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Anatomically Based Geometric Modelling Using Medical Image Data: Methods and Programs

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Abstracts: The human organs geometric modeling software which can achieve two-dimensional medical image browsing, pretreatment and three dimensional (3D) reconstruction in this paper is designed. This software implements medical image segmentation using the method combining the region growing and the interactive segmentation. Also, the MC surface reconstruction algorithm is utilized to achieve the three-dimensional reconstruction. Furthermore, the software is projected by Visual C++. And then, to legitimately express the structural information of skeleton and muscle, the software is employed to obtain the geometric model using the segmentation and three-dimensional reconstruction for data of skeleton and muscle medical images of the object of study.

Keywords: 3D geometric modelling, medical image segmentation, modeling methods, modeling programs

1. INTRODUCTION

Our research team is working for the virtual surgery system. The 3D geometric modeling of the human tissue or organ is the core module of the virtual surgery system. The 3D geometric modeling can be employed to aid doctor to diagnose patients accurately and efficiently so as to improve the success rate of surgery. In this paper, the implementation method of the geometric modeling software in the virtual surgery system is mainly introduced. The 3D geometric modeling of the human tissue consists of the preprocessing and three-dimensional reconstruction of medical images. There into, the core operations of the preprocessing of images are the segmentation of medical images. Ramanujam Kayalvizh *et al.* proposed a new intelligent arithmetic, that is, the Particle Swarm Optimization (PSO) [1]. I. Cruz-Aceves *et al.* put forward an automatic image segmentation method based on active contour model theory and estimation of distribution algorithms [2]. Nihar Ranjan Nayak *et al.* proposed improved clustering algorithm which is applicable to gray images by evaluating three different kinds of clustering algorithms [3]. For general medical images, the accuracy of computer automatic segmentation methods is difficult to meet the requirements. Therefore, the interactive operation in the image segmentation must be required so as to obtain more accurate segmentation results. Mariofanna Milanova et al. proposed a image segmentation method based on vision to determine its location in this paper, which applied the Chan-Vess model to the image segmentation [4]. Liu Zaitao et al. put forward a new method of the complex medical image segmentation according to the Hierarchical characteristics of human visual perception [5]. R. Delgado-Gonzalo *et al.* proposed an interactive image segmentation method based on B-spline [6]. Chavez-Aragon et al. provided a network platform, which collected the MRI images of volunteers to form a knowledge base of solutions for the image segmentation of hip [7]. Although methods of image segmentation proposed in recent years emerge in endlessly, as a result of the inhere difficulties of the medical image segmentation, it is difficult to obtain satisfactory results for any individual method of the computer image segmentation, whether automatic or interactive segmentation. This paper combined the region growing method based on the gray level difference with interactive segmentation based on the Edge Fill Algorithm, which satisfied the general requirements of the medical image segmentation.

There are many methods about three-dimensional reconstruction [8-11]. In this paper, the MC algorithm is employed. Compared with other algorithms, the MC algorithm is easily procedural and the rate to generate three-dimensional models is rapid. Besides, the method, which utilizes general computer graphics hardware to implement rapidly geometric transformation and mapping, occupies less memory and its portability is strong. Furthermore, the surface structure of human tissue can be performed commendably to meet the requirements of virtual surgery system for 3D models.

On the basis of implementing region growing module, interactive segmentation module and 3D reconstruction by programming, a geometric modeling software in human organs, which is set of 2D medical image browsing, preprocessing and 3D geometric reconstruction, was projected. This software not only can be used independently but also is a part of the virtual surgery system. The expected features of the software include: (1) Medical images can be imported largely and then zoomed in and out for convenient observations. (2) A variety of medical image segmentation can be provided and image enhancement, noise reduction,

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segmentation, erase and fixing vulnerabilities for medical images can be conducted in software. (3) The three-dimensional reconstruction can be carried out after preprocessing the images. Whereafter, the three-dimensional geometrical modeling can be displayed in the interface. Also, the model can be zoom, rotated and moved, etc. (4) The Smooth handling for the surface of three-dimensional geometrical modeling can be conducted easily so that it can be closer to the real tissues and organs of human. (5) Cutting function of arbitrary cross-section can be operated in the three-dimensional geometrical modeling in order to observe for users. (6) The data files in multiple formats can be exported to provide interfaces with other software.

