by Mo Jamshdi, Thomas Kailath, Vladik Kreinovitch, Bijan Tadayon, Saeid Tadayon, James Tien, Rafik Alieve, Witold Pedrycz, Laczlo Koczy, Imre Rudas, Anthony Nolan, Takesh Yamakawa, George Bekey, and Mohammad Akbarzadeh-T

Celebrating the Life of Lotfi A. Zadeh

The Distinguished Father of Fuzzy Logic Passes Away at Age 96

Prof. Lotfi Zadeh, creator of the field of fuzzy systems and many of its branches, passed away on 6 September 2017 at his home in Berkeley, California. Prof. Zadeh was born in Baku in the Soviet Union (now Azerbaijan) in 1921 to an Iranian-Azari father (Rahim Asghar-Zadeh) from Ardebil, Iran, and a Russian mother (Fanny Asgharzadeh) from Moscow. When he was ten years old, the family moved to Tehran, where the young Zadeh went to the American Missionary School (now Alborz High School) and learned English and Farsi. Later, after graduating, he entered the University of Tehran's Daneshkadeh Fanni (School of Engineering). After graduation, he worked for the U.S. Army in Tehran during World War II. In 1944, he moved to the United States and attended the Massachusetts Institute of Technology in Cambridge. He went on to receive his M.S. and Ph.D. degrees in electrical engineering from Columba University in New York.

On 20 March 1946, during Nowruz, he married Fay Sand, the daughter of a Latvian immigrant in Tehran. Prof. Zadeh started his academic career at Columbia University, New York, in 1949, and by 1959, when he left Columbia for the University of California (UC) at Berkeley, he was a well-established full professor and scientist in electrical circuits and systems engineering.

Prof. Zadeh always thought outside of the box and created numerous theories in his fields of expertise. His early contributions were in circuits and systems theories at both Columbia and UC Berkeley. In the early 1960s, he realized that his knowledge of systems engineering lacked a role for the human being and its reasoning. In 1965, he published the article "Fuzzy Sets," where he introduced knowledge-based linguistic mathematics, e.g., the values "short" or "tall" for height. These words are known as *fuzzy variables*. He unveiled a new way of looking at uncertainty similar to, but not the same as, probability theory. Naturally, he was confronted with scientists and engineers who looked at systems theory in an exact, binary manner versus his fuzzy set, which can take on infinite values between false (zero) and true (one). He accepted all criticisms with a grain of salt and used to say, "I have a thick skin and take all your comments with compliments."

Lotfi A. Zadeh

He received more than 35 honorary doctorate degrees and numerous honors and awards from countries around the world, including Japan, the United States, the Soviet Union, Russia, Azerbaijan, and Iran. He was also a member of many academies, among other honors, and more than 30 technical journals bear his name as honorary editor. In 2011, at age 90, he published the concept of Z-numbers to add a degree of uncertainty to the numerical value of fuzzy numbers, which was patented in 2013. That patent was an impetus to create a startup company, Z-Advanced Computing, in Potomac, Maryland. Approximately 30,000 patents have been filled in the United States alone based on his theories of fuzzy systems, computing with words, Z-numbers, and more. His works, ideas, and patents have penetrated almost every aspect of our lives, from smart cameras to the smooth transmission of cars, elevators, home appliances, Google searches, and more.

Over the last few years, old age caught up to Prof. Zadeh, and his wife Fay Zadeh's (Sand's) passing several months ago was unbearable to him. The loss of Prof. Zadeh is a great one to humanity and the science of artificial intelligence (AI) and systems and control engineering. Fields like systems engineering, computer science, mathematics, and more have lost a giant in those fields. I express

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my deepest condolences to all scientists around the world who have either followed his works, known him, or seen him.

Here are some distinctive quotes from Prof. Zadeh, extracted from Fay Zadeh's (Sand's) book:

1) "I agree entirely with everything you did not say."
2) "To survive in this place, you need to kill yourself" (said during his term as chairman of the Department of Electrical Engineering and Computer Sciences at UC Berkeley).
3) "If I am on my death bed and they say there is a good garage sale nearby, I will try to get up" (making fun of his known love of garage sales).

For more, see Zadeh's (Sand's) book *My Life and Travels with the Father of Fuzzy Logic*.

Citations

Prof. Zadeh holds the all-time record of Google Scholar citations.

	All	Since 2012
Citations	186,416	68,793
h-index	106	69
I10-index	317	181

—Lutcher Brown, University of Texas, San Antonio, who knew Prof. Zadeh for 49 years and coined his title of "The Father of Fuzzy Logic" in 1992.

A Great Mentor and Friend

Prof. Zadeh's passing was a great loss to the world and to me, personally, as he had been a great mentor and friend since 1959. My master's degree thesis that year solved the problem of identifying linear time-variant (LTV) communication channels, which he appreciated since his doctoral work was on LTV systems. Prof. Zadeh was then the predominant figure in system theory, so his support greatly helped me over the years. His physical condition was poor when we visited him two years ago, but his mind was sharp, sending a typically generous note the day after. The memory of this colossus will remain forever.

—Thomas Kailath

During the 2014 Norbert Weiner IEEE Systems, Man, and Cybernetics Panel. Participants (from left to right): Prof. Bill Rouse, Prof. Keith W. Hipel, Prof. Zadeh, Dr. Dimitar Filev, Dr. José del R. Milan, Prof. Larry Hall, and the late Prof. Bill Gruver. (Photo courtesy of Dr. Keith Hipel, University of Waterloo.)

Unique Abilities

Some researchers generate ideas, others promote them, some combine different ideas, and still others implement these ideas into practice. Prof. Zadeh had a unique ability to excel in almost all of this and left only implementation to others. I admire his great ideas as well as his unique ability to promote them. He would enter to a skeptical and sometimes hostile audience, like an early Christian being led to the lions, and use plain words, simple examples, and a smile on his face to convince many skeptics; the lions have been magically tamed. The world needs people like him!

—Vladik Kreinovich

Top Scientist and Visionary

Prof. Zadeh was our mentor, advisor, teacher, and friend. He was an exemplary human being. He and his wife were very friendly, and they both had a great sense of humor. He is one of the top scientists and visionaries of all time, impacting computer science, electrical engineering, and applied mathematics for generations to come. He will be greatly remembered in history and science books hundreds and thousands of years from now. We all lost a great friend and a scientific giant. We miss him and his wife very much.

—Bijan Tadayon and Saied Tadayon

Thoughtful and Courteous

Prof. Zadeh will be remembered not only for his impressive seven decades of contributions to computational reasoning, as expressed in natural language, fuzzy logic, and soft computing, but also for his thoughtfulness and courtesy. I distinctly recall the first time I read about his view on complex systems and decision processes [1]; I was very impressed. Those of us who were fortunate enough to know him and his lovely wife Fay, we have been blessed.

—James Tien

Ahead of His Time

Prof. Zadeh was a universally recognized scientist who broke through many traditional obstacles and was ahead of his time by 50–100 years. He was a very genial, simple man and, at the same time, a man of principle. His simplicity equaled his greatness. He was always enthusiastic in research and collaboration and brought a lot of ideas to draw together theory and practice.

