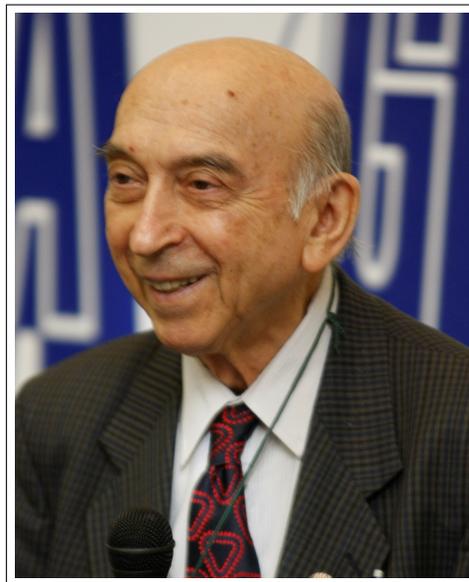CCC Publications

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Zadeh's Centenary

I. Dzitac

Lotfi A. Zadeh (1921-2017)

Ioan Dzitac
1. Aurel Vlaicu University of Arad
310330 Arad, Elena Dragoi, 2, Romania, ioan.dzitac@uav.ro
2. Agora University of Oradea
Piata Tineretului, 8, 410526 Oradea, Romania, idzitac@univagora.ro

Abstract

This is the introductory paper in a special issue on fuzzy logic dedicated to the centenary of the birth of Lotfi A. Zadeh published by International Journal of Computers Communications & Control (IJCCC). In 1965, Lotfi A. Zadeh published in the journal „Information and Control" the article titled „Fuzzy sets", which today reaches over 117 thousand citations. The total sum of citations for all his papers is above 253 thousand. Based on the notion of fuzzy sets, fuzzy logic and the concept of soft computing emerged, bringing extremely important implications to the field of Artificial Intelligence (AI). In 2017, I published, whith F.G. Filip and M.J. Manolescu, a 42-page long paper in the IJCCC about the life and masterwork of Lotfi A. Zadeh, from which I will use some information in this material [15].

Keywords: Zadeh, fuzzy sets, fuzzy logic, soft computing, centenary.

1 Introduction

Lotfi A. Zadeh, the father of fuzzy sets and fuzzy logic, was a very kind, non-assertive, multidisciplinary scientist (engineer, mathematician, computer scientist, logician, AI researcher). He was born on February 4th, 1921, in Baku, Azerbaijan. His mother was a paediatric doctor (of Russian-Jewish ethnicity) and his father was a reporter delegated in Iran (of Azerbaijani-Iranian ethnicity).

Please note what Lotfi A. Zadeh had to say regarding his ethnicity/nationality: „The question really isn't whether I'm American, Russian, Iranian, Azerbaijani, or anything else. I've been shaped by all these people and cultures and I feel quite comfortable among all of them." [85].

In 1905, Lotfi's mother, Fanya Korenman, together with her family, moved from Russia to Baku and settled there. She graduated the girls-only school in Tbilisi (Georgia) in 1918, and then graduated with a degree in Paediatric Medicine from the State University of Azerbaijan. Lotfi's father, Rahim Aleskerzade, graduated with a degree in Journalism from the State University of Azerbaijan. Lotfi's parents met in university and got married in 1920 in Baku.

When Lotfi was 10 years old (in 1931), Zadeh's family moved to Teheran, Iran. There, Lotfi graduated from both high school and then college with a degree in Electrical Engineering. In 1943, he immigrated to the USA, where he obtained his Master's Degree from Massachusetts Institute of Technology (MIT). Later, he obtained his PhD from Columbia University, where he worked for a year. He then became a professor at University of California, Berkeley. There, Zadeh was the director of the Research Institute Berkeley Initiative in Soft Computing (BISC) from 1991 to his death. Lotfi A. Zadeh passed away on September 6th, 2017 in California, the USA. He was in good shape and very active until almost the last moment.

