3D Reconstruction of Trabecular Bone Using Visualization and Modeling Techniques: A Review

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ABSTRACT
Three dimensional (3D) imaging methods in this digital age is one of the important things for visualizing the morphological data of medical images. Numerous medical diagnosis, simulation, and morphological analyses can be done through the new improved technology as computer-assisted tools for image segmentation and reconstruction of 3D models. This paper furthermore explains the developing of 3D reconstruction techniques using the cancellous bone sample obtained from Micro Computed Tomography images. As the important morphological parameters of the sample such as the bone volume fraction, bone density, trabecular number, trabecular thickness, trabecular separation and the degree of anisotropy are also been analyzed from the 3D visual model.

Keywords
3D reconstruction, Image Segmentation, Cancellous Bone, Micro-CT, Trabecular bone

1. INTRODUCTION
Cancellous bone is the spongy interior layer of bone that shelters the bone marrow. It can also be called a spongy bone or trabecular bone which is a two-phase material composed with the porous solid and fluid. Typically found on the edges of rounded bones such as arms and legs. Apart different from compact bone that certainly more strong and robust, it is somewhat more flexible and is useful in jointed bones.

Trabecular architecture has been deliberated as an important factor of osteoporosis disease and as well other pathological conditions in bone. Parameters such as bone volume fraction, trabecular number, trabecular thickness, trabecular separation, and surface-to-volume ratio of bone is the common measurement of the trabecular structure. These parameters have been studied for different anatomical sites and physiological circumstances such as aging [3], bone disease [4], and recently remodeling caused by chemical treatment [5]. A related parameter that is the degree of anisotropy of trabecular bone was observed to highly correlate with increase in fracture risk of the bone [2]. Trabecular connectivity based on topological measurement has also been practical for predicting various changes in mechanical properties with bone failure [10]. Figure 1 [7] shows three different types of trabecular architectures as found at different anatomical sites in the human skeleton.

![Figure 1: Variations of trabecular bone architecture.]

The aim of this study is to develop an image processing system for the analysis of the trabecular structure that will have the possibility to predict failure of bone pathology. In addition, we briefly discuss about the visualization techniques has been choose and summarize this paper with the advantages of 3D models and 3D viewing.

2. IMAGE PROCESSING IN MEDICAL VIEW
There is a need of proper imaging techniques in order to reconstruct 3D model for medical image and tomographic imaging or known as micro-CT has always be the exact techniques to choose so. It was introduced to discover the 3D structural design of bone [6]. The process of micro-CT scan consist of contiguous series of image slices been captured non-invasively with each of slice represent a cut through the scanned structure of particular thickness [14]. The resulting of the process is a series of 2D images displaying a thickness value of the sample. Medical images data are normally stored in DICOM (.dcm) format, and dedicated image readers are necessary for the visualization process [14]. The pixels within each slice are characterized by scalar values that can be interpreted as intensity values and yet this value within that pixel matrix is a standard measurement of material properties at that specific location of the scanned image [14]. Due to its high resolution, micro-CT can obtain precise 3D images at the microlevel of trabecular structure [Homminga J]. Primarily, it can provide images for soft tissues structure and also for hard tissues.
3. REVIEW OF 3D RECONSTRUCTION AND MODELING TECHNIQUES

Introduced by Sun and Starly, the roadmap of the reconstruction of three-dimensional anatomic model from micro CT/MRI images is described, see figure 3 below. In the process shown in the roadmap, the CT/MRI images are integrated using 2D segmentation and 3D region growth and this volumetric image data extracts more meaningful, derivative images via three-dimensional anatomic view [15].

A dedicated software which is called Amira ® are being utilized for geometric reconstruction of trabecular structures from three-dimensional medical image data, i.e. the generation of surface and volume meshes in a finite-element sense. Sequences of medical images in DICOM format can be easily imported [14]. The resulting 3D scalar fields can be visualized and inherent structures can be analyzed in many different ways [14].

The direct volume rendering process creates an image according to that opacity function in the figure 5(a) [13]. The software named above also allows the user to create an isosurface at certain gray value, see figure 5(b) [13].

Though 3D scalar field can already be visualized directly using so-called volume rendering techniques [8, 12], such data cannot be modified in an easy way and do not provide a reasonable input for finite element simulation [13]. The most popular methods do approximate an implicit surface (e.g., via an iso-value) from a 3D scalar field with a polygonal representation [11]. Dividing a 3D scalar field on base of a grey value threshold into fore- and background voxels only works if structures of interest are separable that way [1]. The so-called marching cubes algorithm [11] and its derivatives do reconstruct such implicit surfaces according to this principle using a fast look-up method, see figure 4.

Figure 6 shows the three-dimensional model of the cancellous bone has been reconstructed with technique discussed in this paper.
4. CONCLUSION AND FUTURE TRENDS

A highly interactive software system for 3D data analysis, visualization, and geometry reconstruction known as Amira® has been indentified be able to perform 3D geometry reconstruction pipeline from 3D medical image data and also finite element meshes of the image.

From the 3D reconstruction of the cancellous bone specimen, research about all the morphological parameters from the 3D model might become a new frame work on development of intelligent classifier that can be used as a predictor to cancellous bone failure characteristic by using virtual experiment on the 3D reconstructed model.

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6. REFERENCES