The Computational Brain Computational Neuroscience

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Computational Neuroscience Models of the Basal Ganglia

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.

Memory and the Computational Brain

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.

Analysis of Neural Data

The thirty original contributions in this book provide a working definition of"computational neuroscience" as the area in which problems lie simultaneously within computerscience and neuroscience. They review this emerging field in historical and philosophical overviewsand in stimulating summaries of recent results. Leading researchers address the structure of thebrain and the computational problems associated with describing and understanding this structure atthe synaptic, neural, map, and system levels.The overview chapters discuss the early days of thefield, provide a philosophical analysis of the problems associated with confusion between brainmetaphor and brain theory, and take up the scope and structure of computationalneuroscience.Synaptic-level structure is addressed in chapters that relate the properties ofdendritic branches, spines, and synapses to the biophysics of computation and provide a connectionbetween real neuron architectures and neural network simulations.The network-level chapters take upthe preattentive perception of 3-D forms, oscillation in neural networks, the neurobiologicalsignificance of new learning models, and the analysis of neural

assemblies and local learningrides.Map-level structure is explored in chapters on the bat echolocation system, cat orientationmaps, primate stereo vision cortical cognitive maps, dynamic remapping in primate visual cortex, andcomputer-aided reconstruction of topographic and columnar maps in primates.The system-level chaptersfocus on the oculomotor system VLSI models of early vision, schemas for high-level vision,goal-directed movements, modular learning, effects of applied electric current fields on corticalneural activity neuropsychological studies of brain and mind, and an information-theoretic view ofanalog representation in striate cortex.Eric L. Schwartz is Professor of Brain Research and ResearchProfessor of Computer Science, Courant Institute of Mathematical Sciences, New York UniversityMedical Center. Computational Neuroscience is included in the System Development FoundationBenchmark Series.

Principles of Brain Dynamics

Our perception of the world is driven by input from the sensory nerves. This input arrives encoded as sequences of identical spikes. Much of neural computation involves processing these spike trains. What does it mean to say that a certain set of spikes is the right answer to a computational problem? In what sense does a spike train convey information about the sensory world? Spikes begins by providing precise formulations of these and related questions about the representation of sensory signals in neural spike trains. The answers to these

questions are then pursued in experiments on sensory neurons. The authors invite the reader to play the role of a hypothetical observer inside the brain who makes decisions based on the incoming spike trains. Rather than asking how a neuron responds to a given stimulus, the authors ask how the brain could make inferences about an unknown stimulus from a given neural response. The flavor of some problems faced by the organism is captured by analyzing the way in which the observer can make a running reconstruction of the sensory stimulus as it evolves in time. These ideas are illustrated by examples from experiments on several biological systems. Intended for neurobiologists with an interest in mathematical analysis of neural data as well as the growing number of physicists and mathematicians interested in information processing by "real" nervous systems, Spikes provides a self-contained review of relevant concepts in information theory and statistical decision theory. A quantitative framework is used to pose precise questions about the structure of the neural code. These questions in turn influence both the design and analysis of experiments on sensory neurons.

The Computational Brain

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.

The Deep Learning Revolution

"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"--

Spikes

This exciting new book presents a highly complex subject of vision, focussing on the visual information processing and computational operations in the visual system that lead to representations of objects in the brain. In addition to visual processing, it also considers how visual imputs reach and are involved in the computations underlying a wide range of behaviour, thus providing a foundation for understanding the operation of a number of different brain systems. This fascinating book will be of value to all those interested in understanding how the brain works, and in understanding vision, attention, memory, emotion, motivation and action.

