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The introduction and development of fuzzy sets theory and applications in Finland

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The introduction of fuzziness in Finland

The introduction and development of fuzzy sets theory and applications in Finland happened by pure chance at an unlikely moment in time. There was an exchange agreement in place between Finland and Romania in 1974 to accept researchers for 2 week visits to get to know useful people for scientific cooperation in both countries. The program paid for all travel cost and the host country for hotel and per diem; thus as Christer Carlsson was offered an invitation to go as an exchange researcher to Bucharest he – of course – accepted at once. At that time he was listed by Academy of Finland as a cybernetician in their exchange programs with socialist Eastern Europe (in fact, his doctoral thesis was in Operational Research, Systems Theory and Management Science but this was (loosely/vaguely) accepted as cybernetics).

In Bucharest the first morning was spent at a very high level meeting (on the level of the Academy of Science) and it turned out that the political people could not communicate with him as nobody was fluent in English and he did not know any French (the unofficial second language among educated people in Romania). Thus the man at the end of the table gave orders to find somebody who knew English and after a while Dr Constantin Negoita appeared and told him that the high level guys did not know what to do with him and that a move over to the Academy of Economic Studies to find some nice optimization work to do was in order. At his laboratory there was a bohemian guy who was a talented cello player and an extreme mathematician, Dan Ralescu. His first words were – "good, you got saved from the politicians (could be interpreted as "the people who do not know anything") – do you know anything about fuzzy sets?" Thus two weeks were spent working through the theory and some applications of fuzzy sets; Christer Carlsson's contribution was to share insights about real world, industrial planning, problem solving and decision making; time was also spent discussing and arguing about the few benefits and multiple shortcomings of the socialist economic system.

The next year – 1975 – there was an international conference on general systems theory in Bucharest, Dr C V Negoita was on the organizing committee and made sure that Christer Carlsson participated in the conference. In Bucharest Hannu Nurmi, who had defended his thesis in Political Science in 1974, attended the same conference (in typical Finnish fashion it turned out that Carlsson and Nurmi lived almost as neighbours and travelled on the same bus to work every morning but had to go to another country in order to get to know each other). One of the results of

this conference was that it was decided in the fall 1975 to start a study group on fuzzy sets in Turku. The driving force was Professor Olavi Hellman at University of Turku, he was professor of applied mathematics and a keen developer of operational research applications for industry and the Finnish defence forces. He had heard a few things about the theory of fuzzy sets and thought that the mathematics was sloppily done and could be improved. Thus work got started on this by first translating and reading up on the text book by Negoita and Ralescu [*Multimi vagi si aplicatiile lor* – re-published as *Applications of Fuzzy Sets to Systems Analysis* by Birkhäuser Verlag in 1975] – a bit of a challenge as the book was in Romanian but as Olavi Hellman noted, "mathematics is a universal language". Again we had a bit of luck, there was a German language lecturer at Åbo Akademi university who had studied Romanian as the minor for her Master's degree in Linguistics and she translated the Romanian text to German as an exercise; this we could read and in this way we got a first comprehensive text on the theory of fuzzy sets. Our first step was to decide on a Finnish concept for the theory of fuzzy sets and we decided on "sumean joukon teoria" (there were variations over the years, the version "sumea joukko teoria" was interpreted as the theory being fuzzy ("sumea") and was not even proper Finnish).

Later it turned out that our efforts were not the first presentations of fuzzy sets in Finland – prof Hans Blomberg at the Systems Analysis Laboratory at the University of Technology in Helsinki had invited Lotfi Zadeh to give a talk in 1970; the ideas of fuzzy sets were not well received – one of the participants described the theory as "poorly done probability theory". About this we did not know anything and as Prof Hellman was a renowned mathematician – and very sharp in his answers and comments if somebody wanted to question him – we were able to get going with building the foundations for Finnish applications of fuzzy sets theory.

The first official results were the Master's thesis by Jorma Mattila in applied mathematics in 1978 and the doctoral thesis by Christer Carlsson in 1977, which was one of the first proposals that fuzzy sets theory would be useful for management applications – this was later followed up with a chapter in the book that Hans-Jürgen Zimmermann, Brian Gaines and Lotfi Zadeh edited for the TIMS Studies in Management Science (1984).