I met Prof. Zadeh for the first time in Moscow at the Institute of Control Sciences of the Academy of Sciences

Prof. Zadeh (left) and Dr. Filev during the 2014 Norbert Weiner IEEE SMC Panel. (Photo courtesy of Dr. Keith Hipel, University of Waterloo.)

At the conclusion to the 2014 Norbert Weiner SMC Panel. (From left): Prof. Vladik Kreinovich, Prof. Rouse, Prof. Hipel, Prof. Zadeh, Dr. Filev, Dr. Milan, Prof. Hall, and Prof. Gruver. (Photo courtesy of Dr. Keith Hipel, University of Waterloo.)

of the U.S.S.R. in 1965. Our scientific cooperation and family friendship began in the 1980s. We completed several joint projects on fuzzy logic, computing with words, and, mainly, modern decision theory with imperfect information. In cooperation with Prof. Zadeh, my colleagues and I wrote the first book devoted to his idea of Z-numbers, *The Arithmetic of Z-Numbers*. Now, at the suggestion of Prof. Zadeh, we have prepared a new book, *Fuzzy Logic Theory and Applications*, *Part I* (L. Zadeh and R. Aliev) and *Part II* (Editors L. Zadeh and R. Aliev).

I will never forget his permanent and comprehensive support of our scientific activities. The loss of Prof. Zadeh is a loss for all mankind. My heart will always have positive memories of him.

—Rafik Aliev

Pushing Forward the Frontier

I can vividly recall my early meetings with Prof. Zadeh. The first one was at the International Fuzzy Systems Association (IFSA) Congress in Tokyo. His plenary talk was inspiring with lucidly posed arguments; this provided new perspectives and helped me position the research known from the literature in a completely new, enriched perspective. The time was hectic, and Prof. Zadeh was surrounded by a crowd and not easily accessible. However, we managed to have a brief conversation. What I found striking was his ability to listen, offer advice, and encourage.

From a broader perspective, this second IFSA Congress was successful and very important to the development of fuzzy sets worldwide. Japan was booming at this time; fuzzy sets were on the rise, the term *fuzzy* was en vogue, a plethora of applications of fuzzy sets was embraced by the Japanese industry (e.g., the Sendai railway system and home appliances, to recall the most obvious examples). The presentations made by the pioneers and eminent Japanese researchers and engineers were highly attractive and influential; for the first time, what had been known in the literature about fuzzy controllers was shown completely through a large number of experimental setups. The Congress was a turning point for academia and industry. It was an event loaded with enthusiasm, dedication, and the ingenuity of the young and rapidly growing community.

The next meeting with Prof. Zadeh took place in quite a different environment and happened during my postdoctoral research stay in The Netherlands. Prof. Zadeh came to Delft to give a seminar on what must have been one of the stops during his busy trip to Europe. The talk was enlightening, and there was more time for discussion in a far more relaxed environment than the one during the IFSA Congress. This was during the time Prof. Zadeh was preoccupied by the ideas of PRUF (an acronym for Possibilistic Relational Universal Fuzzy), which was used for test-score semantics for natural languages and meaning representation. This framework was at the center of our discussion.

Our frequent-but-brief encounters, considering the hectic conference settings, were always inspiring. Prof. Zadeh's comments were essential, technically far reaching, and inspiring. He always showed his sense of humor and wit.

Our interaction expanded when I assumed the role of editor-in-chief of the journal *Information Sciences*.

Since then, I had the privilege of having a number of papers authored by Prof. Zadeh published in the journal. He published one of his first seminal papers in *Information Sciences* [2], which was coauthored by E.T. Lee and part of a comprehensive three-part treatise. He also authored another groundbreaking paper: "The Concept of a Linguistic Variable and Its Application to Approximate Reasoning" [3]–[5].

These contributions were a Rosetta Stone of fuzzy sets, bringing a vision of the area and pushing forward the frontiers of research. Since my time as editor-in-chief, I was able to fully appreciate Prof. Zadeh's style of writing. His works are impeccable, lucidly written, with a clear, carefully articulated message, and a great deal of attention paid to every detail. His most recent original papers published in *Information Sciences* can be found in [6]–[11]. Papers that were published just a short while ago that went far beyond fuzzy sets, both being inspiring and innovative, can be found in [12] and [13].

Now that Prof. Zadeh is no longer with us, and looking back at all these long years, I feel, today, as all of us do, very fortunate and gratified by his friendship. It was truly remarkable to have the honor of receiving Prof. Zadeh's advice, support, and encouragement for so many years. I do believe that his legacy will stay in the research community; his visions will inspire and encourage us to move forward in exploring new, uncharted territories of intelligent systems.

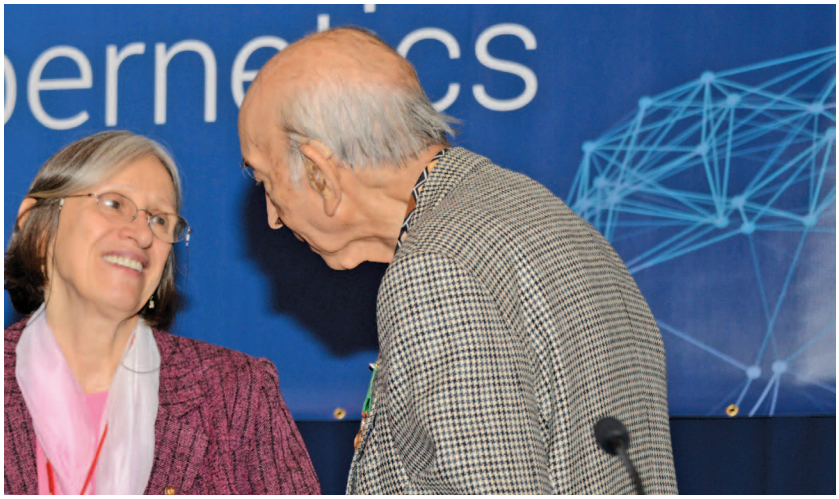
—Witold Pedrycz

Cordial and Encouraging

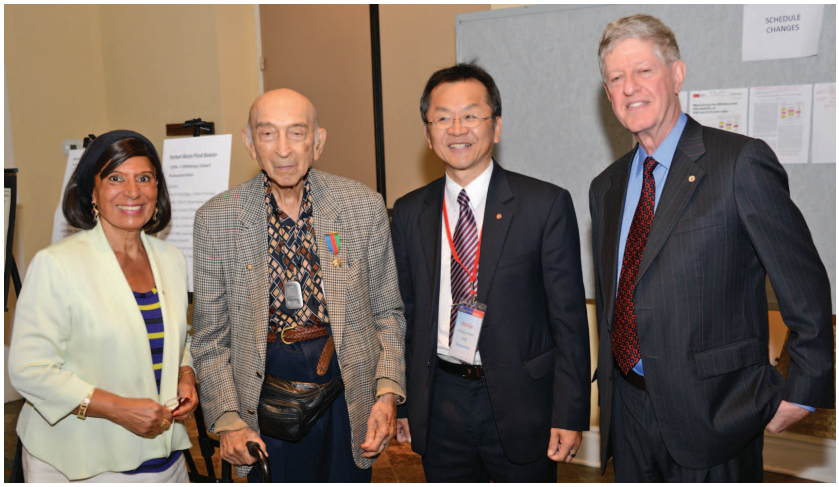
After reading Prof. Zadeh's papers in 1973, I wrote my first manuscript, on interacting operations, and sent it to him. He replied very cordially and sent me his most recent work. In 1975, he came to Hungary, and I spent a wonderful week with him and Fay.

