive in human cognition. Most words in natural language are labels of such classes. This paper is a concise exposition of what I consider to be my principal contributions to the development of fuzzy set theory and fuzzy logic. Among the contributions which are discussed are: introduction of the concept of a fuzzy set, FL-generalization, the concept of a linguistic variable, information granulation, precisiation of meaning, generalized theory of uncertainty (GTU), the concept of a restriction, restriction-centered theory of truth and meaning, the information principle, and similarity-based definitions of possibility and probability.

Keywords: Fuzzy set theory; Fuzzy logic; Possibility theory; Approximate reasoning

1. Preamble

I was asked by the editors of Fuzzy Sets and Systems to prepare a position paper describing my view of the evolution of fuzzy logic and its current status. What follows has a much more modest objective; it is a retrospective view focused on my contributions, and a glimpse into my crystal ball. At my age, it has become difficult to write long papers. For this reason, the exposition which follows is neither as complete nor as detailed as it should be. My work reflects my background. What follows is a brief self-introduction.

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2. Self-introduction

I was born in Baku, Azerbaijan, on February 4th, 1921. At that time, Azerbaijan was a part of the Soviet Union. My parents were Iranian citizens. My father was a foreign correspondent and a businessman. My mother was an MD. When I was ten, my parents decided to return to Iran because there was an economic crisis in the Soviet Union. I was in 3rd grade of an elementary school when my parents left Baku. In the elementary school, I was deeply influenced by the prevailing climate of veneration of science and engineering. This influence has shaped my intellectual development throughout my life.

In Tehran, the capital of Iran, my parents placed me in an American Missionary School, the American College, later renamed as Alborz. In the American College, instruction was in English, and my teachers were Presbyterian missionaries, mostly from the Midwest. For me, they were role models. I fell in love with the United States and decided that it is the country in which I would like to live, study and work. At the time, this was a distant objective.

After graduating from the American College, I entered the College of Engineering, called Fanni, of the University of Tehran, three years after the university was established. At Fanni, most of my professors were graduates of elite universities in France. The dominant influence was French. Most of our books and class notes were in French. Instruction was rigorous and strict. I was graduated in 1942 with a degree in Electrical Engineering. There were three students in my class. After my graduation, I had an association with the Persian Gulf Command of the US Army. My association made it possible for me to obtain an immigrant visa for studying and working in the United States. At that time, the quota for such visas was 100. I applied for admission to MIT as a graduate student in Electrical Engineering. I arrived in the United States in July, 1944. This was the beginning of a new phase in my life. It was a new world—a world I was in love with. To my surprise, studying at MIT was easier than studying at Fanni. Much of what I learned at MIT was new for me.

I received my Master's degree in Electrical Engineering in 1946. I could have stayed at MIT to study toward a PhD degree, but I decided to move to New York to be close to my parents. In New York, I was fortunate to get a job as an instructor in Electrical Engineering at Columbia University. I received my PhD degree from Columbia in 1949.

The early years in my academic career coincided with the birth of the age of computers and information. It was an exciting period, spurred by competition between the United States and the Soviet Union. At Columbia, my research was focused on system theory and information systems. Probability theory had a position of centrality in my work. My first paper, published in 1949 in the Journal of Applied Physics, was entitled, "Probability criterion for the design of servomechanisms" [1]. My second paper, published also in the Journal of Applied Physics in 1950, was entitled, "An extension of Wiener's theory of prediction" [2]. I had a close relationship with the Department of Mathematical Statistics and its Chair, Herbert Robbins, a brilliant mathematician, who became my best friend. At Columbia, I progressed through the ranks and was promoted to full professorship in 1958. In 1959, I moved to UC Berkeley, where I am at present.

3. Early history

Although I am not a mathematician by training, I have always been close to the world of mathematics and mathematicians. Throughout my academic career, my work was focused on applications of mathematics to real-world problems. More concretely, during the period 1950–1960, my research was concerned, in the main, with systems analysis, optimization and information systems. Probability theory played an important role in my work. Another area of interest was multivalued logic, nonbinary systems and automata theory. Reflecting this interest, I supervised two PhD theses on multivalued switching systems (Oscar Lowenschuss [3]) and nonbinary coding (Werner Ulrich [4]). My interest in multivalued logic was heightened by spending my sabbatical leave at the Institute for Advanced Study, Princeton, New Jersey. In Princeton, I became acquainted with some of the leading logicians and philosophers, among them Kleene, Quine, Kreisel and others. Attending their lectures and seminars was a fascinating experience. Subsequently, Kleene became my mentor and supporter. On his recommendation, I was invited to give a lecture on fuzzy set at the International Congress of Mathematicians in Moscow, 1966. In Moscow, I was fortunate to have an opportunity to have a meeting with Kolmogorov to discuss fuzzy sets. In the Soviet Union, Kolmogorov was an object of veneration. Kolmogorov was treated as a national treasure, but I was struck by the fact that his salary was just several times higher than the average salary. At the time, the Soviet Union was largely an egalitarian society. Kolmogorov