Archives for the Philosophy and History of Soft Computing

Issue 1/2016

INTERNATIONAL ONLINE JOURNAL OPEN ACCESS

ISSN 2341-0183

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George J. Klir (1932–2016)

and research on foundations of fuzzy logic and relations with probability theory

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Figure 1: George Kllir

George Klir passed away on May 27, 2016. His work heavily influenced the work of many scientists around the Globe. He was very active in the community in different capacities which included founding and editing the International Journal of General Systems Journal (IJGS) and serving as the president of the International Fuzzy Systems Association (IFSA). He was heavily involved in research and discussion on foundations of fuzzy systems and relations with other uncertainty theories including the probability theory. A deep analysis of George's contribution to the field is a topic of future studies. These notes are rather limited personal recollections of influence of his work that I witnessed and I expect will influence future research. I hope that these notes will demonstrate that while physically George is not with us anymore his work continues to influence us and gives impulses to new research.

For me his death was very personal sad news. I spent at SUNY Binghamton as a visiting professor working with him under his kind invitations most of the 1994-1995 academic year. We first met at the Fuzzy Systems conference in Bechyně in late 1980th in his native Czechia. My first paper influenced by his work was presented at the 11th European Meeting on Cybernetics in Vienna in 1992 that we discussed with George. That George's influential paper was entitled: "Is there more to uncertainty than some probability theorists might have us believe?" (IJGS, 1989). In his paper George provides argument for both the possibility theory and the evidence theory based on their successful application to solve one of the signal processing problems of aircraft signal recognition. My paper had shown that the same problem can be solved by more traditional Markov chains too. It started our many discussions on relations between the emerging new theories of uncertainty and the probability theory.

The results of that discussion are still relevant to the current status of clarification of relations between fuzzy systems and probability theory. When the problem is solved by one method it is quite possible to reformulate the solution in the terms of another method. Many examples of this exist in many different fields. Thus it is not surprising that the solution was reformulated as a Markov chain. We cannot expect that the solution found by one method will be the only solution forever.

The most important question that surfaced in that discussion was the question: "Is the solution with the belief functions and the possibility theory the most natural way to find a solution?" In other words: "Is the solution with the Markov chains an artificial way to find the solution in the first place?" The answer is that it is quite subjective. First of all it depends on the knowledge of the different methods by a scientist. Second one is that it depends on whether the task lends itself to a particular method more

naturally without introducing artificial concepts that are not part of the original task formulation in the domain terms. The third factor that influences the answer is the simplicity of the method, a simpler method that is also less justified often is easier to apply. For instance, the requirement to have a full joint probability for the accurate solution can be beyond the reach due to lack of data for estimating it, but a heuristic aggregation method, that does not use it, can be implemented. Thus in the future, instead of searching for the tasks that will be unique for solving by a given new uncertainty theory, it will be better to focus on finding the tasks with an easiness of justified formulation of the solution in terms of that new uncertainty theory.

Another encounter with George on foundations was about Gaines's standard logic of uncertainty (SLU). Gaines had shown that by adding to SLU one specific property one can obtain a standard probability logic and by adding another property - a fuzzy logic. In my short paper "Analysis of Gaines's logic of uncertainty" (NAFIPS '90, Toronto), it was shown that joint adding of these properties gives classical twovalued logic. The topic of our discussion with George was to understand how these mathematical results can shed a light on interpretations of these differences and possibly find unique areas for each of these theories in dealing with real world uncertainties. The attractiveness of Gaines' result was the fact that theories do not include one another at the mathematical level. The conclusion of that discussion was that it requires interpretation of specific lattices and that the results themselves are not sufficient to find these distinctive interpretations. Analysis of these opportunities still is a promising way to clarify the relations between fuzzy and probability logics. Thus this topic is not just of historic interest, but is rather an unfinished work that awaits future researchers. This is just one of many examples of the topics in which George was involved and influenced developments and will influence in the future.

Our discussions on foundations of fuzzy systems where only a small part of the discussion that George held with many people for years. In 1994 he discussed foundation issues in his paper as a response to the paper by Laviolette and Seaman in IEEE Trans. on Fuzzy Systems. In 2007 George took a big part in a large discussion on Elkan's theorem and his paper on the paradoxical success of fuzzy logic in the International Journal of Intelligent Systems. In 2009 he published a paper with colleagues on misunderstandings, misconceptions, and oversights in using fuzzy sets to model concepts in psychology in the International Journal of Approximate Reasoning. Most recently in 2014, while George did not directly participate in the Berkeley Initiative in Soft Computing (BISC) discussion of foundations, Dr. Zadeh published his previous correspondence with George as an argument in the discussion.

In 1995 we published with George a paper at the ISUMA/NAFIPS conference at the University of Maryland "Linguistic Context Spaces and Modal Logic" again to clary relations of fuzzy systems with probability theory. Later in 1996 IJGS published its expanded version. For a long time that paper and our discussion with George that preceded that publication was left mostly unnoticed beyond the discussion at NAFIPS 1995 until most recent discussion on foundations at BISC initiated by Dr. Zadeh. In a series of BISC posts in 2014 and later publications, I used the approach presented in the paper with George to solve test tasks formulated by Dr. Zadeh.

The idea of that joint paper with George is that the probability theory has a concept of a probability space (Kolmogorov's space) that carries the contextual information, which is critical for solving applied tasks, and the fuzzy logic needs a similar concept to carry contextual information. We introduced this concept and called it the linguistic context space. It is based on the combination of Zadeh's concept of linguistic variable and a set of probability spaces that represent each membership function of the linguistic variable. It is well known that the probability theory lacks an internal concept of linguistic variable, which is one of the pillars of the fuzzy systems. Therefore this approach integrates strong sides of both theories. I am very grateful to George that he was among the few people who recognized early the need for the context spaces for fuzzy systems, and his contribution to development of this concept.

In conclusion, a few words about George as a person. He always was very respectful to everybody, extremely candid and tactful to the people who disagree with him. He did not hide those disagreements; moreover he often started his presentations at the conferences from the comments of reviewers of his paper with an attempt to find a common ground. May his soul rest in peace!