Hans-Jürgen Zimmermann had started the EURO Working Group on Fuzzy Sets in 1974 as part of the EURO Association, the European organisation for Operational Research and he very quickly attracted a growing group of researchers to work on the new theory. At the same time he started both the European Journal of Operational Research and the Fuzzy Sets and Systems journal, both with North-Holland (now Elsevier) and both

have become very significant landmarks in the development of European research in both Operational Research and fuzzy sets theory. The EURO Working Group on Fuzzy Sets met at both the annual EURO conferences and at the biannual European Meeting on Cybernetics and Systems Research in Vienna; the latter meeting because Eastern European researchers could travel to Vienna but had visa problems to many EURO member countries.

Hans Zimmermann suddenly suggested at the EMCSR 1978 in Vienna that Christer Carlsson take over the chairmanship of the EURO WG on Fuzzy Sets; this was rather an overwhelming proposal for a very junior researcher but in true Finnish fashion he of course accepted the challenge. Carlsson was running the EURO WG for about six years after which Prof Marc Roubens (at Mons Polytechnique at that time) took over the chairmanship. "I cannot, of course, claim to have made landmark contributions to the theory of fuzzy sets but the network of researchers was started that first met and started cooperation and later became life-time friends and built significant contributions to both the theory and to the IFSA", Carlsson notes.

Here there is not space to go through the whole list, but a number of people that contributed to the development of fuzzy sets in Finland will be mentioned.

Prof. Jorma Mattila wrote his Licentiate thesis in applied mathematics (*Key Constructions for a Fuzzy Logic*) in 1984 and his doctoral thesis (*Calculus of Modifier Operators in Fuzzy Logic*) in 1989; the Finnish pioneer group on fuzzy sets acted as mentors for Mattila's work on fuzzy logic.

Adjunct Prof. Vesa A. Niskanen started his work on fuzzy systems in the late 1970's when he wrote his Licentiate's thesis on fuzzy logic in the Department of Philosophy at the University of Helsinki in 1980. He had heard about fuzzy systems from Professor Mauri Åhlberg in private discussions in the Department of Education in Helsinki and these discussions inspired him to study fuzzy systems. Vesa Niskanen defended his doctoral thesis (*A Fuzzy System with Linguistic Values: Some Logical and Methodological Considerations and Applications*) in 1986; in this context he met Professors Christer Carlsson and Hannu Nurmi for the first time; they were the recognized experts on fuzzy systems in Finland and were invited to serve as reviewers of Niskanen's thesis; Professor Hannu Nurmi acted as the ex officio opponent at Niskanen's dissertation.

Esko Turunen defended his doctoral thesis in applied mathematics – *A Mathematical Study of Fuzzy Logic. An Algebraic Approach* – in 1994 at the Lappeenranta University of Technology. With some simplification it can be said that the early contributions to fuzzy sets in Finland originated in

applied mathematics, operational research and logic.

Jari Kortelainen defended his doctoral thesis on fuzzy mathematics at the Lappeenranta University in 2000, and his thesis received in that year the distinguished Rolf Nevanlinna Prize. Other notable and active scholars to be mentioned are Tapio Rauma, Esko Juuso, Raija Koivisto, Kirsi Virrantaus, Heikki Koivo, Timo Honkela, Erkki Oja, Jarkko Niittymäki, Osmo Kaleva and Tero Joronen, inter alia. Both Antti Niemi and Heikki Puolakka wrote textbooks on fuzzy systems which were published by the National Board of Schools.

In general, it should be noted that the universities in Helsinki, Turku, Tampere, Lappeenranta, Jyväskylä and Oulu have been active in research on fuzzy sets and applications in a wide range of research areas.

Hannu Nurmi's first encounters with fuzzy systems took place in mid-1970's. The conceptual apparatus of fuzzy sets seemed appropriate for dealing with imprecise notions that abound in political and social sciences. The applications of fuzzy systems that Nurmi initially found most worth exploring were decision analysis and game theory (Nurmi 1975, 1977). It soon turned out, however, that before much progress could be made in these areas, some work on preference modelling was necessary. This, in turn, led to the field where Nurmi has done the bulk of his work on applied fuzzy sets, viz. collective decision making (1981a, 1981b). Most of this research has been conducted in close collaboration with Mario Fedrizzi (Trento), Janusz Kacprzyk (Warsaw) and Slawomir Zadrozny (Warsaw). Settimo Termini (Naples and Palermo) and Aldo De Luca (Naples) also were very important contacts in Nurmi's early work. Since mid-1980's Nurmi has visited the Systems Research Institute of the Polish Academy of Sciences regularly in order to pursue joint projects with Kacrpzyk and Zadrozny. This research collaboration is still ongoing.