Zadeh was married to Fay Zadeh (1920-2016) [70] and had two children, Stella Zadeh (1948-2006) and Norman Zada (b. 1964). According to his testament, Lotfi Zadeh was buried in the Honorary Alley of Baku Cemetery, Azerbaijan. On his grave, the national artist and academician, Omar Eldarov, sculpted a tombstone, which according to Eldarov has an authentic and unique style: "There is a door symbol in the tombstone, which means that Lotfi Zadeh opened the door of world science, and the symbols that reflected on the door have been developed, which is a great opening to science" [88]. On the door of tombstone is written the definition of *Fuzzy sets* pioneered by Zadeh in 1965 [71]:

$$A = \{\langle x, \mu(x) \rangle \, | x \in X\} \tag{1}$$

where $\mu(x) : X \to [0,1]$ is the membership function (MF) of A, which describes the membership degree of each element x to the fuzzy set A. The closer $\mu(x)$ is to 1, the more likely x belongs to A.

Figure 1: Lotfi A. Zadeh's Tombstone on Honor Alley in Baku [88]

2 From Cantor to Zadeh: The birth and difficult recognition of set theories in mathematics

It goes without saying that both the Classic Set Theory (Cantor, 1870), and Zadeh's Fuzzy Set Theory (Zadeh, 1965), were met with resistance and hostility by the conservatives of the scientific circle. Both Cantor and Zadeh deserve all the respect for their courage.

In mathematics, it is well known that between the notion of a set and logic there is an equivalence. In 1870, the German mathematician Georg Cantor (1845-1918) introduced the notion of a set, known today as classic set or crisp set. In a crisp set, an element is either a member of the set (exclusively) or not (tertium non datur). This is inspired by classic logic, also known as Aristotelian logic, named after Aristotle (384 BC - 322 BC), Plato's disciple (427 - 347 BC). In mathematics, the crisp set is also associated with Boolean logic, named so after the British philosopher, mathematician and logician, George Boole (1815-1864). Boole introduced the notion of lattice, which was the starting point of defining the Boolean algebra. Boolean logic was the base of logic circuits which were used for von Neuman type architecture.

However, Cantor was opposed by a handful of mathematicians. One of them was Leopold Kronecker (1823-1891) who famously called Cantor a charlatan, a renegade, and a "corruptor of youth". Nonetheless, the harsh criticism was followed by great recognition and awards. In 1904, the Royal London Society offered Medalia Sylvester, the greatest honorary award in mathematics. David Hilbert (1862-1943), one of the greatest influencers in mathematics during the end of 19th century and the beginning of 20th century, aggrandized Cantor's theory by predicting that: "No one will drive us from the paradise which Cantor created for us". Later, it became so that no theory in mathematics is sufficiently rigorous without it being expressed in the language of set theory.

Even after a few decades after Cantor's death, another important mathematician and philosopher, Ludwig Wittgenstein (1889-1951) still lamented that mathematics is "ridden through and through with the pernicious idioms of set theory", which he dismissed as "utter nonsense" that is "laughable" and "wrong".

In 1965, Lotfi A. Zadeh (1921-2017) introduced the notion of fuzzy set, which was at the base of the emergence of fuzzy logic (a logic with many values) [71]. Initially, some members of the academic circle met Zadeh's theory with hatred and hostility. The engineer and mathematician Rudolph Kálmán (1930-2016) called fuzzy logic "a kind of scientific permissiveness". The mathematician William Kahan dismissed it as "the cocaine of science".

However, early as 1968, the Romanian mathematician logician and Computer Science pioneer, Grigore C. Moisil, in his paper "Łukasiewiczian Algebras" [34] validated Zadeh's theory through a memorial acknowledgement: "During professor L. Zadeh visit to Bucharest, in the autumn 1967, I became aquainted with his work about "fuzzy sets" as a set theory in a logic with totaly ordered set of logical values. The present work exposes the logic of propositions with a totaly ordered set of logical values. The models of this logic of propositions uses an algebraic technic very closed to that given by us in the study of models for propositional logic with a finite number of logic values." (see Figure 3). Professor Ioana Moisil, who offered me her uncle's paper, told me that she had met prof. Zadeh in 1967, in her childhood days, when he visited her uncle, the famous Grigore C. Moisil [35].

In 1974 Ebrahim (Abe) H. Mamdani (1942-2010) published the paper "Application of fuzzy algorithms for control of simple dynamic plant" [28]. In the 80s', engineers from Sendai, Japan, incorporated fuzzy logic in the plan schemes of the new metro system, using it for the famous starts and stops of the system. It was the second practical success, after that of Mamdani in 1974. Mamdani followed to publish also other lot of papers in the field such as [29, 30] etc.