Lectures in Supercomputational Neuroscience

Memory and the Computational Brain offers a provocative argument that goes to the heart of neuroscience, proposing that the field can and should benefit from the recent advances of cognitive science and the development of information theory over the course of the last several decades. A provocative argument that impacts across the fields of linguistics, cognitive science, and neuroscience, suggesting new perspectives on learning mechanisms in the brain Proposes that the field of neuroscience can and should benefit from the recent advances of cognitive science and the development of information theory Suggests that the architecture of the brain is structured precisely for learning and for memory, and integrates the concept of an addressable read/write memory mechanism into the foundations of neuroscience Based on lectures in the prestigious Blackwell-Maryland Lectures in Language and Cognition, and now significantly reworked and expanded to make it ideal for students and faculty

Computational Neuroscience and Cognitive Modelling

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

Graphical Models

Biology undergraduates, medical students and life-science graduate students often have limited mathematical skills. Similarly, physics, math and engineering students have little patience for the detailed facts that make up much of biological knowledge. Teaching computational neuroscience as an integrated discipline requires that both groups be brought forward onto common ground. This book does this by making ancillary material available in an appendix and providing basic explanations without becoming bogged down in unnecessary details. The book will be suitable for undergraduates and beginning graduate students taking a computational neuroscience course and also to anyone with an interest in the uses of the computer in modeling the nervous system.

Computational Neuroscience: Theoretical Insights into Brain Function

This text introduces the reader to the main ideas in the field of computational cognitive neuroscience. The aim of the discipline is to understand how the brain embodies the mind by using biologically based computational models which simulate neuronal networks.

From Neuron to Cognition via Computational Neuroscience

This book exemplifies the interplay between the general formal framework of graphical models and the exploration of new algorithm and architectures. The selections range from foundational papers of historical importance to results at the cutting edge of research. Graphical models use graphs to represent and manipulate joint probability distributions. They have their roots in artificial intelligence, statistics, and neural networks. The clean mathematical formalism of the graphical models framework makes it possible to understand a wide variety of network-based approaches to computation, and in particular to understand many neural network algorithms and architectures as instances of a broader probabilistic methodology. It also makes it possible to identify novel features of neural network algorithms and architectures and to extend them to more general graphical models.This book exemplifies the interplay between the general formal framework of graphical models and the exploration of new algorithms and architectures. The selections range from foundational papers of historical importance to results at the cutting edge of research. Contributors H. Attias, C. M. Bishop, B. J. Frey, Z. Ghahramani, D. Heckerman, G. E. Hinton, R. Hofmann, R. A. Jacobs, Michael I. Jordan, H. J. Kappen, A. Krogh, R. Neal, S. K. Riis, F. B. Rodríguez, L. K. Saul, Terrence J. Sejnowski, P. Smyth, M. E. Tipping, V. Tresp, Y. Weiss

Computational Models of Brain and Behavior

Psychiatrists and neuroscientists discuss the potential of computational

approaches to address problems in psychiatry including diagnosis, treatment, and integration with neurobiology.

Bayesian Brain

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 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

Cognitive and Computational Neuroscience

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 to connect basic neuroscience to clinical medicine.

Computational Neuroscience of Vision

The book is a compendium of the aforementioned subclass of models of Basal Ganglia, which presents some the key existent theories of Basal Ganglia function. The book presents computational models of basal ganglia-related disorders, including Parkinson's disease, schizophrenia, and addiction. Importantly, it highlights the applications of understanding the role of the basal ganglia to treat neurological and psychiatric disorders. The purpose of the present book is to amend and expand on James Houk's book (MIT press; ASIN: B010BF4U9K) by providing a comprehensive overview on computational models of the basal ganglia. This book caters to researchers and academics from the area of computational cognitive neuroscience.

Encyclopedia of Computational Neuroscience

"Learning and Computational Neuroscience" presents recent advances in understanding the brain processes underlying learning and memory, including neural systems analyses of dynamic circuit interactions in the brain and computational models capable of describing simple forms of learning and performance. Its principal aim is to show how each approach is related to and benefits the other, providing a powerful strategy for understanding cognitive processes.Michael Gabriel is Professor of Psychology at the University of Illinois. John Moore is Professor of Psychology and Associate Professor of Computer and Information Science at the University of Massachusetts at Amherst.Contributors:

Michael Gabriel and John Moore. Joseph E. LeDoux, Bruce S. Kapp, Amy Wilson, Jeffrey P. Pascoe, William Supple, Paul J. Whalen, Norman W. Weinberger, John H. Ashe, Raju Metherate, David M. Diamond, Jon S. Bakin, J. Michael Cassady. Nestor A. Schmajuk. Malcolm W. Brown. Theodore W. Berger, German Barri onuevo, Steven P. Levitan, Donald N. Krieger, Robert J. H. Sclabassi. Neil E. Berthier, Diana E. J. Blazis. E. James Kehoe. John E. Desmond. A. Harry Klopf, James S. Morgan. Richard S. Sutton, Andrew G. Barto. Christopher J. C. H. Watkins.

Biophysics of Computation

The papers of this volume focus on the foundational aspects of computer science, the thematic origin and stronghold of LNCS, under the title "Computing and Software Science: State of the Art and Perspectives". They are organized in two parts: The first part, Computation and Complexity, presents a collection of expository papers on fashionable themes in algorithmics, optimization, and complexity. The second part, Methods, Languages and Tools for Future System Development, aims at sketching the methodological evolution that helps guaranteeing that future systems meet their increasingly critical requirements. Chapter 3 is available open access under a Creative Commons Attribution 4.0 International License via link.springer.com.

20 Years of Computational Neuroscience

How deep learning—from Google Translate to driverless cars to personal cognitive assistants—is changing our lives and transforming every sector of the economy. The deep learning revolution has brought us driverless cars, the greatly improved Google Translate, fluent conversations with Siri and Alexa, and enormous profits from automated trading on the New York Stock Exchange. Deep learning networks can play poker better than professional poker players and defeat a world champion at Go. In this book, Terry Sejnowski explains how deep learning went from being an arcane academic field to a disruptive technology in the information economy. Sejnowski played an important role in the founding of deep learning, as one of a small group of researchers in the 1980s who challenged the prevailing logic-and-symbol based version of AI. The new version of AI Sejnowski and others developed, which became deep learning, is fueled instead by data. Deep networks learn from data in the same way that babies experience the world, starting with fresh eyes and gradually acquiring the skills needed to navigate novel environments. Learning algorithms extract information from raw data; information can be used to create knowledge; knowledge underlies understanding; understanding leads to wisdom. Someday a driverless car will know the road better than you do and drive with more skill; a deep learning network will diagnose your illness; a personal cognitive assistant will augment your puny human brain. It took nature many millions of years to evolve human intelligence; AI is on a trajectory measured in decades.

Sejnowski prepares us for a deep learning future.

Computational Neuroscience

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.

An Introductory Course in Computational Neuroscience

This volume is a report on the state of philosophy in a number of significant areas.

Fundamentals of Computational Neuroscience

When funding agencies and policy organizations consider the role of modeling and simulation in modern biology, the question is often posed, what has been accomplished ? This book will be organized around a symposium on the 20 year history of the CNS meetings, to be held as part of CNS 2010 in San Antonio Texas in July 2010. The book, like the symposium is intended to summarize progress made in Computational Neuroscience over the last 20 years while also considering current challenges in the field. As described in the table of contents, the chapter's authors have been selected to provide wide coverage of the applications of computational techniques to a broad range of questions and model systems in neuroscience. The proposed book will include several features that establish the history of the field. For each article, its author will select an article originally appearing in a CNS conference proceedings from 15 – 20 years ago. These short (less than 6 page) articles will provide illustrations of the state of the field 20 years ago. The new articles will describe what has been learned about the subject in the following 20 years, and pose specific challenges for the next 20 years. The second historical mechanism will be the reproduction of the first 12 years of posters from the CNS meeting. These posters in and of themselves have become famous in the field (they hang in the halls of the NIH in Bethesda Maryland) and were constructed as allegories for the state and development of computational neuroscience. The posters were designed by the book's editor, who will, for the first time, provide a

written description of each poster.

Computational Neuroscience in Epilepsy

Conscience: The Origins of Moral Intuition

Introduction to computer modeling of the brain, to understand how people think. Networks of interacting neurons produce complex emergent behavior including perception, attention, motor control, learning, memory, language, and executive functions (motivation, decision making, planning, etc).

