COMPUTATIONAL NEUROSCIENCE

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Aims and Scope

Optimization has been expanding in all directions at an astonishing rate during the last few decades. New algorithmic and theoretical techniques have been developed, the diffusion into other disciplines has proceeded at a rapid pace, and our knowledge of all aspects of the field has grown even more profound. At the same time, one of the most striking trends in optimization is the constantly increasing emphasis on the interdisciplinary nature of the field. Optimization has been a basic tool in all areas of applied mathematics, engineering, medicine, economics and other sciences.

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Computational Neuroscience

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To our parents

Preface

ΔΥΟ ΓΑΡ ΕΠΙΣΤΗΜΗ ΤΕ ΚΑΙ ΔΟΞΑ ΩΝ ΤΟ ΜΕΝ ΕΠΙΣΘΑΣΘΑΙ ΠΟΙΕΕΙ ΤΟ ΔΕ ΑΓΝΟΕΕΙΝ.

ΙΠΠΟΚΡΑΤΗΣ (460 π.Χ-360 π.Χ.)

There are in fact two things, science and opinion; the former begets knowledge, the latter ignorance.

Hippocrates (460BC-360BC)

This book represents a collection of recent advances in computational studies in neuroscience research that practically applies to a collaborative and integrative environment in engineering and medical domains. This work has been designed to address the explosion of interest by academic researchers and practitioners in highly-effective coordination between computational models and tools and quantitative investigation of neuroscientific data. To bridge the vital gap between science and medicine, this book brings together diverse research areas ranging from medical signal processing, image analysis, and data mining to neural network modeling, regulation of gene expression, and brain dynamics.

We hope that this work will also be of value to investigators and practitioners in academic institutions who become involved in computational modeling as an aid in translating information in neuroscientific data to their colleagues in medical domain. This volume will be very appealing to graduate (and advanced undergraduate) students, researchers, and practitioners across a wide range of industries (e.g., pharmaceutical, chemical, biological sciences), who require a detailed overview of the practical aspects of computational modeling in real-life neuroscience problems. For this reason, our audience is assumed to be very diverse and heterogenous, including:

- researchers from engineering, computer science, statistics, and mathematics domains as well as medical and biological scientists;
- physicians working in scientific research to understand how basic science can be linked with biological systems.

The book presents a collection of papers, several of which have been presented at DIMACS Conference on Computational Neuroscience that took place at the University of Florida on February 20 – 21, 2008. It is consisted of three major research themes in this book: data mining and medical data processing, brain modeling, and analysis of brain dynamics and neural synchronization. Each theme addresses the answer to a classical, yet extremely important, question in neuroscience, "How do we go from the mathematical modeling and computational techniques to the practical investigations of neuroscience problems?"

The first theme includes six chapters focused on data mining and medical data processing. The first chapter, by Paiva et al. lay down the platform of this book by presenting a complete methodological framework based on optimization for reproducing Hilbert spaces of spike trains. In the second chapter, Anderson et al. propose graph-theoretic models to investigate functional cooperation in the human brain. Not only can these models be applied to cognitive studies, they may also be used in diagnosis studies. In the third chapter, Sakkalis and Zervakis propose a framework for extracting time frequency features from electroencephalographic (EEG) recordings through the use of wavelet analysis. In the fourth chapter Chih-I Hung et al. present an application of independent component analysis (ICA) transformation into Creutzfeldt–Jakob disease. In the fifth chapter, Ramezani and Fatemizadeh discuss a comparison study of classification methods using various data preprocessing procedures applied to functional magnetic resonance imaging (fMRI) data for the detection of brain activation. In the sixth chapter, Fan et al. discuss the most well-known methods in biclustering applied to a neuroscientific application in evaluating the therapeutic intervention using vagus nerve stimulation treatment for patients with epilepsy. In the seventh chapter, Achler and Amir propose a genetic classifier used in the study of gene expression regulation.

The second theme includes five chapters that provide reviews and challenges in brain modeling in respect of human behavior and brain disease. In the eighth chapter, Ramírez et al. provide a review of the inverse source localization problem for neuroelectromagnetic source imaging of brain dynamics. In the ninth chapter, Wu et al. propose an approach based on the queuing theory and reinforcement learning for modeling the brain function and interpreting the human behavior. In the tenth and eleventh chapters, Cutsuridis suggests deterministic mathematical model for modeling neural networks of voluntary single-joint movement organization in normal subjects as well as patients with Parkinson's disease. In the twelfth chapter, Kawai et al. propose a parametric model for optical time series data of the respiratory neural network in the brainstem. In the thirteenth chapter, Leondopulos and Micheli-Tzanakou give an overview of the closed-loop deep brain stimulation technology and in the fourteenth chapter, Garzon and Neel present a novel approach to build fine grain models of the human brain with a large number of neurons inspired by recent advances in computing based on DNA modecules.

The third theme includes six chapters that focus on quantitative analyses of EEG recordings to investigate the brain dynamics and neural synchronization. In the fifteenth chapter, Sabesan et al. investigate the synchronization in the neural networks based on information flow, measured by the metric of network transfer entropy, among different brain areas. In the sixteenth chapter, Pardalos et al. describe an optimization-based model for estimating all Lyapunov exponents to characterize the dynamics of EEG recordings. In the seventeenth chapter, Faith et al. report the potential use of nonlinear dynamics for analyzing EEG recordings to evaluate the efficacy of antiepileptic drugs. In the eighteenth chapter, Kammerdiner and Pardalos study the synchronization of EEG recordings using the measures of phase synchronization and cointergrated VAR. In the nineteenth chapter, Liu et al. use the concept of mutual information to measure the coupling strength of EEG recordings in order to evaluate the efficacy of antiepileptic drugs in a very rare brain disease. In the last chapter, Sackellares et al. propose a seizure monitoring and alert system to be used in an intensive care unit based on statistical analyses of EEG recordings.

The completion of this issue would not have been possible without the assistance of many of our colleagues. We wish to express our gratitude to the authors for submitting and revising their work. We wish to express our sincere appreciation to anonymous referees for their careful reviewing. Their constructive comments contributed greatly to the quality of the issue. We cannot thank them enough for their time, efforts, and dedication to make this volume successful. The experience has been challenging, yet extremely rewarding. We truly hope that the reader will find the presented fundamental research and application papers presented as stimulating and valuable as we did.

USA,
July 2009

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