This was followed by a chain of electronic products based on fuzzy control, from household equipment to self-driven helicopters. Moreover, throughout the years, many scientists brought significant contributions to the development of the theory, including Grigore C. Mosil (1906-1973), Joseph Goguen (1941-2006) [21, 22, 23, 24], John R. Ragazzini (1912-1988), Richard E. Bellman (1920- 1984)[5], Hans-Jürgen Zimmermann (n. 1934), Ronald R. Yager [69] and many more.

In 1993, the Romanian professor Horia-Nicolai Teodorescu established the Grigore C. Moisil Gold Medal (made of gold, with the help of external sponsors). The first one was awarded to Zadeh at a conference in Aachen (EUFIT). Zadeh was very proud of this medal, as he was saying: „Moisil was a dear friend and the second most famous supporter of mine" [76].

Many more Romanian mathematicians, computer scientists and engineers have quite recently developed research studies in the field of fuzzy mathematics and applications, obtaining notable practical and theoretical results. Grigore C. Moisil (1968) and Dan Butnariu (1978) had important theoretical contributions [9, 10, 11]. The ICI-Bucharest group (from 1974), formed by Constantin
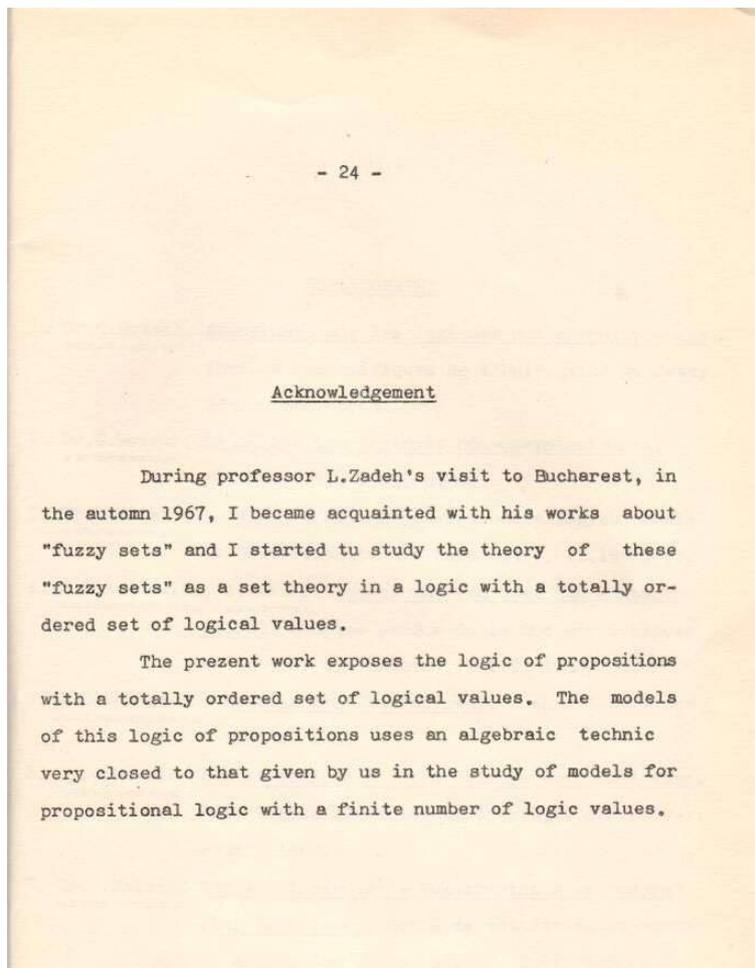
Figure 2: Acknowledgment by Grigore C. Moisil in paper "Łukasiewiczian Algebras" (1968,[34])

Figure 3: F.G. Filip, L.A. Zadeh, I. Moisil, V. Baltac & P. Borne at ICCCC2008

V. Negoita and Dan A. Ralescu [41, 42, 45], Dan A. Ralescu and Anca Ralescu [51, 52], Mircea Sularia, Dorin Rădulescu, Ducu Ștefănescu, Dan Drafta have accomplished, besides theoretical developments, many successful practical applications (in constructions, zoo technical farms, etc.). C.V. Negoita [41, 42, 43, 45, 46] had also an important contribution to the establishment of the "Fuzzy Sets and Systems" Journal.

