HOW I GOT INTERESTED IN FUZZINESS

To Professor L. A. Zadeh

BY

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It was the winter of 1974. I stopped by Evans Hall to pay a visit to Professor Michel Loeve, on behalf of my adviser, Professor J. Kampe de Feriet. As we took the elevator down to go to the Faculty club for lunch, there was a man standing in front of us whom I had never seen before. Professor Loeve introduced him to me: "This is Professor Zadeh". As we sat at the same table in the Faculty club, after learning that my doctoral research was in probability and information theory, Professor Zadeh asked me "Do you ever hear the term linguistic probability"? When I replied "no", he asked me to stop by his office in the afternoon so that he can give me a preprint of his recent work.

My stay in the Bay Area was very short, but I did manage to take a quick look at Professor Zadeh's work. What struck me right away was that, essentially, it was about semantic information, a very important topic, but difficult to formulate mathematically. I ran into Professor Zadeh one more time, and he gave me the doctoral thesis of Michio Sugeno to make a Xerox copy of. I did not digest right away the deep concept of fuzziness, but the mathematical concept of (Sugeno) fuzzy measures reminded me of Kampe de Feriet's generalized information measures. By that time, I was looking at establishing some connections between information without probability and Choquet capacities.

The following summer, I spent few months at Berkeley as a tourist. Although my main interest lays in statistical inference in diffusion processes, I did read carefully Professor Zadeh's work on fuzziness. This new type of uncertainty arises in a different context. I struggled to imagine situations in which fuzziness is useful for information processing.

In the winter of 1975, I left France for the University of California at Berkeley at the invitation of Professor Zadeh.

It was the time when buzz words like "expert systems", "combination of evidence", "natural language processing" had just begun to appear. As a matter of fact, early in 1976, I had the chance to look at G. Shafer's thesis on a mathematical theory of evidence. And, Professor Zadeh handed to me a hand-written letter of I. R. Goodman claiming that there exists a canonical relation between fuzzy sets and random sets, and without such a connection, the theory of fuzzy sets cannot be firmly established. I observed the amazing fact that, like fuzzy sets, belief functions (in the theory of evidence) are also related to random sets. So, formally, we are not escaping the probability empire! However, that impression is misleading. The first thing to observe is this. Suppose we restrict ourselves to statistical evidence. The relation between belief functions and random sets does not completely specify the way in which evidence should be combined. Mathematically speaking, this has something to do with non-additive set-functions. While in any inference machinery "conditional measures" are essential, we do not have a Radon-Nikodym theorem for non-additive set-functions. The second is that this is related to knowledge representation. Decision making in the face of uncertainty is a common and important human activity. Some aspects of it have become a science. When the uncertainty involved is attributed to randomness, we have available statistical decision theory, based on probabilistic laws. There are two basic ingredients in the Bayesian approach to decision making. The first is knowledge representation. If the problem is the location of an unknown parameter, knowledge of that location is represented by a probability distribution. "Objective" information about that parameter can be obtained through sampling. But in the Bayesian procedure, one uses additional information, generally more subjective in nature. This subjective information is often an issue for debate. However, the Bayesian principle seems convincing. Any kind of information available should be used in the decision making process. In any case, no addition mathematical tools are needed to process this added information. It concerns probability distributions only, and the logic used is classical two-valued logic.

But in building expert systems or in improving existing ones, one quickly surmises that the Bayesian methodology is too restrictive. Knowledge is present which cannot be expressed in the form of probability distributions. Indeed, this knowledge is often expressed in natural language which cannot always be put easily into mathematical terms. This poses the problem of information modeling. If information in the form of if-then rules, for example, expressed in natural language, is to be used, this information must be translated into mathematical terms for processing. In any case, unlike the situation in Bayesian decision-making, data might not be represented in the form of probability measures, and the combination of various types of information becomes a technical problem. New mathematical tools are needed, including new logics for reasoning, modeling of semantic information via, say, fuzzy set theory. If ... then ... statements represent knowledge in a very general form. Not all knowledge is probabilistic. This raises the problem of the existence of various types of uncertainty in knowledge. Let's look at fuzziness. By its own nature, concepts expressed in our natural language are in general fuzzy in the sense that they are not sharply defined and are highly subjective. This has been noticed whenever one tries to look at semantic information. Fuzzy concepts are well-understood and considered as primitives. Modeling of knowledge consists of translating knowledge into some mathematical form. When we apply Zadeh's proposal to modeling of fuzzy concepts, we quickly realize that it is so simple! A fuzzy concept is simply "characterized" by a membership function.

In introducing fuzzy concepts, we are guided by common sense. The theory is difficult since there are not enough analytic tools, and we are reminded of the theory of numbers. The difficulty is at a very basic level, namely how to assign a membership function to a linguistic label in natural language? The similar situation in statistics is well-defined, since we postulate that each random quantity is a random variable so that its law, say its density function, is unknown but unique, and hence the estimation problem from data makes sense. The situation is not clear at all in the fuzzy case. The thesis that meaning is a matter of degree is reasonable, but besides approximate representations, the mental machinery which maps each fuzzy concept to its membership function is still a mystery. Moreover, the subjectivity in specifying the meaning of a concept clearly indicates that a class of functions, and not a single one, might have to be taken into account. Perhaps there is something invariant in the meaning of a fuzzy concept, such as the shape of its membership function.

The success of fuzzy control in the mid 80's revealed some interesting points. First, it specified the domain of applications of fuzzy technology. We recall the concern of researchers in the field of decision-making in the face of uncertainty: when fuzziness was addressed, one had the impression that it was a competing alternative to randomness. That is not true. Rather, it is complementary in situations where statistical assumptions cannot be made. Second, and what is really interesting, is that the fuzzy approach opens the door to new types of challenging problems, exemplified by the design of systems when only experts' knowledge is available.

The beginning of the 90's seems to be the beginning of the acceptance of fuzzy technology in the effort to produce more intelligent machines. As such, it is anticipated that, as we look back at the history of science, more basic research will emerge. Science progresses from empirical investigations to theoretical justifications. When one proposed methodology proves its success in practical applications, it will give the confidence to mathematicians to join in for theoretical contributions. It has only been 20 years since Zadeh spelled out explicitly what a fuzzy set is. Specifically, it is anticipated that research on a mathematical theory of identification and control of systems using fuzzy techniques will emerge. It will shed light on the design methodology of fuzzy systems as well as the reliability of such systems.

I have followed the development of fuzzy theory for 17 years now, and it is a good feeling to see that the theory has gotten out of the "dark ages". Every time I happened to drop by Evans Hall and sat in Zadeh's seminar, Professor Zadeh smiled and introduced me to the young and newcomers to the field as a veteran!

It is even more than a good feeling, it is an honor to be invited to be on the endowed LIFE Chair of Fuzzy Theory in Japan for 92-93.