

Theoretical Neuroscience Computational And Mathematical Modeling Of Neural Systems Computational Neuroscience

Designed primarily as an introduction to realistic modeling methods, Computational Neuroscience: Realistic Modeling for Experimentalists focuses on methodological approaches, selecting appropriate methods, and identifying potential pitfalls. The author addresses varying levels of complexity, from molecular interactions within single neurons to the

This book is intended for use in advanced graduate courses in statistics / machine learning, as well as for all experimental neuroscientists seeking to understand statistical methods at a deeper level, and theoretical neuroscientists with a limited background in statistics. It reviews almost all areas of applied statistics, from basic statistical estimation and test theory, linear and nonlinear approaches for regression and classification, to model selection and methods for dimensionality reduction, density estimation and unsupervised clustering. Its focus, however, is linear and nonlinear time series analysis from a dynamical systems perspective, based on which it aims to convey an understanding also of the dynamical mechanisms that could have generated observed time series. Further, it integrates computational modeling of behavioral and neural dynamics with statistical estimation and hypothesis testing. This way computational models in neuroscience are not only explanatory frameworks, but become powerful, quantitative data-analytical tools in themselves that enable researchers to look beyond the data surface and unravel underlying mechanisms. Interactive examples of most methods are provided through a package of MatLab routines, encouraging a playful approach to the subject, and providing readers with a better feel for the practical aspects of the methods covered. "Computational neuroscience is essential for integrating and providing a basis for understanding the myriads of remarkable laboratory data on nervous system functions. Daniel Durstewitz has excellently covered the breadth of computational neuroscience from statistical interpretations of data to biophysically based modeling of the neurobiological sources of those data. His presentation is clear, pedagogically sound, and readily useable by experts and beginners alike. It is a pleasure to recommend this very well crafted discussion to experimental neuroscientists as well as mathematically well versed Physicists. The book acts as a window to the issues, to the questions, and to the tools for finding the answers to interesting inquiries about brains and how they function." Henry D. I. Abarbanel Physics and Scripps Institution of Oceanography, University of California, San Diego "This book delivers a clear and thorough introduction to sophisticated analysis approaches useful in computational neuroscience. The models described and the examples provided will help readers develop critical intuitions into what the methods reveal about data. The overall approach of the book reflects the extensive experience Prof. Durstewitz has developed as a leading practitioner of computational neuroscience. " Bruno B. Averbeck This volume gathers contributions from theoretical, experimental and computational researchers who are working on various topics in theoretical/computational/mathematical neuroscience. The focus is on mathematical modeling, analytical and numerical topics, and statistical analysis in neuroscience with

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applications. The following subjects are considered: mathematical modelling in Neuroscience, analytical and numerical topics; statistical analysis in Neuroscience; Neural Networks; Theoretical Neuroscience. The book is addressed to researchers involved in mathematical models applied to neuroscience.

This solid introduction uses the principles of physics and the tools of mathematics to approach fundamental questions of neuroscience.

Realistic Modeling for Experimentalists

Models of the Mind

Brain Computation as Hierarchical Abstraction

Fundamentals of Computational Neuroscience

Computational and Mathematical Modeling of Neural Systems

A Theory Revolutionizing Technology and Science

Exploring the Neural Code

How does the brain work? After a century of research, we still lack a coherent view of how neurons process signals and control our activities. But as the field of computational neuroscience continues to evolve, we find that it provides a theoretical foundation and a set of technological approaches that can significantly enhance our understanding.

Explains the relationship of electrophysiology, nonlinear dynamics, and the computational properties of neurons, with each concept presented in terms of both neuroscience and mathematics and illustrated using geometrical intuition. In order to model neuronal behavior or to interpret the results of modeling studies, neuroscientists must call upon methods of nonlinear dynamics. This book offers an introduction to nonlinear dynamical systems theory for researchers and graduate students in neuroscience. It also provides an overview of neuroscience for mathematicians who want to learn the basic facts of electrophysiology. Dynamical Systems in Neuroscience presents a systematic study of the relationship of electrophysiology, nonlinear dynamics, and computational properties of neurons. It emphasizes that information processing in the brain depends not only on the electrophysiological properties of neurons but also on their dynamical properties. The book introduces dynamical systems, starting with one- and two-dimensional Hodgkin-Huxley-type models and continuing to a description of bursting systems. Each chapter proceeds from the simple to the complex, and provides sample problems at the end. The book explains all necessary mathematical concepts using geometrical intuition; it includes many figures and few equations, making it especially suitable for non-mathematicians. Each concept is

presented in terms of both neuroscience and mathematics, providing a link between the two disciplines. Nonlinear dynamical systems theory is at the core of computational neuroscience research, but it is not a standard part of the graduate neuroscience curriculum—or taught by math or physics department in a way that is suitable for students of biology. This book offers neuroscience students and researchers a comprehensive account of concepts and methods increasingly used in computational neuroscience. An additional chapter on synchronization, with more advanced material, can be found at the author's website, www.izhikevich.com.

