

Studies in Computational Intelligence, Volume 103

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Devendra K. Chaturvedi

Soft Computing

Techniques and its Applications in Electrical
Engineering

With 320 Figures and 132 Tables

 Springer

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Foreword

Soft computing, as explained by Prof. Lotfi Zadeh, is a consortium of methodologies (working synergistically, not competitively) that, in one form or another, exploits the tolerance for imprecision, uncertainty, approximate reasoning and partial truth, to achieve tractability, robustness, low-cost solution, and close resemblance with human-like decision making. It has flexible information processing capability for representation and evaluation of various real life ambiguous and uncertain situations. Therefore, soft computing provides the foundation for the conception and design of high MIQ (Machine IQ) systems. Fuzzy logic having capability of handling uncertainty arising from, say, vagueness, incompleteness, overlapping concepts; neural networks providing machinery for adaptation and learning, genetic algorithms for optimization and learning, and probabilistic reasoning for inference were considered to be the basic ingredients of soft computing. Recently, the theory of rough sets of Prof. Z. Pawlak, having capability of handling uncertainty arising from granularity in the domain of discourse, is found to be another significant component.

Since the aforesaid characteristic features are important in designing intelligent systems and making any computer application successful, several research centres related to soft computing have been established over the world, dedicated to conduct research both for the development of its theory and demonstrating real life applications. The Department of Science & Technology (DST), Govt. of India, has established, in this line, the nation's first Soft Computing Research Center at Indian Statistical Institute, Kolkata, in 2004.

One of the challenges of soft computing research lies in judicious integration of the merits of its component technologies so that the resulting one has application-specific advantages, which can not be achieved using the individual techniques alone, in decision making. Among all such integrations, neuro-fuzzy hybridization is the most visible one realized so far. Recently, rough-fuzzy computing has drawn the attention of researchers as a strong paradigm for handling uncertainty in many real life problems, e.g., bioinformatics, web intelligence, and data mining & knowledge discovery. Since it has led to the concept of fuzzy-granulation, or f-granulation, it has a strong

relevance to the Computational Theory of Perceptions (CTP), which provides the capability to compute and reason not using any measurements, but with perception-based information. The perception-based information is inherently imprecise and fuzzy-granular, reflecting the finite ability of the sensory organs (and finally the brain) to resolve details and store information. Typical daily life examples based on CTP include car parking, driving in city, cooking meal, and summarizing story. The next decade is expected to bear the testimony of many stimulating issues and solutions in this domain.

The present volume titled “Soft Computing and its Applications” by Dr. D.K. Chaturvedi, an experienced researcher from Faculty of Engineering, Dayalbagh Educational Institute, Agra, India, deals with the introduction and basic concepts of fuzzy logic, artificial neural networks and genetic algorithms, and their role in certain combinations. It also describes some applications like load forecasting problem and power system identification. I believe the chapters would help in understanding not only the basic issues and characteristic features of soft computing, but also the aforesaid problems of CTP and in formulating possible solutions. Dr. Chaturvedi deserves congratulations for bringing out the nice piece of work.

Kolkata, India
November 3, 2007

Sankar K. Pal
Director
Indian Statistical Institute

Preface

The modern science is still striving to develop consciousness-based machine. In the last century, enormous industrial and technological developments had taken place. Technology had developed laterally well up to the biggest giant-sized complexes and also to the smallest molecular nano mechanisms. Thus, having explored to the maxima of the two extreme fields, technology is exploring now vertically to reach the dizzy heights of soft computing, subtle soft computing, and the millennium wonder of reaching the almost uncharted height of evolving consciousness in computers (machines). This book makes its small and humble contribution to this new astounding scenario and possibly the greatest of all mechanical wonders, to transfer consciousness of man to machine. Prior to World War II, numerical calculations were done with mechanical calculators. Simulated by military requirements during World War II, the first version modern digital computers began to make their appearance in late 1940s and early 1950s. During that pioneering period, a number of different approaches to digital computer organization and digital computing techniques were investigated. Primarily, as a result of the constraints imposed by the available electronics technology, the designers of digital computers soon focused their attention on the concept of computer system architecture, which was championed by Dr. John Von Neumann, who first implemented it in the computer constructed for the Institute of Advanced Studies at Princeton. Because of the pervasiveness of the Von Neumann architecture in digital computers, during the 1950s and 1960s, most numerical analysts and other computer users concentrated their efforts on developing algorithms and software packages suitable to these types of computers. In 1960s and 1970s, there were numerous modifications and improvements to computers of the earlier generation. The “bottle neck” of Neumann computers was the memory buffer sizes and speeds on it. In the 1990s, there was a quantum leap in the size of computer memory and speeds. As a result of this, Supercomputers have been developed, which could do lacs of calculations within a fraction of a second. Supercomputers can also do all routine task and it could handle it better with multi-coordination than a human being, and thus

reducing a series of simple logical operations. It could store vast information and process the same in a flash. It does not also suffer from the human moods and many vagaries of mind.