One of the effective instruments to make the work on fuzzy sets known and accepted among Finnish researchers were a series of seminars called *Fuzziness in Finland* that were organized by Patrik Eklund and Jorma Mattila and got started in 1993. The seminars were organized on one of the (rather luxury) ferries on the route between Turku – the Åland Islands – Stockholm that the participants could enjoy travelling to and from the Åland Islands, where the seminar was run in beautiful surroundings. Vesa Niskanen joined the organizing team in 1994 when this cruising started from Helsinki. It was organized a last time from Helsinki to Tallinn in 2004 when Lotfi Zadeh was in Finland and participated in the seminar. This seminar attracted participants from the EURO WG network and from the contacts that the Finnish fuzzy sets researchers had built at conferences and

workshops. Early participants included Robert Fullér from the Eötvös Lorand University in Budapest, Mario Fedrizzi from University of Trento and Janusz Kacprzyk from the Systems Research Institute of the Polish Academy of Science. They all have co-authored numerous papers over the years with the Finnish participants - Patrik Eklund, Jorma Mattila, Hannu Nurmi, Pekka Isomursu, Osmo Kaleva, Jari Kortelainen, Harri Koskinen, Vesa Niskanen and Veikko Pohjola. Such visitors as Laszlo Koczy from the University of Technology in Budapest, Burhan Turksen from University of Toronto, Junzo Watada from Waseda University, Toshio Fukuda from Nagoya University and Kaoru Hirota from Tokyo Institute of Technology participated in the *Fuzziness in Finland* seminar in the later years.

Robert Fullér has spent a total of more than 6 years in Finland as a Visting Researcher, Visiting Professor and then as a Finnish Distinguished Professor 2008-2010 with funding from Tekes, the Finnish Funding Agency for Innovation. His research platform in Finland has been the Institute for Advanced Management Systems Research at Åbo Akademi University that Christer Carlsson started in 1992. Robert Fullér, now a Professor at the Obuda University in Budapest, has published about 120 papers with Finnish co-authors, many of them widely and frequently cited, and has been instrumental in making Finnish work on fuzzy sets known to an international audience. Some of the key contributions were collected in text books published by Springer and Kluwer (Carlsson and Fullér (2002), Carlsson, Fedrizzi and Fullér (2003) and Carlsson and Fullér (2011)). Robert Fullér worked with IAMSR researchers in a number of research projects co-funded by the Finnish industry and Tekes, which gave a number of break-through results. One of the most important results was the findings – when working out better methods to plan very large investments (called giga-investments) – that the theory of real options would benefit from replacing the classical assumption on stochastic long-term variations (using Geometric Brownian Motion to represent future variations of up to 15 years) with possibility distributions on fuzzy numbers for the key parameters in the Black-Scholes formula for real options. The first results were published in *Fuzzy Sets and Systems* in 2003 and got accepted (first reluctantly) by the international Real Options Group as an alternative approach to handle long-term variations when working out the profitability of large, strategic investments. This inspired a series of doctoral theses at IAMSR that developed and improved the fuzzy real options methods: Peter Majlender (2004, one of Robert Fullér's students from Budapest), Mikael Collan (2004, now a Professor at Lappeenranta University of Technology), Francisco Alcaraz (2006, now at National Bank of Ireland), Markku Heikkilä (2009, now

postdoc at IAMSR), Jozsef Mezei (2011, one of Robert Fullér's students from Budapest) and Xiaolu Wang (2015, now postdoc at IAMSR). This list shows in a nutshell how innovations introduced by fuzzy sets can change the applicability of classical theory and open up new roads for research.

The Finnish fuzzy sets group played a key role in the International Fuzzy Systems Association to secure its global operations. The banking rules had changed in the EU which made it problematic to transfer payments of membership fees and the proceeds from international conferences to IFSA that in legal terms was an informal association. Vesa Niskanen was the Secretary of IFSA 1999-2003 and took measures to change the status of IFSA to become a registered association according to Finnish law. This changed was approved by the IFSA Council and the economic infrastructure of IFSA was secured by the Åbo Akademi University that accepted to serve as the economic administrator of IFSA on a *pro bono* basis. As a result of this change IFSA has now been able to collect membership fees, the surplus from the international conferences and donations and to pay grants and awards to young researchers of the member societies of IFSA. Niskanen also organized Lotfi Zadeh's nomination to act as the Honorary President of IFSA as well as collected statistical data on IFSA members for the IFSA 2005 Congress in Beijing as Chair of the IFSA Information Committee.

Vesa Niskanen registered the IFSA Society *North European Society for Adaptive and Intelligent Systems* (NSAIS) in Finland by the request of some European scholars. Kauko Leiviskä was the first President and Niskanen is still acting as its Secretary; Pasi Luukka is now the President. NSAIS was sponsored by Omron Finland for many years because Niskanen was cooperating with this company.

