REALISTIC MODELING OF THE HUMAN HEAD FROM AVAILABLE INFORMATION

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ABSTRACT

In electromagnetic source imaging, realistic head modeling is essential for accurate source localization. To generate a realistic head model, the main tissues of the head must be classified from high-resolution 3-D head images. Different imaging modalities contribute differing information for segmentation, widely-available magnetic resonance (MR) imaging, in particular, providing good soft tissue contrast. Once the head tissues are classified, the resulting tissue segments are converted to meshes for use in finite-element modeling (FEM) or boundary-element modeling (BEM). It is possible to obtain different intensity values for each tissue type using multiple MR pulse sequences. Because of the low skull water content, it is not possible to differentiate skull and sinuses using the MR images; proton density (PD) MR images can be used for this purpose. T1- and T2-weighted MR images are suitable for classifying soft tissues. Often T1-weighted MR images alone are used for this segmentation. However, it is hard to distinguish cerebrospinal fluid (CSF) from skull using only T1-weighted images.

THE NEED FOR REALISTIC MODELS

It has been shown experimentally and by simulation studies that using spherical head models cause localization errors.

Experimental studies

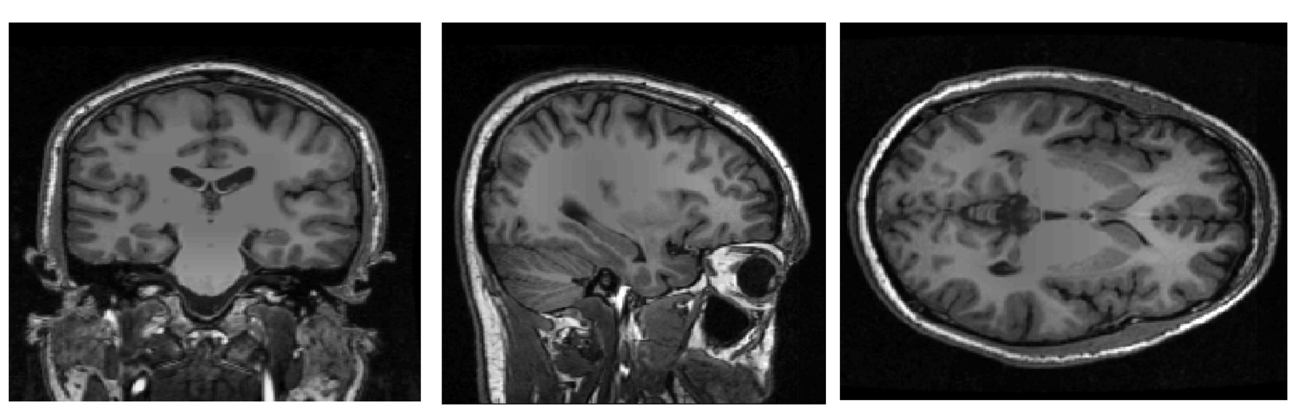
- Saline filled conductor ⇒ 10 mm loc. error (Henderson & Butler, 1975)
- Human skull ⇒ 35 mm error (Weinberg et al, 1986)

Simulation studies

- 3-layer model ⇒ 15-25 mm (Roth et al, 1993)
- 3-layer model ⇒ 9-14 mm (Vanrumste et al, 2002)
- Skull ⇒ 25 mm (Fletcher et al, 1993)
- 3-layer model ⇒ ~8mm (Akalin Acar, 2005)

