Optimization of high spatiotemporal resolution brain imaging using combined MEG, MRI, and fMRI

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Magnetoencephology (MEG) is a non-invasive tool to investigate human brain function with a high temporal resolution of milliseconds [1, 2] by measuring neuromagnetic fields. MEG is closely related to electroencephalography (EEG), which measures the electric potential distributions generated by the same sources. MEG is selectively sensitive to source currents that are tangential with respect to the surface of the head whereas EEG detects both the tangential and radial source components. Localization of the sources with these methods is complicated by the non-uniqueness of the electromagnetic inverse problem. To render the solution unique several source models with different constraints have been proposed.

A common MEG source modeling approach is to assume the extent of activation is small and, consequently, the measured fields can be accounted for by modeling the source by a set of equivalent current dipoles (ECDs). If multiple sources are simultaneously active, reliable estimation of the source parameters becomes complicated due to the non-linear relationship between the source locations and the measured signals. While global optimization algorithms have been tailored to accomplish this task [3], the most feasible solutions combine optimization algorithms with partly heuristic interactive approaches, motivated by prior physiological and anatomical information. In addition, the dipole maybe an oversimplification as a model for spatially extended source activity.

To overcome these difficulties, several distributed current solutions have been proposed. A widely employed distributed source localization approach in MEG is based on the ℓ_2-norm prior, resulting in diffuse minimum-norm estimates (MNE) [4-6]. More focal estimates can be obtained by using an ℓ_1-norm prior; the corresponding minimum-norm solution is often called the minimum-current estimate (MCE) [7]. Nevertheless, distributed source modeling is challenging in terms of optimizing parameters for source estimation. Specifically, anatomical information from high resolution MRI can be used to constraint the source localization with improved accuracy [8]. The biases of distributed source modeling toward superficial source locations (close to the MEG sensors) can be potentially alleviated using appropriate depth weighting [9].

We also investigate the cross-talk/point-spread function of the MEG inverse determined by a regularization parameter, which is usually related to signal-to-noise ratio (SNR). Furthermore, we extend the incorporation of functional MRI weighting to spectral analysis in order to improve the spatial localization accuracy of oscillatory activity recorded by MEG.

References

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