Christer Carlsson, one of the *Founding Fathers of IFSA* in 1985, was elected IFSA Vice President in 2009, President-Elect in 2011 and served as President of IFSA 2013-15.

Niskanen met Prof. Jorma Mattila from Lappeenranta University in the late 80's in various seminars, and these meetings initiated their future cooperation and friendship in many ways. In those days Niskanen also started cooperation with Prof. Veikko Pohjola at University of Oulu and Prof. Raija Koivisto at VTT in Tampere.

In the early 90's Niskanen met Director Eero Silvennoinen from Tekes, the Finnish Funding Agency for Innovation, in the Finnish Artificial Intelligence conference in Otaniemi, and after their discussion Director Silvennoinen was so interested in fuzzy systems that he initiated in Tekes a technology programme on artificial intelligence. This programme, which received substantial funding from Tekes, was known as Adaptive and

Intelligent Systems Technology Programme, and from the beginning such scholars in fuzzy systems as Prof. Carlsson and Prof. Patrik Eklund (then and now at University of Umeå in Sweden) were active persons in this venture. This programme was so successful that it was continued a few years more than it was first planned in the 90's.

Niskanen had many appearances in the Finnish mass media on fuzzy systems since the 90's, and Lotfi Zadeh also attended these interviews several times. The Finnish broadcasting company (YLE) even produced a special TV program (two times 45 minutes) on fuzzy systems. In this manner a broader Finnish audience got familiar with fuzzy systems and Prof. Zadeh.

Niskanen organized three summer schools in Helsinki on fuzzy systems in 2000-2001 and 2004 with such distinguished keynote speakers as Lotfi Zadeh, Teuvo Kohonen, Jaakko Hintikka, Laszlo Koczy and Christer Carlsson.

Since the 90's, Niskanen has also acted as an ex officio opponent or reviewer to several Master's and Doctoral' theses on fuzzy systems in Finland. In this context Niskanen started cooperation with Rector Matti Pursula and Dr. Jarkko Niittymäki in the Helsinki University of Technology and later with Prof. Kirsi Virrantaus. Niskanen also organized that Lotfi Zadeh was once ex officio opponent at the University of Tampere.

Niskanen paid his first visit to BISC Group in Berkeley in 1995. In 1997 Tekes invited Prof. Zadeh to visit a conference organized by the foregoing technology programme, and on this occasion started the closer cooperation, and later the family-level friendship, between him and Niskanen. Since that year, Niskanen has visited many times in Berkeley, and he has also hosted with Prof. Carlsson and Tekes Zadeh's many visits to Finland. Through Niskanen's and Lotfi Zadeh's initiatives Tekes was able to negotiated an agreement with UC Berkeley and has partly funded the BISC Group.

Niskanen's other central international contacts, which stem from the late 80's, include Professors Laszlo Koczy (Hungary), Robert Fuller (Hungary), Junzo Watada (Japan), Kaoru Hirota (Japan), Toshio Fukuda (Japan), Burhan Turksen (Canada & Turkey), Janusz Kacprzyk (Poland), Witold Pedrycz (Canada), Zenn Bien (Korea, also cooperation with KOSEF), Paul Wang (USA), Masoud Nikravesh (USA), Patrik Eklund (Finland & Sweden,), Mustafa Gunes (Turkey), Jon Teichrow (USA) and Rudolph Seising (Spain & Germany).

In the beginning of this millennium Niskanen initiated Prof. Zadeh's membership as a foreign member of the Finnish Academy of Sciences and

Letters and with the important contribution of Prof. Jorma Mattila that Prof. Zadeh was appointed Doctor Honoris Causa at the University of Lappeenranta.

In 2005 Lotfi Zadeh, Niskanen and Masoud Nikravesh made plans for organizing the 40th anniversary of fuzzy systems in Berkeley. Niskanen and Nikravesh then selected members to organization committee and made the list of invited guests as well as organized other practical issues with some of their colleagues. These celebrations took place in Berkeley in autumn 2005.

Niskanen's later activities include memberships in the Learning Business Plan Project with Prof. Paula Kyrö in Aalto University (funded by Ministry of Trade and Industry), Kuljen Project with Prof. Raija Koivisto in VTT (funded by Tekes) and Project on Fuzzy Cognitive maps (with Laszlo Koczy and Miklos Hartwagner and funded by Ecole Centrale in Paris). In addition to scientific articles, he has also written books on fuzzy systems, one in Finnish published by WSOY and the other in English published by Springer.

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