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Comparison of direct and reciprocal forward modeling approaches in EEG source analysis

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Abstract

Our presentation will focus on a comparison between the reciprocal or adjoint approach (AA) (Vallaghe et al., 2009) and the partial integration (PI) direct approach using the transfer matrix approach (Wolters et al., 2004; Vorwerk, 2011) for realistic forward modeling in EEG source analysis.
Following (Vallaghe et al., 2009), the AA is deduced using the adjoint method and Riesz representation theorem is used in order to depict the connection between the AA and the EEG forward problem. Next, the PI is derived and used for a comparison with the AA (Wagner 2011). In order to investigate realistically shaped head models including tissue inhomogeneities and anisotropy, the finite element method (FEM) is used for numerical realization of both forward modeling approaches. The underlying theory will be discussed and the connection between lead field approach, Helmholtz' principle of reciprocity and the AA will be demonstrated in detail.
By means of a validation of our implementation in tetrahedral as well as hexahedral anisotropic multi-compartment spherical shell models, an estimation of the computational complexity and a derivation of closed formulas, we will show that the AA and PI are essentially identical (Wagner, 2011).
However, the AA can be used to calculate and investigate lead field sensitivity distributions that serve as sensitivity maps for the considered pairs of electrodes (lead) in EEG source analysis.
Sensitivity maps can be used to (1) assess the influence of an arbitrary dipolar source on the potential difference between a fixed lead at a glance; (2) identify the orientation of certain dipoles needed to maximize the potential difference measured between the considered lead in an intuitive way; (3) visually predict the differences in forward modeling when extending a head model from a standard homogenized three-compartment model to a more realistic one.

Literature

[1] Vallaghe, S., Papadopoulo, T., Clerc, M., The adjoint method for general EEG and MEG sensor-based lead field equations, Phys.Med.Biol., 54, pp. 135-147, (2009).
[2] Vorwerk, J., Comparison of numerical approaches to the EEG forward problem, Diploma Thesis (Mathematics), Institute for Biomagnetism and Biosignalanalysis and Institute for Computational and Applied Mathematics, University of Muenster, (2011).
[3] Wagner, S., An adjoint FEM approach for the EEG forward problem, Diploma Thesis (Mathematics), Institute for Biomagnetism and Biosignalanalysis and Institute for Computational and Applied Mathematics, University of Muenster, (2011).
[4] Wolters, C.H., Grasedyck, L., Hackbusch, W., Efficient computation of lead field bases and influence matrix for the FEM-based EEG and MEG inverse problem, Inverse Problems, 20(4), pp. 1099-1116, (2004).