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Localization of cortical activity using parsimonious linear estimates

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Abstract

Introduction

Localization of brain activity has been explored by electrical modalities using magnetoencephalogram (MEG) and electroencephalogram (EEG) as well as metabolic hemodynamic responses from functional magnetic resonance imaging (fMRI). Previous studies employing linear estimation subjected to biophysical and/or anatomical constraints and combined MEG/EEG/fMRI data provide estimates of current sources in human brain mapping experiments (Dale and Sereno, 1993; Hämäläinen and Ilmoniemi, 1994). Here we propose a novel estimation approach based on the Bayesian statistics with an a priori term spanning both spatial and temporal domains to provide a “parsimonious” solution. Simulations employing a realistic cortical mesh as the source space demonstrate the principles of this technique.

Methods

A realistic surface model for the neocortex was constructed from segmented data from high-resolution T1-weighted MRI data consisting 340,000 vertices (Dale et al., 1999; Fischl et al., 1999). The source space consisted of 3500 dipole sources on this surface. The magnetic field data measured by a 306-channel MEG system (102 magnetometers and 204 planar gradiometers) with each of these dipole as a source was calculated using the Boundary Element Method (Oostendorp and van Oosterom, 1989). Simulated MEG signals were computed using a current dipole located at the central gyrus of the left hemisphere with a bi-phasic activation.

A linear estimate for the source current distribution, X, can be written as:

$$\hat{X} = WY$$

where W is the inverse operator and Y is the data from MEG/EEG sensors.

Parsimonious inverse operator was further calculated from minimization of total cost:

$$\hat{W} = \arg\min_{W} \{ \|AWY - Y\|_2 + \lambda \cdot \| \|WY\|_{L-time} \|_{L-space} \}$$

where A is forward matrix and λ is regularization. The two terms represent the discrepancy between the measured and model data and a prior information deviation collapsed in temporal domain using L-time norm followed by spatial domain using L-space norm respectively. Minimization of this cost function was