USING T1-WEIGHTED MR IMAGES

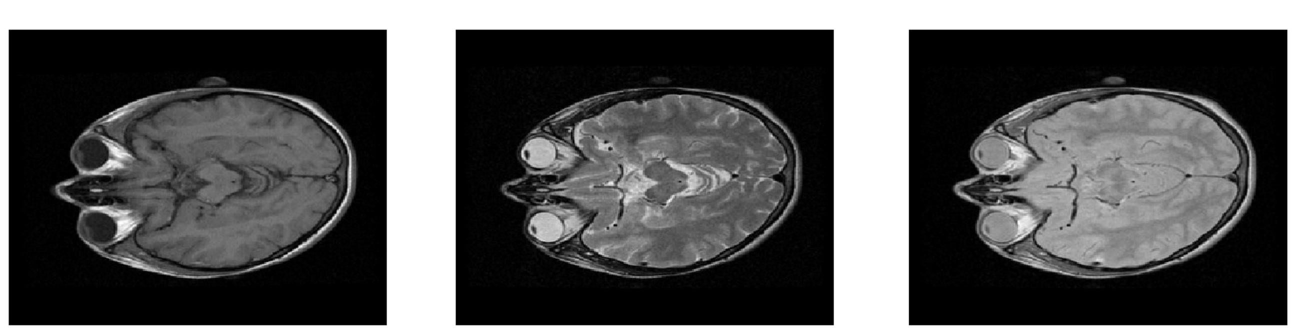
When tomographic images of the subject are available, head tissue modeling is possible. Using only T1-weighted MR images, a four-layer head model consisting of scalp, skull, CSF, brain is generated. The CSF (inner skull) boundary is obtained using an eroded skull boundary and a dilated brain boundary.



coronal sagittal axial

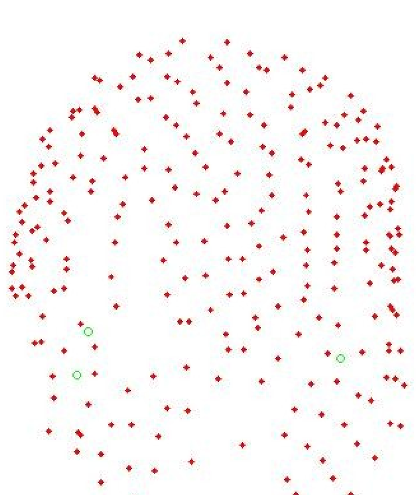
USING MULTIMODAL MR IMAGES

If multimodal MR images are available, a higher-quality segmentation can be obtained including the eyes, and more accurate CSF segmentation. In T1-weighted images, it is not possible to differentiate CSF from skull. In T2-weighted images, CSF has a high contrast.