Computational Cognitive Neuroscience

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

Computational Modeling Methods for Neuroscientists

A comprehensive Introduction to the world of brain and behavior computational models This book provides a broad collection of articles covering different aspects

of computational modeling efforts in psychology and neuroscience. Specifically, it discusses models that span different brain regions (hippocampus, amygdala, basal ganglia, visual cortex), different species (humans, rats, fruit flies), and different modeling methods (neural network, Bayesian, reinforcement learning, data fitting, and Hodgkin-Huxley models, among others). Computational Models of Brain and Behavior is divided into four sections: (a) Models of brain disorders; (b) Neural models of behavioral processes; (c) Models of neural processes, brain regions and neurotransmitters, and (d) Neural modeling approaches. It provides in-depth coverage of models of psychiatric disorders, including depression, posttraumatic stress disorder (PTSD), schizophrenia, and dyslexia; models of neurological disorders, including Alzheimer's disease, Parkinson's disease, and epilepsy; early sensory and perceptual processes; models of olfaction; higher/systems level models and low-level models; Pavlovian and instrumental conditioning; linking information theory to neurobiology; and more. Covers computational approximations to intellectual disability in down syndrome Discusses computational models of pharmacological and immunological treatment in Alzheimer's disease Examines neural circuit models of serotonergic system (from microcircuits to cognition) Educates on information theory, memory, prediction, and timing in associative learning Computational Models of Brain and Behavior is written for advanced undergraduate, Master's and PhD-level students—as well as researchers involved in computational neuroscience modeling research.

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

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

Computational Neuroscience

"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 prerequisitesI 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 contex. 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.

Meaning and Method

Trains researchers and graduate students in state-of-the-art statistical and machine learning methods to build models with real-world data.

From Computer to Brain

Experimental and theoretical neuroscientists use Bayesian approaches to analyze

the brain mechanisms of perception, decision-making, and motor control.

Brain Computation as Hierarchical Abstraction

How do we determine right from wrong? Conscience illuminates the answer through science and philosophy. In her brilliant work Touching a Nerve, Patricia S. Churchland, the distinguished founder of neurophilosophy, drew from scientific research on the brain to understand its philosophical and ethical implications for identity, consciousness, free will, and memory. In Conscience, she explores how moral systems arise from our physical selves in combination with environmental demands. All social groups have ideals for behavior, even though ethics vary among different cultures and among individuals within each culture. In trying to understand why, Churchland brings together an understanding of the influences of nature and nurture. She looks to evolution to elucidate how, from birth, our brains are configured to form bonds, to cooperate, and to care. She shows how children grow up in society to learn, through repetition and rewards, the norms, values, and behavior that their parents embrace. Conscience delves into scientific studies, particularly the fascinating work on twins, to deepen our understanding of whether people have a predisposition to embrace specific ethical stands. Research on psychopaths illuminates the knowledge about those who abide by no moral system and the explanations science gives for these disturbing individuals. Churchland then turns to philosophy—that of Socrates, Aquinas, and contemporary thinkers

like Owen Flanagan—to explore why morality is central to all societies, how it is transmitted through the generations, and why different cultures live by different morals. Her unparalleled ability to join ideas rarely put into dialogue brings light to a subject that speaks to the meaning of being human.

Principles of Computational Modelling in Neuroscience

Written from the physicist's perspective, this book introduces computational neuroscience with in-depth contributions by system neuroscientists. The authors set forth a conceptual model for complex networks of neurons that incorporates important features of the brain. The computational implementation on supercomputers, discussed in detail, enables you to adapt the algorithm for your own research. Worked-out examples of applications are provided.

Computational Psychiatry

"The Computational Brain addresses a broad audience: neuroscientists, computer scientists, cognitive scientists, and philosophers. It is written for both the expert and novice. A basic overview of neuroscience and computational theory is provided, followed by a study of some of the most recent and sophisticated modeling work in the context of relevant neurobiological research. Technical terms

are clearly explained in the text, and definitions are provided in an extensive glossary. The appendix contains a précis of neurobiological techniques."--Jacket.

