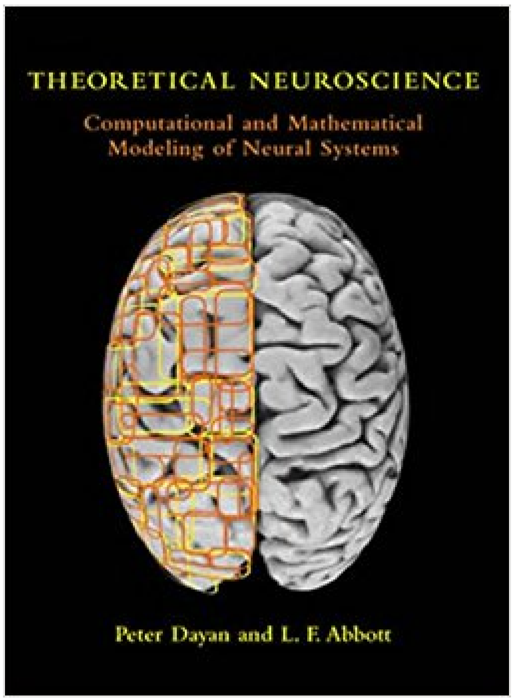
Theoretical Neuroscience: Computational And Mathematical Modeling Of Neural Systems (Computational Neuroscience Series)



Synopsis

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.

Book Information

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Customer Reviews

Peter Dayan and L.F. Abbott have crafted an excellent introduction to the various methods of modeling nervous system function. The chapters dealing with neural coding and information theory are particularly welcome because these are new areas that are not well represented in existing texts. (Phillip S. Ulinski)Dayan and Abbott inspire us with a work of tremendous breadth, and each chapter is more exciting than the next. Everyone with an interest in neuroscience will want to read this book. A truly remarkable effort by two of the leaders in the field. (P. Read Montague, Professor, Division of Neuroscience, and Director, Center for Theoretical Neuroscience, Baylor College of Medicine)It will not be surprising if this book becomes the standard text for students and researchers entering theoretical neuroscience for years to come. (M. Brandon Westover Philosophical Psychology)Not only does the book set a high standard for theoretical neuroscience, it defines the field. (Dmitri Chklovskii Neuron)An excellent book. There are a few volumes already available in theoretical neuroscience but none have the scope that this one does. (Bard Ermentrout, Department of Mathematics, University of Pittsburgh) Theoretical Neuroscience provides a rigorous introduction to how neurons code, compute, and adapt. It is a remarkable synthesis of advances from many areas of neuroscience into a coherent computational framework. This book sets the standards for a new generation of modelers. (Terrence J. Sejnowski, Howard Hughes Medical Institute, Salk Institute for Biological Studies, and University of California, San Diego)The first comprehensive textbook on computational neuroscience. The topics covered span the gamut from biophysical faithful single cell models to neural networks, from the way nervous systems encode information in spike trains to how this information might be decoded, and from synaptic plasticity to supervised and unsupervised learning. And all of this is presented in a sophisticated yet accessible manner. A must buy for anybody who cares about the way brains compute. (Christof Koch, Lois and Victor Troendle Professor of Cognitive and Behavioral Biology, California Institute of Technology) Theoretical Neuroscience marks a milestone in the scientific maturation of integrative neuroscience. In the last decade, computational and mathematical modelling have developed into an integral part of the field, and now we finally have a textbook that reflects the changes in the way our science is being done. It will be a standard source of knowledge for the coming generation of students, both theoretical and experimental. I urge anyone who wants to be part of the development of this science in the next decades to get this book. Read it, and let your students read it. (John Hertz, Nordita (Nordic Institute for Theoretical Physics), Denmark)

L.F. Abbott is the Nancy Lurie Marks Professor of Neuroscience and Director of the Volen Center for Complex Systems at Brandeis University. He is the coeditor of Neural Codes and Distributed Representations (MIT Press, 1999).

Yes, the book is heavy in mathematics. This is, after all, a book about COMPUTATIONAL neuroscience! Mathematics is a human language, like English or Mandarin. It happens to be a PRECISE languags. Be prepared to embrace the math, and do know you need to understand enough math so that the math itself speaks to you, like English or Mandarin prose. If you are not prepared for that, then think twice of purchasing this book or taking a class based on this book.I know, I know, many people go in to medicine in order to avoid math. I think that is to the eternal shame of the modern practitioner, but just know that computational neuroscience is not for you.I don't give many reviews five stars, or even one star. Those stars are too many standard deviations from the norm for most work. This is a good book, better than merely competent. With my math background, I am finding it very useful and understandable read.

While I would like to say that this book is all encompassing, it only briefly touches upon one of the very important camps of computational neuroscience - the spiking models. Be warned that you will be viewing theoretical neuroscience through one lens targeted mainly at firing rates. A brief distinction: spiking models include the dynamic changes of the individual spikes of neurons into neural models, and tend to focus on the contribution of the temporal and electrical components of the neuronal action potentials as they move down the axons and interact with other neurons. Firing rate models condense this spiking behavior into a probability distribution governing the rate at which the neuron fires (think Hertz). This is a fantastically written book, but I would suggest izhikevich's book as a companion.