Later on, the field was enriched by the important contributions of some other Romanian researchers such as: George Georgescu [20], Sergiu Rudeanu [54], Afrodita Iorgulescu and Ioana

Leustean (Bucharest), Horia-Nicolai Teodorescu [61, 62], Hariton Costin (Iasi), Radu-Emil Precup [48, 49, 50] and Dorel Mihet [32], Stefan Preitl, Octavian Prostean (Timisoara), Răzvan Andonie and Ilie Gîrbacea (Brasov), Sorin Gal [4], Barnabas Bede [3, 4], Adrian Ioan Ban [2], Tiberiu Vesselenyi, Simona Dzitac and Ioan Felea [17, 18, 19, 64, 65] (Oradea), Dan Dumitrescu (Cluj-Napoca), Marius Balas and Valentina Balas [26], Marius Tomescu, Sorin Nădăban [37, 38, 39, 40] (Arad), Vasile Lupulescu (Târgu-Jiu)[27] etc.

3 Lotfi A. Zadeh's visits to Romania an his influence to my scientific activity

3.1 How I met Zadeh

In 2007, attending a computer science conference (SOFA2007), I have met such a humble old man, that I could not believe I was talking to the famous researcher Lotfi A. Zadeh, the father of fuzzy logic, whose articles, which are currently cited a quarter million times, I have studied. Back then, he was 86 years old and he was travelling the world, being an honorary guest to a variety of computer science conferences. He was full of creative energy and continuously emanating generosity, accepting to attend international conferences, without any award, only for travelling and stay costs covered.

I was unknown to him, having published until then only two papers that had the word fuzzy in the title, but I dared to invite him at my conference, ICCCC2008, organized by Agora University in Băile Felix, Oradea, Romania. He accepted! And he came!

I waited for him at the airport in Budapest. Being 87 years old, he was traveling unattended from San Francisco, where he lived and was the active director of the research institute BISC at University of California, Berkeley (position that he held until his death in 2017, at 96 years old). He took a nap in the car. However, when he woke up he started to tell me about his first visit in Romania and the encouragements offered by Grigore C. Moisil, in 1967, two years after, with great courage, he published "Fuzzy Sets". He really needed those pats on the back because many mathematicians, logicians and engineers met his theories with skepticism and sometimes even with mockery. Regarding the ICCCC2008 conference, I told him I have scheduled his speech in the morning, but that if the time zone is troublesome I can reschedule it to a more convenient time. He said that there is no need, he easily adapts to any time zone.

Figure 4: Ioan Dzitac and Lotfi A. Zadeh at ICCCC2008

Unfortunately, the age, the exhaustion, all the flights (over 200.000 miles with United Airlines) and the frequent time zone changes truly affected Zadeh. At the New Years' celebration of 2008-

2009 he had a cerebral attack. Fortunately, he survived and he returned to his position at BISC, continuing to publish articles. However, he stopped his overseas travels.

After an exploratory workshop at ICCCC2008, we have edited the volume "From Natural Language to Soft Computing: New Paradigms in Artificial Intelligence" (Editors: Lotfi A. Zadeh, Dan Tufis, Florin Gheorghe Filip, Ioan Dzitac) [87]. Here are the messages exchanged with Zadeh for this collaboration:

1) "Dear Professor Dzitac, Please accept my apology for not writing to you earlier. I was away on travel much of the time during the past three weeks. With regard to sending you a paper for publication in your book, I do not have a written version of my presentation. I have other papers, which are attached, which are scheduled for publication in journals. Currently, I am working on a paper but it is on a subject different from the one that I presented in your Conference. I appreciate your including my name as a co-editor of your book "From Natural Language to Soft Computing: New Paradigms in Artificial Intelligence." However, be sure to list my name after the names of Professor Tufis, Filip and yourself. I should like to take this opportunity again to extend to you, Professor Tufis, Professor Filip and your associates my great appreciation for the very warm welcome which was extended to me in Oradea. With my warmest regards, Sincerely, Lotfi Zadeh." (From: Lotfi A. Zadeh, Sent:Wednesday, July 23, 2008 2:21 AM; To: Ioan Dzitac).

