MY LIFE AND WORK - A RETROSPECTIVE VIEW

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I have been asked to write a preface to this issue—a preface focused on my life and work. For me, it is a difficult task. I feel uncomfortable when I write about myself. There are some people who think very highly of themselves. I am not one of them. But at this point in my life, nearing my 90th birthday, I feel that there is an obligation to respond affirmatively to the request to write about my life and work. This is the light in which the following should be read.

I was born on February 4, 1921, in Baku, the capital of Azerbaijan—then a part of the Soviet Union. My parents were Iranian citizens. My father was a foreign correspondent for the newspaper, Iran, a leading newspaper in Iran at that time. In addition, he was a businessman. My mother studied medicine. Foreign correspondents had a privileged position because it was important for the government to present to the outside world a favorable view of what was going on inside. I was the only child and a pampered child. We always had a maid and I had a governess.

I was enrolled in the Elementary School Number 16. It was a very good school and I still have fond memories of my student days. As was the rule in the Soviet era, what was extolled was science, scientists and engineers. Under this influence, I decided at an early age that what I wanted was to become an engineer. This decision became the core of my outlook on life.

Although my parents had no problems in maintaining a high standard of living, the situation around us in the late twenties was getting grim. I remember very long lines at bakeries, with bread a hard to get commodity. A food crisis was in the making. In 1931, my parents decided to return to Iran, taking me with them. In Baku, I completed three years of elementary school. In Tehran, my parents enrolled me in a missionary school, the American College. In relation to School Number 16, the American College was in a different world. In School Number 16, believing in God was viewed as a criminal offense. At the American College we had chapel at 10 am every day, singing hymns and reciting the Bible. When I was enrolled in the American College, through an administrative mistake I was placed in the eighth grade, not knowing Farsi and not knowing English. Miraculously I survived, but what happened is that the Ministry of Education issued a regulation requiring that all students in foreign schools should have completed at least six years in an Iranian school. At the end of my eighth year, I was forced to transfer to sixth grade in an Iranian school. Miraculously, I survived again. After completing my sixth grade in the Iranian school and passing a nation-wide examination, I returned to the American College as a student in the ninth grade. I still do not quite understand how I managed to jump from the third grade to the eighth grade, from the eighth grade to the sixth grade and back to the ninth grade.

The last four years at the American College presented no problems. Most of my teachers were Presbyterian missionaries from the Midwest. For me, they were role models—dedicated, principled, well-educated and fair-minded. At a distance, I fell in love with the United States and American values. During my student days at the American College, I met Fay, my wife.
who at that time was a student at the Women's branch of the American College. We were acquaintances but not close friends.

After graduating from the American College, I decided to apply for admission to the University of Tehran. I had to pass a stiff nationwide entrance examination. I passed the examination, ranking number 3. At that time, rankings were very important and highly ranked students got a lot of publicity. In Iran, knowledge and culture has always been put on a pedestal.

My years at the University of Tehran were happy years in my life. In Tehran, I had many friends, especially within the Russian-speaking community. As in Baku, we lived very well. My mother was an MD and my father was a partner in a building supply company. We had a maid and I had a car and a valet. At the American College, the ambient culture was Anglo Saxon Protestant. At the University of Tehran, the ambient culture was Iranian and French. Most of my professors were graduates of elite French universities. The standards of instruction were very high. At that time, the regime in Iran was anti-clerical. Some of my professors had communist sympathies. During my student days and thereafter, my outlook on the world was not influenced by the prevailing views. In a photo, I am shown in my study with a sign above the desk saying in Russian один, meaning Alone. This was a proclamation of my commitment to nonconformity—a commitment which I adhered to throughout my life.

In Europe, Germany was preparing to invade other countries. War seemed to be imminent. I graduated from the University of Tehran in 1942 with a degree in Electrical Engineering. At that time, Iran was occupied by the Allies with Americans controlling the center, including Tehran. My father ran a company which supplied construction materials. Thanks to my knowledge of English, I served as an intermediary between him and the Persian Gulf Command. As an intermediary, I had a high income. I could have stayed in Tehran, acquiring wealth and living in high style, but this was not what I wanted. My calling was to be an engineer working on the frontiers of science. To this end, I decided to leave behind my comfortable life in Tehran and immigrate to the United States in pursuit of a career in the academic world. I applied for admission to MIT and was admitted because at that time MIT did not have many students. I left Tehran early in 1944, traveling to the United States by air and sea. I arrived in New York in July 1944 and moved to Cambridge after spending the summer months working at the International Electronics Corporation. This was my only stint in industry.

