Image Hessian based Automatic Cranium Segmentation for Blackbone and Silenz MRI

Max W.K. Law[1], Jing Yuan[1], Gladys G. Lo[2], Oi Lei Wong[1], Abby Y. Ding[1], and Siu Ki Yu[1]
[1]*Medical Physics and Research Department, Hong Kong Sanatorium & Hospital, Hong Kong, Hong Kong,* [2]*Department of Diagnostic and Interventional Radiology, Hong Kong Sanatorium & Hospital, Hong Kong, Hong Kong*

Introduction: MRI has limited clinical use for cephalometry and radiotherapy planning as compared to CT, despite its advantage in view of superior soft tissue contrast and protecting radiosensitive tissues such as lens and parotid gland. One of the reasons is attributed to the difficulty in differentiation of bone from soft tissues. New MRI pulse sequences have been proposed that are potentially beneficial for bone visualization and delineation. “Blackbone” MRI is a low-distortion 3D gradient echo bone-imaging sequence [1]. “Silenz®” (GE Healthcare, Milwaukee, WI, USA) MRI is another 3D spiral sequence that has ultra-short TE to visualize cortical bone. However, these sequences are not straightforwardly translational to clinical use without accurate bone segmentation and reformatting. This study describes a novel method to automatically segment the cranium for these two MRI sequences. The proposed method identifies the most rapid intensity transitions at the bone-soft tissue interface using image hessian statistics to perform segmentation. We also compared the bone segmentation results by measuring the intensity contrast and thickness consistency of the segmented cranium from these two sequences.

Material and Methods: Four healthy volunteers were received Blackbone and Silenz scans on a 1.5T MRI scanner (Optima MR450w, GE Healthcare, Milwaukee, WI, USA). For Blackbone, TR/TE=8.6/4.2ms. For Silenz, TR/TE=526.5/0.02 ms. Both sequences used flip angle=5^o, FOV=24cm and isotropic voxelsize=1.2mm.

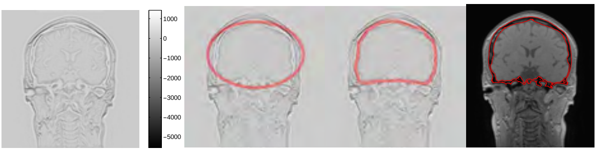

Figure 1. Mid-coronal views of (from left to right) eigenvalue image; affine-registered ellipsoid; deformed ellipsoid; segmentation result.

The craniums were segmented by adding the largest two eigenvalues of the multiscale Hessian tensor [2] of an MR image. It produced an eigenvalue image, which showed bright intensity only inside dark and planar objects in the original MR image. The zero-crossing boundaries in the eigenvalue image corresponded to the local extrema of first order intensity changes, i.e. intensity varied most rapidly. An ellipsoid template was affine-registered to this eigenvalue image. The template was subsequently deformed to follow high value regions of the eigenvalue image using convex relaxation optimization [3]. The resultant segmentation was obtained by moving the boundary of the deformed template to conform to the nearest zero-crossing boundary of the eigenvalue image (Figure 1).

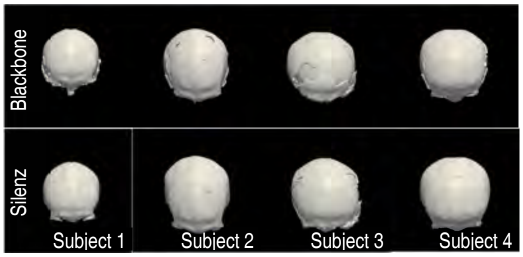

Figure 2. Top views of the segmentations.

The segmentation routine was finished automatically by our customized Matlab script (Matlab 2010a, Mathworks, Natick, MA). The thickness profiles of each segmentation were measured on the mid-sagittal and the mid-coronal planes, i.e. from frontal to occipital bones and from left to right temporal bones. Discrepancy between each thickness profile pair of Blackbone and Silenz was calculated to evaluate bone thickness consistency. Bone intensity contrast was computed as the average intensity difference between the segmented craniums and the brain tissues inside the cranium.

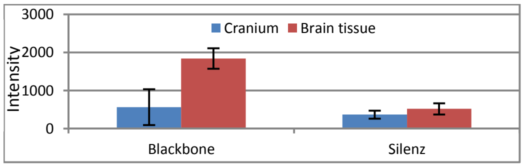

Figure 3. Mean (S.D.) of the intensity of segmented cranium and intracranial brain tissue in Blackbone and Silenz.

Results and Discussion: Automatic cranium segmentation was successful for both sequences in all subjects (Figure 2). It is observed that brain tissue appeared to be brighter in Blackbone than in Silenz, while bone possessed similar intensities in both sequences (Figure 3). Blackbone presented surpassing bone-to-brain tissue intensity contrast than Silenz, and so was postulated to have more accurate segmentation results. This also explained that our algorithm generally provided thicker segmentation in Silenz (Figure 4), possibly caused by the less significant intensity changes across the bone boundaries in Silenz.

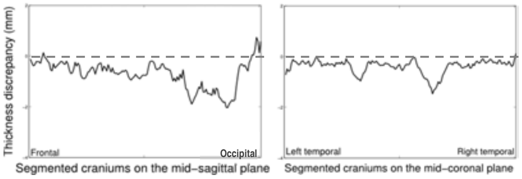

Figure 4. Average of 4 cases of the thickness difference between the segmentations of Blackbone and Silenz, showing positive/negative values if the segmented cranium of Blackbone/Silenz is thicker.

Segmentations of different sequences from the same subject were slightly different due to the ambiguous boundaries between cranium and the rest of the skull. The presence of bright trabecular bone in both sequences also led to minor false negative segmentations. Nevertheless, further assessment of such MRI-based bone segmentation should be conducted with the use of CT images as references in future clinical studies. This study is also limited by the small sample size. To conclude, an MRI-based automatic cranium segmentation method is proposed and its performance is verified for two sequences for bone imaging. This method is beneficial to MR-based cephalometry and radiotherapy planning, to reduce or eliminate ionizing radiation in clinical routine.

References: [1] K. Eley *et al.*, British J. Rad. 2012(85), 272-278; [2] A. Frangi *et al.*, MICCAI., 1998 130-137; [3] C. Nambakhsh *et al.*, MedIA. 2013 (17), 1010-1024.