Following that experience, I had frequent communications with him, invited him many times to Budapest,

Prof. Phil Chen (right) introduces Prof. Zadeh to the late Dr. Gruver (left) while Dr. Ferial El-Hawary looks on. (Photo courtesy of Dr. Keith Hipel, University of Waterloo.)



Prof. Zadeh in a conversation with Dr. Ljiljana Trajkovic. (Photo courtesy of Dr. Keith Hipel, University of Waterloo.)



(From left): Dr. El-Hawary, Prof. Zadeh, Prof. Chen, and the late Dr. Gruver. (Photo courtesy of Dr. Keith Hipel, University of Waterloo.)

and visited Berkeley. He was always very encouraging and supportive, and, gradually, we became friends. In some plenaries, he cited my results presented earlier in the Soda Hall. I keep several "relics," including gifts from him, and I dearly remember when he and Fay attended my 50th birthday celebration in Honolulu.

—Laczlo T. Koczy

A Man by Any Other Name...

Lotfi!

The name for me means a superior life. A life dedicated to science, Nobel Prize-level achievements in science, a man of vision and initiatives, the paterfamilias of the worldwide fuzzy family, a kind person, and a very good friend of mine. After our long-term personal cooperation and his collaboration on the scientific life of Óbuda University, Budapest, Hungary, he became an honorary member of the university and received the Honorary Citizen Award in 2004.

In 2011, the senate of Óbuda University awarded Prof. Zadeh the doctor honoris causa—the honorary doctor title of Óbuda University for his outstanding work in the sciences, pioneering conceptualization of fuzzy sets and fuzzy logic, and constant commitment to strengthening the global network of the fuzzy community. The ceremony was transmitted via the Internet to Budapest, allowing the senate and doctoral council of the university to take part in the event.

—Imre Rudas

The Color Whisperer

Imagine that everyone saw the world in black and white. Then, a quiet and gentle man innovated the color pencil. At first, it was so strange and different that it was rejected. But he kept on working, redrawing the world in color. Finally, after years of being the color whisperer, his ideas spread to surround the planet. Now, everyone uses color, but few even know the name of the gentle spirit who caused the transformation. Prof. Zadeh kept innovating, teaching, and mentoring others and sharing with whoever asked, because he knew he was making the world a better place.

—Anthony Nolan

Stand by Me

It was in Hawaii in 1984 when I first met the great scientist, Prof. Zadeh, where I presented my talk on my first fuzzy logic chip in analog current mode. Since then, I had been supported by him to diffuse the importance of fuzzy hardware systems, especially the several types of fuzzy logic chips, fuzzy controller, fuzzy computer, and more. Prof. Zadeh used to stand by me to provide support and suggestions for every important opportunity, such as establishing the national foundation, Fuzzy Logic Systems Institute, in 1990 and organizing seven international conferences on fuzzy systems (the so-called IIZUKA Conference) from 1988 to 2000 in Iizuka, Japan.

His works, ideas, and patents have penetrated almost every aspect of our lives, from smart cameras to the smooth transmission of cars, elevators, home appliances, Google searches, and more.

—Takeshi Yamakawa

Genius and Gentleman

My wife and I were living in Encino, a suburb of Los Angeles, in the San Fernando Valley of California when a new couple moved in next door. Both houses had mailboxes at the street; our houses were on a hillside, set back from the street. One day, when I went to check for mail, the new lady from next door was also there at her mailbox. I introduced myself and, when I shared details about my work, she said, "Oh, my father is also a professor of electrical engineering. Maybe you've heard of him; his name is Lotfi Zadeh." My neighbor was his daughter Stella. My wife and I became friends with Stella and her husband, and we followed the tragedy of her cancer. We spoke to her husband frequently and followed her transfer to the Mayo Clinic, where she sadly passed away. We have now lost contact with her husband, who has remarried and, while he still practices law, has a second career as a fiction writer.

Prof. Zadeh was a genius and a gentleman, and I am fortunate to have known him as a colleague and friend. I believe that his contributions to engineering that made it possible to design imprecise systems in an optimum way are still not fully appreciated. Most people don't realize that he also had a marvelous sense of humor. I recall sitting with him and a small group of friends while he kept us laughing for hours with endless stories; he was a great storyteller and rare human being.

—George Bekey

A Visionary and Inspiration

I first met Prof. Zadeh when I was a novice Ph.D. degree student at the 1992 World Automation Congress in Santa Fe, New Mexico. Back then, fuzzy logic was big in Japan, and Prof. Zadeh was traveling the world introducing his grand vision everywhere. He was a true visionary, respected academician, and great inspiration to many of us who followed in his footsteps. However, his revolutionary ideas also had their critics, which Prof. Zadeh took with great humility. Perhaps this was another lesson to be learned from this great man. It always amazed me how he could simply introduce a new concept or word, only to be followed by so many

Remembering Lotfi Zadeh

Dimitar Filev

Prof. Lotfi Zadeh, one of the titans of systems science, control theory, and artificial intelligence (AI), invented the concept of fuzzy sets and created the theory of fuzzy logic, fuzzy systems, and approximate reasoning. He was the founder of the broad and long-reaching vision of soft computing as a profound engineering approach to AI combining the power of neural networks, fuzzy systems, evolutionary computing, and machine learning. His interests and contributions expanded from deciphering the complexity of human reasoning and natural language to the very pragmatics of industrial applications of soft computing. Prof. Zadeh was a remarkable icon of scientific research and engineering, yet he was very humble, so I will mention with utmost discretion only some of the accolades that testify to the significance of his legacy and contributions to science, engineering, and humanity in general: membership in the National Academy of Engineering, more than 20 honorary doctorates, copious prestigious national and international awards, three major IEEE medals, and myriad scientific papers with an incredible number of citations and impact on the scientific community.

I had the opportunity to meet Prof. Zadeh for the first time in 1989 at a conference in Iizuka, Japan. Impressed by his enlightening, yet tender and encouraging, discourse and his creative and groundbreaking vision, I was immediately drawn into the vast realm of his ideas about the power of fuzzy modeling, control, and their applications. After that, I had multiple interactions with Prof. Zadeh at conferences, his Berkeley Initiative in Soft Computing (BISC) seminar, and, for the last time in June last year, in his home in Berkeley. I will never forget the 1998 IEEE Conference on Decision and Control in Tampa, Florida, where I had the honor of supporting Prof. Zadeh as a panelist in his debate with Prof. Michael Athans about conventional versus fuzzy control. It was a heated but courteous professional discussion in which Prof. Zadeh's conciliatory but firm and well-justified position made a strong case for the important role of fuzzy control as a task-oriented methodology complementing the well-known classical control techniques, especially in human–machine systems and applications. Over the years, we have witnessed numerous examples attesting Prof. Zadeh's vision; multiple successful intelligent control applications where fuzzy systems were introduced within the framework of heuristic strategies at a higher control level (e.g., supervisory control and the formalization of heuristic tasks and goals) and in conjunction with control algorithms that require subjective information, which could be challenging to formalize within the framework of conventional control.

