



Neural Codes and Distributed Representations

Foundations of Neural Computation

Edited by

Laurence Abbott

Terrence J. Sejnowski

Neural Codes And Distributed Representations Foundations Of Neural Computation Computational Neuroscience

**National Research Council, Division on
Engineering and Physical
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on Frontiers at the Interface of
Computing and Biology**

Neural Codes And Distributed Representations Foundations Of Neural Computation Computational Neuroscience:

Neural Codes and Distributed Representations L. F. Abbott, Terrence Joseph Sejnowski, 1999 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 The present volume focuses on neural codes and representations topics of broad interest to neuroscientists and modelers The topics addressed are how neurons encode information through action potential firing patterns how populations of neurons represent information and how individual neurons use dendritic processing and biophysical properties of synapses to decode spike trains The papers encompass a wide range of levels of investigation from dendrites and neurons to networks and systems

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 function and neural circuits

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

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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 concepts

Dynamical Systems in Neuroscience Eugene M. Izhikevich, 2010-01-22 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

Graphical Models Michael Irwin Jordan, Terrence Joseph Sejnowski, 2001 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 Rodriguez L K Saul Terrence J Sejnowski P

Smyth M E Tipping V Tresp Y Weiss **The Computational Brain, 25th Anniversary Edition** Patricia S. Churchland, Terrence J. Sejnowski, 2016-10-28 An anniversary edition of the classic work that influenced a generation of neuroscientists and cognitive neuroscientists Before The Computational Brain was published in 1992 conceptual frameworks for brain function were based on the behavior of single neurons applied globally In The Computational Brain Patricia Churchland and Terrence Sejnowski developed a different conceptual framework based on large populations of neurons They did this by showing that patterns of activities among the units in trained artificial neural network models had properties that resembled those recorded from populations of neurons recorded one at a time It is one of the first books to bring together computational concepts and behavioral data within a neurobiological framework Aimed at a broad audience of neuroscientists computer scientists cognitive scientists and philosophers The Computational Brain is written for both expert and novice This anniversary edition offers a new preface by the authors that puts the book in the context of current research This approach influenced a generation of researchers Even today when neuroscientists can routinely record from hundreds of neurons using optics rather than electricity and the 2013 White House BRAIN initiative heralded a new era in innovative neurotechnologies the main message of The Computational Brain is still relevant Neural Engineering Chris Eliasmith, Charles H. Anderson, 2003 A synthesis of current approaches to adapting engineering tools to the study of neurobiological systems Bayesian Brain Kenji Doya, 2007 Experimental and theoretical neuroscientists use Bayesian approaches to analyze the brain mechanisms of perception decision making and motor control Computational Vision Hanspeter A. Mallot, 2000 This text provides an introduction to computational aspects of early vision in particular color stereo and visual navigation It integrates approaches from psychophysics and quantitative neurobiology as well as theories and algorithms from machine vision and photogrammetry When presenting mathematical material it uses detailed verbal descriptions and illustrations to clarify complex points The text is suitable for upper level students in neuroscience biology and psychology who have basic mathematical skills and are interested in studying the mathematical modeling of perception

Case Studies in Neural Data Analysis Mark A. Kramer, Uri T. Eden, 2016-11-04 A practical guide to neural data analysis techniques that presents sample datasets and hands on methods for analyzing the data As neural data becomes increasingly complex neuroscientists now require skills in computer programming statistics and data analysis This book teaches practical neural data analysis techniques by presenting example datasets and developing techniques and tools for analyzing them Each chapter begins with a specific example of neural data which motivates mathematical and statistical analysis methods that are then applied to the data This practical hands on approach is unique among data analysis textbooks and guides and equips the reader with the tools necessary for real world neural data analysis The book begins with an introduction to MATLAB the most common programming platform in neuroscience which is used in the book Readers familiar with MATLAB can skip this chapter and might decide to focus on data type or method type The book goes on to cover neural

field data and spike train data spectral analysis generalized linear models coherence and cross frequency coupling Each chapter offers a stand alone case study that can be used separately as part of a targeted investigation The book includes some mathematical discussion but does not focus on mathematical or statistical theory emphasizing the practical instead References are included for readers who want to explore the theoretical more deeply The data and accompanying MATLAB code are freely available on the authors website The book can be used for upper level undergraduate or graduate courses or as a professional reference A version of this textbook with all of the examples in Python is available on the MIT Press website

Theoretical Neuroscience Peter Dayan, Laurence F. Abbott, 2005-08-12 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

Modeling Neural Circuits Made Simple with Python Robert Rosenbaum, 2024-03-19 An accessible undergraduate textbook in computational neuroscience that provides an introduction to the mathematical and computational modeling of neurons and networks of neurons Understanding the brain is a major frontier of modern science Given the complexity of neural circuits advancing that understanding requires mathematical and computational approaches This accessible undergraduate textbook in computational neuroscience provides an introduction to the mathematical and computational modeling of neurons and networks of neurons Starting with the biophysics of single neurons Robert Rosenbaum incrementally builds to explanations of neural coding learning and the relationship between biological and artificial neural networks Examples with real neural data demonstrate how computational models can be used to understand phenomena observed in neural recordings Based on years of classroom experience the material has been carefully streamlined to provide all the content needed to build a foundation for modeling neural circuits in a one semester course Proven in the classroom Example rich student friendly approach Includes Python code and a mathematical appendix reviewing the requisite background in calculus linear algebra and probability Ideal for engineering science and mathematics majors and for self study