T1-weighted T2-weighted Proton Density

USING DIGITIZER LOCATIONS



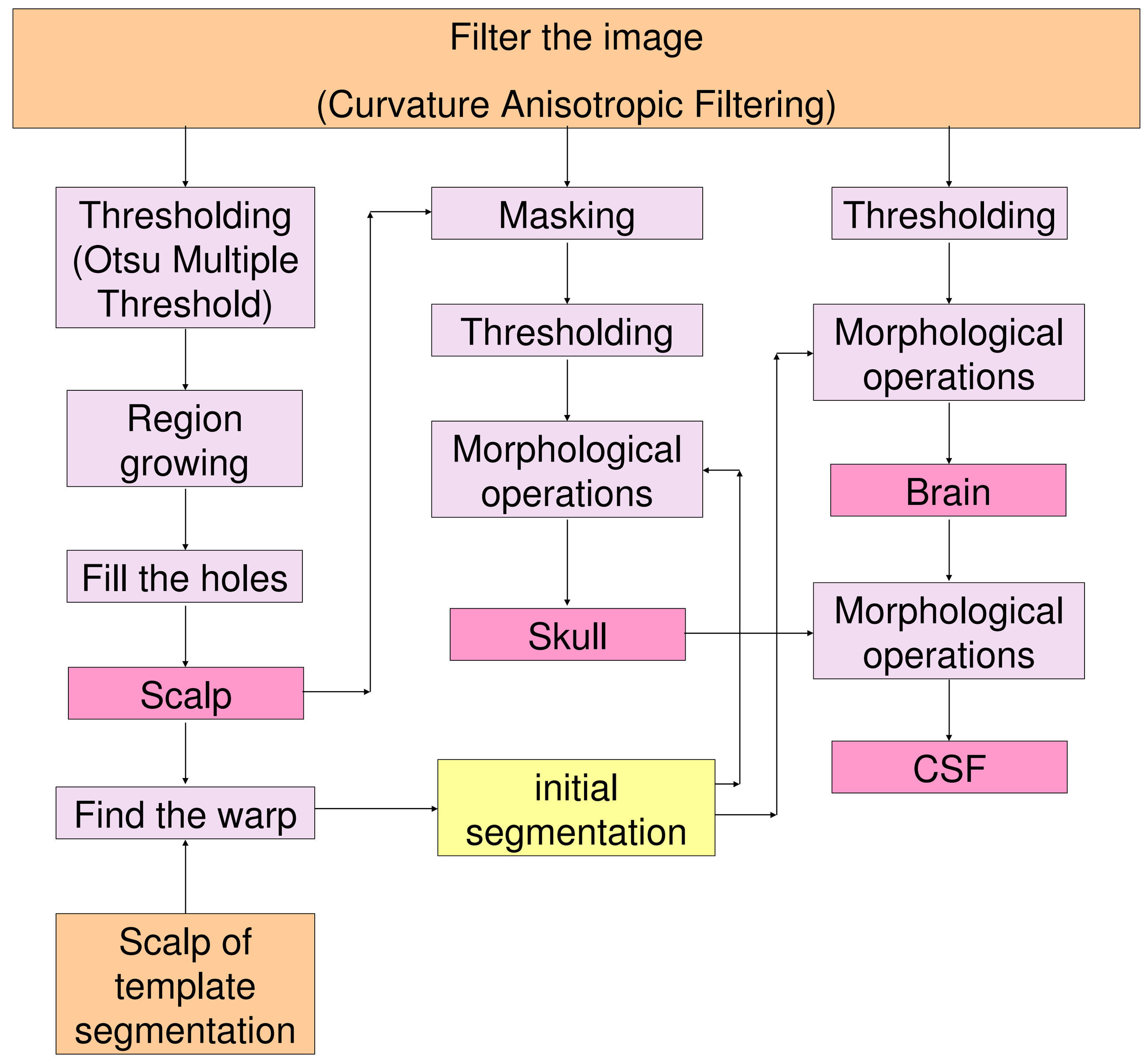
Digitizer locations

Some subjects may not have tomographic head images; for their data the only available spatial information may be the digitized locations of the EEG electrodes. For these subjects, a standardized head model may be warped to the measured electrode locations. A possible approach is to register the head and digitizer locations to the same coordinate system and then, using deformable models, to warp the head model to the regularized digitized locations [2].

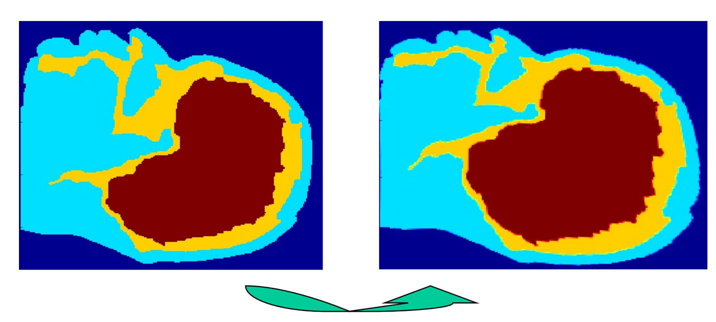
METHOD: SEGMENTATION

For segmentation of T1-weighted and multimodal MR images various methods are used including Otsu thresholding, region growing, morphological operations, curvature anisotropic filtering and registration.

When multimodal MR data is available, the skull and scalp is extracted from PD images, and the CSF is extracted from T2-weighted images.