Prof. Zadeh was one of the founding members and an active participant in the IEEE Systems, Man, and Cybernetics Society (SMCS) conferences and events. We all remember his remarkable keynote at the annual SMCS conference in San Diego, California, in 2014. He was a major supporter of the idea of expanding the SMCS toward soft cybernetics, brain modeling, brain–computer interfaces, and human–machine systems. For many years, the IEEE SMC Technical Committee on Soft Computing has been the largest and most active technical community within the SMCS, maintaining and developing Prof. Zadeh's vision for a smart collaborative use of the methods and tools of computational intelligence.

For all of us who had the privilege to know him and have been touched by his vision and ideas, Prof. Zadeh will remain in our hearts forever as a scientific giant and a man of exceptional intelligence and great humanity.

Zadeh visiting the home of Hideyuki Takagi in Fukuoka, Japan, in 2004.

Hideyuki Takagi

Prof. Zadeh hosted me during my visiting research at the University of California at Berkeley from October 1991 to September 1993. Thanks to this opportunity, I could concentrate my research on fusing neural networks, fuzzy systems, and genetic algorithms as well as helping with the management of his BISC seminar. He introduced me to many researchers when they visited him, which helped me to form researcher networks that have benefited my joint research and organizing conferences.

I have three pieces of memorabilia of Prof. and Mrs. Zadeh. The first one is a single-handled pot that Fay presented us when our family started Berkeley life, and we still use it regularly at our home. The second one is a stuffed bear that was a Christmas present from Fay and Prof. Zadeh to our daughter when she was two years old. She always brought it in spite of several moves for her school and work, and it is still in her bedroom even after more than a quarter of a century.

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Remembering Lotfi Zadeh *(continued from page 47)*

The last one is a set of studio monitor speakers, Yamaha Monitor NS-1000. Prof. Zadeh was a famous audio maniac, and their house on Berkeley Hill was full of his audio sets. Fay finally got fed up with the piles of audio sets and left their home for a brief period after leaving a note for Prof. Zadeh, "I will not return until they are sold off." Prof. Zadeh sold some of them with sorrow. My Yamaha monitor is one of them, and I am still enjoying its sound in our living room.

Eddie Tunstel

The late Prof. Zadeh, whom we lost in September 2017, was a world-renowned luminary who, as an active member, appreciated the value of the SMCS and made it a professional home for many years. Beyond his technical accomplishments and long-lasting contributions, I remember him for his very calm demeanor and unassuming personality. He was also very equitable in inspiring scholars at any stage of their careers, as he encouraged me with reassuring compliments after I presented one of my first conference papers involving fuzzy logic more than two decades ago. Having interacted with him since then on a number of occasions at the SMCS annual flagship conference and other conferences, I know that he is sorely missed by all who knew him.

Among many elements of his legacy, the SMCS has been a consistent backdrop for the past half-century. That association spans a period including the 1973 publication of his seminal manuscript introducing rule-based fuzzy logic in *IEEE Transactions on Systems, Man, and Cybernetics* and, more recently, the SMCS's establishment of the Lotfi A. Zadeh Pioneer Award in 2014. That award honors a person or persons with outstanding and pioneering contributions to academic and/or industrial research in systems science and engineering, human–machine systems, and/or cybernetics. This honor was first awarded in October 2017 at the IEEE SMC 2017 conference in Banff, Canada, posthumously to Prof. Zadeh himself.

At the University of South California (USC), Prof. Jerry M. Mendel hosted Prof. Zadeh. Mendel and Zadeh at USC stand with three of Mendel's former students (from left): John Kormylo, Mendel, Fred Aminzadeh, Zadeh, and Mostafa Shiva.

Although Prof. Zadeh will be missed, we continue to benefit from his documented foresight on ideas supporting the fields of interest of the SMCS. Whether they are based on concepts from his earlier career focused on the development of systems theory and analysis, including early thoughts from his 1950 article on the notion of thinking machines, or based on more recent ideas for computing with words, Prof. Zadeh's foresights remain relevant today and into the emerging technological future. Furthermore, as we encounter semblances of his pioneering character among our colleagues worldwide, the IEEE SMCS. will continue to recognize and honor such exemplars with his namesake pioneer award.

Jerry M. Mendel

I have spent more than 30 years working on many aspects of fuzzy sets and systems, but for more than 20 of those years my attention has been focused on so-called type-2 fuzzy sets and systems. I have often wondered, "Why (around 1975) did Prof. Zadeh invent type-2 fuzzy sets when there was so much that needed to be done with type-1 fuzzy sets?" I never did get a satisfactory answer about this from him, so I can only speculate on why. During the 1960s and early 1970s, he was under attack for his works on fuzzy sets (what courage it took for a brilliant system theorist to go "fuzzy"), and one such attack was about the membership function of a fuzzy set (e.g., how could a fuzzy set be an uncertainty model if, once its membership function parameters are specified, there is nothing uncertain about it?). Perhaps a type-2 fuzzy set was a response to this attack, or maybe he realized from the very beginning of fuzzy sets that requiring something that is "fuzzy" to be precise seemed like a contradiction.

To many, the word "fuzzy" still has a negative connotation when used in a technical context. Of course, Prof. Zadeh was aware of this but felt that, in 1965, fuzzy was the best word for him to use for this kind of a set. I feel that, after more than 50 years, the time has come for these sets to be called Zadehian (or Zadeh) sets. Such sets would have the property of fuzziness. Let's do this to honor this great scholar in perpetuity.

Enric Trillas and Alejandro Sobrino

This section presents a dialogue between its two authors, Enric Trillas (ET), and Alejandro Sobrino (AS), concerning both the man and the engineer, scientist, and thinker whom they both had the fortune of knowing personally.

ET: I learned about and read Prof. Zadeh's 1965 paper "Fuzzy Sets" [S11] in 1975 and met him personally in July 1977, and we maintained a long, sincere friendship that lasted up

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Remembering Lotfi Zadeh *(continued from page 48)*

to his passing away; the last e-mails we exchanged were at the end of June 2017. I find it impossible to evaluate the full value that those 40 years of friendship have for me; I did learn a lot from the lectures I heard from Prof. Zadeh and the papers of his that I read, but mainly from the discussions and the conversations we used to have on wide variety of topics. For me, Prof. Zadeh was an unforgettable master who, along with Karl Menger, I believe had the greatest influence on my research activities. The imprints of their works are clearly evident behind my own thought; for instance, Menger's addendum to Occam's Razor or Prof. Zadeh's view on the constraint imposed by trying to attain too much precision. For me, Prof. Zadeh was up there among the most creative researchers of the 20th century.