But, the super computers cannot infer or acquire any knowledge from its information contents. It cannot think sensibly and talk intelligently. It could not recognize a person or could not relate his family background.

On the Other hand, as human beings, we continuously evolve our value judgment about the information we receive and instinctively process them. Our judgment is based on our feelings, tastes, knowledge and experience. But computers are incapable of such judgments. A computer can be programmed (instructed), i.e. to generate poetry or music, but it cannot appraise or judge its quality.

Hence, there is a genuine and compulsory need for some other logic, which can handle such real life scenario. In 1965, Prof. Lofti A. Zadeh at the University of California, introduced an identification tool by which this degree of truth can be handled by fuzzy set theoretic approach. With the invention of fuzzy chips in 1980s fuzzy logic received a great boost in the industry.

Now in this twentyfirst century, along with fuzzy logic, Artificial Neural Network (ANN), and Evolutionary Algorithms (EA) are receiving intensive attention, in both academics and industry. All these techniques are kept under one umbrella called “soft computing.” Enormous research had already been done on soft computing techniques to identify a model and control of its different systems.

This book is an introduction to some new fields in soft computing with its principal components of fuzzy logic, ANN, and EA, and it is hoped that it would be quite useful to study the fundamental concepts on these topics for the pursuit of allied research.

Intuitive consciousness/wisdom is also one of the frontline areas in soft computing, which has to be always cultivated by meditation. This is, indeed, an extraordinary challenge and virtually a new wondrous phenomenon to include such phenomena into the computers.

The approach in this book is

- To provide an understanding of the soft computing field
- To work through soft computing (ANN, fuzzy systems, and genetic algorithms) using examples
- To integrate pseudo-code operational summaries and Matlab codes
- To present computer simulation
- To include real world applications
- To highlight the distinctive work of human consciousness in machine.

Organization of the Book

This book begins with the introduction of soft computing and is divided into four parts.

The first part deals with the historical developments in the exciting field of neural science to understand the brain and its functioning (Chap. 2). This is followed by the working of ANN and their architectures (Chap. 3). The feed forward back-propagation ANNs are widely used in operations and control of the various industrial processes and plants, for modeling and simulation of systems, and for forecasting purposes. The ANN needs many pairs of input–output (X – Y) as training and testing data. The relation between input and output, the size of neural network, type of neuron and connectivity of neurons among various layers generally contribute to training time of the neural network. The study has been conducted to observe the effect of range of normalization like 0–1, -1 – 1 , 0–0.9, etc., the type of mapping of input–output pairs like X – Y , X – ΔY , ΔX – Y , and ΔX – ΔY and their sequence of presentation, threshold, and aggregation functions used for different neurons (i.e. neuron structure) on training time. In addition, influence of noise in the input–output data on accuracy of learning and training time has been studied. The noise in input–output data has major contribution in generalization of ANN. The neural network model has been developed to study the above-mentioned issues for DC machines modeling to predict armature current and speed, and for short-term load forecasting problems (Chap. 4). Efforts have been taken in the past to reduce the training time of ANN by selection of an optimal network and modification in learning algorithms. A new (generalized) neuron model using neuro-fuzzy approach to overcome the problems of ANN incorporating the features of fuzzy systems at a neuron level had been developed and tested on various bench mark problems (Chap. 5). Taking benefit of the characteristics of the GN, it is used for various applications such as machines modeling, electrical load forecasting system, aircraft landing control system, load frequency controller, and power system stabilization problem (Chap. 6).

In the second part, the book concentrates on the introduction of fuzzy logic concepts and basics of fuzzy systems (Chap. 7). Fuzzy logic is applied to a great extent in controlling the process, plants, and various complex systems because of its inherent advantages like simplicity, ease in design, robustness, and adaptivity. It is established that this approach works very well especially when the systems are not transparent. Also, the effect of different connectives (like intersection, union, and compensatory operators as well as averaging operators), different implication methods, different compositional rules, different membership functions of fuzzy sets and their degrees of overlapping, and different defuzzification methods have been studied in the context of fuzzy system based modeling of electrical machines and load forecasting problems.

The third part lays the foundation for genetic algorithms (GA) and its variant (Chap. 9). In Chap. 10, the application of GA for load forecasting problems is discussed. The most difficult and crucial part of fuzzy system development is the knowledge acquisition. System dynamics technique (causal relationships) helps in the knowledge acquisition and representation of it. The integrated approach of systems dynamics technique and fuzzy systems has been used for socio-economic systems like HIV/AIDS population forecasting problem.

