Neuro-Fuzzy Architectures and Hybrid Learning

Studies in Fuzziness and Soft Computing

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and 3 Tables

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This book is dedicated to the memory of the late Professor Ernest Czogala whose contribution and inspiration to develop the implication-based neuro-fuzzy systems should be greatly acknowledged. His final book entitled "Fuzzy and Neuro-Fuzzy Intelligent Systems" is closely related to the subject of this book.

This work is also dedicated to Professor Lotfi A. Zadeh known as the "Father of Fuzzy Logic", who laid the foundations of fuzzy sets and systems, and whose outstanding scientific activity is still appreciated and admired by all. His ideas and writings have shaped and inspired the contents of this book.

Foreword

The advent of the computer age has set in motion a profound shift in our perception of science – its structure, its aims and its evolution. Traditionally, the principal domains of science were, and are, considered to be mathematics, physics, chemistry, biology, astronomy and related disciplines. But today, and to an increasing extent, scientific progress is being driven by a quest for machine intelligence – for systems which possess a high MIQ (Machine IQ) and can perform a wide variety of physical and mental tasks with minimal human intervention.

The role model for intelligent systems is the human mind. The influence of the human mind as a role model is clearly visible in the methodologies which have emerged, mainly during the past two decades, for the conception, design and utilization of intelligent systems. At the center of these methodologies are fuzzy logic (FL); neurocomputing (NC); evolutionary computing (EC); probabilistic computing (PC); chaotic computing (CC); and machine learning (ML). Collectively, these methodologies constitute what is called soft computing (SC). In this perspective, soft computing is basically a coalition of methodologies which collectively provide a body of concepts and techniques for automation of reasoning and decision-making in an environment of imprecision, uncertainty and partial truth.

There are two facets of soft computing which are of basic importance. First, the constituent methodologies of SC are, for the most part, complementary rather than competitive. And second, the SC methodologies are synergistic in the sense that, in general, better results can be achieved when they are used in combination, rather than in a stand-alone mode. At this juncture, a combination which has highest visibility is that of

neuro-fuzzy systems. But other combinations, such as neuro-genetic systems, fuzzy-genetic systems, and neuro-fuzzy-genetic systems are growing in visibility and importance. It is logical to expect that eventually almost all high MIQ systems will be of hybrid type.

This is the backdrop against which the publication of Professor Danuta Rutkowska's work, "Neuro-Fuzzy Architectures and Hybrid Learning," or NFAHL for short, should be viewed. Professor Rutkowska is one of the leading contributors to the theory of neuro-fuzzy systems and her expertise is reflected in the organization of NFAHL, the choice of subject matter and the high quality of exposition.

Historically, the first paper to consider a facet of neuro-fuzzy systems was that of S.C. Lee and E.T. Lee, published in 1974. Subsequently, important contributions were made by Butnariu, Chorayan, Rocha and Kosko. But the theory of neuro-fuzzy systems as we know it today, owes much to the pioneering work of H. Takagi and I. Hayashi at Matsushita, in the late eighties, which won them the basic patent on systems with neuro-fuzzy architecture.

A key issue which is highlighted with keen insight in NFAHL is that of parameter adjustment in fuzzy systems using neural network techniques and, reciprocally, parameter adjustment in neural networks using fuzzy if-then rules. Furthermore, parameter adjustment in both neural and fuzzy systems can be carried out through the use of genetic algorithms. The extensive coverage of this basic issue in Professor Rutkowska's work is one of its many outstanding features.

In my view, the natural starting point for parameter adjustment in both fuzzy and neural systems is multistage dynamic programming. However, the curse of dimensionality forces resort to gradient methods, which lead to backpropagation in the context of neural networks, and similar techniques for fuzzy systems which were developed by Takagi-Sugeno, Lin, Jang, Wang and others. A closely related technique is that of radial basis functions, which has been developed independently in the contexts of both neural networks and fuzzy systems.

In both neural network theory and fuzzy systems theory there is a widely held misconception centering on the concept of universal approximation. Specifically, in neural network theory it is accepted without question that any continuous function on a compact domain can be approximated arbitrarily closely by a multilayer neural network. The same is believed to be true for the class of additive fuzzy systems, from which a conclusion is drawn that there is an equivalence between neural networks and fuzzy systems.

What is not widely recognized is that universal approximation is valid only if the function which is approximated is known. Thus, if one starts with a black box which contains a function which satisfies the conditions of the approximation theorem, but is not known a priori, it is not possible

to guarantee that it approximates to the function in the box to a given epsilon.

The universal approximation theorem is merely a point of tangency between the theories of neural networks and fuzzy systems. The agendas of the two theories are quite different, which explains why the two theories are complementary and synergistic, rather than competitive in nature. The highly insightful treatment of the synergism of neural network theory, fuzzy systems theory and genetic algorithm is a major contribution of Professor Rutkowska's work.

As was alluded to already, as we move farther into the age of machine intelligence and automated reasoning, what is likely to happen is that most high MIQ (Machine IQ) systems will be of hybrid type, employing a combination of methodologies of soft computing – and especially neurocomputing, fuzzy logic and evolutionary computing – to achieve superior performance. In this perspective, Professor Rutkowska's work lays the groundwork for the conception, design and utilization of such systems.

Professor Rutkowska has authored a book which is an outstanding contribution to our understanding and our knowledge of systems which have the capability to learn from experience. Dr. Rutkowska and the publisher, Physica-Verlag, deserve our thanks and plaudits.

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Berkeley, CA
May 7, 2001

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