AS: I started reading Prof. Zadeh's works in 1985 and met him in person for the first time in 1996, at the XXVI IEEE Multiple-Valued Logic Symposium that we organized at the University of Santiago de Compostela, Spain. My initial approach to fuzzy logic was through the book, *Introducción a la Lógica Formal (Introduction to Formal Logic)* by the Spanish philosopher of logic, Alfredo Deaño, who, in a few lines, approached the principal features of what was, back then, a new type of logic. In a footnote, he said that fuzzy logic attempts to explain imprecision in a precise way. Using a metaphor, he said that it is like an oral theory of stuttering, offering explanations about stuttering but without stuttering. This phrase captivated me in such a way that I found myself desperate to learn more about the topic. As there was no such thing as the Internet, I audaciously wrote to Prof. Zadeh asking him for papers, which he kindly sent to me a few months later. His papers caused a double impression on me; on the one hand, they were so exquisitely written. If language is a window to our mind, I conjectured that Prof. Zadeh's mind would be like his writing: exciting, creative, brilliant. On the other hand, his papers frequently illustrated mathematical or logical notions with examples using natural language. Although the topics dealt with were sometimes cryptic for a graduate in philosophy, the examples provided the reader with accurate insights. Giving and selecting suitable examples is a sign of clear and distinctive intuition, which Prof. Zadeh undoubtedly possessed.

ET and AS: Hence, this short narrative cannot be a typical obituary, nor can it merely contain impartial and independent views. It endeavors to present a passionate picture of the Prof. Zadeh we knew, a number of hints on how, and in line with the previous comments, we see the work of one of the most creative researchers we have had the great opportunity of knowing personally, admiring him, and intellectually benefiting from both his thought and his work. Prof. Zadeh was not only an engineer and a scientist but also an innovative thinker [S5], and this account is no more than a personal, respectful, and warm tribute to his memory offered by two researchers, not only working in different fields, but belonging to different generations.

Some Personal Memories of Zadeh

ET: Prof. Zadeh had a great personal attractiveness; people approached him in a truly incredible way, one example of which is, perhaps, an extreme case that occurred in the spring of 1981 in Berkeley. After working all morning at Evans Hall, Prof. Zadeh and those of us who were there with him at the time went for lunch at the famous Three Cs cafeteria, located outside the campus on Hearst Street. As the weather that day was so good, we sat at a table outside the cafeteria to eat. Prof. Zadeh had his usual, a frugal crêpe and a cup of darjeeling tea. We were in the middle of a pleasant conversation when a beautiful, elegantly dressed woman came out from the cafeteria, walking in the direction of our table; we all gawked at her. Just as she was about to walk past us, Prof. Zadeh said to her, "Please, come and join us!" And she did. After talking for a while, and even if the conversation seemed to be between old friends, it became patently obvious that she and Prof. Zadeh had never met each other before.

Prof. Zadeh was a man who loved culture and beauty, as most of the artistic pictures he took over many years show, with photos not only of scientists and engineers but also dancers, writers, singers, politicians, and more. One day in 1980, I was invited to lunch at Fay and Prof. Zadeh's home on Mendocino Avenue. At that time, the living room in the house was full of very large loudspeakers and, while waiting for Fay, Prof. Zadeh and I were talking about Italian opera and its singers, something about which I was, and still am, very passionate. Prof. Zadeh proceeded to put a record on and said to me, "This is an exam for you," and asked me "What is the song and who is the singer?" I answered, "It's *Nessun dorma* from Puccini's *Turandot*, and the singer is Luciano Pavarotti," and he said to me in a soft voice "We're going to be good friends." In fact, and for 40 years, not only were we good friends, but loyal ones, too.

In private situations, Prof. Zadeh had a great sense of humor. Maybe it was in 1983 when Sergei Ovchinnikov, Elie Sanchez, and I were invited to lunch at Fay and Prof. Zadeh's home. Sergei had left the Soviet Union a few years before and had only very recently recovered his books, which had finally been sent to him from Moscow, after the inordinately long time the authorities took to scrutinize them one by one. Prof. Zadeh presented us with three red shirts, identical to the one he was wearing, and asked us to put them on to take a group photo. But as Sergei attempted to gently refuse, Zadeh said "Sergei, please, put the shirt on, even if it is *too*

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radical for you!" Sergei did as he was told, and the picture of the four turned out very nice and was published in a paper by Sergei as well as in a book in homage to Prof. Zadeh [S3]. It is just a shame you can't make out the red in the black and white photograph.

Not only was Prof. Zadeh very kind with everyone, and particularly with young researchers with whom he always engaged in conversation and advised in kind, simple terms, but he always gave his oral presentations without any attempt to show one iota of personal superiority over the audience. Only once did I ever see him lose his temper in public; it was at a seminar in Berkeley, back in the mid-1980s, when a young researcher presented his ideas in an excessively shocking and bombastic style. He quoted Henri Poincaré, but wrote on the blackboard "Pointcarré." Prof. Zadeh suddenly leapt up from his seat toward the blackboard and, while rubbing out "Pointcarré" and writing "Poincaré," shouted earnestly at the speaker, "Be careful with spellings!" The speaker blushed, finished off quickly, and was never seen or heard by us again.

I did not always fully agree with Prof. Zadeh during our conversations, but I always came out enriched by the discussion; he inspired me to keep turning things over and over in my mind. One example of such an occasion is the following story.

Given a predicate P and its membership function m_P, to represent the membership function of its antonym aP, Zadeh maintained that this should be done by taking $m_{aP}(x) = m_P(a+b-x)$; that is, by considering the symmetry $s(x) = a+b-x$ in $[a, b]$, and defining $m_{aP} = m_P(s(x))$, for all x. Agreeing on the use of a symmetry to reflect the opposition between P and aP, I tried to convince him that the symmetry should depend on P, that it cannot be the same for all P in $[a, b]$; he refused to accept it, and all the examples he certainly managed to give me some good antonyms. It took me a while to realize that if the graph of m_P is either decreasing or nondecreasing, as was the case in all the examples given by Prof. Zadeh, just the symmetry $a+b-x$ is fine, but that the problem arises when this graphic is not monotonic [S9]. Knowing full well that to convince Prof. Zadeh I would have to provide him with a concrete counterexample, I decided to postpone the discussion. The next day and, finally, the predicate "close to four" in [0, 10] whose antonym should be "far from four," gave me the solution, since with the symmetry $10 - x$, we obtain a membership function corresponding to the predicate "close to six." I immediately returned to broach the subject with Prof. Zadeh and, after joking with me by saying, "Well, but 'close to six' already implies 'far from four,'" he accepted that the symmetry should be taken accordingly with the characteristics of P, that it should be s_P but not only s.