"This book argues that computational models in behavioral neuroscience must be taken with caution, and advocates for the study of mathematical models of existing theories as complementary to neuro-psychological models and computational models"--

Since its founding in 1989 by Terrence Sejnowski, Neural Computation has become the leading journal in the field. Foundations of Neural Computation collects, by topic, the most significant papers that have appeared in the journal over the past nine years. This volume of Foundations of Neural Computation, on unsupervised learning algorithms, focuses on neural network learning algorithms that do not require an explicit teacher. The goal of unsupervised learning is to extract an efficient internal representation of the statistical structure implicit in the inputs. These algorithms provide insights into the development of the cerebral cortex and implicit learning in humans. They are also of interest to engineers working in areas such as computer vision and speech recognition who seek efficient representations of raw input data.

A First Course

From Single Neurons to Networks and Models of Cognition

Mathematics for Neuroscientists

From Neuron to Cognition via Computational Neuroscience

Neuroscience in Education

An Introduction to Scientific Computing in MATLAB

Continual improvements in data collection and processing have had a huge impact on brain research, producing data sets that are often large and complicated. By emphasizing a few fundamental principles, and a handful of ubiquitous techniques, Analysis of Neural Data provides a unified treatment of

analytical methods that have become essential for contemporary researchers. Throughout the book ideas are illustrated with more than 100 examples drawn from the literature, ranging from electrophysiology, to neuroimaging, to behavior. By demonstrating the commonality among various statistical approaches the authors provide the crucial tools for gaining knowledge from diverse types of data. Aimed at experimentalists with only high-school level mathematics, as well as computationally-oriented neuroscientists who have limited familiarity with statistics, *Analysis of Neural Data* serves as both a self-contained introduction and a reference work.

This is an introduction to spiking neurons for advanced undergraduate or graduate students. It can be used with courses in computational neuroscience, theoretical biology, neural modeling, biophysics, or neural networks. It focuses on phenomenological approaches rather than detailed models in order to provide the reader with a conceptual framework. No prior knowledge beyond undergraduate mathematics is necessary to follow the book. Thus it should appeal to students or researchers in physics, mathematics, or computer science interested in biology; moreover it will also be useful for biologists working in mathematical modeling. Epilepsy is a neurological disorder that affects millions of patients worldwide and arises from the concurrent action of multiple pathophysiological processes. The power of mathematical analysis and computational modeling is increasingly utilized in basic and clinical epilepsy research to better understand the relative importance of the multi-faceted, seizure-related changes taking place in the brain during an epileptic seizure. This groundbreaking book is designed to synthesize the current ideas and future directions of the emerging discipline of computational epilepsy research. Chapters address relevant basic questions (e.g., neuronal gain control) as well as long-standing, critically important clinical challenges (e.g., seizure prediction). *Computational Neuroscience in Epilepsy* should be of high interest to a wide range of readers, including undergraduate and graduate students, postdoctoral fellows and faculty working in the fields of basic or clinical neuroscience, epilepsy research, computational modeling and bioengineering. Covers a wide range of topics from molecular to seizure predictions and brain implants to control seizures Contributors are top experts at the forefront of computational epilepsy research Chapter contents are highly relevant to both basic and clinical epilepsy researchers

Computational neuroscience is a relatively new but rapidly expanding area of research which is becoming increasingly influential in shaping the way scientists think about the brain. Computational approaches have been applied at all levels of analysis, from detailed models of single-channel function, transmembrane currents, single-cell electrical activity, and neural signaling to broad theories of sensory perception, memory, and cognition. This book provides a snapshot of this exciting new field by bringing together chapters on a diversity of topics from some of its most important contributors. This includes chapters on neural coding in single cells, in small networks, and across the entire cerebral cortex, visual

processing from the retina to object recognition, neural processing of auditory, vestibular, and electromagnetic stimuli, pattern generation, voluntary movement and posture, motor learning, decision-making and cognition, and algorithms for pattern recognition. Each chapter provides a bridge between a body of data on neural function and a mathematical approach used to interpret and explain that data. These contributions demonstrate how computational approaches have become an essential tool which is integral in many aspects of brain science, from the interpretation of data to the design of new experiments, and to the growth of our understanding of neural function. • Includes contributions by some of the most influential people in the field of computational neuroscience • Demonstrates how computational approaches are being used today to interpret experimental data • Covers a wide range of topics from single neurons, to neural systems, to abstract models of learning

