Digital Neural Networks

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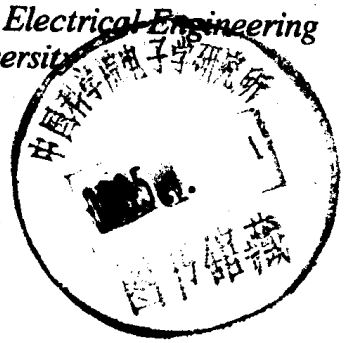
S. Y. Kung

Department of Electrical Engineering
Princeton University



PTR Prentice Hall
Englewood Cliffs, New Jersey 07632

Library of Congress Cataloging-in-Publication Data

Kung, S. Y. (Sun Yuan)
Digital neural networks / S. Y. Kung.
p. cm. — (Prentice-Hall information and system sciences series)
Includes bibliographical references and index.
ISBN 0-13-612326-0
1. Neural networks (Computer science) I. Title. II. Series.
QA76.87.K86 1993
006.3—dc20 92-42737
CIP

Editorial/production supervision: *Kim Gueterman*
Acquisitions editor: *Karen Gettman*
Cover design: *George Cornell*
Buyer: *Mary Elizabeth McCartney*
Copy editor: *Peter J. Zurita*
Series logo design: *A.M. Bruckstein*

A Simon & Schuster Company
Englewood Cliffs, New Jersey 07632

ED92/12

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-612326-0

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

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Preface

Unification. — Confucius, 551-479 B.C

The field of *digital neural networks* brings together scientists who study how the brain works and engineers who build highly parallel and intelligent supercomputers. The main objective of this book is to provide a synergistic and systematic exploration of several fundamental issues on *digital neural networks*. The word *digital* refers to *discrete-time* digital processing systems. The term *neural networks* embodies information processing systems using a combination of *nonlinear, adaptive, network,* and *parallel processing* technologies. Digital neural networks provide a natural link between the rapid advance of (VLSI) microelectronics and parallel processing technology and the increasing need for intelligent processing techniques. This represents a truly interdisciplinary research field which will ultimately lead to the future intelligent processing systems.

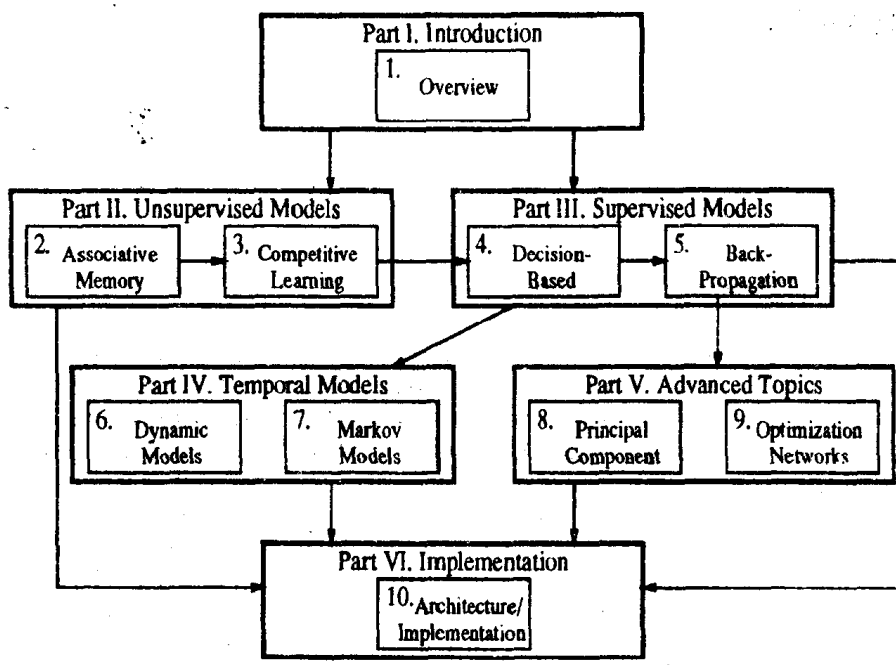
Many excellent reference books on neural networks exist; some place emphasis on the biological view, and others take a physics perspective. In contrast, this book is intended to be a textbook prepared for the discipline of information science and electrical engineering.

The book contains six parts:

- **Part I: Introduction** (Chapter 1);
- **Part II: Unsupervised Models** — associative memory (Chapter 2) and competitive learning networks (Chapter 3);
- **Part III: Supervised Models** — decision and approximation/optimization based neural networks (Chapters 4 & 5);

- **Part IV: Temporal Models** — deterministic and stochastic temporal networks (Chapters 6 & 7);
- **Part V: Advanced Topics** — principal component neural networks (Chapter 8) and stochastic annealing networks (Chapter 9);
- **Part VI: Implementation** (Chapter 10).