2) "Dear Professor Dzitac: I received copies of the Proceedings and the Journal. I was highly impressed in all respects. You and your colleagues have done an outstanding job. I was very pleased with the inclusion of my powerpoint presentation in the Appendix of the Proceedings. Please accept my compliments and congratulations. I should like to take this opportunity to thank you again for the very warm welcome which you extended to me. Participation in your Conference was a very stimulating as well as pleasant experience. With my warm regards. Sincerely, Lotfi Zadeh." (From: Lotfi A. Zadeh [zadeh@eecs.berkeley.edu]; Sent: Thursday, May 07, 2009 9:51 AM, To: Ioan Dzitac; Subject: Congratulations/Dzitac).

3.2 Zadeh and Romanian researchers

After he visited Grigore C. Moisil in 1967, Zadeh visited Romania once again at the invitation of professor Mircea Stelian Petrescu (1933-2020), who was a visiting professor at Zadeh's workplace, University of California, Berkeley.

In 2003, Lotfi A. Zadeh received the Doctor Honoris Causa Award from Aurel Vlaicu University, Arad, Romania, being nominated by professor Valentina Balas, who met him at the IMPU conference in Annecy, France in 2002. Thanks to prof. Balas, Zadeh has returned in Arad (SOFA 2005) and Oradea (SOFA 2007), where I was privileged to meet him personally through prof. Balas.

Figure 5: Keynote lecture of Lotfi A. Zadeh at ICCCC2008

In 2008 he visited Romania for one last time, as a honorary guest of Agora University, Oradea at ICCCC2008. With this occasion, he accepted our invitation to join the editorial team of our journal IJCCC. Since then we had a wonderful and fruitful collaboration.

3.3   Zadeh's influence to my scientific activity

In 2011, we published a special issue in IJCCC titled Special Issue on Fuzzy Sets and Systems - Dedicated to the 90th Birthday of Prof. Lotfi A. Zadeh [6, 16, 26, 31, 33, 46, 47, 53, 55, 56, 59, 61, 86].

In 2015, we published another special issue in IJCCC titled Special Issue on Fuzzy Sets and Applications - Dedicated to the 50th Anniversary of "Fuzzy Sets" Published by Lotfi A. Zadeh [1, 7, 12, 13, 25, 36, 49, 60, 62, 63, 66, 67, 68, 69].

After my meeting with Lotfi A. Zadeh I had publish, alone or in collaboration (with S. Dzitac, F.G. Filip, I. Felea, M.J. Manolescu, S. Nadaban, B. Stanojevic, D. Tufis, T. Vesselenyi, L.A. Zadeh), several contributions in fuzzy logic field, such as [13, 14, 16, 37, 38, 39, 40, 57, 58, 64, 65, 87].

Also, since 2013, I have dedicated some special sessions to the field of Fuzzy Logic and Soft Computing during Information Technology and Quantitavie Manegement (ITQM) conferences, in collaboration with academician Florin Gheorghe Filip, prof. Misu-Jan Manolescu and dr. Simona Dzitac, as follows: ITQM2013 (Suzhou, China), ITQM2014 (Moscova, Rusia), ITQM2015 (Rio de Janeiro, Brazilia), ITQM2016 (Asan, Coreea de Sud), ITQM2017 (Delhi, India), ITQM (Nebraska, SUA) și ITQM2019 (Granada, Spania).

Moreover, I was invited to present several lectures related to fuzzy logic and soft computing in China (2013: Beijing, Suzhou, Chengdu, 2015: Dalian, 2016: Beijing), India (2014: Madurai, 2017: Delhi), Russia (2014: Moscow), Brazil (2015: Rio), Lithuania (2015: Druskininkai), South Korea (2016: Asan) and Spain (Granada, 2019).

4   Contents of this special issue

This special issue includes the following papers and subjects:

(1) Deng & Deng in "Information Volume of Fuzzy Membership Function" propose a novel information volume of fuzzy membership function. The proposed measure covers both the first-order information volume and higher-order information volume(https://doi.org/10.15837/ijccc.2021.1.4106).

(2) Nadaban in "From classical logic to fuzzy logic and quantum logic: a general view" offers a concise and unitary vision upon the algebraic connections between classical logic and its generalizations, such as fuzzy logic and quantum logic (https://doi.org/10.15837/ijccc.2021.1.4125).

