Previous Abstract

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Assessment and improvement on the spatial accuracy in MEG source localization depth weighting corrected minimum-norm estimate

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INTRODUCTION

A popular method to locate sources of neuromagnetic signals is to employ the L2-minim norm solution (1). This minimum-norm estimate (MNE) framework was subsequently extended to incorporate cortical location and orientation constraints (2). Furthermore, nc normalization has been employed to derive the statistical significance of neuronal activa (3). However, MNE has an inherent bias towards surperficial source locations. Here we how one can alleviate this bias with depth weighting correction (DWC) and optimize the amount of correction by introducing source location shift metrics.. Our analysis shows tl DWC order of 1.3 gives minimal depth shift and displacement shift in MNEs with free c fixed dipole orientation constraint while noise-normalized solutions are insensitive to D

METHOD

A realistic anatomical brain surface was constructed from segmented high-resolution T1 weighted MRI data consisting 340,000 vertices (4, 5). The MEG source points were decimated to create 7,500 dipole sources on this surface. The MEG lead fields for a 306- channel MEG system were calculated using the Boundary Element Method (BEM) (6). Simulated MEG signals were computed using single current dipole located at distinct decimated dipole locations with orientation perpendicular to the localized gray matter oı neocotex. Distributed cortical sources were estimated using the MNE approach. Specific

$$\mathbf{x}=\mathbf{W}\mathbf{y}$$
$$\mathbf{W}_{\mathbf{mne}}=\mathbf{R}\mathbf{A}^{\mathbf{T}}(\mathbf{A}\mathbf{R}\mathbf{A}^{\mathbf{T}}+\lambda\mathbf{C})^{-1}$$
$$\mathbf{W}_{\mathbf{SPM}}=\mathbf{W}_{\mathbf{mne}}/\mathbf{sqrt}(\mathbf{diag}(\mathbf{W}_{\mathbf{mne}}\ \mathbf{C}\ \mathbf{W}_{\mathbf{mne}}^{\mathbf{T}}))$$

y denotes the simulated MEG data, and **W** denotes the inverse operator. **A** is the BEM le fields, and **C** is the noise covariance matrix from pre-stimulus baseline. **λ** indicates the regularization parameter. The two inverse operators, $\mathbf{W}_{\mathbf{MNE}}$ and $\mathbf{W}_{\mathbf{SPM}}$ yield the MNE the noise-normalized MNE, respectively. To reduce the bias toward superficial locations adjusted the source covariance matrix, **R**, parametrically by creating a diagonal matrix.

$$\mathbf{R}=\mathbf{1}/|\mathbf{diag}(\mathbf{A}^{\mathbf{T}}\mathbf{A})|^{\mathbf{p}}$$

where **diag** is the opeartor to extract the diagonal entries. The depth-weighting correctio (DWC) parameter **p** was varied systematically from 0.0 to 2.0 in the simulations.

The spatial mis-localization was quantified by two shift metrics: Depth shift ($\mathbf{S}_{\mathbf{depth}}$) is t minimal distance between the source dipole to the inner skull. Displacement shift ($\mathbf{S}_{\mathbf{disp}}$ denotes the distance between the source dipole and the maximum of the estimated sourc distribution.

RESULTS

Figure 2 shows the depth shifts and displacement shifts. The depth shift in both free-orientation and contstrained-orientation MNE solutions is minimized with p = 1.3. DWC does not improve depth shift error significantly in noise-normalized (SPM) solutions.

CONCLUSIONS

The depth-weighting significantly reduces the source location bias in cortically –constra minimum-norm solutions. The same optimum value, p = 1.3, applies to both free-orienta and orientation-constrained solutions. The noise-normalized MNE estimate was found to insensitive to DWC.

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Location errors in source localization. The red arrow indicates the site of the act source and the blue arrow denotes the location of the maximum of the source estin S_{depth} and $S_{displace}$ represent the errors in depth and spatial shifts during sourc localization respectively.

Depth and displacement shifts in MNE and SPM inverse solutions using DWC witl 0.0, 1.0, 1.3, and 2.0. In S_{depth} plots, blue scale indicates shifts toward superficia cortical surfaces, yellow scale indicates shifts toward deep cortical surface. In S_{dis} plots, the color indicates the absolute shifts. All values are given in mm.