Age-specific Template Head Models for EEG Source Analysis

Benjamin Lanfer[1], Robert Spangler[1], John E. Richards[2], Isabella Paul-Jordanov[1]

1 BESA GmbH, Gräfelfing, Germany
2 Department of Psychology, Institute for Mind and Brain, University of South Carolina, Columbia, SC, USA

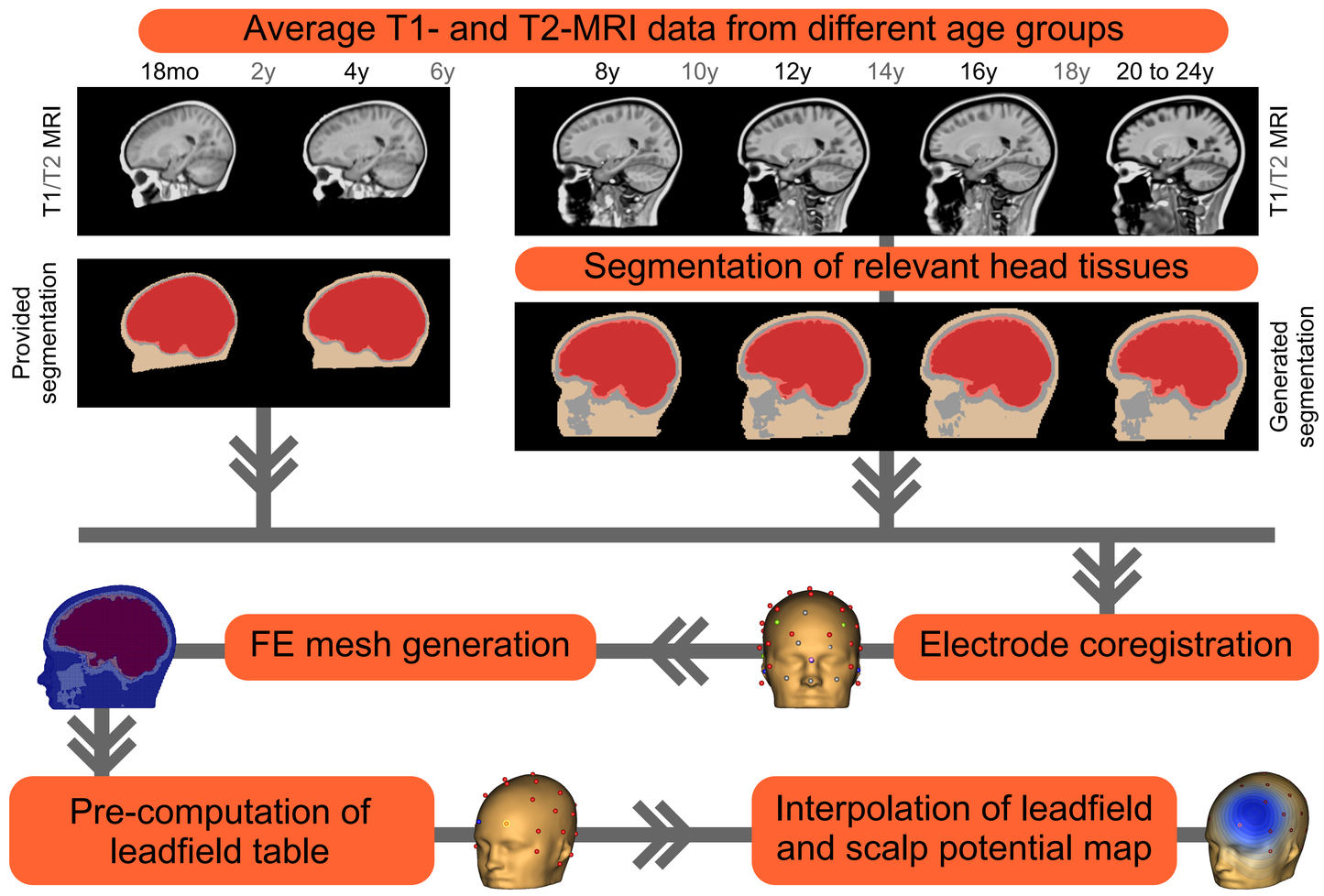
I INTRODUCTION

Incorporating the realistic anatomy of the head into the solution of the EEG forward problem improves the accuracy and reliability of EEG source analysis [1]. Individual realistic head models can be derived from the subject's MRI. In infants and children MRI data are often difficult to collect. However, source analysis accuracy would particularly benefit from realistic head models in children, as head tissue structure differs vastly from adults. A solution might be to use age-specific template models representing the child-typical anatomy.
In this work, we describe a pipeline for EEG source analysis with age-specific head model templates. In addition, a study is presented demonstrating the feasibility of the template models.

