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Integration of Fuzzy Logic and Chaos Theory

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Preface

The 1960s were perhaps a decade of confusion, when scientists faced difficulties in dealing with imprecise information and complex dynamics. A new set theory and then an infinite-valued logic of Lotfi A. Zadeh were so confusing that they were called fuzzy set theory and fuzzy logic; a deterministic system found by E. N. Lorenz to have random behaviours was so unusual that it was lately named a chaotic system. Just like irrational and imaginary numbers, negative energy, anti-matter, etc., fuzzy logic and chaos were gradually and eventually accepted by many, if not all, scientists and engineers as fundamental concepts, theories, as well as technologies.

In particular, fuzzy systems technology has achieved its maturity with widespread applications in many industrial, commercial, and technical fields, ranging from control, automation, and artificial intelligence to image/signal processing, pattern recognition, and electronic commerce. Chaos, on the other hand, was considered one of the three monumental discoveries of the twentieth century together with the theory of relativity and quantum mechanics. As a very special nonlinear dynamical phenomenon, chaos has reached its current outstanding status from being merely a scientific curiosity in the mid-1960s to an applicable technology in the late 1990s.

Finding the intrinsic relation between fuzzy logic and chaos theory is certainly of significant interest and of potential importance. The past 20 years have indeed witnessed some serious explorations of the interactions between fuzzy logic and chaos theory, leading to such research topics as fuzzy modeling of chaotic systems using Takagi–Sugeno models, linguistic descriptions of chaotic systems, fuzzy control of chaos, and a combination of fuzzy control technology and chaos theory for various engineering practices.

A deep-seated reason to study the interactions between fuzzy logic and chaos theory is that they are related at least within the context of human reasoning and information processing. In fact, fuzzy logic resembles human approximate reasoning using imprecise and incomplete information with inaccurate and even self-conflicting data to generate reasonable decisions under such uncertain environments, while chaotic dynamics play a key role in human brains for processing massive amounts of information instantly. It is believed that the capability of humans in controlling chaotic dynamics in their brains is more than just an accidental by-product of the brain's complexity, but

rather, it could be the chief property that makes the human brain different from any artificial-intelligence machines. It is also believed that to understand the complex information processing within the human brain, fuzzy data and fuzzy logical inference are essential, since precise mathematical descriptions of such models and processes are clearly out of question with today's limited scientific knowledge.

With this book we attempt to present some current research progress and results on the interplay of fuzzy logic and chaos theory. More specifically, in this book we collect some state-of-the-art surveys, tutorials, and application examples written by some experts working in the interdisciplinary fields overlapping fuzzy logic and chaos theory. The content of the book covers fuzzy definition of chaos, fuzzy modeling and control of chaotic systems using both Mamdani and Takagi–Sugeno models, fuzzy model identification using genetic algorithms and neural network schemes, bifurcation phenomena and self-referencing in fuzzy systems, complex fuzzy systems and their collective behaviors, as well as some applications of combining fuzzy logic and chaotic dynamics, such as fuzzy–chaos hybrid controllers for nonlinear dynamic systems, and fuzzy model based chaotic cryptosystems.

It is our hope that this book can serve as a handy reference for researchers working in the interdisciplines related, among others, to both fuzzy logic and chaos theory.

We would like to thank all authors for their significant contributions, without which the publication of this book would have not been possible. We are very grateful to Prof. Janusz Kacprzyk for recommending this book to the Springer series, Studies in Fuzziness and Soft Computing, with appreciation going to the editorial and production staff of Springer-Verlag in Heidelberg for their fine work and kind cooperation.

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