
Preface

This book presents a comprehensive up-to-date overview of biologically realistic neural networks. The main emphasis is on the biophysical properties of individual neurons (e.g., cable properties, ionic channels, and synaptic transmission) and their inclusion in neural networks. Concurrently the volume aims to lay the foundations of integrative neuroscience—a field which strives to abandon the archaic computer-brain analogy by implementing the triad: selectionism, neuromorphism, and dynamicism as key paradigms underlying a functional Darwinian brain. For reasons that are discussed in the introductory chapter, this movement away from the field of computational neuroscience is necessary because: (1) computational models are non-integrative, and therefore inept at incorporating into neural networks the biophysical properties of constituent neurons in a practical way; (2) computational properties of neural networks are usually imposed in terms of abstract mechanisms not intrinsic to the real nervous system; and (3) a computational brain underscores the complexity of a Darwinian brain through fictitious notions and simplifications crucial for the formation of a fundamental psychological rather than a biological model.

The overall motivation behind this book is for integrative neuroscience to spawn and take root in the modeling arena. At the level of neural networks, there is not even a single reference dedicated to a rigorous coalescence between analytical reasoning and experimental evidence. So every effort has been made, while editing this book, to organize the material in a didactic and coherent fashion so that this book will serve not only as a foundation stone, but also as a methodological reference in the field. The book makes no pretense to be complete and does not cover all the work in the field (although the methods and techniques should serve more generic operations for other neuronal systems than those already mentioned in the book). Hopefully it will encourage others to make further progress in integrative neuroscience.

The book falls into seven distinct sections. Chapters 1–2 constitute an elementary introduction to the subject and a historical survey of neuronal modeling, respectively. Chapters 3–5 encompass the cellular level with an emphasis on nonsynaptic transmission, and computational models of single neurons from the retina and amygdala. Chapters 6–7 characterize the physico-chemical mechanisms underlying synaptic plasticity in biochemical networks and synaptic transmission in axonal networks. Chapters 8–10 form a hard core of basic theory of small-scale biophysical neural networks. Chapters 11–12 deal with mesoscopic theories of neural networks with an application to the auditory cortex. Chapters 13–14 are concerned with large-scale modeling and macroscopic theories of hippocampal neural networks. Chapter 15 has been included to serve as an advanced overview of the numerical methods in neural modeling. A number of problems are included at the end of each chapter to give a more in-depth appraisal of the contents, and each chapter ends with some predictions in relation to future developments.

The material contained in this volume requires some basic understanding of methods in neural modeling such as numerical solution of differential equations, and elementary knowledge of nonlinear dynamics. It may serve as a textbook for graduate and advanced undergraduate students in biomathematics, biomedical engineering, biophysics, zoology, and neural science taking a course in integrative neuroscience. The book will also serve as a general reference on neural modeling to professional researchers and postgraduate students. Experimentalists interested in quantitative aspects of neuroscience as well as artificial neural network modelers interested in solving difficult problems constrained by experiment will profit from this book.

The initiative for the production of this book began in the fall of 1998 to counter the belief that biophysics of computation represents a faithful paradigm for neural networks. I thank Luciano da F. Costa, the late Kohyu Fukunishi, the late Aron Gutman, Nick Leibovic, Masayoshi Naito, and Jay Rosenberg for assistance. Thanks are due to Nancy Wolitzer and the staff at Mary Ann Liebert, Inc. who went through the painstaking task of preparing this edition of the book with great care.

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