Biophysics of Computation

Mathematical Foundations of Neuroscience

Computational Neuroscience in Epilepsy

The good, the bad, and the ugly

Computational Neuroscience for Advancing Artificial Intelligence: Models, Methods and Applications

Mathematics and Computation

Information Processing in Single Neurons

MATLAB for Neuroscientists serves as the only complete study manual and teaching resource for MATLAB, the globally accepted standard for scientific computing, in the neurosciences and psychology. This unique introduction can be used to learn the entire empirical and experimental process (including stimulus generation, experimental control, data collection, data analysis, modeling, and more), and the 2nd Edition continues to ensure that a wide variety of computational problems can be addressed in a single programming environment. This updated edition features additional material on the creation of visual stimuli, advanced psychophysics, analysis of LFP data, choice probabilities, synchrony, and advanced spectral analysis. Users at a variety of levels—advanced undergraduates, beginning graduate students, and researchers looking to modernize their skills—will learn to design and implement their own analytical tools, and gain the fluency required to meet the computational needs of neuroscience practitioners. The first complete volume on MATLAB focusing on neuroscience and psychology applications Problem-based approach with many examples from neuroscience and cognitive psychology using real data Illustrated in full color throughout Careful tutorial approach, by authors who are award-winning educators with strong teaching experience

"For the neuroscientist or psychologist who cringes at the sight of

mathematical formulae and whose eyes glaze over at terms like differential equations, linear algebra, vectors, matrices, Bayes' rule, and Boolean logic, this book just might be the therapy needed." - Anjan Chatterjee, Professor of Neurology, University of Pennsylvania

"Anderson provides a gentle introduction to computational aspects of psychological science, managing to respect the reader's intelligence while also being completely unintimidating. Using carefully-selected computational demonstrations, he guides students through a wide array of important approaches and tools, with little in the way of prerequisites...I recommend it with enthusiasm." - Asohan Amarasingham, The City University of New York

This unique, self-contained and accessible textbook provides an introduction to computational modelling neuroscience accessible to readers with little or no background in computing or mathematics. Organized into thematic sections, the book spans from modelling integrate and firing neurons to playing the game Rock, Paper, Scissors in ACT-R. This non-technical guide shows how basic knowledge and modern computers can be combined for interesting simulations, progressing from early exercises utilizing spreadsheets, to simple programs in Python. Key Features include: Interleaved chapters that show how traditional computing constructs are simply disguised versions of the spread sheet methods. Mathematical facts and notation needed to understand the modelling methods are presented at their most basic and are interleaved with biographical and historical notes for context. Numerous worked examples to demonstrate the themes and procedures of cognitive modelling. An excellent text for postgraduate students taking courses in research methods, computational neuroscience, computational modelling, cognitive science and neuroscience. It will be especially valuable to psychology students. Comprehensive introduction to the neural network models currently under intensive study for computational applications. It also provides coverage of neural network applications in a variety of problems of both theoretical and practical interest.

Computational Neuroscience - A First Course provides an essential introduction to computational neuroscience and equips readers with a fundamental understanding of modeling the nervous system at the membrane, cellular, and network level. The book, which grew out of a lecture series held regularly for more than ten years to graduate students in neuroscience with backgrounds in biology, psychology and medicine, takes its readers on a journey through three fundamental domains of computational neuroscience: membrane biophysics, systems theory and artificial neural networks. The required mathematical concepts are kept as intuitive and simple as possible

throughout the book, making it fully accessible to readers who are less familiar with mathematics. Overall, Computational Neuroscience - A First Course represents an essential reference guide for all neuroscientists who use computational methods in their daily work, as well as for any theoretical scientist approaching the field of computational neuroscience.

