GENERATING ANATOMICAL HUMAN HEAD MODEL FOR SPECIFIC ABSORPTION RATE ESTIMATION IN PARALLEL MR EXCITATION

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Target Audience: Experts conducting EM simulations for SAR estimation purposes, medical image processing specialists.

Purpose: Efficiently generate patient specific head models with a level of sophistication sufficient for SAR estimation purposes in 7T parallel MR excitation systems.

Methods: *Acquisition:* Two 3D datasets were acquired through the MP RAGE method (orientation: sagittal, TR/TE: 2200/4.11 msec, TA: 7 min., FA: 12°, FoV: 256X256, radial projections:192, voxel size: 1mm isotropic) and the 3D T1-UTE method (TR/TE: 8.95/0.05 msec, TA: 10 min., FA: 7°, FoV: 256X256, radial projections:67000,voxel size: 1.14mm isotropic) using a clinical 3T MR scanner. *Tissue Analysis:* To generate head models, it was necessary to determine which tissues to segment. For this purpose, the head part of the Virtual Family male model (Duke)[1] was adopted, where voxel grey values were substituted with corresponding tissue dielectric conductivities. Thereafter, a morphological gradient filter was applied resulting in conductivity differences at tissue boundaries. A simple threshold afterwards highlighted tissues with the highest dielectric contrasts at their boundaries. Resulting list of tissues includes fat, bone, skin, muscle, spinal cord, air cavities, and the eye region. Due to dielectric property similarities, it was not necessary to segment all head tissues. Instead, tissues were categorized into the nine groups shown in Figure 1. In the view of segmentation complexity and geometry of anatomical structures, some tissues were categorized with groups other than what the graph shows, such as the "Lens" tissue which was categorized as part of the "Eye Region", despite the graph showing it as part of the "Soft Tissues". As for brain gray matter (GM), it is as much essential as brain white matter (WM) and cerebrospinal fluid (CSF) to get a valid head SAR estimation, due to the dielectric contrast with its anatomical surrounding.

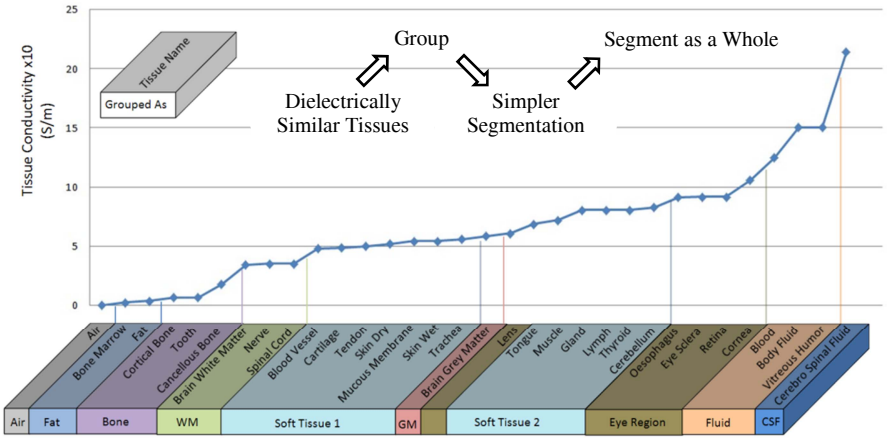

Figure 1: Head tissues in the ascending order of dielectric conductivity. Tissue group boundaries are at considerable conductivity changes.

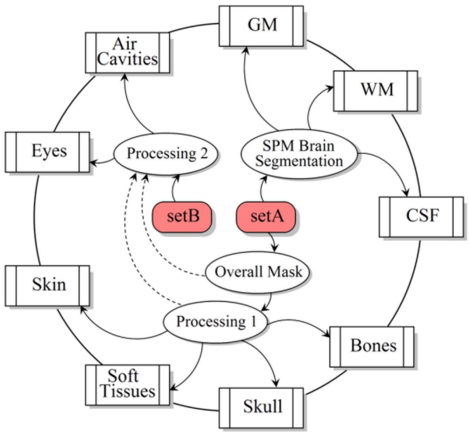

Figure 2: A simplified diagram of the segmentation procedure. MR acquired images are at the center (in red), followed by processes (ovals), and the segmented tissues at the outermost perimeter (columned squares). Solid lines indicate image data flow, while dashed lines indicate parameter flow.