After what was certainly a pyrrhic victory, I duly forgot the question that, nevertheless, remained hidden in my subconscious up until many years later, when I returned to it while writing a paper, along with a number of colleagues, on computation with antonyms [S7]. It was after I had computed the antonym of "close to four" by using a symmetry in [0, 10] decomposed into several parts, each one corresponding to the subintervals in which $m_{\text{around 4}}$ is monotonic, constructing it like $a+b-x$ but with a and b being the extremes of the corresponding subinterval, and obtaining a function easily recognizable as a membership function representing "far from four." For me, sooner or later, discussions with Prof. Zadeh always turned out to be fruitful.

Throughout Prof. Zadeh's life, the efforts he made in continuously encouraging people to work on fuzzy logic were remarkable. Even if he almost always published papers with just his own signature (he liked to work alone), he never refused to discuss his results with anybody; his lectures were typically rounded off with, "Please, don't hesitate to contradict me!" A highly frugal person, he never ate too much, smoked, or drank alcohol. His health was punished by the many years of making trips around the world to deliver addresses at a multitude of conferences in different countries. For instance, after the serious heart attack he suffered at the end of 2009, he told me that he had flown over 100,000 mi that year.

Prof. Zadeh enjoyed contact with people of different cultures and maintained a healthy respect for them all. He was not a nationalistic person; rather, he preferred multicultural growth for people. The academic and industrial culture of fuzzy logic spread all over the world.

AS: Prof. Zadeh was an engineer who loved mathematics. He believed that mathematics provided an accurate analysis of both natural and anthropocentric problems. In fact, and as he explained, before 1964, he asked prominent mathematicians Herbert Robbins and Richard Bellman [S4] to develop a mathematical theory of sets with unsharp boundaries, a request which, owing to the numerous commitments that the two mathematicians had back then, was not met. In 1964, on his own, Prof. Zadeh came up with the notion of fuzzy sets specified through a membership function, which he published in 1965 [S11] and is currently one of the most-cited papers from the 20th century.

Prof. Zadeh's main concern was with precisiation and formalization. Precisiation is to change vagueness, a linguistic-philosophical concept, into fuzziness, a measurable or scientific one [S9]. Formalization is to provide mathematical models to understand problems from science or humanities; as they usually show borderline cases, Prof.

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Zadeh advanced fuzzy logic, a logic that represents classes with unsharp edges.

Prof. Zadeh was a huge fan of mathematics and somewhat skeptical about the humanities. He demonstrated a certain degree of disdain with philosophical works emphasizing the vagueness of natural language, such as Wittgenstein's *Philosophical Investigations*. He was also critical with Eleanor Rosh's and George Lakoff's approaches from cognitive science, as they did not use mathematical equations but vague notions such as categories or hedging [S4]. He did not fully agree with approaches from philosophy, as it addresses vagueness without introducing precision. In his view, and resorting to the previous metaphor, for him, philosophy seemed to be a kind of stuttering theory that explains its subject while stuttering.

In any case, he contributed to the conversation with a paper [S12] to the philosophy journal *Synthese* in a special volume devoted to the logic semantic of vagueness. In the references section he quoted works from M. Black, W.V. Quine, K. Fine, and C.G. Hempel, but in an unspecific way without correspondence to specific entries in the text. It seems as if the philosophers inspired him with ideas, but not to realize them. In turn, Prof. Zadeh was not warmly received in the arena of philosophy, where vagueness prevails over fuzziness and subjectivity overcomes objectivity. Philosophy pursues complexity, and, by analyzing a problem, philosophers expect to uncover certain other problems instead of solving the one that they are attempting to address, an attitude that is the complete antithesis of that of an engineer.

As an engineer, Prof. Zadeh was a pragmatic man seeking useful models to manage problems that admit solutions by precisiating the meaning of the words used to enunciate them. He provided inference rules for gathering plausible conclusions based on vague premises. Although the term *fuzzy logic* is not always welcome in mathematics or philosophy, it has become a widely used paradigm and accepted in the fields of cognitive science and AI. Qualified by some philosophers as a kind of techno-logic (i.e., a logic just for technology) rather than a type of logic, it has been worthy of that denomination with diverse, bright, and useful applications.

On What Will Remain Associated with Zadeh's Name

AS: Surely, the best homage to the intellectual legacy of Prof. Zadeh would be a critical approach to what he published. However, his passing away is too recent to attempt to embark on such an intellectual task wherein, in any case, we should take into account the moment in which he introduced the new ideas. For instance, if the concept of fuzzy sets was received as a genuine intellectual shock in 1965, that of soft computing in the early 1990s, beyond the relevance thereof, was something like "blowin' in the wind," in the words of Bob Dylan. At that time, hybrid methodologies were already starting to be seen as necessary tools for trying to reach some suboptimal solutions to computational problems that could not be addressed by any of them separately. Concerning computing with words and perceptions (CWP) [S13], not only did he return to and expand on the original goals of fuzzy logic, but he touched on one of the main shortcomings of AI.

ET: Relating Prof. Zadeh's name with its new, more central ideas depends on who is trying to do so; it is the *Quidquit recipitur ad modus recipientis recipitur* of Thomas of Aquinas. People grasp new concepts as their personal formation and interests allow them to do so, both not always completely coinciding with those of the introducers of these concepts; once a liquid is in a bottle, it adopts the bottle's form. Anyone who is captivated by the ideas of Prof. Zadeh will grasp them in the way that they are able to do so and in relation to the ongoing issues. Also, and at least at the very beginning, there were many important scientists in the United States who simply rejected these ideas, going as far as demonstrating their loathing for them; a situation that changes, diminishing over time, owing to the technological successes attained by some of them and, mainly, those concerning fuzzy control reached after the pioneering work of Abe Mamdani in the United Kingdom [S8] and the industrial success in home appliances and more relevant technological achievements made by some important Japanese industries. Notwithstanding, and from very early, in Japan and Europe, and even in the old Soviet Union, Prof. Zadeh's new ideas were received with notable interest and without the intellectual preemptions voiced against them by certain American scientists. In this regard, and far from the typical struggles between groups of scientists for capturing research funds from official agencies, it should not to be forgotten that in the mid-1970s, the space race was at full throttle, confronting the United States and the old Soviet Union, and for which precision and precise computations were very important; the quest for not only studying imprecision but benefiting from it collided with the prevailing scientific interest in crisp methods.

AS: In the particular case of Spain, for instance, these ideas were first and, more or less, simultaneously but independently grasped in the areas of philosophy, mathematics, and statistics. The first as a consequence of the interest in linguistic vagueness; the second through the possibility of extending the mathematical representation of the imprecise linguistic statements that Boolean algebra, classical set

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theory, does not permit; and the third through the non-realistic precision imposed on questions and answers in opinion polls. All of them were, actually, related with certain aspects of plain language.

ET: After his 1965 paper "Fuzzy Sets," 53 years later, there are six concepts that undoubtedly deserve to be linked with Prof. Zadeh's name [S14]. The first of these is the concept of fuzzy sets as a nebulous entity giving extension in a given universe of discourse to an imprecise predicate and contextually represented by a specifically designed membership function. The second is the algebra of fuzzy sets reached through their membership functions. The third is the concept of a linguistic variable. The fourth is the compositional rule of inference. The fifth is the principle of extension, and the sixth is the idea of a generalized constraint. Without them, it is difficult to imagine how fuzzy sets could have been applied to technology as successfully as it was and still is, and, even less so, how Prof. Zadeh could have come up with the ideas in CWP [S13]. Let's say something on each one of these six basic concepts.