Slow reading but very thorough

Its a perfect summary of computational neuroscience. However, it will be a tall order to tackle if this is your first foray into neuroscience - it might be a better idea to start off with an elementary neuroscience textbook and graduate into this one..

This is a must have for every neuroscientist.

This book is a detailed overview of the computational modeling of nervous systems from the molecular and cellular level and from the standpoint of human psychophysics and psychology. They divide their conception of modeling into descriptive, mechanistic, and interpretive models. My sole interest was in Part 3, which covers the mathematical modeling of adaptation and learning, so my review will be confined to these chapters. The virtue of this book, and others like it, is the insistence on empirical validation of the models, and not their justification by "thought experiments" and arm-chair reasoning, as is typically done in philosophy. Part 3 begins with a discussion of synaptic plasticity and to what degree it explains learning and memory. The goal here is to develop mathematical models to understand how experience and training modify the neuronal synapses and how these changes effect the neuronal patterns and the eventual behavior. The Hebb model of neuronal firing is ubiquitous in this area of research, and the authors discuss it as a rule that synapses change in proportion to the correlation of the activities of pre- and postsynaptic neurons. Experimental data is immediately given that illustrates long-term potentiation (LTP) and long-term depression (LTD). The authors concentrate mostly on models based on unsupervised learning in this chapter. The rules for synaptic modification are given as differential equations and describe the rate of change of the synaptic weights with respect to the pre- and postsynaptic activity. The covariance and BCM rules are discussed, the first separately requiring postsynaptic and presynaptic activity, the second requiring both simultaneously. The authors consider ocular dominance in the context of unsupervised learning and study the effect of plasticity on multiple neurons. The last section of the chapter covers supervised learning, in which a set of inputs and the desired outputs are imposed during training. In the next chapter, the authors consider the area of reinforcement learning, beginning with a discussion of the mathematical models for classical conditioning, and introducing the temporal difference learning algorithm. The authors discuss the Rescorla-Wagner rule , which is a trial-by-trial learning rule for the weight adjustments, in terms of the reward, the prediction, and the learning rate. They then discuss more realistic policies such as static action choice, where the reward/punishment immediately follows the action taken, and sequential action choice, where rewards may be delayed. The authors discuss foraging behavior of bees as an example of static action choice, reducing it to a stochastic two-armed bandit problem. The maze task for rats is discussed as an example of sequential action choice, and the authors reduce it to the "actor-critic algorithm." A generalized reinforcement learning algorithm is then discussed, with the rat water maze problem given as an example. Chapter 10 is an overview of what the authors call "representational learning", which, as they explain, is a study of neural representations from a computational point of view. The goal is to begin with sensory input and find out how representations are generated on the basis of these inputs. That such representations are necessary is based on for example the consideration of the visual system, since, argue the authors, what is presented at the retina is too crude for an accurate representation of the visual world. The main strategy in the chapter is to begin with a deterministic or probabilistic input and construct a recognition algorithm that gives an estimate of the input. The algorithms constructed are all based on unsupervised learning, and hence the existence and nature of the causes must be computed using heuristics and the statistics of the input data. These two requirements are met via the construction of first a generative model and then a recognition model in the chapter. The familiar 'expectation maximization' is discussed as a method of optimization between real and synthetic data in generative models. A detailed overview of expectation maximization is given in the context of 'density estimation'. The authors then move on to discuss causal models for density estimation, such as Gaussian mixtures, the K-means algorithm, factor analysis, and principal components analysis. They then discuss sparse coding, as a technique to deal with the fact that the cortical activity is not Gaussian. They illustrate an experimental sample, showing the activity follows an exponential distribution in a neuron in the inferotemporal area of the macaque brain. The reader will recognize 'sparse' probability distributions as being 'heavy-tailed', i.e. having values close to zero usually, but ones far from zero sometimes. The authors emphasize the difficulties in the computation of the recognition distribution explicitly. The Olshausen/Field model is used to give a deterministic approximate recognition model for this purpose. The authors then give a fairly detailed overview of a two-layer, nonlinear 'Helmholtz machine' with binary inputs. They illustrate how to obtain the expectation maximization in terms of the Kullback-Leibler divergence. The learning in this model takes place via stochastic sampling and occurs in two phases, the so-called "wake and sleep" algorithm. The last section of the chapter gives a general discussion of how recent interest in coding, transmitting, and decoding images has led to much more research into representational learning algorithms. They discuss multi-resolution decomposition and its relationship to the coding algorithms available.

Very useful and detailed, and relatively cheap

This is a very good book and I recommend it. As only slight criticism, the book should really start at Part II because beginning with neurons is more logical than starting with a high-level view. Nonetheless, a reader can do this himself so it is a nonissue.

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