To me, MIT was a new world. Throughout the war, MIT was the Mecca of research in electronics, communications, and what later developed into information technology. I had a feeling
that I am at the frontiers of a new era. Many subjects were new to me. At the University of Tehran, I got excellent training in the basic sciences but my exposure to the world of electronics was not there. In Iran, at the time I was a student at the University, there was no industry and no research. I took courses in armature winding of motors but nothing related to electronic circuits. At MIT, it did not take me a long time to absorb the new ideas. In fact, I found that MIT was less demanding than the University of Tehran. In most cases, I could complete the exams in half the time. My Master’s thesis dealt with helical antennas but I was inspired, above all, by Professor Guillemin’s lectures on circuit theory.

I graduated from MIT with a Masters degree in electrical engineering in February 1946. My parents came to the United States shortly thereafter and settled in New York. I did not want to be away from them. I decided not to continue my graduate studies at MIT toward a Ph.D. degree, and moved to New York. Professor Guillemin tried to persuade me not to do so. Here is what he said in his letter of recommendation. “I regard Mr. Zadeh as one of the most brilliant students that it has recently been my pleasure to know. You will be fortunate indeed if he decides to join your staff. I say this will feeling for I had hoped to be able to get Mr. Zadeh to take part in research activities here at MIT and shall very definitely regret losing him.”

I was very fortunate in finding a position as an instructor in electrical engineering at Columbia University—a leading university in the United States. I shudder at the thought of where I would be today if I had to take a job at a teaching university in the New York area, with no research and no opportunity to move upward. In March of 1946, I married Fay, the love of my life. My move to Columbia University and marrying Fay were decisive events in my life.

After spending three years as an instructor, I received my Ph.D. degree in 1949 under the supervision of Professor John R. Ragazzini. My thesis was concerned with the frequency analysis of time-varying networks. But my interests began to shift to systems analysis and information systems. In 1950, I published a significant paper “An extension of Wiener’s theory of prediction,” co-authored with Professor Ragazzini. In 1952, I co-authored with Professor Ragazzini a paper on what has come to be known as the z-transform method—a method which is in wide use today in digital signal processing. During the next few years, I was brimming with ideas, publishing about ten papers per year. In 1954, I was promoted to the rank of Associate Professor, and was promoted to the rank of Professor in 1957. In 1956-57, I was a visiting member of the Institute for Advanced Study in Princeton, New Jersey, where I became acquainted with some of the leading intellects at that time. Of particular importance was my auditing a course on logic taught by Stephen Kleene. His lectures were inspirational. He became my mentor in logic.

In the fifties, I became very interested in probability theory and its application to decision analysis. My best friend was Herbert Robbins, a brilliant mathematician and Chair of the Department of Mathematical Statistics. Another very close friend was Richard Bellman, the father of dynamic programming. Robbins and Bellman had a profound influence on my intellectual outlook.

In the fifties, my work made me a visible figure in the world of systems analysis and information systems. My position at Columbia University was secure, but clouds began to appear in the blue sky. A conflict developed between my Department and the Electronics Research Laboratory—a laboratory supported by the Air Force—over giving tenure appointments in the Department to employees of the Laboratory. This was equivalent to selling such appointments—this is what I refer to today as money-centricity. I was an opponent of money-centricity then, as I am now. Professor John Whinnery, who was Chair of Electrical Engineering at UC Berkeley, heard about the conflict. He was passing through New York on a Sunday in January 1959. He called me at home to inquire if I would be interested in moving to Berkeley. There were pros and cons.
Eventually, I decided to leave my comfortable position at Columbia University and move to Berkeley, knowing that at UC I would have to work much harder than I had to at Columbia. In July of 1959, Fay, Stella, Norman and I started on a long journey by car to Berkeley. Moving to Berkeley was a decisive event for me and my family.