Computational Explorations in Cognitive Neuroscience

The new edition of Fundamentals of Computational Neuroscience build on the success and strengths of the first edition. It introduces the theoretical foundations of neuroscience with a focus on the nature of information processing in the brain. The book covers the introduction and motivation of simplified models of neurons that are suitable for exploring information processing in large brain-like networks. Additionally, it introduces several fundamental networkarchitectures and discusses their relevance for information processing in the brain, giving some examples of models of higher-order cognitive functions to demonstrate the advanced insight that can begained with such studies.

Learning and Computational Neuroscience

A textbook for students with limited background in mathematics and computer coding, emphasizing computer tutorials that guide readers in producing models of neural behavior. This introductory text teaches students to understand, simulate, and analyze the complex behaviors of individual neurons and brain circuits. It is

built around computer tutorials that guide students in producing models of neural behavior, with the associated Matlab code freely available online. From these models students learn how individual neurons function and how, when connected, neurons cooperate in a circuit. The book demonstrates through simulated models how oscillations, multistability, post-stimulus rebounds, and chaos can arise within either single neurons or circuits, and it explores their roles in the brain. The book first presents essential background in neuroscience, physics, mathematics, and Matlab, with explanations illustrated by many example problems. Subsequent chapters cover the neuron and spike production; single spike trains and the underlying cognitive processes; conductance-based models; the simulation of synaptic connections; firing-rate models of large-scale circuit operation; dynamical systems and their components; synaptic plasticity; and techniques for analysis of neuron population datasets, including principal components analysis, hidden Markov modeling, and Bayesian decoding. Accessible to undergraduates in life sciences with limited background in mathematics and computer coding, the book can be used in a "flipped" or "inverted" teaching approach, with class time devoted to hands-on work on the computer tutorials. It can also be a resource for graduate students in the life sciences who wish to gain computing skills and a deeper knowledge of neural function and neural circuits.

Computational Neuroscience

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

Neuronal Dynamics

Experimental and theoretical approaches to global brain dynamics that draw on the latest research in the field. The consideration of time or dynamics is fundamental for all aspects of mental activity—perception, cognition, and emotion—because the main feature of brain activity is the continuous change of the underlying brain states even in a constant environment. The application of nonlinear dynamics to the study of brain activity began to flourish in the 1990s when combined with empirical observations from modern morphological and physiological observations. This book offers perspectives on brain dynamics that draw on the latest advances in research in the field. It includes contributions from both theoreticians and experimentalists, offering an eclectic treatment of fundamental issues. Topics addressed range from experimental and computational approaches to transient brain dynamics to the free-energy principle as a global

brain theory. The book concludes with a short but rigorous guide to modern nonlinear dynamics and their application to neural dynamics.

Memory and the Computational Brain

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

Computing and Software Science

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.

Data-Driven Computational Neuroscience

Memory and the Computational Brain offers a provocative argument that goes to the heart of neuroscience, proposing that the field can and should benefit from the recent advances of cognitive science and the development of information theory

over the course of the last several decades. A provocative argument that impacts across the fields of linguistics, cognitive science, and neuroscience, suggesting new perspectives on learning mechanisms in the brain Proposes that the field of neuroscience can and should benefit from the recent advances of cognitive science and the development of information theory Suggests that the architecture of the brain is structured precisely for learning and for memory, and integrates the concept of an addressable read/write memory mechanism into the foundations of neuroscience Based on lectures in the prestigious Blackwell-Maryland Lectures in Language and Cognition, and now significantly reworked and expanded to make it ideal for students and faculty

ROMANCE ACTION & ADVENTURE MYSTERY & THRILLER BIOGRAPHIES & HISTORY CHILDREN'S YOUNG ADULT FANTASY HISTORICAL FICTION HORROR LITERARY FICTION NON-FICTION SCIENCE FICTION