Bone Segmentation Algorithm by Using Geometric Features in Magnetic Resonance Imaging

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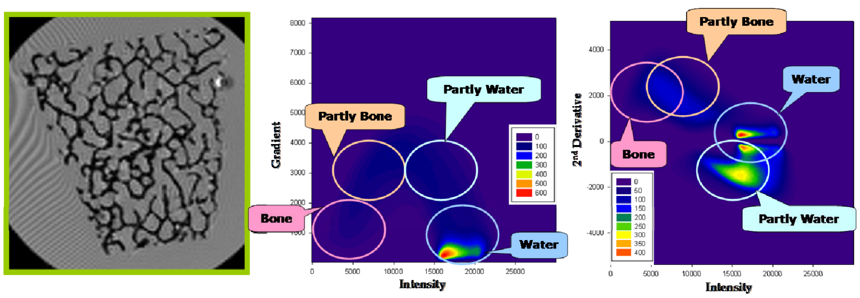
Introduction

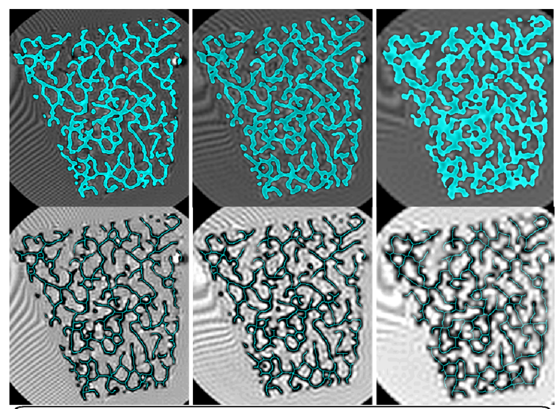
It is known that the analysis of bone microstructure is important for the prediction of bone strength. As a imaging modality for visualizing bone microstructure, micro MR technique has been studied[1][2]. But for micro MR imaging, the resolution of the image is limited by scan time. Thus, partial volume effect (PVE) should be appeared in the coarse resolution images in the real world. To overcome PVE, many image processing algorithms have been produced. In this study, we developed bone segmentation algorithm that can be applied to coarse resolutions of magnetic resonance image.

Materials and Methods

MRI: Bone specimens were removed at distal femoral condyle during knee joint replacement procedure. They were cut by a saw (1x1x1 cm^3) and then fixed in formalin for storage. In preparation for scanning, the bone specimens were defatted, degassed, and immersed in 0.5% gadopentetate doped water. Three dimensional trabecular bone images of the bone specimens were obtained on a 4.7T Bruker BioSpec MRI with 40cm bore size. A 2.5cm birdcage coil with quadrature detection was used. Bone marrow susceptibility difference causes blurring at the trabecular bone marrow interface and it is also necessary to reduce scanning time to obtain high resolution 3D trabecular images. Thus, a 3D fast large-angle spin-echo (FLASE) sequence with 140^o pulse (TR = 100 ms and TE = 10ms) was used to overcome the above two problems. The resolutions of the three 3D images were 65x65x65 μm^3, 130x130x130 μm^3, 160x160x160 μm^3, 196x196x196 μm^3, 230x230x230 μm^3 and 260x260x260 μm^3 respectively. **Bone segmentation process:** We applied cubic interpolation to increase image resolution. At each image, we segmented bone structure by using geometric features, in addition to intensity values. Geometric features such as gradient and 2^{nd} derivative values were calculated at every voxel position. After feature calculation process, k-means clustering was applied to classify bone and water regions. Bone region was characterized by small intensity, gradient values and large 2^{nd} derivative values. Other regions (partly bone, partly water and water region) could be characterized as similar manner shown in Figure1. The classification results were incorporated for the automatic selection of operational parameters, especially for bone intensity and 2^{nd} derivative threshold values. And we applied 3D morphological thinning for extracting centerlines of bone structures. The voxels on the centerlines were visualized to evaluate the performance of this segmentation algorithm qualitatively.



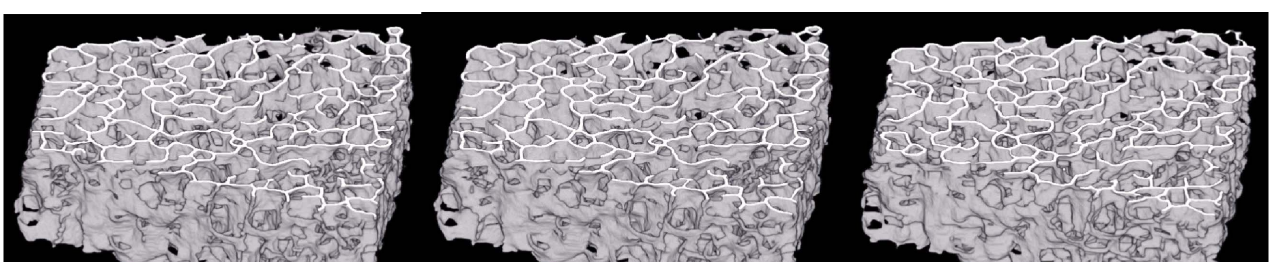
(a) (b) (c)
Figure 1. 2-Dimensional Histograms
(a) 160μm image, (b) intensity and gradient histogram, (c) intensity and 2nd derivative histogram



(a) (b) (c)
Figure 2. Bone segmentation (upper) and centerline detection (lower) results on different resolution images
(a) 130μm image, (b) 196μm image, (c) 260μm image

Results and Discussion

Figure2 showed the bone segmentation results. As the image resolution became coarser, the bone region tended to be found larger because of PVE. But the connectivity was relatively well maintained around all resolution images. The extracted centerlines in 130μm image were well matched with those in 196μm image, but were slightly different in 260μm image because the collapse of small structures due to PVE. This trend could be shown more clearly in Figure3. We made automatic bone segmentation algorithm based on the geometric features. This algorithm could be applied to coarse resolution images.



(a) (b) (c)
Figure 3. Volume rendering results of centerline voxels
(a) 130μm resolution result, (b) 196μm resolution result, (c) 260μm resolution result

References

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