At Berkeley, there were many new challenges. As anticipated, I had to work much harder at UC than I had to at Columbia, but the challenges and pressures were good for me. I coauthored a book with Professor Charles DeSoer in which a novel state-based approach to linear system theory was described. In 1963, I was on semi-sabbatical leave at MIT. While I was there, I received a message from John Whinnery, who was Dean of Engineering at that time, saying that he would like me to serve as Chair of Electrical Engineering. Although administration was not my cup of tea, I felt obliged to respond affirmatively to his request. This was an important event in my career.

In 1965, I was invited to attend a conference in the Soviet Union which was held on board of Admiral Ankhimov—a ship that years later, sank in the Black Sea. On the way to the conference, Fay and I stopped in Baku for one day. It was a memorable visit after leaving Baku in 1931. I met many leading figures at that time, including Professor Ibragimov, whom I met again on my visit to Baku in 2008. I also met my cousin, Jannat Selimova. Fay and I were overwhelmed by the warm hospitality. My visit to Baku brought back memories of my childhood.

As Chair of EE, I found myself involved in a bitter conflict with Computer Science over whether Computer Science should be within EE or on the outside. A preemptive move on my part was to request that the name of the Department be changed to EECS. This request was approved by the University in 1967. Eventually, almost all EE departments in the United States have changed their name, mostly to Department of Electrical and Computer Engineering. Changing the name of the Department and building-up a program in Computer Science were important achievements, in recognition of which I was awarded the IEEE Education Medal.

While I was serving as Chair, I continued to do a lot of thinking about basic issues in systems analysis, especially the issue of unsharpness of class boundaries. In July of 1964, I was attending a conference in New York and was staying at the home of my parents. They were away. I had a dinner engagement but it had to be canceled. I was alone in the apartment. My thoughts turned to the unsharpness of class boundaries. It was at that point that the simple concept of a fuzzy set occurred to me. It did not take me long to put my thoughts together and write a paper on the subject. This was the genesis of fuzzy set theory. I knew that the word “fuzzy” would make the theory controversial. Knowing how the real world functions, I submitted my paper to Information and Control because I was a member of the Editorial Board. There was just one review—which was very lukewarm. I believe that my paper would have been rejected if I were not on the Editorial Board. Today, with over 26,000 Google Scholar citations, “Fuzzy sets” is by far the highest cited paper in Information and Control.

My paper was a turning point in my research. Since 1965, almost all of my papers relate to fuzzy set theory and fuzzy logic. As I expected, my 1965 paper drew a mixed reaction, partly because the word “fuzzy” is generally used in a pejorative sense, but, more substantively, because unsharpness of class boundaries was not considered in science and engineering. In large measure, comments on my paper were skeptical or hostile. An exception was Japan. In 1968, I began to receive letters from Japan expressing interest in application of fuzzy set theory to pattern recognition. In the years which followed, in Japan fuzzy set theory and fuzzy logic became objects of extensive research and wide-ranging application, especially in the realm of consumer
A very visible application was the subway system in the city of Sendai—a fuzzy-logic-based system designed and built by Hitachi and Kawasaki Heavy Industries. The system began to operate in 1987 and is considered to be a great success.

My term as Chair came to an end in 1968. I decided to switch from systems analysis to computer science. To this end, I spent a year at the IBM Research Laboratory, San Jose, CA, and with project MAC at MIT. Upon my return to Berkeley in 1969 I began to teach courses in computer science, especially in the area of database systems and AI. To teach these courses I had to learn a lot that was new to me. It was a challenge and it did me a lot of good. Freed from administrative duties, I could focus my efforts on acquisition of knowledge about new theories and exploration of new ideas. One such idea was the concept of a linguistic variable. The concept occurred to me while I was watching a performance at the San Francisco Opera. I recognized at once that it was an idea that opened the door to important applications of fuzzy set theory. Today, the concept of a linguistic variable and the related concept of a fuzzy if-then rule are employed in almost all applications of fuzzy set theory and fuzzy logic. I described these concepts in a 1973 paper, “Outline of a new approach to the analysis of complex systems and decision processes,” published in the IEEE Transactions on SMC, and in my 1975 paper in Information Sciences, “The concept of a linguistic variable and its application to approximate reasoning.” Both papers are among the highest cited papers in SMC Transactions and Information Sciences, respectively.

