Improving EEG/MEG Source Analysis in Children

Organizers: Carsten Wolters and Robert Oostenveld

Room: # 103

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Improving Source Reconstruction for MEG and EEG in Children

The European Brain Council (EBC) has recommended disorders of the brain to be prioritized for funding. One successful example of this is the Marie Curie Innovative Training Network ChildBrain (see http://www.childbrain.eu) which aims on the one hand to train young researchers and on the other hand to utilize evidence-based neuroscientific knowledge for helping children, especially those at high risk for dropout due to neurocognitive disorders, to meet future educational and societal demands.

In the ChildBrain network we develop new, innovative brain imaging-based tools in collaboration between research and industry and that can be applied by researchers and clinicians.

MEG and EEG data acquisition (movements and SNR) and modelling (volume conduction) are specifically challenging in children. In this proposed Biomag2016 session we will highlight the ChildBrain brain research methods work package. This provides not only value to the use of MEG and EEG in children, but will also contribute to improving the application in adults.

Speakers:

- **Abinash Pant** (BESA GmbH, Germany)
  "An automatic Markov Random Field-based approach for segmentation of volume conductor models of the human head"

The accurate solution of the EEG and MEG forward problem requires taking into account information about a subject's individual anatomy. This information is contained in the volume conductor model which describes the electrical properties of the subject's head. Commonly, individual models are constructed by first segmenting the head into the different tissue compartments based on the available medical image data. Next, a suitable discretization of the head domain is computed, and previously published tissue conductivities are assigned.
Here, we propose a new automatic segmentation approach for segmenting the tissues of the head. The approach is formulated in a Bayesian framework. A-priori knowledge about the anatomy is included from two sources. A Markov Random Field model encodes our knowledge about the general arrangement of the head tissues. Secondly, a custom probabilistic tissue atlas further facilitates the segmentation.
Validation studies versus CT-based and manual segmentations were performed. Results prove the accuracy and reliability of the proposed approach. Average accuracies for the skull segmentation reached values of 88%.

In the ChildBrain project an approach for segmenting volume conductor models of infant subjects and patients will be developed. An outlook will discuss the related challenges and how we are aiming to solve them.

- **Theo Papadopoulo** (INRIA, France)
  "Modeling thin tissue compartments using the immersed FEM (continuous Galerkin) "

  This presentation will describe a trilinear immersed finite element method for solving the electroencephalography forward problem, which is a three-dimensional elliptic interface problem in the head geometry. The method uses hexahedral Cartesian meshes (i.e. 3D images which can be explored using standard visualization tools for MR images) independent of the interfaces between head tissues, thus avoiding the sometimes difficult task of generating geometry fitting meshes (which is exacerbated for child head volume conductors which contain close interfaces requiring a very high number of elements to obtain numerically good mesh representations). Brain interfaces are provided as level set representations, which are also 3D images. Such level set representations can directly be used in head segmentation tools but can be also easily obtained from meshes. The finite element space is locally modified to better approximate the continuity properties of the solution (continuous potential and normal currents despite a discontinuity of the conductivity). Numerical results show that this method achieves the same accuracy as the standard linear finite element method with geometry fitting meshes without the hassle of creating meshes for the complex head domain.

- **Andreas Nüßing** (Univ. of Münster, Germany)
  "The unfitted discontinuous Galerkin FEM for the EEG forward problem"

  We introduce and evaluate the unfitted discontinuous Galerkin finite element method (UDG-FEM) for solving the EEG forward problem. This new approach for source analysis does not use a geometry conforming volume triangulation, but instead uses a structured mesh that does not resolve the geometry. The geometry is described using level set functions and is incorporated implicitly in its mathematical formulation. As no triangulation is necessary, the complexity of a simulation pipeline and the need for manual interaction for patient specific simulations can be reduced and is comparable with that of the FEM for hexahedral meshes. In addition it maintains conservation laws on a discrete level. We will present the theory for UDG-FEM forward modelin g, its validation using quasi-analytical solutions in multi-layer sphere models and an evaluation of the new method in a comparison with competing approaches. Results show convergence and ind icate a good overall accuracy of the UDG-FEM approach. UDG-FEM performs comparable or even better than competing approaches while providing a less complex simulation pipeline. As we will show, the new method is especially important for solving the forward problem in child brain res earch.

- **Johannes Vorwerk** (Univ. of Münster, Germany)
  "The FieldTrip-SimBio pipeline for FEM-based EEG forward computations"

  For accurate EEG source analysis it is necessary to precisely simulate the electric field generated by a minimal patch of active brain tissue. This is called the forward problem of EEG. It has been shown in a variety of studies that the achieved accuracy in solving the forward problem strongly depends on an accurate representation of the conductive features of the head. Therefore, the use of realistic head models is inevitable. It can be achieved using the finite element method (FEM), which was shown to achieve high accuracies in sphere and realistic head model studies. However, despite the advantages of realistic head modeling, the generation of the necessary meshes is often considered too time consuming.

  In this talk, the FieldTrip-SimBio pipeline for FEM-based EEG forward simulations is introduced. This pipeline allows for the easy generation of individual, five-compartment realistic head models and the computation of EEG forward solutions using FEM. Being included in the FieldTrip-toolbox, also tools for data preprocessing and subsequent source analysis are directly available. Besides the presentation of the pipeline-workflow, the accuracy of the achieved segmentation is evaluated, and examplarily the results of a source analysis of somatosensory evoked potentials (SEP) using the FieldTrip-SimBio pipeline is shown.

- **Jukka Nenonen** (Elekta Oy, Finland)
  "Improving the SNR in pediatric MEG studies"

  Pediatric magnetoencephalography (MEG) presents particular challenges to signal processing and source imaging. The main difficulty is the fact that children tend to move substantially during the measurement, which sometimes compromises the quality of data. Continuous head position tracking and sensor-level movement compensation algorithms have been developed, such as data decomposition and reconstruction with the Signal Space Separation (SSS) method. However, large head movements cause increased reconstruction noise if the varying distance-related SNR is not taken into account in the SSS process. Additional difficulties arise if pediatric patients have magnetized material or implanted stimulators, causing significant movement-modulated interference.
  We present novel signal processing methods for improved movement correction and for suppressing sensor noise and artifacts: 1) Improved regularization method reduces reconstruction noise associated with large head movements. 2) Cross-validation SSS model separates the spatially correlated part (brain-related signals + magnetic interference) and uncorrelated part (sensor noise and artifacts) of a multichannel MEG signal. 3) Utilization of signal and noise covariance information in SSS decomposition reduces the overall sensor noise levels through enhanced numerical stability.

  We demonstrate that the new SSS workflow potentially broadens the application of pediatric MEG both in clinical and research studies.