The last part of this book covers the synergism between different components of soft computing technology such as GA, fuzzy systems, and ANN. The GA-fuzzy system based approach is used for power system applications such as optimal electrical power flow problem, transmission pricing in deregulated environment and congestion management problems (Chap. 11). The GA-fuzzy (GAF) approach has also been used for load forecasting problems on long-term basis.

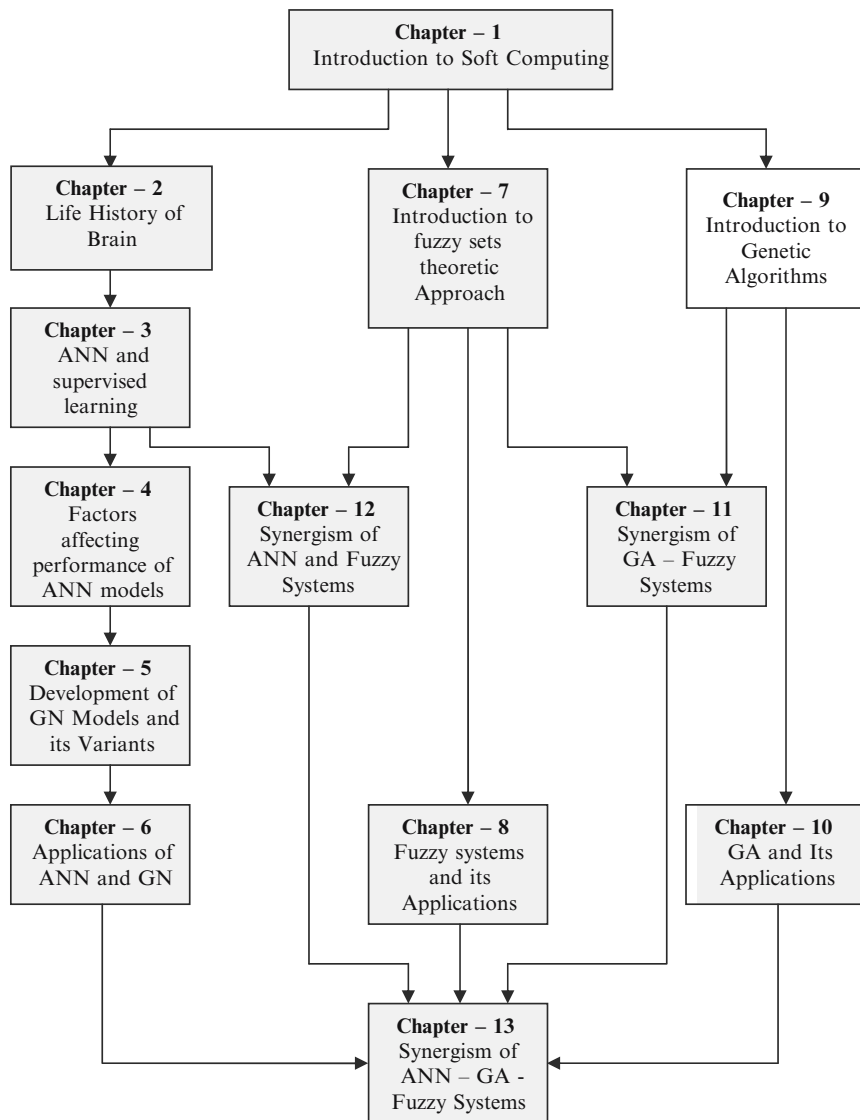


Fig. P1. Schematic outline of the book

Chapter 12 deals with the Adaptive Neuro-Fuzzy Inference System (ANFIS). The back-propagation learning algorithm is generally used to train ANN and GN. The back-propagation learning has various drawbacks such as slowness in learning, stuck in local minima, and requires functional derivative of aggregation and threshold functions to minimize error function. Various researchers have suggested a number of improvements in simple back-propagation learning algorithm developed by Widrow and Holf (1956). Chapter 13 deals with the synergism of feed forward ANN with GA as the learning mechanism to overcome some of the disadvantages of back-propagation learning mechanism to minimize the error function of ANN. GA optimization is slow and depends on the number of variables. To improve the convergence of GA, a modified GA is developed in which the GA parameters like cross-over probability (P_c), mutation probability (P_m), and population size (popsize) are modified using fuzzy system with concentration of genes. The ANN-GA-fuzzy system integrated approach is applied to different benchmark problems to test this approach. The schematic outline of the book is shown in Fig. P1.

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