For Lotfi Zadeh on his 90th Birthday

Sanjoy K. Mitter
Department of Electrical Engineering and Computer Science
and
The Laboratory for Information and Decision Systems
MIT
Cambridge, MA 02139 USA

January 26, 2011

I met Lotfi Zadeh in 1965 when he arranged for me to attend a conference devoted to Mathematical Programming and Optimal Control in Colorado Springs, Colorado. Lotfi was undoubtedly one of the major inspirations behind the organization of this conference. The fact that Optimal Control Problems in Discrete-time could be viewed as Mathematical Programming Problems and the Maximum Principle could be obtained using Duality Theory of Nonlinear Programming, perhaps not in full generality, was recognized at that time. To view Optimal Control Problems as Mathematical Programming Problems in Infinite Dimensional Spaces required new ideas and the development of new technical apparatus. At Berkeley, the doctoral theses of Pravin Varaiya and Richard Van Slyke, written under Lotfi Zadeh's direction, were devoted to Mathematical Programming in Infinite Dimensional Spaces. A part of my thesis written at Imperial College, London was also devoted to Mathematical Programming in Infinite Dimensional Spaces. One of the high points of this meeting was the presence of Soviet mathematicians L.S. Pontryagin and R.V. Gamkrelidze. The memory of this meeting is still quite fresh in my mind.

This was a time of great foment in the Systems and Control Field. Elsewhere, I have characterized the advent of the State Space Theory of Systems, specially linear systems (time-invariant and time-varying), and the reconciliation of the input-output and state-space view of systems as a scientific revolution in the sense of Thomas Kuhn. The contribution of Lotfi to this revolution is decisive. The book, *Linear Systems Theory: A State Space Approach* by Lotfi Zadeh and the late Charles Desoer, both a text book and a monograph, set new standards of mathematical and conceptual rigor in engineering. One may say, it ushered in a new field—mathematical engineering. The influence of this book on successive generations of students, myself included, cannot be overstated.

At about the same time, a parallel effort was going on in an attempt to unify Linear Systems Theory and Automata Theory. More importantly, Lotfi recognized the need for bringing Electrical Engineering and Computer Science together, intellectually and institutionally. In a certain sense, he foresaw the inevitability of the digital world being thrust upon us and that this needed to be reflected in the structure of our educational system. The existence of an Electrical Engineering and Computer Science Department at Berkeley is very much Lotfi's creation.

We live in a uncertain world. John Maynard Keynes recognized developing an intellectual framework for dealing with uncertainty to be the fundamental problem of Economics. Nearer to the control field, the founders of feedback control—Black, Nyquist, Bode—clear understood that the need for feedback control arises from dealing with the effects of modeling uncertainty (in their case, modeling uncertainty in the components of feedback amplifiers) on the performance of a system. The distinction between model uncertainty and measurement, or external uncertainty, is a non-trivial distinction. The question then arises as to how one should model uncertainty, be it in structure, measurement or environment. We owe the fundamental insight to Lotfi Zadeh that it is not possible or does not make sense to model uncertainty in every situation probabilistically. For one thing, to obtain a probabilistic model, a probability space needs to be fabricated and it is unclear how to do that unless its existence can be justified on physical grounds. This is particularly dubious in Economics, Social Science and Cognitive Science. In my view, the major failure of the field of Artificial Intelligence has been its inability to deal with problems of Perception, Cognition and Situated Action. It is essential that an intellectual framework for dealing with ambiguity and uncertainty be in place if we are going to make a scientific contribution here.

Lotfi's answer to this challenge has been the development of the theory of Fuzzy Sets and Fuzzy Logic. He wanted to develop a theory which would be precise and be an alternative to probability theory in modeling ambiguity and uncertainty. His ideas on soft computing and computing with words are also meant to provide a theoretical framework for understanding the behavior of systems which requires a less rigid description. This is surely a step in the right direction.

I want to end this short tribute by pointing out another dimension to Lotfi's intellect: what I would call the moral dimension. He has been one of the few voices to protest the intellectual subversion of the university under the corrosive influence of money. This is particularly glaring in the so-called "elite research" universities. As he remarked, "We used to look for money to do research. Now, we look for research to get money." I find it astonishing that the primary function of a research university is often framed as one of competing against other research universities. Lotfi also has spoken eloquently in public forums about the savage nature of modern capitalism as practiced in the USA (and UK) today. I hope my colleagues at my own institution and elsewhere are listening.