The first and the second concepts constituted the starting point for everything that followed in applying fuzzy set theory to both theoretical and practical problems, and they also meant a departure from earlier attempts at the very idea of a fuzzy set. For instance, it was Karl Menger who introduced the concept of a hazy set as a cloud of points with positive probability of belonging to a classical set, but Prof. Zadeh expanded on the notion (of which he was unaware in 1965) by liberating it from probability, since not all cases of uncertainty appearing in plain language correspond to a probabilistically measurable event; not all linguistic uncertainties are random and, hence, the supposition of the additive law is, at least, problematic. Additionally, Max Black introduced the compatibility, or profile function, to represent an imprecise word, but neither Menger nor Black ever introduced an algebra with the new elements, as Prof. Zadeh did in his first 1965 paper. These algebras, further extended with more representations of the involved connectives than those initially presented by Prof. Zadeh, opened up the possibility of fuzzy sets being operative in many different situations and depending on the contextual meaning of the words involved.

In fact, Prof. Zadeh accomplished what John von Neumann called for back in the 1950s [S10], which entailed considering the semantics of concepts, not only the syntactical formulas of a presumed universal validity. In addition, Prof. Zadeh introduced the armamentarium of mathematical analysis into these problems, as had also been called for by von Neumann. It should not be forgotten that Prof. Zadeh came from the time of cybernetics, where mathematical analysis played an important role.

The sixth concept, formulated by Prof. Zadeh many years after 1965, once again clearly entailed entering into the domain of representing plain language, where "x is P" is true does not have the same meaning as "probable" or "possible." These constrained statements are submitted to be computed by means of both the membership function m_P and the measures for true, probable, possible, and so on. In short, Prof. Zadeh took a step further along the pathway embarked on by George Boole in the mid-19th century to represent linguistic statements, surpassing earlier attempts such as those of Menger and Black.

AS: Returning to the second concept for a while, this would also mean the penetration of fuzzy sets into plain language, where even the simplest connectives "and," "or," and "not" are not universal, as is the case with precise words (e.g., the intersection, union, and complement of sets). Rather, they vary contextually. In a long statement with several occurrences of such connectives, it cannot be assumed that they can all be represented by the same function. In fact, in his 1965 paper, "Fuzzy Sets" [S11], Prof. Zadeh introduced several possibilities for representing these connectives, such as, e.g., and for the case of the conjunction, the functions minimum and product, and the Lukasiewicz operation, which were subsequently generalized to open up further possibilities for representing imprecise statements.

ET: The third and sixth concepts help greatly in dealing with common sense reasoning expressed in plain language, since the concepts involved therein, such as age, are often not handled by means of numerical values but by linguistic values, such as "young," "old," "middle-aged," "very young," "not young," "not old," and so on, which can be constructed from a principal value (e.g., young), its antonym (e.g., old), and negation (e.g., not young), and combining them by using semantic hedges like "very." To sum up, these concepts assist in common sense reasoning by shading the taken linguistic principal values. The concept of a linguistic variable was essential for Prof. Zadeh's proposal CWP in the late 1990s (i.e., the establishment of a calculus allowing representation and reasoning, with precise and imprecise complex statements in either a plain or semi-artificial language, and based on fuzzy logic). It constitutes a step further along the path of Leibniz's famous dictum, "Calculemus!"

The fourth and the fifth concepts are technical in the sense of allowing two important operative problems to be solved: obtaining logical consequences from a set of imprecise premises and extending classical operations to the fuzzy field, respectively. The first is essential for the problem that underlies fuzzy control (i.e., how to obtain the output

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resulting from a set of imprecise linguistic rules describing the behavior of a dynamic system and an observed fact thereof). The second was fundamental for extending the arithmetic operations of addition, rest, multiplication, and division to fuzzy numbers for computing, e.g., "around four" plus "around nine," and so on. It also allowed an arithmetic of fuzzy numbers to be established as well as linguistic expressions such as "the probability that John is young is tall" to be addressed. The Extension Principle is widely used in problems that concern CWP, along with the extensive use of linguistic variables and generalized constraints.

Conclusion

ET: The most remarkable thing in Prof. Zadeh's post-1965 work is that it meant something like the opening of a door toward scientific analysis and the technological exploitation of linguistic imprecision. This is work that allows representation through sets, attained thanks to the work on which George Boole embarked in the mid-19th century, to be extended to other fields.

Language is permeated by such a large amount of imprecise words that the impossibility of their mathematical representation through the Boolean algebra of classical or crisp sets, based in its specification axiom, is a powerful limitation (even if it is not the only one) on the possibility of, first, mechanizing plain language, and, second, common sense or ordinary reasoning. Without fuzzy sets and fuzzy relations, it is not actually possible to make machines think like people with precisely used terms. This limitation is too strong to capture many of the nuances of plain language. Ortholattices, De Morgan algebras, and even the weaker typical standard algebras of fuzzy sets are successful for some parts of language but are endowed with laws and properties that cannot always be supposed in plain language and ordinary reasoning. In addition, it is not evident that Kolmogorov's theory of probability is applicable to the not-always-random uncertainty appearing in linguistic statements, owing essentially to the impossibility in many cases of assuming the additive law, even though imprecise events may admit perfect classifications or partitions. Often, with imprecise events, a totality is not recognizable as a sum of disjoint parts. For instance, Prof. Zadeh's measures of possibility are not additive. The loss and gain of imprecise information cannot be seen as it can be with precise information.

Without the possibility of representing plain language and ordinary reasoning, it will be very difficult, if not impossible, to untie the famous Gordian Knot of AI. The true future for such a goal lies in continuing along the lines of CWP established by Prof. Zadeh. Nonetheless, beforehand, we will need to learn more about the natural phenomena of language, reasoning, and creativity, and, according to my understanding, what would help to do so would be to develop a type of physics for these three natural phenomena [S6].

Just as physics deals with matter, energy, and movement, CWP should address an experimentally based theoretic science that, up until now, has not existed. To attain such a science, significant experiments would need to be designed and conducted by searching for the actual uses of linguistic connectives, hedges, quantifiers, relations of inference and analogy, and so on, on the Internet [S2]. This, at least, would serve to refine the use of the mathematical operations usually employed to design them. Since the meaning of words in plain language is always context dependent and purpose driven, fuzzy sets are not only a matter of degree but, at least with regard to their application to reality, a matter of design. Badly designing the membership functions representing fuzzy terms could easily lead to solving a problem other than the one currently posed.

AS: I don't believe that there will ever be a single calculus of language, but who knows if there could be a family of calculus for each specific part of language? Ultimately, Boolean algebras are useful for representing precise reasoning, with either random or possibilistic types of uncertainty; orthomodular lattices serve for the uncertain case of quantum physics; standard algebras of fuzzy sets take care of several cases of imprecise and uncertain reasoning, and so on. A calculus of language would require a combination of logics, but at the present, that challenge would seem to be a chimera. In any case, a good deal of the history of science and technology lies in the pursuit of utopias.