A Neural Architecture for Biological Cognition

A Comprehensive Approach

Computational Glioscience

Foundations of Neural Computation

Theoretical Neuroscience

Principles of Computational Modelling in Neuroscience

Computational Neuroscience: Theoretical Insights into Brain Function

Two distinguished neuroscientists distil general principles from more than a century of scientific study, “reverse engineering” the brain to understand its design. Neuroscience research has exploded, with more than fifty thousand neuroscientists applying increasingly advanced methods. A mountain of new facts and mechanisms has emerged. And yet a principled framework to organize this knowledge has been missing. In this book, Peter Sterling and Simon Laughlin, two leading neuroscientists, strive to fill this gap, outlining a set of organizing principles to explain the whys of neural design that allow the brain to compute so efficiently. Setting out to “reverse engineer” the brain—disassembling it to understand it—Sterling and Laughlin first consider why an animal should need a brain, tracing computational abilities from bacterium to protozoa to worm. They examine bigger brains and the advantages of “anticipatory regulation”; identify constraints on neural design and the need to “nanofy”; and demonstrate the routes to efficiency in an integrated molecular system, phototransduction. They show that the principles of neural design at finer scales and lower levels apply at larger scales and higher levels; describe neural wiring efficiency; and discuss learning as a principle of biological design that includes “save only what is needed.” Sterling and Laughlin avoid speculation about how the brain might work and endeavor to make sense of what is already known. Their distinctive contribution is to gather a coherent set of basic rules and exemplify them across spatial and functional scales.

A guide to computational modeling methods in neuroscience, covering a range of modeling scales from molecular reactions to large neural networks. This book offers an introduction to current methods in computational modeling in neuroscience. The book describes realistic modeling methods at levels of complexity ranging from molecular interactions to large neural networks. A “how to” book rather than an analytical account, it focuses on the presentation of methodological approaches, including the selection of the appropriate method and its potential pitfalls. It is intended for experimental neuroscientists and graduate students who have little formal training in mathematical methods, but it will also be useful for scientists with theoretical backgrounds who want to start using data-driven modeling methods. The mathematics needed are kept to an introductory level; the first chapter explains the mathematical methods the reader needs to master to understand the rest of the book. The chapters are written by scientists who have successfully integrated data-driven modeling with

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experimental work, so all of the material is accessible to experimentalists. The chapters offer comprehensive coverage with little overlap and extensive cross-references, moving from basic building blocks to more complex applications. Contributors Pablo Achard, Haroon Anwar, Upinder S. Bhalla, Michiel Berends, Nicolas Brunel, Ronald L. Calabrese, Brenda Claiborne, Hugo Cornelis, Erik De Schutter, Alain Destexhe, Bard Ermentrout, Kristen Harris, Sean Hill, John R. Huguenard, William R. Holmes, Gwen Jacobs, Gwendal LeMasson, Henry Markram, Reinoud Maex, Astrid A. Prinz, Imad Riachi, John Rinzel, Arnd Roth, Felix Schürmann, Werner Van Geit, Mark C. W. van Rossum, Stefan Wils

The book "Cognitive and Computational Neuroscience - Principles, Algorithms and Applications" will answer the following question and statements: System-level neural modeling: what and why? We know a lot about the brain! Need to integrate data: molecular/cellular/system levels. Complexity: need to abstract away higher-order principles. Models are tools to develop explicit theories, constrained by multiple levels (neural and behavioral). Key: models (should) make novel testable predictions on both neural and behavioral levels. Models are useful tools for guiding experiments. The hope is that the information provided in this book will trigger new researches that will help connect basic neuroscience to clinical medicine.

The annual Computational Neuroscience Meeting (CNS) began in 1990 as a small workshop called Analysis and Modeling of Neural Systems. The goal of the workshop was to explore the boundary between neuroscience and computation. Riding on the success of several seminal papers, physicists had made "Neural Networks" fashionable, and soon the quantitative methods used in these abstract model networks started permeating the methods and ideas of experimental neuroscientists. Although experimental neurophysiological approaches provided many advances, it became increasingly evident that mathematical and computational techniques would be required to achieve a comprehensive and quantitative understanding of neural system function. "Computational Neuroscience" emerged to complement experimental neurophysiology. The Encyclopedia of Computational Neuroscience, published in conjunction with the Organization for Computational Neuroscience, will be an extensive reference work consultable by both researchers and graduate level students. It will be a dynamic, living reference, updatable and containing linkouts and multimedia content whenever relevant.

