Exploiting Typical Clinical Imaging Constraints for 3D Outer Bone Segmentation

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Abstract

We present a method for extracting outer bone surfaces from a 3D CT image sequence using a novel segmentation scheme on each image. A 3D mesh of the bone surface is then generate using the marching cubes algorithm. The new segmentation algorithm makes use of several imaging constraints which greatly simplify the problem including : (i) the cross-sectional size of a bone is approximately known and (ii) the geometric shape of a cross-section is approximately known. In clinical practice using commercial CT scanners, these quantities are typically known and serve to greatly simplify the segmentation problem. By segmenting the image data, the algorithm is capable of uniquely extracting the bone outer surface in contrast to other methods which often include extra surfaces or surfaces with holes. This paper presents the segmentation method and shows results for extracting tibia bone outer surfaces.

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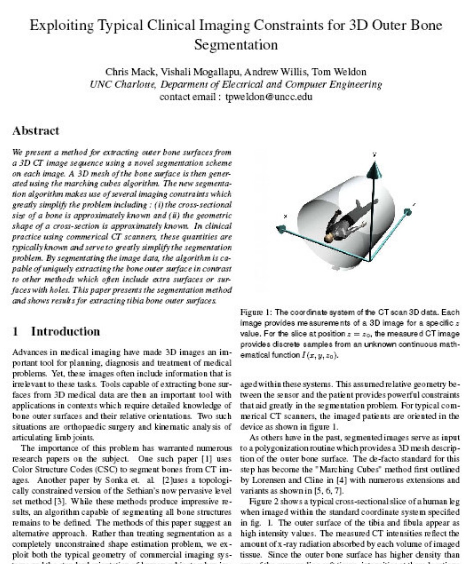

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We present a method for extracting outer bone surfaces from a 3D CT image sequence using a novel segmentation scheme on each image. A 3D mesh of the bone surface is then generated using the marching cubes algorithm. The new segmentation algorithm makes use of several imaging constraints which greatly simplify the problem including : (i) the cross-sectional size of a bone is approximately known and (ii) the geometric shape of a cross-section is approximately known. In clinical practice using commerical CT scanners, these quantities are typically known and serve to greatly simplify the segmentation problem. By segmentating the image data, the algorithm is capable of uniquely extracting the bone outer surface in contrast to other methods which often include extra surfaces or surfaces with holes. This paper presents the segmentation method and shows results for extracting tibia bone outer surfaces.

Figure 1: The coordinate system of the CT scan 3D data. Each image provides measurements of a 3D image for a specific z value. For the slice at position $z = z_0$, the measured CT image provides discrete samples from an unknown continuous mathematical function $I(x, y, z_0)$.

1 Introduction

Advances in medical imaging have made 3D images an important tool for planning, diagnosis and treatment of medical problems. Yet, these images often include information that is irrelevant to these tasks. Tools capable of extracting bone surfaces from 3D medical data are then an important tool with applications in contexts which require detailed knowledge of bone outer surfaces and their relative orientations. Two such situations are orthopaedic surgery and kinematic analysis of articulating limb joints.

The importance of this problem has warranted numerous research papers on the subject. One such paper [1] uses Color Structure Codes (CSC) to segment bones from CT images. Another paper by Sonka et. al. [2]uses a topologically constrained version of the Sethian's now pervasive level set method [3]. While these methods produce impressive results, an algorithm capable of segmenting all bone structures remains to be defined. The methods of this paper suggest an alternative approach. Rather than treating segmentation as a completely unconstrained shape estimation problem, we exploit both the typical geometry of commercial imaging systems and the standard orientation of human subjects when imaged within these systems. This assumed relative geometry between the sensor and the patient provides powerful constraints that aid greatly in the segmentation problem. For typical commerical CT scanners, the imaged patients are oriented in the device as shown in figure 1.

As others have in the past, segmented images serve as input to a polygonization routine which provides a 3D mesh description of the outer bone surface. The de-facto standard for this step has become the "Marching Cubes" method first outlined by Lorensen and Cline in [4] with numerous extensions and variants as shown in [5, 6, 7].

Figure 2 shows a typical cross-sectional slice of a human leg when imaged within the standard coordinate system specified in fig. 1. The outer surface of the tibia and fibula appear as high intensity values. The measured CT intensities reflect the amount of x-ray radiation absorbed by each volume of imaged tissue. Since the outer bone surface has higher density than any of the surrounding soft tissue, intensities at these locations