Foreword

Close to a quarter of a century has passed since fuzzy control made its debut. During this period, the literature on fuzzy control and its applications has grown at a geometrical rate. Taking as an index of growth, the number of papers in the INSPEC database with "fuzzy control" in the title have grown from 38 during 1970–1979 to 214 during 1980–1989 and to 4,356 during 1990–1999, with the data for 1999 not yet complete. And yet fuzzy control has been, and remains, an object of controversy with some—especially within the academic control systems establishment—expressing the view that anything that can be done with fuzzy control can be done equally well with conventional methods. This view is reflected in the fact that almost no papers on fuzzy control have been published in the *IEEE Transactions on Automatic Control* and this is the backdrop against which the publication of Professor Ying's monumental work *Fuzzy Control and Modeling: Analytical Foundations and Applications* should be viewed.

First, a bit of history. When I wrote my first paper on fuzzy sets in 1965, my expectation was that the theory of fuzzy sets would find its main applications in the realm of what may be called *humanistic systems*—systems exemplified by economic systems, societal systems, biological systems, linguistics, and psychology. It did not take me long, however, to see that the theory could be applied to *mechanistic systems*, especially to control. The groundwork for such applications was laid in my papers "Toward a Theory of Fuzzy Systems" (1971); "A Rationale for Fuzzy Control" (1972); "Outline of a New Approach to the Analysis of Complex Systems and Decision Processes" (1973); and "On the Analysis of Large Scale Systems" (1974). These papers, especially my 1973 paper, introduced the basic concepts of a linguistic variable, fuzzy if-then rule, and fuzzy graph. These concepts have played, and are continuing to play, key roles in almost all applications of fuzzy set theory (or fuzzy logic), including fuzzy control.

Although the basic ideas underlying fuzzy control were introduced in these papers, it was the seminal work of Mamdani and Assilian in 1974–1975, which showed that the ideas could be used to construct a working model of a fuzzy control system. This was the beginning of the era of fuzzy control.

What is not fully recognized, however, is that fuzzy control (FC) and conventional crisp control (CC) are, for the most part, complementary rather than competitive. Thus, FC is rule-based whereas CC is differential-equation-based; FC is task-oriented whereas CC is set-point-oriented; and CC is model-based whereas, in the case of FC, what suffices is a linguistic, rule-based description of the model. Today we see more clearly that fundamentally CC is measurement-based whereas FC is perception-based. In this sense, the role model for FC is the remarkable human capability to perform a wide variety of tasks without any measurements and any computations. A canonical example of such tasks is that of driving a car in city traffic. Classical control provides no methods for automation of tasks of this type.

Because it is close to human intuition, fuzzy control is easy to learn and easy to apply. For this reason, there are many applications of fuzzy control in the realm of consumer products. However, as a system becomes more complex, a limited mastery of fuzzy rule-based techniques ceases to be adequate. This is when a deep understanding of the theory of fuzzy control becomes a necessity, and it is this necessity that motivates the analytical theory of fuzzy control developed in the work of Professor Ying.

Professor Ying's book contains much that is new, important, and detailed. Particularly noteworthy are the chapters that focus on the Mamdani and Takagi-Sugeno types of controllers. In these chapters, a novel approach to stability theory is described and a theory of universal approximation is developed in detail. His linkage of basic theory to real-world applications is very impressive.

The last chapter in the book deals with a subject in which Professor Ying is a foremost authority, namely, application of fuzzy control to biomedical systems. Such applications are likely to grow in importance in the years ahead.

Professor Ying's work should go a long way toward countering the view that fuzzy control is a collection of applications without a solid theory. The deep theory of fuzzy control developed by Professor Ying is of great importance both as a theory and as a foundation for major advances in applications of fuzzy control in industry, biomedicine, and other fields. As the author of *Fuzzy Control and Modeling: Analytical Foundations and Applications*, he and the publisher, the IEEE Press, deserve our thanks and congratulations.

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