ET: Fundamentally, Prof. Zadeh poses an intriguing problem to researchers, concerning not only the modeling and representation of plain language and ordinary reasoning [S13], [S14] but also its exploitation for arriving at machines that will actually think like people. That is, he confronts us with the ultimate problem of AI.

AS: AI has to address that ascribed to Seymour Papert's superhuman human fallacy [S1], which says that a machine does not think unless it shows superhuman skills. But human intelligence is characterized by providing, through the processes of trial and error, partial, revisable, and provisional solutions to problems that are frequently unsharp. In this task, tolerant and robust systems will be desirable, and Prof. Zadeh's fuzzy logic provides interesting tools that contribute to this aim.

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Bart Kosko

Prof. Zadeh was a consummate intellectual of the old school. You could talk or argue with him about anything. No subject was out of bounds or likely to give offense. The goal was always deeper insight into the matter at hand. The method was simply giving reasons for claims.

This helps explain why Prof. Zadeh could make so many profound intellectual contributions in so many fields. He thought issues through from their foundations, and he did it alone. He usually worked and published as a sole author and struck research gold this way many times.

A good example is Prof. Zadeh's 1963 reformulation of multiobjective nonlinear optimization in *IEEE Transactions on Automatic Control*. He took a fresh look at optimal control theory and found it unduly restrictive. The theory had, in a key sense, trivialized how to compare systems. Prof. Zadeh rejected the assumption that the performance of a system can be measured by a single number and argued for a vector description and corresponding multiobjective optimization. He relaxed the strong assumption of a total order over systems to a mere partial order. This elegant little paper launched its own scholarly light cone of Pareto and other techniques for multiobjective optimization.

The more famous example is Prof. Zadeh's seminal formulation of fuzzy set theory in his 1965 paper, "Fuzzy Sets." The paper boldly extended bivalent sets to multivalent sets. Prof. Zadeh's deep insight was akin to that of Henri Lebesgue's when he reformulated the integral in 1902: he focused on the range of a function rather than its domain. The function here was a set's indicator function that states whether a given element does or does not belong to the set. Prof. Zadeh saw that, in general, these indicator values could be any number in the continuum of the unit interval, so set membership was now a matter of degree, and fuzzy sets were born.

No one who knew Prof. Zadeh or his work doubts that he would have won a Nobel Prize if they gave such a prize for the information sciences. A giant has passed.

Madan M. Gupta

Fuzzy logic, a new mathematical tool for the analysis and management of uncertainty that arises from human cognitive processes such as thinking, reasoning, and perception. It was introduced in 1965 by Prof. Zadeh, "The Father of Fuzzy Logic." Over the last five decades, this new mathematical logic, unlike Boolean (binary) logic, has revolutionized relevant tools and computing methods for the analysis and management of cognitive uncertainty. More recently, fuzzy logical tools have been used to introduce virtual intelligence into the household, entertainment, automobiles, and space industries. Fuzzy mathematics have been extensively explored to develop a new class of expert systems for potential applications in fields such as medical diagnosis, the control of complex processes, manufacturing processes, art, architecture, music composition, mining and space exploration, management science, court of law, and stock market evaluation. In general, this innovative method of mathematics has proven to be very useful in the creation of a new class of intelligence—virtual intelligence—that can solve a category of problems where human intelligence is intimately needed.

The theory of fuzzy logic was introduced to me at its very early stages of inception by its founder, Prof. Zadeh, during the second International Federation of Automatic Control (IFAC) Symposium held in Dubrovnik, Yugoslavia (formerly), on 26–31 August 1968. I recall my first, pleasant meeting with Fay and Lotfi at the breakfast table in the hotel on the first

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day of the conference. At that time, to me, the theory of fuzzy logic was purely a mathematical curiosity, which led me to explore the field in greater depths. Over the last five decades, I have witnessed the various phases of its development, from the very heavy criticisms by notable scientist and mathematicians to the successful industrial applications. Prof. Zadeh introduced to us the notion of graded membership, a concept that is quite pervasive in human cognitive processes. This theory, which captures the vagueness in our thought processes, revolutionized the field of logic with, as we have seen, many innovative mathematical ideas.

My Personal Association with Prof. Zadeh

Ever since my association with the field of fuzzy logic and cognitive uncertainty, in 1968, the Intelligent Systems Research Laboratory at the University of Saskatchewan, Canada, has contributed significantly to this innovative field. We have done academic research in this field concerning neural systems, which has appeared in several international conferences [organized by the IFAC, IEEE, International Society for Optics and Photonics, American Society of Mechanical Engineers, North American Fuzzy Information Processing Society (NAFIPS), International Fuzzy Systems Association (IFSA), American Control Conference, and more], research journals, books, and encyclopedias. We have aided the field in its development through the publications of our books (three authored and more than 20 edited), organization of international conferences, symposia, and workshops, and, most importantly, in the foundation of many international associations such as IFSA and NAFIP and in the founding of many international journals that are devoted to fuzzy logic and fuzzy-neural systems.

I had the honor of meeting with Lotfi and Fay many times during international conferences, in Berkeley, and roughly five times when I had invited him to visit our university. Prof. Zadeh's last visit was during 22–24 May 2006, when he was bestowed by the University of Saskatchewan with an honorary D.Sc. for his work in the field of fuzzy logic. At the reception, which was held at President Peter MacKinnon's residence, someone made the remark: "As a matter of fact, Prof. Zadeh is honoring our university as well by accepting this D.Sc. honor." Also, at the banquet of the biennial conference of NAFIPS: New Frontiers in Fuzzy Logic and Soft Computing, which was held at the University of California, Berkeley, on 19–22 June 1996, I had the honor of naming Prof. Zadeh as "The Father of Fuzzy Logic" and his wife, Fay, as "The Mother of Fuzzy Logic." I recall Fay asking "Madan, how can I be a mother when I did not make any contribution to this field?" And my response to her was "How he can be a father if you are not a mother?"

Prof. Zadeh has laid down a scientific path through his earlier work on Z-transforms and, in his more recent publication, Z-numbers, which will lead our future generation into the depths of perception and cognition.

at various future gatherings. Fuzzy logic, soft computing, Z-numbers, and the machine-intelligence quotient are only few outcomes of this incredible man's intellect. His timeless contributions will undoubtedly continue to resonate within the scientific world and profoundly impact human lives everywhere.

It has been 25 years since I first met Prof. Zadeh in person, and I am now finishing my second sabbatical in Berkeley as his last visiting scholar. I have many fond memories of him in every corner of this laboratory and his home, as he and Fay were always gracious and kind. However, perhaps, my most profound memory comes from those proud and young Iranian and Iranian-American students who would knock on this laboratory's door, hoping for a chance to meet the great Prof. Zadeh in person. We all dearly miss him so much here and at the roundtables. May God bless him.

—Mohammad Akbarzadeh-T

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