MARROW SPACE USED FOR HIGH RESOLUTION IMAGE SEGMENTATION OF CANCELLOUS AND CORTICAL BONE

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INTRODUCTION

Image analyses are used widely to evaluate the 3D architecture of bone in a nondestructive way. To evaluate the cancellous bone architecture and cortical structure, it is more desirable to analyze all of the cancellous bone and all of cortical bone, respectively, from a given sample region.

Because manual methods are tedious, time-consuming and subjective, efforts have been made to do segmentation automatically [1]. In the current study, we develop a novel automatic segmentation method that is useful for high throughput, high resolution image studies.

METHODS

The basic idea of our method is that a contiguous three-dimensional (3D) non-bone region that is located inside the whole bone region of interest (WBROI) can be defined as the marrow region. Any bone material that is surrounded by the marrow region is considered cancellous bone while bone that is outside of the marrow region is cortical bone. The metaphyses of proximal tibiae of rats scanned in vivo are used here to illustrate the method.

There are three steps to the segmentation:

1). Create a 3D cavity model of WBROI;
In this 3D model, using a simple threshold, all non-bone voxels of the WBROI are identified (set to 1), and all other voxels are “turned off” (set to zero).

2). Create 3D marrow model of WBROI;
The marrow region is defined based on the following observations/assumptions: For a 3D bone structure, i) Marrow voxels are connected to each other and form one and only one marrow cavity; ii) All cavities in cortex are isolated from the contiguous marrow cavity; iii) The marrow cavity is the largest cavity among all cavities found in the WBROI.

To find the marrow region, an image slice is chosen as a start point. The largest cavity (LC) in this image slice must be part of the marrow cavity. The cavity elements that are connected to LC are defined as marrow elements while considering only two slices at a time and moving in two directions through the stack. The whole marrow cavity is identified by continuing the same process from the last slice to the first slice, and then from the first slice to the last slice.

3). Create a cancellous mask and segment cancellous bone from cortical bone.
A mask is created by first dilating and then eroding the marrow region (slice by slice in 2-D) such that the mask covers only marrow and cancellous bone (Figure 1). The bone elements that are covered by this mask are cancellous bone, and the bone elements that are not covered by the mask are cortical bone.

RESULTS

Thirty-six image stacks (from OVX and sham rats scanned at different times) were processed with both a manual segmentation method and the automated method. There was excellent agreement between the two methods with the automated method requiring 5% of the time.

DISCUSSION

The present method offers a fast, automatic and objective means to segment cancellous bone from cortical bone, and also has the ability to distinguish cavities in cortex automatically and objectively.

Although the metaphyses of proximal tibiae of rats are used in this study as an example to show how the method works, the method has potential to separate cancellous bone from cortical bone of other bones with complex structure and irregular shape. The prerequisite of the method is the high resolution of the image so that marrow region and cancellous bone structure can be separately identified.

REFERENCE

[1] Helterbrand et al. (1997). *Bone*, **21**, 401-405

Figure (a) Bone tissue image with marrow in red color and bone in white color

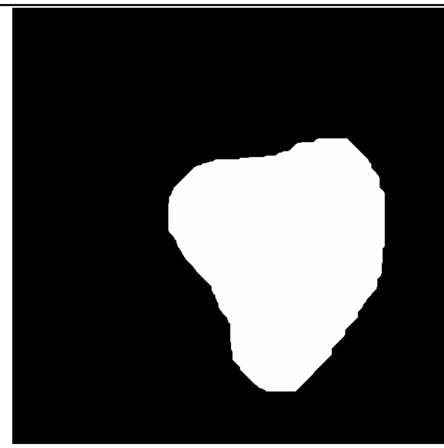

Figure (b) Dilate 2D marrow region and enlarge the image slice

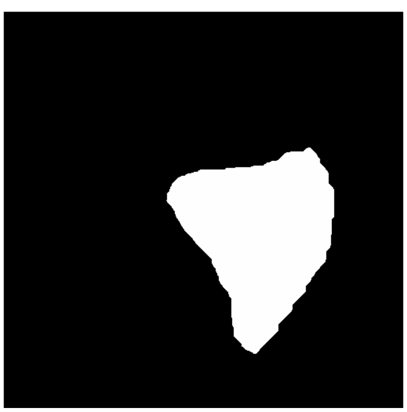

Figure (c) Fill and erode figure (b), and shrink the image slice to its original size

Figure (d) The cancellous mask is in green and blue color. Cancellous bone is in blue color. Cortical bone is in white color

Figure 1: Marrow region is dilated and eroded to find the cancellous mask