Bibliographical data

Wolters, Carsten Hermann

Influence of Tissue Conductivity Inhomogeneity and Anisotropy on EEG/MEG based Source Localization in the Human Brain

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Abstract

The inverse problem in Electro- and Magneto-EncephaloGraphy (EEG/MEG) aims at reconstructing the underlying current distribution in the human brain using potential differences and/or magnetic fluxes that are measured non-invasively directly, or at a close distance, from the head surface. The solution requires repeated computation of the forward problem, i.e., the simulation of EEG and MEG fields for a given dipolar source in the brain using a volume-conduction model of the head. The associated differential equations are derived from the Maxwell equations. Not only do various head tissues exhibit different conductivities, some of them are also anisotropic conductors as, e.g., skull and brain white matter. To our knowledge, previous work has not extensively investigated the impact of modeling tissue anisotropy on source reconstruction. Currently, there are no readily available methods that allow direct conductivity measurements. Furthermore, there is still a lack of sufficiently powerful software packages that would yield significant reduction of the computation time involved in such complex models hence satisfying the time-restrictions for the solution of the inverse problem.

In this dissertation, techniques of multimodal Magnetic Resonance Imaging (MRI) are presented in order to generate high-resolution realistically shaped anisotropic volume conductor models. One focus is the presentation of an improved segmentation of the skull by means of a bimodal T1/PD-MRI approach. The eigenvectors of the conductivity tensors in anisotropic white matter are determined using whole head Diffusion-Tensor-MRI. The Finite Element (FE) method in combination with a parallel algebraic multigrid solver yields a highly efficient solution of the forward problem. After giving an overview of state-of-the-art inverse methods, new regularization concepts are presented. Next, the sensitivity of inverse methods to tissue anisotropy is tested. The results show that skull anisotropy affects significantly EEG source reconstruction whereas white matter anisotropy affects both EEG and MEG source reconstructions. Therefore, high-resolution FE forward modeling is crucial for an accurate solution of the inverse problem in EEG and MEG.