

# Fully Automated Volume of Interest Segmentation in the Virtual Bone Biopsy

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## Introduction

The Virtual Bone Biopsy (VBB) [1] is a tool for assessing trabecular bone architecture, orientation, and connectivity using 3D in-vivo micro-MRI scans at certain skeletal locations including the distal radius and distal tibia. In order to track changes due to treatment or disease progression, VBB has been used in longitudinal clinical research studies [2,3]. For large scale projects involving hundreds of patients studied at multiple time points, it is desirable to have an automated system for image segmentation so that the trabecular bone region of interest (ROI) can be automatically extracted from the 3D MRI data set and subject to VBB processing without the need for time-consuming user intervention. Past approaches have involved semi-automatic techniques where the user interactively masks out the ROI [4]. Here we describe a new fully automatic ROI segmentation algorithm for 3D MRI of trabecular bone.

## Methods

The segmentation algorithm consists of five steps. The first four steps are implemented on each 2D slice independently, and the fifth step establishes consistency between slices. **Step 1:** A local threshold is applied to identify the layer of cortical bone surrounding the trabecular bone ROI (Figure 2b). Cortical bone appears dark in the MRI scan (see Figure 1). Due to non-constant coil sensitivity throughout the field of view, a single global threshold would be inadequate. Therefore, a separate threshold is applied in 20x20 pixel neighborhoods throughout the image (Figure 1). To avoid discontinuity problems caused by artificial cutoffs at the boundaries of these neighborhoods, the local threshold is applied again on a collection of 10x10 pixel shifted neighborhoods (see Figure 1), and the two thresholds are combined. **Step 2:** The region identified in Step 1 is dilated by two pixels (Figure 2c) in order to reduce error in Step 3. **Step 3:** The largest connected component (toward the center of the image) of the complement of the cortical bone region is identified (Figure 2d). **Step 4:** Small holes in the ROI are filled in (Figure 2e). These holes result when pieces of trabecular bone (also dark in the MRI scan) are included with the cortical bone in the threshold of Step 1. **Step 5:** The individual slices are made consistent with one another using an algorithm that iteratively removes pixels from the ROI that are not consistent with neighboring slices (i.e. a pixel is removed if in one of the neighboring slices there are no nearby ROI pixels). This final step eliminates isolated problems in Steps 1-4 occurring in individual slices.

The algorithm was applied to 25 images of the distal tibia acquired as a part of a clinical research study. The images were acquired using the 3D FLASE [5] pulse sequence, with a resolution of  $137 \times 137 \times 410 \mu\text{m}^3$  for 32 slices. The isolated ROI was then input into the VBB processing chain. In order to reduce memory and disk space usage, each image was manually cropped (using a rough 2D rectangle) before the algorithm was applied.

## Results

According to visual inspection, the algorithm worked successfully with no user intervention in every case. The segmentation steps leading to VBB processing are illustrated for one particular scan in Figure 2. Processing time was less than 30 seconds per scan on a standard workstation. Each segmented ROI was then processed using the VBB processing chain, including skeletonization and topological classification (see [1]).

## Conclusion

We have described a new algorithm for automatically isolating the region of interest for in-vivo images of trabecular bone. The algorithm has been incorporated into the Virtual Bone Biopsy, and allows for efficient, reliable processing in large scale clinical studies.

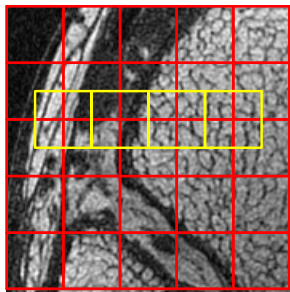


Figure 1. The first step is to apply a threshold locally in a collection of 20x20 pixel neighborhoods (red squares). To avoid discontinuity problems at the boundaries, a second local threshold is applied to a collection of squares shifted by 10x10 pixels (yellow squares). The two thresholds are then combined.

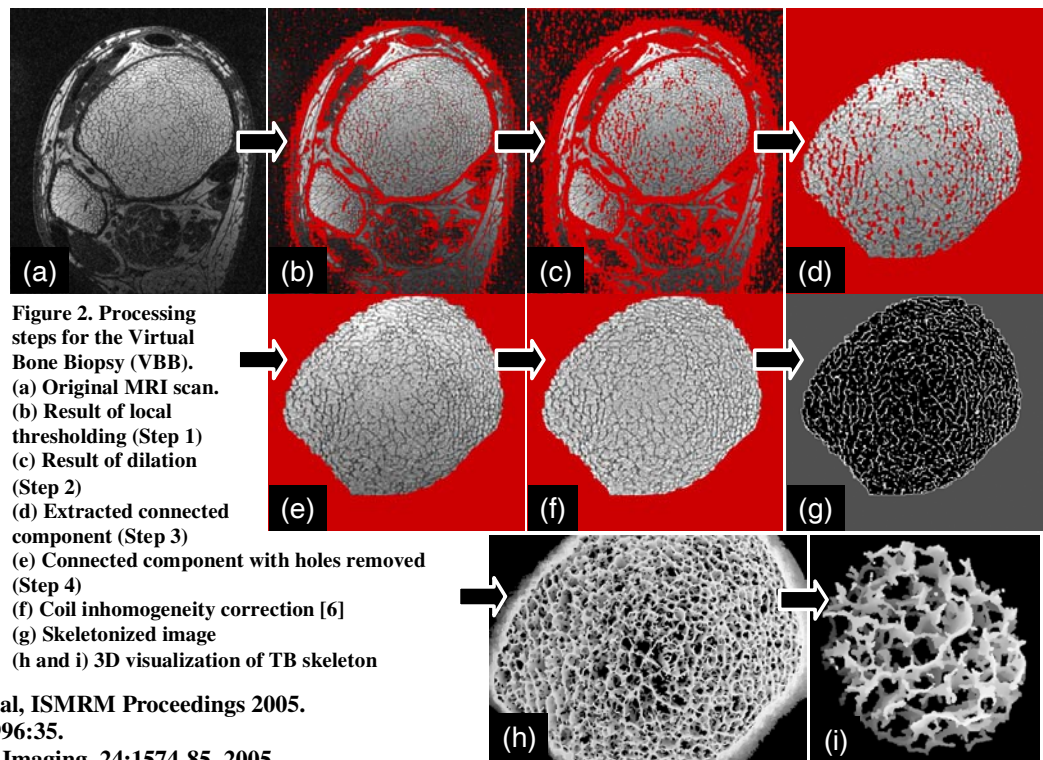


Figure 2. Processing steps for the Virtual Bone Biopsy (VBB). (a) Original MRI scan. (b) Result of local thresholding (Step 1) (c) Result of dilation (Step 2) (d) Extracted connected component (Step 3) (e) Connected component with holes removed (Step 4) (f) Coil inhomogeneity correction [6] (g) Skeletonized image (h and i) 3D visualization of TB skeleton

## References:

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