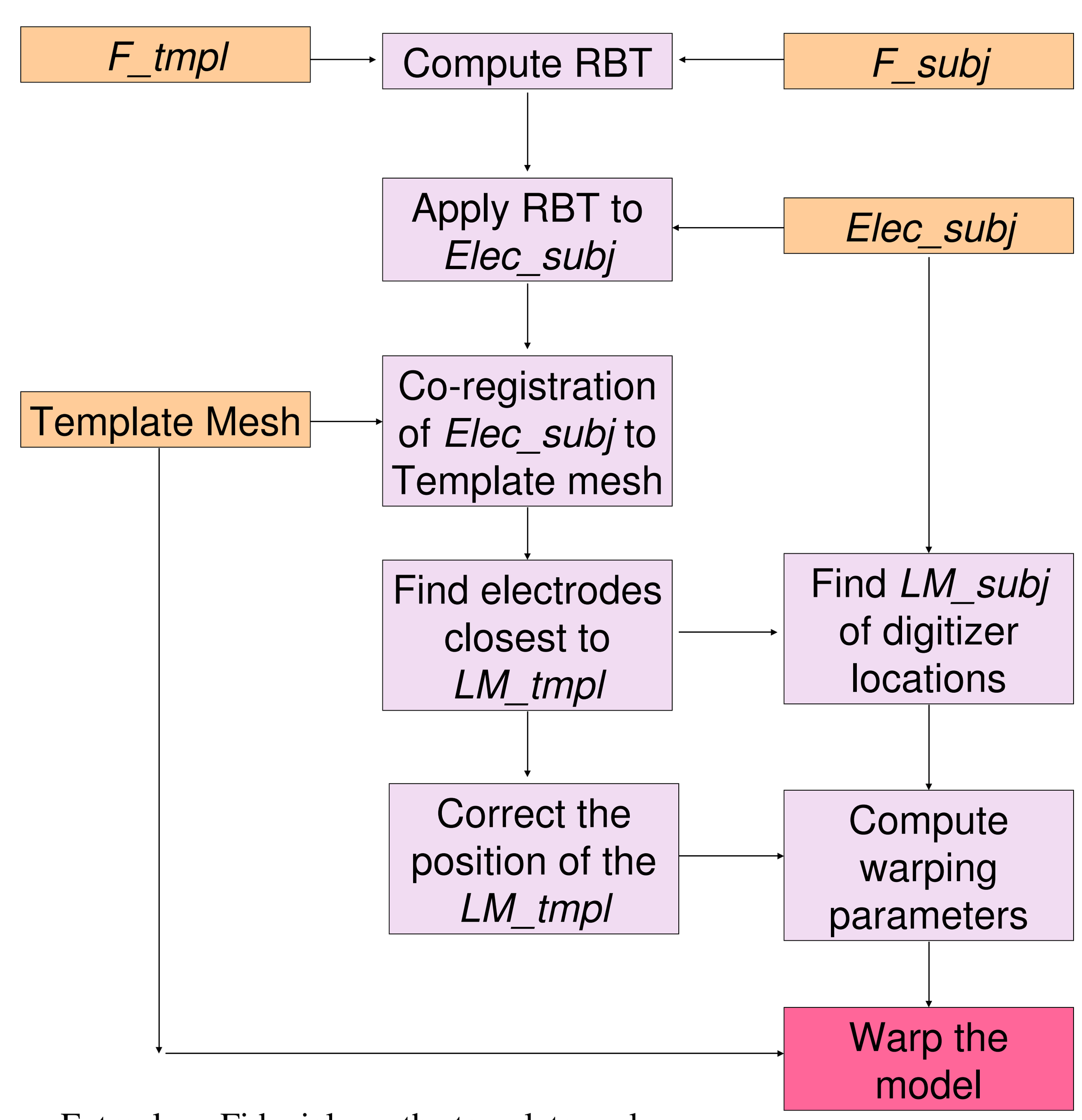
By registering a template head with the MR image, and warping the template segmentation, an initial segmentation is computed



The following software is used for segmentation: Matlab Image Processing Toolbox, ITK - Insight Toolkit [4], and AIR – Automated Image Registration [5].

METHOD: WARPING to DIGITIZER LOCATIONS

The warping is computed based on *fiducials* which are the Nasion, left and right preauricular points. The digitized points are transformed onto the template mesh and matching landmarks are located. The thin plate spline (TPS) warp [1] parameters are computed using these landmarks.