Segmentation: Segmentation of brain tissues was based on the dataset acquired through the MP RAGE method (depicted as setA) due to the good contrast between brain WM, GM, and CSF. This segmentation was achieved through the SPM software[2]. Segmentation of the skull, cortical bones, and the soft tissues was also based on setA. As for the segmentation of air cavities and the eye region, it was based on the dataset acquired through the T1-UTE method (depicted as setB). The multistage segmentation scheme was designed and implemented in the MeVisLab-2.3 environment[3]. It included pre-segmentation processing, anisotropic diffusion filter based on the Perona-Malik algorithm[4], regular and interval thresholding, 2D and 3D component connectivity check, morphological and set operations, and hole filling based on ITKGrayscaleFillholeImageFilter[5]. Figure 2 demonstrates a simplified diagram of the segmentation procedure, where the acquired MR images are at the center followed by processes, and the segmented tissues at the outermost perimeter of the circle. At this point, our segmentation scheme includes two user-interactive stages; one to manually select the "Eye region" mask among other masks, the other to exclude the inferior part of "Skull" from "Air Cavities" mask. *Simulations:* As part of our quality check stage, three simulations were conducted to verify the quality of our model and the tissue grouping from the EM perspective, through the FDTD method (SEMCAD-X, SPEAG Inc., Zürich), using a head coil model with 8-pTx elements operating in the bird cage mode at 294 MHz. One simulation was conducted over Duke's head with all tissues included, a second with Duke's head where tissues were categorized into the nine groups previously mentioned, and a third simulation with our generated head model.

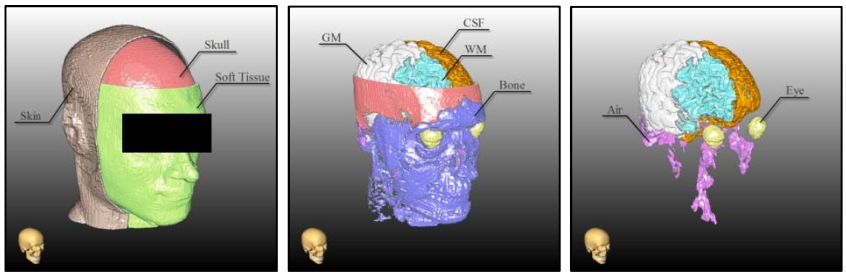

Figure 3: The generated head model with the segmented tissues: skin, skull (red), soft tissue (green), brain GM (white), WM (cyan), CSF (orange), bone (purple), air (pink),eye (yellow).

Results and Discussion: Fig. 3 demonstrates a head model generated through the presented scheme. It consists of Skin, Skull, Soft Tissues, GM, WM, CSF, Bone, Air Cavities, and Eye tissues, with 1mm isotropic resolution. Pre-processing the datasets and running the segmentation scheme took ~1 minute, on a 6-core workstation at 3.33GHz CPU. The manual steps require ~10 seconds of the trained operator's time. Although "Fat" was not included in the current list of segmented tissues, due to the complexity of the task, it is an ongoing work. As part of our broader project, generated head models are combined with their corresponding whole-body models (with six tissue types).

Conclusion: Nine head tissues were successfully segmented based on T1-UTE and MP RAGE acquired MR datasets, forming a subject-specific 3D head model for EM simulations and SAR estimation purposes. The list of segmented tissues include brain WM, brain GM, CSF, air cavities, the eye region, skull, cortical bones, skin, and the soft (water-rich) tissues.

References: 1. A. Christ *et. al.* Phys. Med. Biol. 55 (2010) N23-N38. 2. http://www.fil.ion.ucl.ac.uk/spm/ 3. http://www.mevislab.de 4. P. Perona, J. Malik, Proc. IEEE Computer Society Workshop on Computer Vision, pp. 16-22. 5. http://www.itk.org/doxygen/html/index.html

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