Fundamentals of Neural Network Modeling Randolph W. Parks, Daniel S. Levine, Debra L. Long, 1998 Provides an introduction to the neural network modeling of complex cognitive and neuropsychological processes Over the past few years computer modeling has become more prevalent in the clinical sciences as an alternative to traditional symbol processing models This book provides an introduction to the neural network modeling of complex cognitive and neuropsychological

processes It is intended to make the neural network approach accessible to practicing neuropsychologists psychologists neurologists and psychiatrists It will also be a useful resource for computer scientists mathematicians and interdisciplinary cognitive neuroscientists The editors in their introduction and contributors explain the basic concepts behind modeling and avoid the use of high level mathematics The book is divided into four parts Part I provides an extensive but basic overview of neural network modeling including its history present and future trends It also includes chapters on attention memory and primate studies Part II discusses neural network models of behavioral states such as alcohol dependence learned helplessness depression and waking and sleeping Part III presents neural network models of neuropsychological tests such as the Wisconsin Card Sorting Task the Tower of Hanoi and the Stroop Test Finally part IV describes the application of neural network models to dementia models of acetylcholine and memory verbal fluency Parkinsons disease and Alzheimers disease Contributors J Wesson Ashford Rajendra D Badgaiyan Jean P Banquet Yves Burnod Nelson Butters John Cardoso Agnes S Chan Jean Pierre Changeux Kerry L Coburn Jonathan D Cohen Laurent Cohen Jose L Contreras Vidal Antonio R Damasio Hanna Damasio Stanislas Dehaene Martha J Farah Joaquin M Fuster Philippe Gaussier Angelika Gissler Dylan G Harwood Michael E Hasselmo J Allan Hobson Sam Leven Daniel S Levine Debra L Long Roderick K Mahurin Raymond L Ownby Randolph W Parks Michael I Posner David P Salmon David Servan Schreiber Chantal E Stern Jeffrey P Sutton Lynette J Tippet Daniel Tranel Bradley Wyble

Neural Computation ,2005

Brain Computation as Hierarchical Abstraction Dana H. Ballard,2015-02-20 An argument that the complexities of brain function can be understood hierarchically in terms of different levels of abstraction as silicon computing is The vast differences between the brains neural circuitry and a computers silicon circuitry might suggest that they have nothing in common In fact as Dana Ballard argues in this book computational tools are essential for understanding brain function Ballard shows that the hierarchical organization of the brain has many parallels with the hierarchical organization of computing as in silicon computing the complexities of brain computation can be dramatically simplified when its computation is factored into different levels of abstraction Drawing on several decades of progress in computational neuroscience together with recent results in Bayesian and reinforcement learning methodologies Ballard factors the brains principal computational issues in terms of their natural place in an overall hierarchy Each of these factors leads to a fresh perspective A neural level focuses on the basic forebrain functions and shows how processing demands dictate the extensive use of timing based circuitry and an overall organization of tabular memories An embodiment level organization works in reverse making extensive use of multiplexing and on demand processing to achieve fast parallel computation An awareness level focuses on the brains representations of emotion attention and consciousness showing that they can operate with great economy in the context of the neural and embodiment substrates

Principles of Brain Dynamics Mikhail I. Rabinovich,Karl J. Friston,Pablo Varona,2023-12-05 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

Unsupervised Learning Geoffrey Hinton, Terrence J. Sejnowski, 1999-05-24 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

Catalyzing Inquiry at the Interface of Computing and Biology National Research Council, Division on Engineering and Physical Sciences, Computer Science and Telecommunications Board, Committee on Frontiers at the Interface of Computing and Biology, 2006-01-01 Advances in computer science and technology and in biology over the last several years have opened up the possibility for computing to help answer fundamental questions in biology and for biology to help with new approaches to computing Making the most of the research opportunities at the interface of computing and biology requires the active participation of people from both fields While past attempts have been made in this direction circumstances today appear to be much more favorable for progress To help take advantage of these opportunities this study was requested of the NRC by the National Science Foundation the Department of Defense the National Institutes of Health and the Department of Energy The report provides the basis for establishing cross disciplinary collaboration between biology and computing including an analysis of potential impediments and strategies for overcoming them The report also presents a wealth of examples that should encourage students in the biological sciences to look for ways to enable them to be more effective users of computing in their studies

Self-organizing Map Formation Klaus Obermayer, Terrence Joseph Sejnowski, 2001 This book provides an overview of self organizing map formation including recent developments Self organizing maps form a branch of unsupervised learning which is the study of what can be determined about the statistical properties of input data without explicit feedback from a teacher The articles are drawn from the journal Neural Computation

The book consists of five sections. The first section looks at attempts to model the organization of cortical maps and at the theory and applications of the related artificial neural network algorithms. The second section analyzes topographic maps and their formation via objective functions. The third section discusses cortical maps of stimulus features. The fourth section discusses self-organizing maps for unsupervised data analysis. The fifth section discusses extensions of self-organizing maps including two surprising applications of mapping algorithms to standard computer science problems: combinatorial optimization and sorting.

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