Cell, Network and Data Analysis

Advanced Data Analysis in Neuroscience

Integrating Statistical and Computational Models

A Foundation for Motor Learning

Computational Modeling Methods for Neuroscientists

Principles, Algorithms and Applications

Computational Neuroscience

This book applies methods from nonlinear dynamics to problems in neuroscience. It uses modern mathematical approaches to understand patterns of neuronal activity seen in experiments and models of neuronal behavior. The intended audience is researchers interested in applying mathematics to important problems in neuroscience, and neuroscientists who would like to

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understand how to create models, as well as the mathematical and computational methods for analyzing them. The authors take a very broad approach and use many different methods to solve and understand complex models of neurons and circuits. They explain and combine numerical, analytical, dynamical systems and perturbation methods to produce a modern approach to the types of model equations that arise in neuroscience. There are extensive chapters on the role of noise, multiple time scales and spatial interactions in generating complex activity patterns found in experiments. The early chapters require little more than basic calculus and some elementary differential equations and can form the core of a computational neuroscience course. Later chapters can be used as a basis for a graduate class and as a source for current research in mathematical neuroscience. The book contains a large number of illustrations, chapter summaries and hundreds of exercises which are motivated by issues that arise in biology, and involve both computation and analysis. Bard Ermentrout is Professor of Computational Biology and Professor of Mathematics at the University of Pittsburgh. David Terman is Professor of Mathematics at the Ohio State University.

In the past ten years, there has been growing interest in applying our knowledge of the functioning of the human brain to the field of education-including reading, learning, language and mathematics. This has resulted in the development of a number of new practices in education-some good, some bad and some just crazy. The 'good' is nearly always sound cognitive research that has clear implications for educational practice. The 'bad' is the use of neuroscience jargon to lure the unwary and to give an apparent scientific aura to flawed educational programs with no evidence base and which no reputable neuroscientist would endorse. The 'ugly' is simplistic interpretation and misapplication of cognitive theories leading to errors in their application. More and better could be done if neuroscientists and educationalists acknowledge the limits of their disciplines and start listening to each other. Neuroscience in Education brings together an international group of leading psychologists, neuroscientists, educationalists and geneticists to critically review some of these new developments, examining the science behind these practices, the validity of the theories on which they are based, and whether they work. It will be fascinating reading for anyone involved in education, including teachers, psychologists, neuroscientists, and policy makers as well as interested parents.

How powerful new methods in nonlinear control engineering can be applied to neuroscience, from fundamental model formulation to

advanced medical applications. Over the past sixty years, powerful methods of model-based control engineering have been responsible for such dramatic advances in engineering systems as autoland aircraft, autonomous vehicles, and even weather forecasting. Over those same decades, our models of the nervous system have evolved from single-cell membranes to neuronal networks to large-scale models of the human brain. Yet until recently control theory was completely inapplicable to the types of nonlinear models being developed in neuroscience. The revolution in nonlinear control engineering in the late 1990s has made the intersection of control theory and neuroscience possible. In *Neural Control Engineering*, Steven Schiff seeks to bridge the two fields, examining the application of new methods in nonlinear control engineering to neuroscience. After presenting extensive material on formulating computational neuroscience models in a control environment—including some fundamentals of the algorithms helpful in crossing the divide from intuition to effective application—Schiff examines a range of applications, including brain-machine interfaces and neural stimulation. He reports on research that he and his colleagues have undertaken showing that nonlinear control theory methods can be applied to models of single cells, small neuronal networks, and large-scale networks in disease states of Parkinson's disease and epilepsy. With *Neural Control Engineering* the reader acquires a working knowledge of the fundamentals of control theory and computational neuroscience sufficient not only to understand the literature in this transdisciplinary area but also to begin working to advance the field. The book will serve as an essential guide for scientists in either biology or engineering and for physicians who wish to gain expertise in these areas.

The new edition of *Fundamentals of Computational Neuroscience* build on the success and strengths of the first edition.

Completely redesigned and revised, it introduces the theoretical foundations of neuroscience with a focus on the nature of information processing in the brain.

Analysis of Neural Data

Nonlinear Dynamics in Computational Neuroscience

Cognitive and Computational Neuroscience

Models, Methods and Applications

The Geometry of Excitability and Bursting

A Student's Introduction to Methods and Procedures

Single Neurons, Populations, Plasticity

Mathematics for Neuroscientists, Second Edition, presents a comprehensive introduction to mathematical and computational methods used in neuroscience to describe and model neural components of the brain from ion channels to single

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neurons, neural networks and their relation to behavior. The book contains more than 200 figures generated using Matlab code available to the student and scholar.

Mathematical concepts are introduced hand in hand with neuroscience, emphasizing the connection between experimental results and theory. Fully revised material and corrected text Additional chapters on extracellular potentials, motion detection and neurovascular coupling Revised selection of exercises with solutions More than 200 Matlab scripts reproducing the figures as well as a selection of equivalent Python scripts

The authoritative reference on NEURON, the simulation environment for modeling biological neurons and neural networks that enjoys wide use in the experimental and computational neuroscience communities. This book shows how to use NEURON to construct and apply empirically based models. Written primarily for neuroscience investigators, teachers, and students, it assumes no previous knowledge of computer programming or numerical methods. Readers with a background in the physical sciences or mathematics, who have some knowledge about brain cells and circuits and are interested in computational modeling, will also find it helpful. The NEURON Book covers material that ranges from the inner workings of this program, to practical considerations involved in specifying the anatomical and biophysical properties that are to be represented in models. It uses a problem-solving approach, with many working examples that readers can try for themselves.