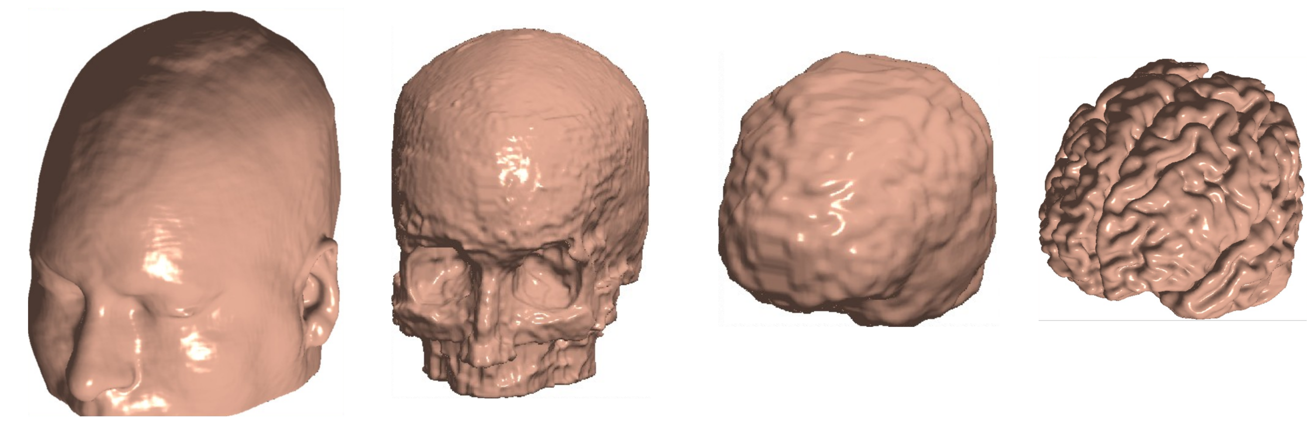


F_tmpl : Fiducials on the template scalp
F_subj : Fiducials on the subject head
LM_tmpl: Landmarks on the MNI scalp
LM_subj : Landmarks on the MNI scalp
Mesh_tmpl: Template mesh
Elec_subj : Digitizer locations on the subject

See illustration on right.

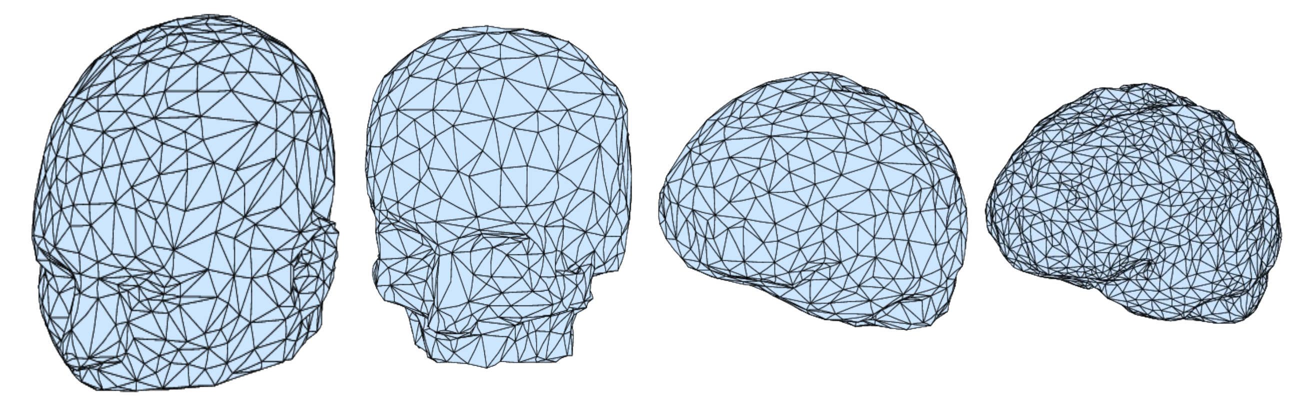
SEGMENTATION RESULTS

Segmentation results from T1-weighted images are shown below.



