Automatic MRI Bone Segmentation

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1 Motivation

Magnetic Resonance Imaging (MRI) provides a safe and non-invasive way to study internal tissues and create detailed musculoskeletal models of the body. Aside from clinical applications, these models can be used in areas ranging from character animation to assistive robotics, where accurate models of human motion are important. However, obtaining these musculoskeletal models requires manually segmenting bones and muscles, a prohibitively time-consuming process; segmenting one knee alone takes an expert hours [1]. Automatic segmentation could allow the mass generation of musculoskeletal models.

2 Current Methods

Current methods for automatic segmentation rely on prior datasets to warp canonical segmentations or use machine learning approaches to generate new segmentations [1]–[3]. However, these methods require the existence of prior manual segmentations, which are only available from clinics

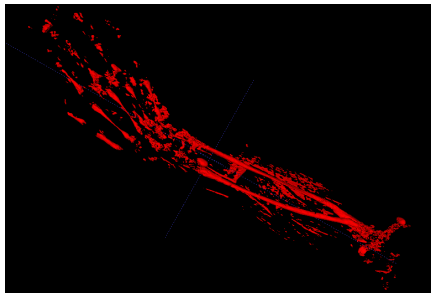

Figure 1: A basic attempt at bone segmentation using Otsu thresholding. The result is noisy and fails to capture major parts of the bones.

for frequently segmented regions such as hip and knee joints. Other methods start from very rough manual segmentations and use boundary-seeking algorithms to refine the segmentations [4] [5].

3 Proposal

I propose to develop a fully automated pipeline in MATLAB for the segmentation of arm bones that does not require prior models. A preliminary attempt on basic Otsu thresholding performed poorly (Figure 1). I will extend some of the more advanced the 2D digital image processing techniques covered in class to work with 3D volumetric MRI scans. Difficulties include inconsistent lighting, high noise levels, and varying appearances in bone due to the cortical and trabecular bone tissues.

Over the summer, I worked on a full musculoskeletal segmentation of the arm (Figure 2). I will use this as a ground truth to evaluate the performance of my automatic segmentation.

This project will not use an Android device.

Goals

1. Image denoising and brightness equalization
   I will try various denoising techniques to suppress the grainy texture of the image and equalize the brightness of the image so that the center of the MRI image is not substantially brighter than the edges.

2. Binarization
   I will try to extract the bone segmentations by binarizing using different 3D sliding windows. I will isolate the radius and ulna by extracting the two largest connected regions. If binarization works well, I will then determine a metric that can be used to find good windows automatically. My hypothesis is that binarization will not suffice.

3. Edge detection
   I will also try to extract the radius and ulna bone segmentations by edge detection. My plan is to perform 2D canny edge detection along all three axes, and then combine the results to find surfaces. Alternatively, I may try to extend the 2D edge detectors to detect oriented surfaces in 3D. After edge detection, I will determine a way to isolate the bone surfaces from other surfaces.

4. Smoothing
   Both methods may require post-processing smoothing or hole filling to produce complete

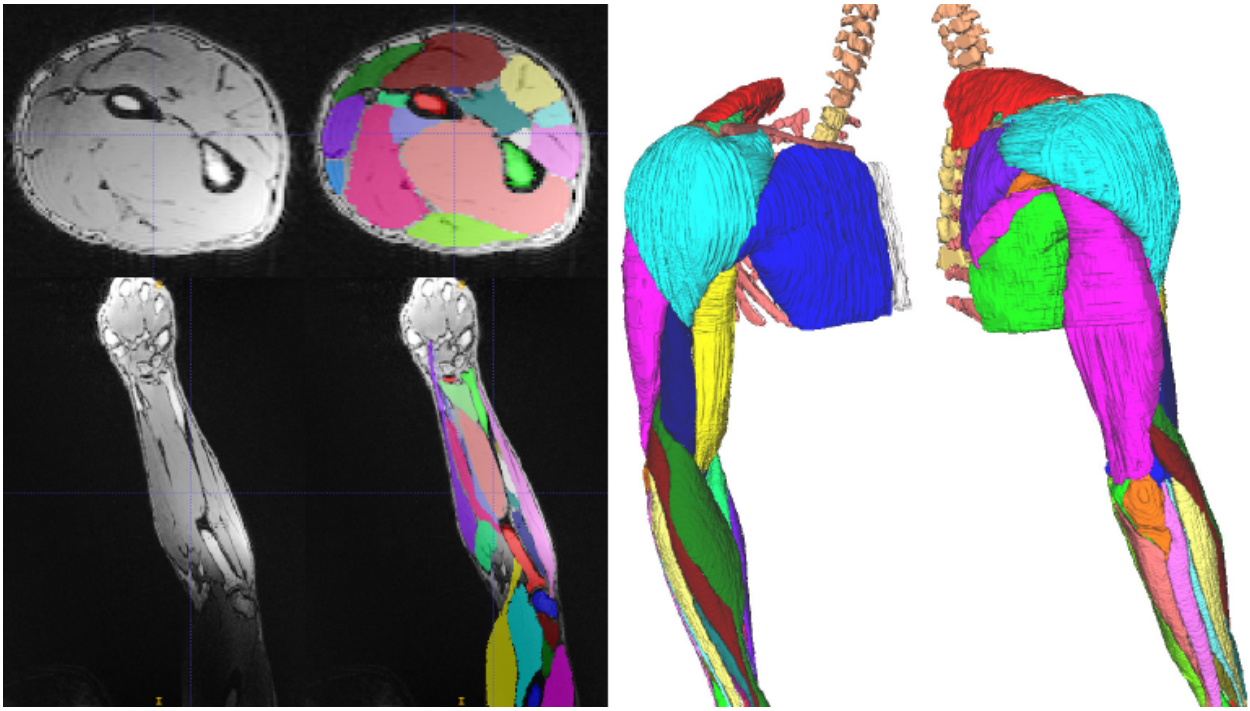

Figure 2: A full manual segmentation of arm muscles and bones.

segmentations.

5. Evaluation
   I will use the area under the receiver operator characteristic (AUC) to determine the accuracy of the automatic segmentation relative to the ground truth radius and ulna.

6. Extension
   If the segmentation of the radius and ulna go well, I will attempt to segment other bones such as the humerus and hand bones using the same algorithms. However, because my manual segmentations of the other bones are not very accurate, I will not be able to score the automatic segmentations. If time permits, I will improve the segmentations so that scoring is possible.

References

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