Fundamentals of Computational Neuroscience

Second Edition

Thomas P. Trappenberg

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Fundamentals of Computational Neuroscience Thomas Trappenberg, 2009-10-29 Computational neuroscience is the theoretical study of the brain to uncover the principles and mechanisms that guide the development organization information processing and mental functions of the nervous system Although not a new area it is only recently that enough knowledge has been gathered to establish computational neuroscience as a scientific discipline in its own right Given the complexity of the field and its increasing importance in progressing our understanding of how the brain works there has long been a need for an introductory text on what is often assumed to be an impenetrable topic 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 network architectures 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 be gained with such studies Each chapter starts by introducing its topic with experimental facts and conceptual questions related to the study of brain function An additional feature is the inclusion of simple Matlab programs that can be used to explore many of the mechanisms explained in the book An accompanying webpage includes programs for download The book will be the essential text for anyone in the brain sciences who wants to get to grips with this topic

Fundamentals of Computational Neuroscience Thomas P. Trappenberg, 2022-11-28 Computational neuroscience is the theoretical study of the brain to uncover the principles and mechanisms that guide the development organization information processing and mental functions of the nervous system Although not a new area it is only recently that enough knowledge has been gathered to establish computational neuroscience as a scientific discipline in its own right Given the complexity of the field and its increasing importance in progressing our understanding of how the brain works there has long been a need for an introductory text on what is often assumed to be an impenetrable topic The new edition of Fundamentals of Computational Neuroscience build on the success and strengths of the previous editions 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 network architectures 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 be gained with such studies Each chapter starts by introducing its topic with experimental facts and conceptual questions related to the study of brain function An additional feature is the inclusion of simple Matlab programs that can be used to explore many of the mechanisms explained in the book An accompanying webpage includes

programs for download The book will be the essential text for anyone in the brain sciences who wants to get to grips with this The Cambridge Handbook of Cognitive Science Keith Frankish, William Ramsey, 2012-07-19 An authoritative up to topic date survey of the state of the art in cognitive science written for non specialists Dynamic Thinking Gregor Schöner, John P. Spencer, 2016 This book describes a new theoretical approach Dynamic Field Theory DFT that explains how people think Fundamentals of Computational Neuroscience Thomas P. Trappenberg, 2002 **An Introductory Course** in Computational Neuroscience Paul Miller, 2018-10-09 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 From Computer to Brain William W. Lytton, 2002-10-01 Biology undergraduates medical function and neural circuits 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

From Neuron to Cognition via Computational Neuroscience Michael A. Arbib, James J. Bonaiuto, 2016-11-04 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 Computational Neuroscience Eric L. Schwartz, 1990 The thirty original contributions in this book provide a working definition of computational neuroscience as the area in which problems lie simultaneously within computer science and neuroscience They review this emerging field in historical and philosophical overviews and in stimulating summaries of recent results Leading researchers address the structure of the brain and the computational problems associated with describing and understanding this structure at the synaptic neural map and system levels The overview chapters discuss the early days of the field provide a philosophical analysis of the problems associated with confusion between brain metaphor and brain theory and take up the scope and structure of computational neuroscience Synaptic level structure is addressed in chapters that relate the properties of dendritic branches spines and synapses to the biophysics of computation and provide a connection between real neuron architectures and neural network simulations The network level chapters take up the preattentive perception of 3 D forms oscillation in neural networks the neurobiological significance of new learning models and the analysis of neural assemblies and local learning rides Map level structure is explored in chapters on the bat echolocation system cat orientation maps primate stereo vision cortical cognitive maps dynamic remapping in primate visual cortex and computer aided reconstruction of topographic and columnar maps in primates The system level chapters focus 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 cortical neural activity neuropsychological studies of brain and mind and an information theoretic view of analog representation in striate cortex Eric L Schwartz is Professor of Brain Research and Research Professor of Computer Science Courant Institute of Mathematical Sciences New York University Medical Center Computational Neuroscienceis included in the System Development Foundation Benchmark Series

Computational Neuroscience Hanspeter A. Mallot, 2013-06-30

Cognitive and Computational Neuroscience Seyyed Abed Hosseini,2018 Computational Cognitive Neuroscience Yuko Munakata, Michael Frank, Thomas Hazy,2012-09 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

Cognitive and Computational Neuroscience - Principles, Algorithms and Applications Seyved Abed Hosseini, 2018 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 GARETH MORGAN. THOMAS, 2025 The Computational Neurobiology of Reaching and Pointing Reza Shadmehr, Steven P. Wise, 2004-10-28 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 **Theoretical Neuroscience** Peter Dayan, L. F. Abbott, 2001 Nonlinear Dynamics in Computational Neuroscience Fernando Corinto, Alessandro Torcini, 2018-07-09 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 Computational Neuroscience: Modeling and Applications Scott Carter, 2019-06-06 Computational neuroscience is the branch of neuroscience that uses mathematical models theoretical analysis and abstractions to understand the development structure and information processing of the nervous system It also attempts to understand the principles that govern the physiology and cognitive abilities of the nervous system Computational neuroscience models help in the understanding of biological phenomena at different spatial temporal scales It covers all aspects of membrane currents proteins network oscillations learning memory etc Research in computational neuroscience delves into the concepts of consciousness and the processes of cognition sensory processing memory and axonal patterning and development This book discusses the fundamentals as well as modern approaches of computational neuroscience It covers all the important aspects of modeling and their applications Different approaches evaluations methodologies and advanced studies have been included in this book With state of the art inputs by acclaimed experts of this field this book targets students and researchers alike

Computational Neuroscience: Theoretical Insights Into Brain Function Paul Cisek, Trevor Drew, John Kalaska, 2007-11-14 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 Hippocampal Microcircuits Vassilis Cutsuridis, Bruce P. Graham, Stuart Cobb, Imre Vida, 2019-02-21 This is the 2nd edition of a very well received and popular book that reflects the current state of the art of the ongoing research avenues concerning the hippocampus and processing units bridging the gap between single cell activity network activity and global brain function It aims to provide a methodology to anyone interested in developing microcircuit level models of the hippocampus The book is divided into two thematic areas I Experimental background and II Computational analysis In part I leading experimental neuroscientists discuss the morphological physiological and molecular characteristics as well as the connectivity and synaptic properties of the various cell types found in the hippocampus Behaviour related ensemble activity patterns of morphologically identified neurons in anesthetized and freely moving animals provide insights on the function of the hippocampal areas In part II computational neuroscientists present models of the hippocampal microcircuits at various levels of detail e g single cell level network level etc Synaptomics and connectomics models of hippocampal structures are initially discussed Then network models of memory rhythm generation and spatial navigation are presented followed by abstract and biophysical models of synaptic plasticity Network models of hippocampal implicated disorders epilepsy and schizophrenia are then detailed and how their network topologies connectivities and activities change in these diseases Finally two chapters are dedicated to describing simulator environments of single neurons and networks currently used by computational neuroscientists in developing their models and modelling tools to parametrically constrain them This engaging volume is invaluable to experimental and computational neuroscientists electrical engineers physicists mathematicians and others interested in developing microcircuit models of the hippocampus Graduate level students and trainees in all of these fields can find this book a significant source of information

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