(3) Precup et al. in "Data- Driven Model-Free Sliding Mode and Fuzzy Control with Experimental Validation" propose four data-driven model-free continuous-time control algorithms built around an intelligent Proportional-Integral controller by adding nonlinear components as sliding mode and fuzzy control. Validation of results uses experiments to control the payload position of 3D crane systems(https://doi.org/10.15837/ijccc.2021.1.4076).

(4) Radu et al. present in "Bibliometric Analysis of Fuzzy Logic Research in International Scientific Databases" an interesting bibliometric analysis of fuzzy logic research in international scientific databases (https://doi.org/10.15837/ijccc.2021.1.4120).

(5) Shi presents in "My Early Researches on Fuzzy Set and Fuzzy Logic" his early contributions in fuzzy mathematics field (https://doi.org/10.15837/ijccc.2021.1.4090).

(6) Stanojevic & Stanojevic introduce in "Approximate membership function shapes of solutions to intuitionistic fuzzy transportation problems" a mathematical model with disjunctive system of constraints in modeling transportation problems in fuzzy environment, thus improving an existing solution approach to transportation problems with fuzzy parameters, and mathematical models able to provide approximate membership functions shapes to the optimal values of the decision variables, thus extending the solution approach to full fuzzy transportation problems. There also expand approach to solving full intuitionistic fuzzy transportation problems consistently respecting the extension principle(https://doi.org/10.15837/ijccc.2021.1.4057).

(7) Teodorescu & Teodorescu in "Noncommutative Logic Systems with Applications in Management and Engineering" suggest variants of salience-based, noncommutative and non-associative fuzzy logic (prominence logic) that may better model natural language and reasoning when using linguistic variables (https://doi.org/10.15837/ijccc.2021.1.4028).

(8) Wu et al. present a review entitled "Soft Computing Techniques and Their Applications in Intelligent Industrial Control Systems: A Survey". The authors describe an interesting survey manuscript on industrial applications of soft computing in control (https://doi.org/10.15837/ijccc.2021.1.142).

(9) Wu & Xu present in "Fuzzy Logic in Decision Support: Methods, Applications and Future Trends" some applications and future trends of fuzzy logic in decision support that illustrates that the combination of fuzzy logic and decision making method has an extensive research prospect.

This paper can help researchers to identify the frontiers of fuzzy logic in the field of decision making(https://doi.org/10.15837/ijccc.2021.1.4044).

(10) Zhang et al. in "V2V Routing in VANET Based on Fuzzy Logic and Reinforcement Learning" introduce the virtual grid to divide the vehicle network into clusters. The node's centrality and mobility, and bandwidth efficiency are processed by the Fuzzy Logic system to select the most suitable cluster head with the stable communication links in the cluster (https://doi.org/10.15837/ijccc.2021.1.4123).

5   Conclusions

Lotfi A. Zadeh has been a system theorist, a computer scientist, a physicist, and an engineer. Several key notions in Zadeh's thinking that are worth mentioning, namely optimality, uncertainty, reasoning, and meaning. Also, the concept of discrete variables and its tension with the concept of continuum plays a central part in his work [15].

He published the vast majority of his papers as single author, but he has also worked together with John R. Ragazzini (1912-1988), Richard E. Bellman (1920-1984), Charles A. Desoer (1926-2010), and a few other scientists.

Lotfi A. Zadeh marked the main directions in fuzzy logic and its applications in his works [71, 72, 73, 74, 75, 78, 79, 80, 81, 82, 83, 84, 86, 87].

Today fuzzy logic has many useful applications, from consumer smart products to industrial intelligent products, such as: washing machines, air conditioners, cameras, camcorders,fuzzy/neuro-fuzzy expert systems, fuzzy data/information mining, fuzzy search engines, microcontrollers, microprocessors, signal processing, fuzzy/neuro-fuzzy controllers, edge detectors,speech recognition, fuzzy decision making in economy/medecine, knowledge management, fuzzy thinking, etc. [15].

In two papers from this issue, (4) and partialy in (8), were presented several bibliometric analysis of the impact and influence of fuzzy logic topic in scientific literature.

Lotfi A. Zadeh, the inventor of Fuzzy Logic, passed away in 2017, but Fuzzy Logic is alive and is flourishing through his followers.

In respect of his great contribution to scientific knowledge, this special issue of IJCCC on fuzzy logic is dedicated to the centenary of the birth of Lotfi A. Zadeh.

Acknowledgements

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