The concept of a linguistic variable—a variable whose values are words rather than numbers—opened the door to a wide-ranging enlargement of the role of natural languages in science and engineering. It is a deep-seated tradition in science to accord much more respect to numbers than to words. As a countertraditional concept, the concept of a linguistic variable raised questions regarding the validity of according more respect to numbers than to words. By raising the question, the concept of a linguistic variable sparked a great deal of opposition. Here is what Rudolf Kalman, a brilliant scientist and a student in my courses at Columbia, had to say:

I would like to comment briefly on Professor Zadeh's presentation. His proposals could be severely, ferociously, even brutally criticized from a technical point of view. This would be out of place here. But a blunt question remains: Is Professor Zadeh presenting important ideas or is he indulging in wishful thinking? No doubt Professor Zadeh's enthusiasm for fuzziness has been reinforced by the prevailing climate in the U.S.—one of unprecedented permissiveness. 'Fuzzification' is a kind of scientific permissiveness; it tends to result in socially appealing slogans unaccompanied by the discipline of hard scientific work and patient observation.

My 1973 paper found an immediate application to fuzzy control in a seminal 1974 work of Mamdani and Assilian. Today, fuzzy control is employed in a wide variety of applications ranging from cameras and household appliances to automobile transmission and ship stabilization.

My first paper on fuzzy logic entitled “Fuzzy logic and approximate reasoning,” was published in 1975 in Synthese. My first paper on possibility theory was published in 1978 in Fuzzy Sets and Systems. This paper provided a basis for application of possibility theory to the semantics of natural languages. This is what I have done in a series of papers starting in 1978, leading to the concept of test-score semantics. I believe that eventually what will become widely recognized is that semantics of natural languages should be based on fuzzy logic.

An important direction in my work was application of fuzzy logic to construction of a computational system of perceptions, CTP. Basically, a natural language is a system for describing
perceptions. In CTP, perceptions are described in a natural language. Then, fuzzy logic is employed to construct computational models of words and propositions, and employ these models as objects of computation and deduction.

For the past fifteen years, my work has been focused on construction of a system of computation which I call Computing with Words (CW or CWW). CW is rooted in the concept of a linguistic variable. CW has two principal components. First, a precisiation module; and second, a computation module. The precisiation module translates natural language into what is referred to as generalized constraint language, GCL. In the computation module, generalized constraints serve as objects of computation. I believe that in coming years, Computing with Words will gain recognition as an important formalism in the conception, design and utilization of intelligent systems.

The year 2008 was a memorable year in my life. I traveled to many conferences, covering 250,000 miles on United. By next to the last conference, was BakuTel 2008, which was held in Baku. This was my second visit to Baku, forty-three years after my first visit in 1965. My participation in BakuTel was a memorable event. I had the honor of having a meeting with President Ilham Aliyev—who impressed me as a truly outstanding personality and a leader with vision and initiative. I also had the honor of being hosted by Professor Ali Abbasov, Minister of Communications and Information Technology. Professor Abbasov was a most gracious host. A leader with vision, intelligence and unbounded energy, Professor Abbasov has played and is continuing to play a pivotal role in advancing the status of communications and information technology in Azerbaijan. My visit to Baku set the stage for collaboration with scientists in Azerbaijan, especially with Professor Telman Aliyev, Professor Rafik Aliyev, Professor Rasim Alquiyev, Associate Professor Shahnaz Shahbazova truly outstanding contributors to fuzzy logic, soft computing and decision-analysis. Among memorable events was my visit to School Number 16 which brought back memories of my childhood. I still carry with me fond memories of my 2008 visit to Baku.

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In December of 2008, I experienced a heart attack. After a period of recovery, I returned to work. What pleases me most is that I have been able to continue my work, coming up with new ideas and writing papers. Fay has always been and continues to be at my side.

This brings to an end a brief account of my life and work. I am deeply grateful to my adopted country, the United States, for giving me an opportunity to develop and propagate my ideas. It is my hope that my ideas, though controversial by nature, will gain acceptance and recognition in the years ahead.