

Preface

Theory and practice of artificial intelligence (AI) have been widely used in many various areas of human activity. When there was intense competition between various methodologies linked to AI, it was Prof. L. Zadeh's perception at the time that more could be gained by cooperation than by claims and counter-claims of superiority. A strong need has appeared for a new approach, theory and technology for the development of intelligent systems with high level of machine intelligence quotient (MIQ).

To answer this question Prof. L. Zadeh suggested so-called soft computing (SC) technology, representing a consortium of such intelligent paradigms as fuzzy logic (FL), neurocomputing (NC), evolutionary computing (EC), probabilistic computing (PC), and chaotic computing (CC) that have allowed the solution of many important real-world problems, which traditional methods of artificial intelligence were unable to do. The main feature of these methodologies in common is that they are more tolerant to imprecision, uncertainty, and partial truth than their hard-computing-based counterparts.

An essential characteristic of soft computing is that its constituent methodologies are, for the most part, complementary rather than competitive. Thus, the basic tenet of soft computing is that, in general, better results can be achieved by employing the constituent methodologies in combination than in a stand-alone mode. Today, a combination that has the highest visibility is that of so-called neuro-fuzzy systems. Another combination which is growing in visibility is neuro-fuzzy-genetic systems.

Neuro-fuzzy hybridization results in a hybrid intelligent system that synergizes these two techniques by combining the human-like reasoning style of fuzzy systems with the learning and connectionist structure of neural networks. The lack of interpretability of neural networks on the one hand and the poor learning capability of fuzzy systems on the other hand are similar problems that limit the application of these tools. Neuro-fuzzy systems are hybrid systems which try to solve this problem by combining the learning capability of connectionist models and the interpretability property of fuzzy systems. In case of a dynamic work environment, the automatic

knowledge base correction in fuzzy systems becomes necessary. On the other hand, artificial neural networks are successfully used in problems connected to knowledge acquisition using learning by examples with the required degree of precision. Incorporating neural networks in fuzzy systems for fuzzification, construction of fuzzy rules, optimization and adaptation of fuzzy knowledge base, implementation of fuzzy reasoning, and defuzzification is the essence of the neuro-fuzzy approach. As a result, neural networks become more transparent, while fuzzy systems become capable of learning. Expert knowledge can be incorporated into the structure of the neuro-fuzzy system. At the same time, the connectionist structure avoids fuzzy inference, which entails a substantial computational burden.

Ordinary neuro-fuzzy systems (i.e. type-1 neuro-fuzzy systems) have been successfully used in a wide range of applications. To design ordinary neuro-fuzzy systems, knowledge of human experts and experimental data are needed for construction of fuzzy rules and membership functions based on available linguistic or numeric information. However, in many cases the available information or data are associated with various types of uncertainty which should be taken into account. This uncertainty can be captured well by using higher order fuzzy sets. Hence, an effective way is to employ type-2 fuzzy sets, which augment fuzzy models with expressive power to develop models that efficiently capture the factor of uncertainty. In this regards, fuzzy type-2 neuro-fuzzy systems can represent and handle uncertain information more effectively than fuzzy type-1 neuro-fuzzy systems and contribute to the robustness and stability of the inference. Type-2 fuzzy sets having offered additional degrees of freedom in combination with neural networks being viewed as parallel computational models with adaptive nature make it possible to directly and more effectively account for model's uncertainties produced by different sources. The concept of type-2 fuzzy sets was initially created by Prof. L. Zadeh as an extension of ordinary fuzzy sets. Then Mendel and Karnik have developed a theory of type-2 fuzzy systems.

In spite of the intensive development of theory and design methods of type-2 neuro-fuzzy systems, the concept of type-2 neuro-fuzzy system is still in its initial stages of crystallization. There is little progress in the area of type-2 fuzzy rule extraction, merging type-2 fuzzy logic system with other constituents of soft computing, namely, with evolutionary computing, etc.

In this view, this book deals with the theory, design principles, and application of hybrid intelligent systems using type-2 fuzzy sets in combination with other paradigms of soft computing technology such as neuro-computing and evolutionary computing.

This book is organized into five chapters. The first chapters is a succinct exposition of the basics of fuzzy logic, with emphasis on those parts of fuzzy logic which are of prime relevance to neuro-fuzzy approach. Here foundations of fuzzy sets theory, including basic concepts and properties of type-1 and type-2 fuzzy sets, elements of fuzzy mathematics, and fuzzy relations are given. This chapter also contains elements of fuzzy logic (in narrow sense of L. Zadeh), which is viewed as a generalization of the various multi-valued logics. This chapter includes compositional rules of inference, choice of fuzzy implications, and

formalization of fuzzy conditional inference using the fuzzy implications suggested by the authors.

Chapter 2 deals with comparative analysis of methods of evolutionary computing and its merging with type-2 fuzzy neural networks. The models of neural networks and, especially, fuzzy and high-order fuzzy networks can be described by complex nonlinear, non-convex, and non-differentiable functions. As evolutionary optimization methods do not require any restrictive properties for the functions or the computational models to work with, they can be effectively used for training of parameters of fuzzy type-2 neural networks. The chapter includes main characteristics of genetic algorithms, particle swarm optimization (PSO), and differential evolution (DE) methods. An emphasis is put on the DE method and its application to the training of all types of neural networks.

Type-1 and type-2 fuzzy neural networks are subject of Chap. 3. This chapter includes for neuro-fuzzy computing, basic architectures and operations of fuzzy feed-forward and recurrent neural networks, several types of fuzzy logical neuron models, logic-oriented neural networks, general and interval type-2 fuzzy neural network's features and their training algorithms.

Chapter 4 contains elements of general and interval type-2 FCM clustering methods, interval type-2 fuzzy clustering using DE, and design of type-2 neural networks with clustering.

Chapter 5 describes application of type-2 neural networks to real-world problems in decision making, forecasting, control, identification and other areas.

The suggested book is devoted in its entirety to a systematic account of major concepts and methodologies of type-2 fuzzy neural networks and presents a unified framework that makes the subject more accessible to students and practitioners.

We would like to express our thanks to Prof. Lotfi A. Zadeh for his constant support, invaluable ideas, and advices.

Baku, Azerbaijan

Rafik Aziz Aliev
Babek Ghalib Guirimov

Type-2 Fuzzy Neural Networks and Their Applications

Aliev, R.A.; Guirimov, B.G.

2014, XIII, 190 p. 73 illus., Hardcover

ISBN: 978-3-319-09071-9