Spatiotemporal Brain Imaging and Modeling

by

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Submitted to the Harvard-M.I.T. Division of Health Sciences and Technology
on December 11, 2003, in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy in Medical and Electrical Engineering

Abstract

This thesis integrates hardware development, data analysis, and mathematical modeling to facilitate our understanding of brain cognition. Exploration of these brain mechanisms requires both structural and functional knowledge to (i) reconstruct the spatial distribution of the activity, (ii) to estimate when these areas are activated and what is the temporal sequence of activations, and (iii)to determine how the information flows in the large-scale neural network during the execution of cognitive and/or behavioral tasks. Advanced noninvasive medical imaging modalities are able to locate brain activities at high spatial and temporal resolutions. Quantitative modeling of these data is needed to understand how large-scale distributed neuronal interactions underlying perceptual, cognitive, and behavioral functions emerge and change over time.

This thesis explores hardware enhancement and novel analytical approaches to improve the spatiotemporal resolution of single (MRI) or combined (MRI/fMRI and MEG/EEG) imaging modalities. In addition, mathematical approaches for identifying large-scale neural networks and their correlation to behavioral measurements are investigated. Part I of the thesis investigates parallel MRI. New hardware and image reconstruction techniques are introduced to improve spatiotemporal resolution and to reduce image distortion in structural and functional MRI. Part II discusses the localization of MEG/EEG signals on the cortical surface using anatomical information from MRI, and takes advantage of the high temporal resolution of MEG/EEG measurements to study cortical oscillations in the human auditory system. Part III introduces a multivariate modeling technique to identify "nodes" and "connectivity" in a large-scale neural network and its correlation to behavior measurements in the human motor system.

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