The human brain is made up of 85 billion neurons, which are connected by over 100 trillion synapses. For more than a century, a diverse array of researchers searched for a language that could be used to capture the essence of what these neurons do and how they communicate – and how those communications create thoughts, perceptions and actions. The language they were looking for was mathematics, and we would not be able to understand the brain as we do today without it. In *Models of the Mind*, author and computational neuroscientist Grace Lindsay explains how mathematical models have allowed scientists to understand and describe many of the brain's processes, including decision-making, sensory processing, quantifying memory, and more. She introduces readers to the most important concepts in modern neuroscience, and highlights the tensions that arise when the abstract world of mathematical modelling collides with the messy details of biology. Each chapter of *Models of the Mind* focuses on mathematical tools that have been applied in a particular area of neuroscience, progressing from the simplest building block of the brain – the individual neuron – through to circuits of interacting neurons, whole brain areas and even the behaviours that brains command. In addition, Grace examines the history of the field, starting with experiments done on frog legs in the late eighteenth century and building to the large models of artificial neural networks that form the basis of modern artificial intelligence. Throughout, she reveals the value of using the elegant language of mathematics to describe the machinery of neuroscience.

This book provides an essential overview of computational neuroscience. It addresses a broad range of aspects, from physiology to nonlinear dynamical approaches to understanding neural computation, and from the simulation of brain circuits to the development of engineering devices and platforms for neuromorphic computation. Written by leading experts in such diverse fields as neuroscience, physics, psychology, neural engineering, cognitive science and applied mathematics, the book reflects the

remarkable advances that have been made in the field of computational neuroscience, an emerging discipline devoted to the study of brain functions in terms of the information-processing properties of the structures forming the nervous system. The contents build on the workshop "Nonlinear Dynamics in Computational Neuroscience: from Physics and Biology to ICT," which was held in Torino, Italy in September 2015.

Encyclopedia of Computational Neuroscience
Spikes

Tutorials in Mathematical Biosciences I

Foundations of Cellular Neurophysiology

Neural Control Engineering

Neuronal Dynamics

Mathematical and Theoretical Neuroscience

Neural network research often builds on the fiction that neurons are simple linear threshold units, completely neglecting the highly dynamic and complex nature of synapses, dendrites, and voltage-dependent ionic currents. Biophysics of Computation: Information Processing in Single Neurons challenges this notion, using richly detailed experimental and theoretical findings from cellular biophysics to explain the repertoire of computational functions available to single neurons. The author shows how individual nerve cells can multiply, integrate, or delay synaptic inputs and how information can be encoded in the voltage across the membrane, in the intracellular calcium concentration, or in the timing of individual spikes. Key topics covered include the linear cable equation; cable theory as applied to passive dendritic trees and dendritic spines; chemical and electrical synapses and how to treat them from a computational point of view; nonlinear interactions of synaptic input in passive and active dendritic trees; the Hodgkin-Huxley model of action potential generation and propagation; phase space analysis; linking stochastic ionic channels to membrane-dependent currents; calcium and potassium currents and their role in information processing; the role of diffusion, buffering and binding of calcium, and other messenger systems in information processing and storage; short- and long-term models of synaptic plasticity; simplified models of single cells; stochastic aspects of neuronal firing; the nature of the neuronal code; and unconventional models of sub-cellular computation. Biophysics of Computation: Information Processing in Single Neurons serves as an ideal text for advanced undergraduate and graduate courses in cellular biophysics, computational neuroscience, and neural networks, and will appeal to students and professionals in neuroscience, electrical and computer engineering, and physics.