II MATERIALS and METHODS

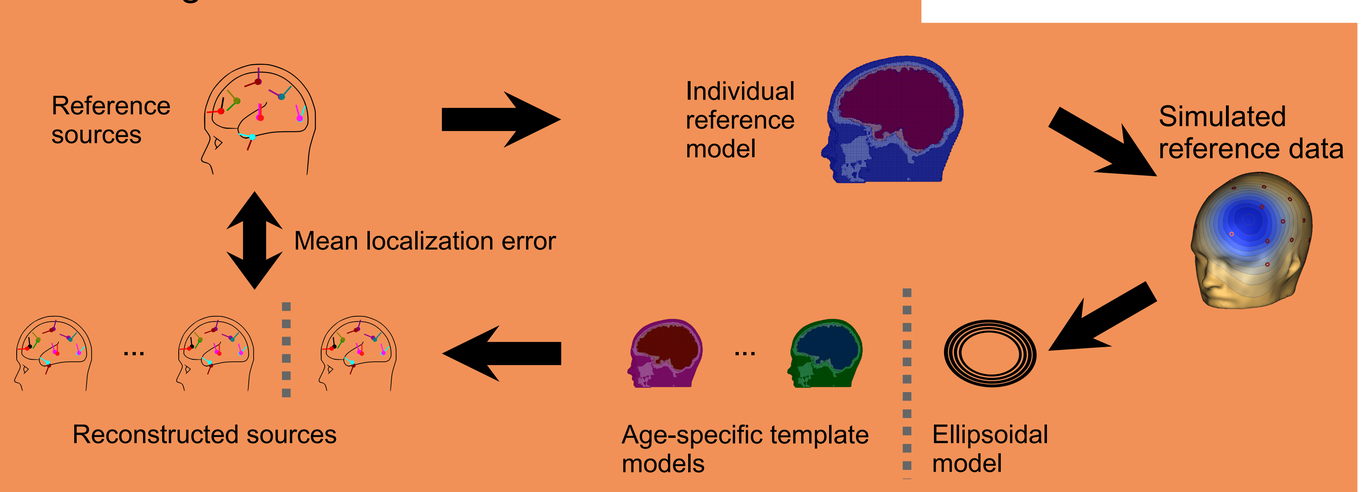
Template Model Creation

- Averaged T1 and T2 MRIs from the Neuro-developmental MRI Database [2] for different age groups [3,4,5]
- Electrode coregistration to segmented scalp [6]
- Markov Random Field segmentation of most relevant head tissues for ages 6 and above [7]
- Generation of 1mm geometry-adapted cube meshes [8]
- Pre-computation of lead field tables for sources on regular 2mm grid covering the whole brain
- Second order Bezier spline interpolation to inter-polate leadfield for sources not lying on grid [9]
- Spherical spline interpolation to interpolate voltages to recorded electrode configuration



Simulation Study

- Reference model created from individual MRI of 12 y/o subject using established pipeline
- Simulation of reference data for sources at 12 positions with radial and tangential orientation
- Source reconstruction of reference data in age-specific template models and ellipsoidal model
- Assessing mean localization error



Evaluation with Interictal Spike Data

- Real, epileptic spike data of same subject
- Dipole fit to rising flank of peak with fixed alpha source
- Comparison of Talairach coordinates of reconstructed sources for individual FEM model, realistic template models, and ellipsoidal model

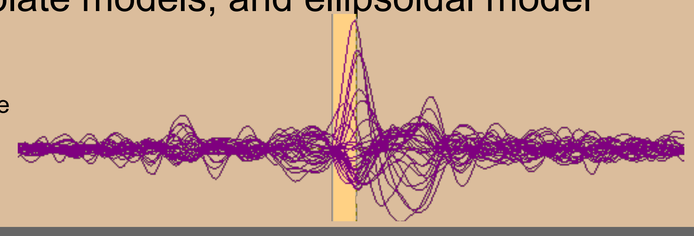


Figure 1: Overplot of EEG spike data. Dipole source is fitted over highlighted fit interval.

III RESULTS

Simulation Study

- Min. error (5.0mm) for age-appropriate template model (12 years)
- Ellipsoidal model yields larger error (13.2mm) than age-appropriate template
- Age-specific template models for younger age groups exhibit larger localization errors