The following road map serves as a guide for teaching or reading.



The topics covered in Chapters 1 - 5 and Chapter 9 follow a rather orthodox neural network presentation, while the topics addressed in Chapters 6 through 8 are somewhat unorthodox in that they stem from the conventional signal processing and system theoretical perspectives. Chapter 10 provides a methodology for mapping neural models to parallel architecture and implementation.

Some unique features of the book:

- It aims at a coherent treatment which links the orthodox and unorthodox approaches to neural models. For this, we introduce what can be called *neural network system theory,* which unifies many diversified neural models.

- It employs an application-driven perspective, particularly signal/image processing and pattern recognition applications. Moreover, it goes on to present an integrated study of the application, algorithm, and architecture aspects of neural networks.

- It provides a working knowledge of various neural models, including theoretical basis, potential applications, and digital implementations. With this cross-disciplinary background, the reader would be better equipped to tackle research and application projects related to neural information processing.

This book is intended to be a textbook for a one-semester graduate or undergraduate course. (It is assumed that the reader has the basic background of advanced calculus, linear system theory, and signal processing. Otherwise, some mathematical treatments in some sections may be too advanced for uninitiated students.) Lectures for an undergraduate or graduate class can be organized from the following recommended sections:

- Chapters 1 - 7, (except Section 5.4)

- Sections 8.2, 8.3, 9.2, and 10.2.

ACKNOWLEDGMENTS

Without enthusiastic support and encouragement from so many friends, it would be impossible to attempt a book on such a dynamic and diversified subject. First, my thanks go to the researchers who have contributed to this rich research literature of neural networks. Their works have provided the foundation for the book. Also, I must apologize for having overlooked many critical topics and references in bibliographical research due to time constraints.

This book is an outgrowth of many semesters' lectures on the subject. I am very much indebted to many of my in-class students for their invaluable questions and contributions on examples and exercises. The advanced part of the book is largely extracted from several Ph. D. dissertations under my supervision. I wish to thank all of them: Drs. Kostas Diamantaras, Mark Goudreau, Jen-Neng Hwang, Wei-Dong Mao, John Vlontzos, and especially Mr. Wei-Hsin Chou and Mr. Jin-Shiuh Taur. They deserve to be named co-authors of the book.

I have benefited greatly the frequent and enlightening exchange and collaboration with many of my colleagues. To name a few: Drs. Alice Chiang, Frank Fallside, Lee Giles, Robert Hecht-Nielsen, Yuhen Hu, Fred Juang, Teuvo Kohonen, Gary Kuhn, H.C. Lee, Lenart Ljung, Christoph von der Malsburg, Alastair McAulay, John Moody, Ulrich Ramacher, and John Sorensen. Their enthusiastic participation in this project has made this prolonged process more bearable and indeed very enjoyable and rewarding. My deep gratitude goes to the reviewers for their critical and constructive suggestions on many drafts of the book. They are Drs. Joshua Alspector, Brad Dickinson, Tony Kuh, Guanghan Xu, Mr. Jerry Murphy, and other anonymous reviewers. My sincere

appreciation goes to my professor and the series editor, Professor Tom Kailath, for many years of inspiration and friendship.

I have been very fortunate to work with Ms. Karen Gettman and Ms. Kim Gueterman at Prentice Hall, who have provided very professional assistance throughout this project. I am grateful to the Department of Electrical Engineering, Princeton University, for making available a very scholarly environment for both teaching and research. I also want to thank the secretarial staff for their tireless and cheerful assistance during this long process: Susan Gafgen, Kim Hegelbach, Emmalee Morrison, and Lynn O'Shaughnessy. Finally, I am pleased to acknowledge that some work presented in this book was supported in part by Grants and Contracts from National Science Foundation, Air Force Office of Scientific Research, and Defense Advanced Research Project Agency.

Princeton, New Jersey **S.Y. Kung**

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PART III SUPERVISED MODELS

PART I: INTRODUCTION

Chapter 1

Overview

1.1 Introduction

Neural networks have become a very popular field of research in cognitive science, neurobiology, computer engineering/science, signal processing, optics, and physics. They represent a very broad range of neural processing models. The purpose of this book is to provide an integrated and cohesive exploration of the fundamental issues on *digital neural networks*. The word "digital" refers to "discrete-time" processing. In terms of data format, it may involve discrete-value or continuous-value signals. The term "neural networks" is characterized by a combined adaptive network and parallel processing technologies. Therefore, the field requires a coherent study and understanding of multi-disciplinary issues, including application-needs, neural models, and parallel processing.

An artificial neural network is an abstract simulation of a real nervous system that contains a collection of *neuron units* communicating with each other via *axon connections*. Such a model bears a strong resemblance to axons and dendrites in a nervous system. Due to its self-organizing and adaptive