An introduction to computational complexity theory, its connections and interactions with mathematics, and its central role in the natural and social sciences, technology, and philosophy Mathematics and Computation provides a broad, conceptual overview of computational complexity theory—the mathematical study of efficient computation. With important

practical applications to computer science and industry, computational complexity theory has evolved into a highly interdisciplinary field, with strong links to most mathematical areas and to a growing number of scientific endeavors. Avi Wigderson takes a sweeping survey of complexity theory, emphasizing the field's insights and challenges. He explains the ideas and motivations leading to key models, notions, and results. In particular, he looks at algorithms and complexity, computations and proofs, randomness and interaction, quantum and arithmetic computation, and cryptography and learning, all as parts of a cohesive whole with numerous cross-influences. Wigderson illustrates the immense breadth of the field, its beauty and richness, and its diverse and growing interactions with other areas of mathematics. He ends with a comprehensive look at the theory of computation, its methodology and aspirations, and the unique and fundamental ways in which it has shaped and will further shape science, technology, and society. For further reading, an extensive bibliography is provided for all topics covered. Mathematics and Computation is useful for undergraduate and graduate students in mathematics, computer science, and related fields, as well as researchers and teachers in these fields. Many parts require little background, and serve as an invitation to newcomers seeking an introduction to the theory of computation. Comprehensive coverage of computational complexity theory, and beyond High-level, intuitive exposition, which brings conceptual clarity to this central and dynamic scientific discipline Historical accounts of the evolution and motivations of central concepts and models A broad view of the theory of computation's influence on science, technology, and society Extensive bibliography with simulations and illustrations by Richard Gray Problem solving is an indispensable part of learning a quantitative science such as neurophysiology. This text for graduate and advanced undergraduate students in neuroscience, physiology, biophysics, and computational neuroscience provides comprehensive, mathematically sophisticated descriptions of modern principles of cellular neurophysiology. It is the only neurophysiology text that gives detailed derivations of equations, worked examples, and homework problem sets (with complete answers). Developed from notes for the course that the authors have taught since 1983, Foundations of Cellular Neurophysiology covers cellular neurophysiology (also some material at the molecular and systems levels) from its physical and mathematical foundations in a way that is far more rigorous than other commonly used texts in this area. The nervous system is made up of a large number of interacting elements. To understand how such a complex system functions requires the construction and analysis of computational models at many different levels. This book provides a step-by-step account of how to model the

neuron and neural circuitry to understand the nervous system at all levels, from ion channels to networks. Starting with a simple model of the neuron as an electrical circuit, gradually more details are added to include the effects of neuronal morphology, synapses, ion channels and intracellular signalling. The principle of abstraction is explained through chapters on simplifying models, and how simplified models can be used in networks. This theme is continued in a final chapter on modelling the development of the nervous system. Requiring an elementary background in neuroscience and some high school mathematics, this textbook is an ideal basis for a course on computational neuroscience.

Unsupervised Learning

The Computational Neurobiology of Reaching and Pointing

Dynamical Systems in Neuroscience

How Physics, Engineering and Mathematics Have Shaped Our Understanding of the Brain

Introduction To The Theory Of Neural Computation

Spiking Neuron Models

Computational Neuroscience and Cognitive Modelling

An introduction to the computational biology of reaching and pointing, with an emphasis on motor learning. Neuroscience involves the study of the nervous system, and its topics range from genetics to inferential reasoning. At its heart, however, lies a search for understanding how the environment affects the nervous system and how the nervous system, in turn, empowers us to interact with and alter our environment. This empowerment requires motor learning. The Computational Neurobiology of Reaching and Pointing addresses the neural mechanisms of one important form of motor learning. The authors integrate material from the computational, behavioral, and neural sciences of motor control that is not available in any other single source. The result is a unified, comprehensive model of reaching and pointing. The book is intended to be used as a text by graduate students in both neuroscience and bioengineering and as a reference source by experts in neuroscience, robotics, and other disciplines. The book begins with an overview of the evolution, anatomy, and physiology of the motor system, including the mechanisms for generating force and maintaining limb stability. The sections that follow, "Computing Locations and Displacements", "Skills, Adaptations, and Trajectories", and "Predictions, Decisions, and Flexibility", present a theory of sensorially guided reaching and pointing that evolves organically based on computational principles rather than a traditional structure-by-structure approach. The book also includes five appendixes that provide brief refreshers on fundamentals of biology, mathematics, physics, and neurophysiology, as well as a glossary of relevant terms. The authors have also made supplemental materials available on the Internet. These web documents provide source code for simulations, step-by-step derivations of certain mathematical formulations, and expanded explanations of some concepts.