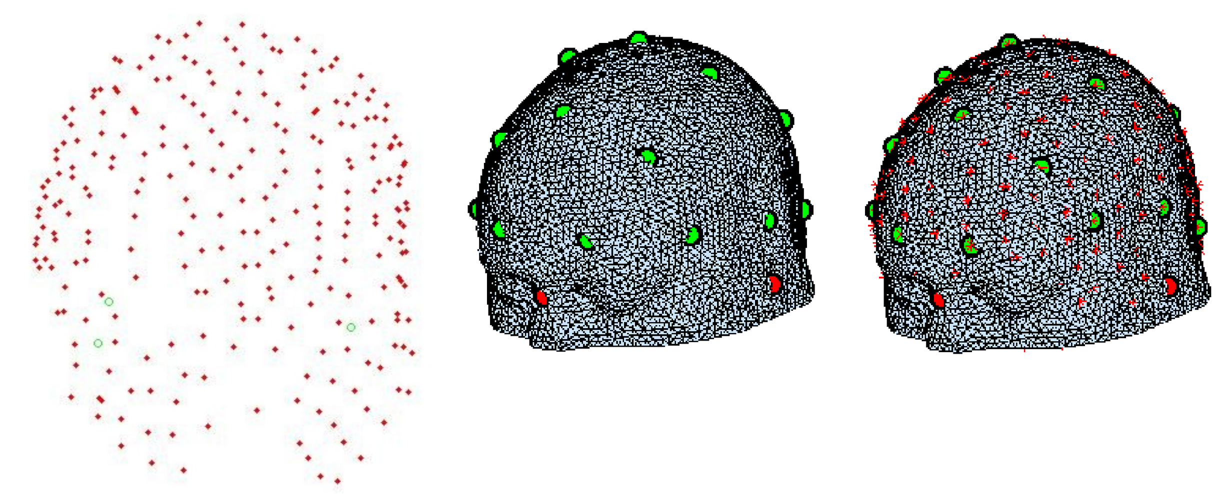
Scalp Skull CSF Brain

BEM meshes were generated from the segmented surfaces using the algorithm described in [3]. The mesh generation algorithm uses triangulation, topological correction and coarsening steps.

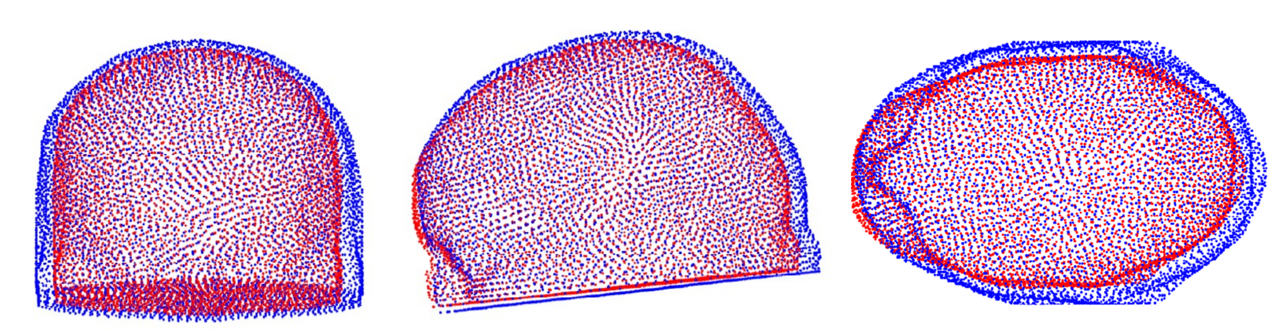


Scalp Skull CSF Brain

MESH WARPING RESULTS



Digitizer locations Template model Warped model



TPS Warping: The nodes of the template mesh (blue) and the warped mesh (red) are illustrated for different views. The warped mesh fits the digitizer locations.

CONCLUSION & DISCUSSION

In this work, generation of realistic head models is discussed using available anatomical data or digitizer locations only. Boundary Element Method is used to solve the forward problem. Details of BEM implementation and mesh generation can be found in [3]. Forward modeling tools for all imagery levels will be built into EEGLAB, a Matlab-based open source environment for electrophysiology (http://sccn.ucsd.edu/eeglab/). A further step should be to apply Finite Element Method (FEM) to take into account anisotropies in skull and white matter tissues.

REFERENCES

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