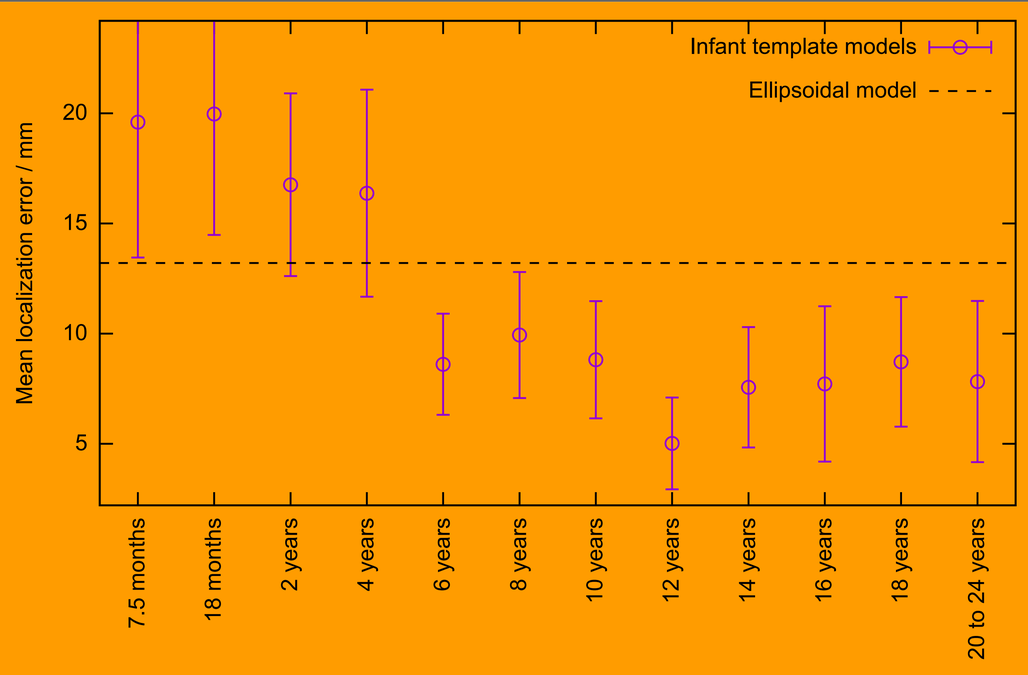


Figure 3: Plot of mean localization errors across reference sources for age-specific template head models. The dashed line indicates the mean localization error of the ellipsoidal model. The error bars indicate one standard deviation.

Evaluation with Interictal Spike Data

- Individual FEM model localizes close to lesion visible in MRI
- Age-appropriate template model reconstructs source in close vicinity of source reconstructed by individual FEM model
- Fitted dipoles for older age-groups (> 6 years) clustered together

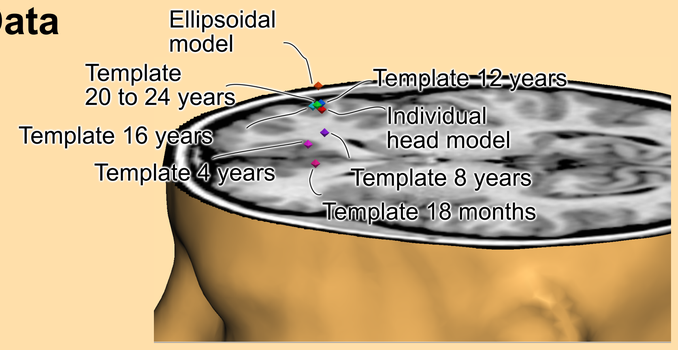


Figure 2: 3D visualization of reconstructed regional source positions for different head models.

IV CONCLUSION and OUTLOOK

Age-specific realistic template head models, as described here, allow the effortless analysis of EEG data taking into account at least the typical anatomical features of the head even when no individual MRI data are available. Using the age-appropriate template model substantially improves source reconstruction as compared to an ellipsoidal model.
In conclusion, we recommend using the realistic template models when accurate source localization is desired but no individual MRI data are available.

[1] Vorwerk, J., Cho, J.-H., Rampp, S., Hamer, H., Knösche, T. R., & Wolters, C. H. (2014). A guideline for head volume conductor modeling in EEG and MEG. NeuroImage, 100, 590–607.
[2] Neurodevelopmental MRI Database. (n.d.). Retrieved May 29, 2015, from http://jerlab.psych.sc.edu/NeurodevelopmentalMRIDatabase/
[3] Sanchez, C. E., Richards, J. E., & Almli, C. R. (2012a). Age-specific MRI templates for pediatric neuroimaging. Developmental Neuropsychology, 37(5), 379–399.
[4] Sanchez, C. E., Richards, J. E., & Almli, C. R. (2012b). Neurodevelopmental MRI brain templates for children from 2 weeks to 4 years of age. Developmental Psychobiology, 54(1), 77–91.
[5] Richards, J. E., & Xie, W. (2015). Chapter One - Brains for All the Ages: Structural Neurodevelopment in Infants and Children from a Life-Span Perspective. In J. B. Benson (Ed.), Advances in Child Development and Behavior (Vol. 48, pp. 1–52).
[6] Chan, T. F., & Vese, L. A. (2001). Active contours without edges. Image Processing, IEEE Transactions on, 10(2), 266-277.
[7] Lanfer, B. (2014, February 7). Automatic Generation of Volume Conductor Models of the Human Head for EEG Source Analysis. Westfälische Wilhelms-Universität Münster, Münster.
[8] Wolters, C. H., Anwander, A., Berti, G., & Hartmann, U. (2007). Geometry-adapted hexahedral meshes improve accuracy of finite-element-method-based EEG source analysis. IEEE TBME, 54(8), 1446-1453.
[7] Yvert, B., Crouzeix-Cheylus, A., & Pernier, J. (2001). Fast realistic modeling in bioelectromagnetism using lead-field interpolation. Human Brain Mapping, 14(1), 48-63.

Corresponding author:
Benjamin Lanfer (benjamin.lanfer@besa.de)
Gräfelfing, Germany