Over the last two decades, the recognition that astrocytes - the predominant type of cortical glial cells - could sense neighboring neuronal activity and release neuroactive agents, has been instrumental in the uncovering of many roles that these cells could play in brain processing and the storage of information. These findings initiated a conceptual revolution that leads to rethinking how brain communication works since they imply that information travels and is processed not just in the neuronal circuitry but in an expanded neuron-glial network. On the other hand the physiological need for astrocyte signaling in brain information processing

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and the modes of action of these cells in computational tasks remain largely undefined. This is due, to a large extent, both to the lack of conclusive experimental evidence, and to a substantial lack of a theoretical framework to address modeling and characterization of the many possible astrocyte functions. This book that we propose aims at filling this gap, providing the first systematic computational approach to the complex, wide subject of neuron-glia interactions. The organization of the book is unique insofar as it considers a selection of “ hot topics ” in glia research that ideally brings together both the novelty of the recent experimental findings in the field and the modelling challenge that they bear. A chapter written by experimentalists, possibly in collaboration with theoreticians, will introduce each topic. The aim of this chapter, that we foresee less technical in its style than in conventional reviews, will be to provide a review as clear as possible, of what is “ established ” and what remains speculative (i.e. the open questions). Each topic will then be presented in its possible different aspects, by 2-3 chapters by theoreticians. These chapters will be edited in order to provide a “ priming ” reference for modeling neuron-glia interactions, suitable both for the graduate student and the professional researcher.

An argument that the complexities of brain function can be understood hierarchically, in terms of different levels of abstraction, as silicon computing is.

A comprehensive, integrated, and accessible textbook presenting core neuroscientific topics from a computational perspective, tracing a path from cells and circuits to behavior and cognition. This textbook presents a wide range of subjects in neuroscience from a computational perspective. It offers a comprehensive, integrated introduction to core topics, using computational tools to trace a path from neurons and circuits to behavior and cognition. Moreover, the chapters show how computational neuroscience—methods for modeling the causal interactions underlying neural systems—complements empirical research in advancing the understanding of brain and behavior. The chapters—all by leaders in the field, and carefully integrated by the editors—cover such subjects as action and motor control; neuroplasticity, neuromodulation, and reinforcement learning; vision; and language—the core of human cognition. The book can be used for advanced undergraduate or graduate level courses. It presents all necessary background in neuroscience beyond basic facts about neurons and synapses and general ideas about the structure and function of the human brain. Students should be familiar with differential equations and probability theory, and be able to pick up the basics of programming in MATLAB and/or Python. Slides, exercises, and other ancillary materials are freely available online, and many of the models described in the chapters are documented in the brain operation database, BODB (which is also described in a book chapter). Contributors Michael A. Arbib, Joseph Ayers, James Bednar, Andrej Bicanski, James J. Bonaiuto, Nicolas Brunel, Jean-Marie Cabelguen, Carmen Canavier, Angelo Cangelosi, Richard P. Cooper, Carlos R. Cortes, Nathaniel Daw, Paul Dean, Peter Ford Dominey, Pierre Enel, Jean-Marc Fellous, Stefano Fusi, Wulfram Gerstner, Frank Grasso, Jacqueline A. Griego, Ziad M. Hafed, Michael E. Hasselmo, Auke Ijspeert, Stephanie Jones, Daniel Kersten, Jeremie Knuesel, Owen Lewis, William W. Lytton, Tomaso Poggio, John Porrill, Tony J. Prescott, John Rinzel, Edmund Rolls, Jonathan Rubin, Nicolas Schweighofer, Mohamed A. Sherif, Malle A. Tagamets, Paul F. M. J. Verschure, Nathan Vierling-Claasen, Xiao-Jing Wang, Christopher Williams, Ransom Winder, Alan L. Yuille

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Chapter 2 is a self-contained introduction to dynamical systems and bifurcation theory, oriented towards neuronal dynamics. The theory is illustrated with a model of Parkinson's disease. Chapter 3 reviews the theory of coupled neural oscillators observed throughout the nervous systems at all levels; it describes how oscillations arise, what pattern they take, and how they depend on excitatory or inhibitory synaptic connections. Chapter 4 specializes to one particular neuronal system, namely, the auditory system. It includes a self-contained introduction, from the anatomy and physiology of the inner ear to the neuronal network that connects the hair cells to the cortex, and describes various models of subsystems.

Theoretical neuroscience provides a quantitative basis for describing what nervous systems do, determining how they function, and uncovering the general principles by which they operate. This text introduces the basic mathematical and computational methods of theoretical neuroscience and presents applications in a variety of areas including vision, sensory-motor integration, development, learning, and memory. The book is divided into three parts. Part I discusses the relationship between sensory stimuli and neural responses, focusing on the representation of information by the spiking activity of neurons. Part II discusses the modeling of neurons and neural circuits on the basis of cellular and synaptic biophysics. Part III analyzes the role of plasticity in development and learning. An appendix covers the mathematical methods used, and exercises are available on the book's Web site.

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