THEORETICAL ADVANCES IN NEURAL COMPUTATION AND LEARNING

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FOREWORD

For any research field to have a lasting impact, there must be a firm theoretical foundation. Neural networks research is no exception. Some of the foundational concepts, established several decades ago, led to the early promise of developing machines exhibiting intelligence. The motivation for studying such machines comes from the fact that the brain is far more efficient in visual processing and speech recognition than existing computers. Undoubtedly, neurobiological systems employ very different computational principles. The study of artificial neural networks aims at understanding these computational principles and applying them in the solutions of engineering problems. Due to the recent advances in both device technology and computational science, we are currently witnessing an explosive growth in the studies of neural networks and their applications.

It may take many years before we have a complete understanding about the mechanisms of neural systems. Before this ultimate goal can be achieved, answers are needed to important fundamental questions such as (a) what can neural networks do that traditional computing techniques cannot, (b) how does the complexity of the network for an application relate to the complexity of that problem, and (c) how much training data are required for the resulting network to learn properly? Everyone working in the field has attempted to answer these questions, but general solutions remain elusive. However, encouraging progress in studying specific neural models has been made by researchers from various disciplines. This volume represents another important step toward understanding the above issues from the perspective of modern developments in computer science.

It is not surprising that the interdisciplinary nature of research in neural networks has led to the formulation of several seemingly diverse paradigms. There should be, I believe, a common thread linking these paradigms, and more efforts toward integrating them should be undertaken. This volume highlights the results of a group of leading researchers and renders the theory of computation more accessible to the research community at large.

The editors, V. Roychowdhury, K.-Y.Siu, and A. Orlitsky, have worked in the general areas of parallel processing and computational complexity theory, and they have contributed significantly toward answering the above questions. It is a real pleasure to see the efforts by these three outstanding young scientists in putting together a volume that captures current trends and indicates future research in the study of the behavior of neural and learning systems. This book will be studied with appreciation by researchers from a wide spectrum of disciplines related to neural and computational science. Theoreticians will find a rich source of ideas that promises to be of relevance for many years to come. Even those whose interests are completely practical may benefit from the theoretical perspective adopted here. This book is a 'must-read' for anyone with research interests in the computational aspects of neural networks. Surely, it deserves the most enthusiastic welcome.

Bernard Widrow
Stanford, California

FOREWORD

I am pleased to have been asked to provide a foreword for this book. The title, "Theoretical Advances in Neural Computation and Learning" is in itself the key to what has happened in the field of neural networks over the past several years. Although neural networks have been touted as black boxes capable of solving a wide range of problems, it is, in fact, the theoretical framework in which neural networks are being put that allows the user to conceptualize the problem. It would have been impossible to develop most of the interesting applications without the important developments that have been made at the theoretical level. Much of the early work on networks seemed to have a "bottom up" flavor. The goal seemed to be to take inspiration from the brain and attempt to implement the observed features. During the 1980's the bottom up nature of neural network research began to change and an increasingly theoretical approach was developed. The change in orientation has been critical to the field. For one thing, it has brought a large number of top notch theorists into the field — mathematicians, physicists, computer scientists, statistician and engineers. Perhaps the key idea that has made its way into the field is the concept of a cost function for learning and the related concept of an energy function for recurrent settling networks. These ideas have provided the primary conceptual tools for neural network users and theorists alike. As these ideas are becoming properly understood, our ability to use neural networks in a wide range of application areas is becoming possible.

The present book provides further clarification of a number of important issues in the field. In particular, it provides us with a further clarification on the issues of network complexity and provides an analysis of a variety of learning networks. A number of issues concerning robustness, the relative advantages of sigmoidal units as compared with threshold units, an interesting analysis of the backpropagation algorithm and other important issues are also addressed. I believe that this will be a useful book which continues the important theoretical analysis of neural networks and their relationships to other statistical and computational techniques.

David E. Rumelhart
Stanford, California

THEORETICAL ADVANCES IN NEURAL COMPUTATION AND LEARNING brings together in one volume some of the recent advances made toward developing a theoretical framework for studying neural networks. A variety of novel techniques from diverse disciplines such as computer science, electrical engineering, statistics, and mathematics have been integrated and applied to develop ground-breaking analytical tools for such studies.

The first part of the book provides a complexity theoretic study of different models of neural computation. Complexity measures for neural models are introduced, and techniques for the efficient design of networks for performing basic computations, as well as analytical tools for understanding the capabilities and limitations of neural computation are discussed. As much of computational complexity theory is concerned with the questions of scale, the results highlighted here describe how the computational cost of a neural network increases with the problem size. Equally important, these results go beyond the study of single neural elements, and establish the computational power of multilayer networks.

In the second part of the book, concepts and results concerning learning using models of neural computation are discussed. Basic concepts such as VC-dimension and PAC-learning are introduced, and recent results relating neural networks to learning theory are derived. In addition, a number of the chapters address fundamental issues concerning learning algorithms such as accuracy and rate of convergence, selection of training data, and efficient algorithms for learning useful classes of mappings.

THEORETICAL ADVANCES IN NEURAL COMPUTATION AND LEARNING emphasizes the computational issues in artificial neural networks and compiles a set of pioneering research works, which together establish a general framework for studying the complexity of neural networks and their learning capabilities. This book presents one of the first efforts to highlight these fundamental results, and attempts to provide a unified platform for a theoretical exploration of neural computation. Each chapter is authored by a leading researcher and/or scholar who has made a significant contribution in this area.

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