The FieldTrip-SimBio pipeline for finite element EEG forward computations in MATLAB: Validation and application

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We present a MATLAB pipeline that allows for an easy computation of EEG forward solutions using the finite element method (FEM) in combination with realistic multi-compartment head models. Previous studies have shown that finite element methods achieve a very good numerical accuracy (Wolters et al., 2007; Vorwerk et al., 2012). The major advantage is the possibility to handle nearly arbitrarily complex geometries, allowing the distinction of compartments of different conductivity in the head with a complex shape, e.g. the CSF (Wolters et al., 2006), skull spongiosa (Dannhauer et al., 2011) or holes in the skull (Lanfer et al., 2012). The high computational effort required for the FEM has been strongly reduced by the introduction of transfer matrices and fast algebraic multigrid solvers (AMG-CG) (Wolters et al., 2004). The remaining main arguments against the practical application of FEM were the effort for the setup of realistic head models, i.e. models with more than just skin, skull and brain as conductive compartments, and the necessity to use a variety of software and toolboxes rather than a single pipeline.
We have integrated the iso-parametric implementation of the Venant FE approach in the SimBio[1] toolbox (Wolters et al., 2007) into the FieldTrip[2] toolbox. Amongst others this allows the use of the FEM with geometry-adapted hexahedral meshes in a fully MATLAB based EEG source analysis. The implementation was realized using native MATLAB code and mex files, ensuring that no additional external binaries need to be compiled by the end-user.
Starting from a segmented MRI of the head tissues, we included the possibility to 1. Easily generate a geometry-adapted hexahedral head model 2. Construct an individual source space fitted to the needs of the FEM 3. Calculate a leadfield using the FEM. Thereby, our pipeline allows the user to combine the high accuracy and flexibility of FE methods with the convenient evaluation pipeline provided by FieldTrip. Using the complete set of functions in the FieldTrip toolbox, EEG preprocessing, FE leadfield computation and subsequent inverse analysis can now be performed in a single MATLAB-based pipeline.

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[1] http://www.simbio.de/ and https://www.mrt.uni-jena.de/simbio
[2] http://www.ru.nl/donders/fieldtrip