Multiresolution piecewise imaging models for electromagnetic brain mapping with application to the time-resolved exploration of somatotopic and retinotopic cortical fields.

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Abstract

When combined with image reconstruction techniques, magnetoencephalography (MEG) and electroencephalography (EEG) may open new windows for the observation and exploration of time-resolved brain processes at the local–regional spatial scale. The ill-posedness of the associated inverse problem however, necessitates the introduction of image models as regularizing priors. Basic priors – e.g. quadratic in the norm of the expected neural currents – yield images of brain activity that are often too smeared for the satisfactory elucidation of specific neuroscience questions that focus on localization. On the other hand, more sophisticated prior image models – even though they would theoretically improve the detection of sparse-focal current distributions – suffer from scalability issues that imped their practical impact.

In this PhD work, my primary objective was to reconcile the best of both approaches. I have derived a multiresolution imaging technique which proceeds iteratively to the fit of image models based on the parcellation of the cortical surface. This latter derives from anatomical and functional priors such as the curvature of the cortical manifold, and/or the coregistration to some atlas relevant to the neuroscience investigation.

Technically, the multiresolution imaging technique is approached as an empirical model selection procedure optimized according to the least-generalized cross validation (GCV) error principle. Further, the piecewise current model is adequately approached using a compact parametric model based on equivalent current multipoles.
The manuscript reviews the multiple generic approaches to MEG/EEG source imaging and details our original contributions (Cottereau et al., NeuroImage, 2007).

We were eager to confront our numerical solutions to the reality of two experimental contexts which may be considered as particularly challenging to MEG and EEG: the resolution of the somatotopic organization of hand fingers projections in the primary somatosensory cortex and the retinotopic organization of visual fields maps in the occipital cortex. Results confirm the increasing surface area of cortical matter involved when moving from the stimulation of the

little finger to the thumb wit a significant degree of overlap. To benefit from the excellent time resolution of MEG, we have designed visual stimuli that are tagged at specific frequency values which i) improve the detection of related steady state brain responses from ongoing brain activity and ii) may speed up the yield of retinotopic maps using MEG/EEG by encoding the visual field using multiplexed frequency-tagged stimuli.