2. METHODS

This paper employs Visual Studio 2010 to design the geometric modeling interface. The core modules of software include: the region growing module, the interactive segmentation module and 3D reconstruction module.

(1) The region growing module

The region growing method that the gray value is regarded as similarity measurement is utilized to segment two-dimensional medical Computed Tomography(CT) images in this module. According to setting parameters of growth criterion, the human tissues interested can be segmented. This module is mainly used for segmenting medical images that gray value is on average, difference of gray value between organization is more apparent and the edge is distinct. With regard to the tissues whose gray difference is smaller or distribution of gray level is uneven, the cavity and excessive segmentation are easy to be conformed. Therefore, for the sake of completing segmentation, interactive segmentation module can be combined with the region growing module.

Fundamentally speaking, the basic idea of the region growing algorithm is that pixels with the same or similar nature are gathered to constitute the region. Firstly, in the interested region, select artificially a pixel point as the seed point. And then, on the basis of growth rule, we will incorporate the pixels which meet requirements around seed points into seed region. Whereafter, these new pixel points are regarded as seed points to repeatedly carry out the above steps until there are not the pixels that meets condition. As thus, a region can be formed [12, 13].

The key to region growing algorithm is growth criterion and selection of seed points, which is related to not specific segmentation problem only, but also the type of medical data to be segmented. Growth criteria may be based on different principles. The difference of the growth criteria has effect on the process of the region growing and segmentation results. As thus, most of growth criteria are based on the local characteristics of images. In this paper, the two-dimensional medical images are regarded as research object. Consequently, the growth criterion selected is based on the regional gray level difference. The flow of this algorithm is: A typical point in some region in the image is selected as seed point according to the purpose of segmentation. After initializing the stack of computer memory, we will store the specified seed point into the stack. Afterwards, take out a member of the top from the stack and scans its eight neighborhoods. When there is some gray value of the pixel to meet the requirement, $|gn-gc|<dv$ and $|gn-gs|<cv$, store the value into stack and repeatedly cycle till there are not the pixels that meet condition. Ultimately, the process comes to end.

(2) The interactive segmentation module

The function of this module is that the two-dimensional CT images loaded is conducted segmentation by interactive segmentation. The polygon is drawn by manual operation. Afterwards, select the interested region. And then, extract and separate so as to accomplish the segmentation for medical images. The tissues or organs whose shape are regular can be segmented better and time relatively is less. As far as irregularly-shaped tissues are concerned, the region growing module frequently are employed to segment tissues along with the interactive segmentation module. Otherwise, time will be consumed largely.

In this paper, the interactive segmentation adopted is Edge Fill Algorithm. According to the segmentation region, the operator can plot arbitrary polygon. Afterwards, the process can automatically separate the area which is surrounded by polygon from the whole region. The process is: initialize images, that is, all points using in signing image are initialized to zero. For another, discrete each edge. That is to say that set the direction of the scan line for the horizontal direction and the separation distance between two adjacent scan lines is seen as the unit distance of the image vertically. The intersections between the polygon and each scan line are assigned as a non-zero value. Fill the polygon. All points which are on the right side of each non-zero point are conducted complement. Whereafter, generate the segmentation result. For signed non-zero points in the image, the pixel points in the exported image are equal to the value of the corresponding points in imported image. Meanwhile, the corresponding points in exported image are assigned as zero, for signed zero points in the image.

(3) The three-dimensional reconstruction module

The classic MC algorithm is employed in the surface reconstruction algorithm. Users can isolate the tissues between the two thresholds by means of setting a high threshold and a low threshold so as to implement the surface reconstruction of medical images. This module makes use of the three-dimensional reconstruction algorithm based on voxel to carry out the 3D reconstruction for a set of two-dimensional medical CT images after segmentation. In addition, users can zoom, shrink, move and rotate the 3D model in order to intuitively observe the physical structure, the size of the lesions, location and other information about the organization. The flow diagram of three-dimensional reconstruction algorithm is as shown in Fig. (**1**).

3. RESULTS

The medical image data derived from the hip CT images of a healthy man, age is 26 years old, height is 175cm and

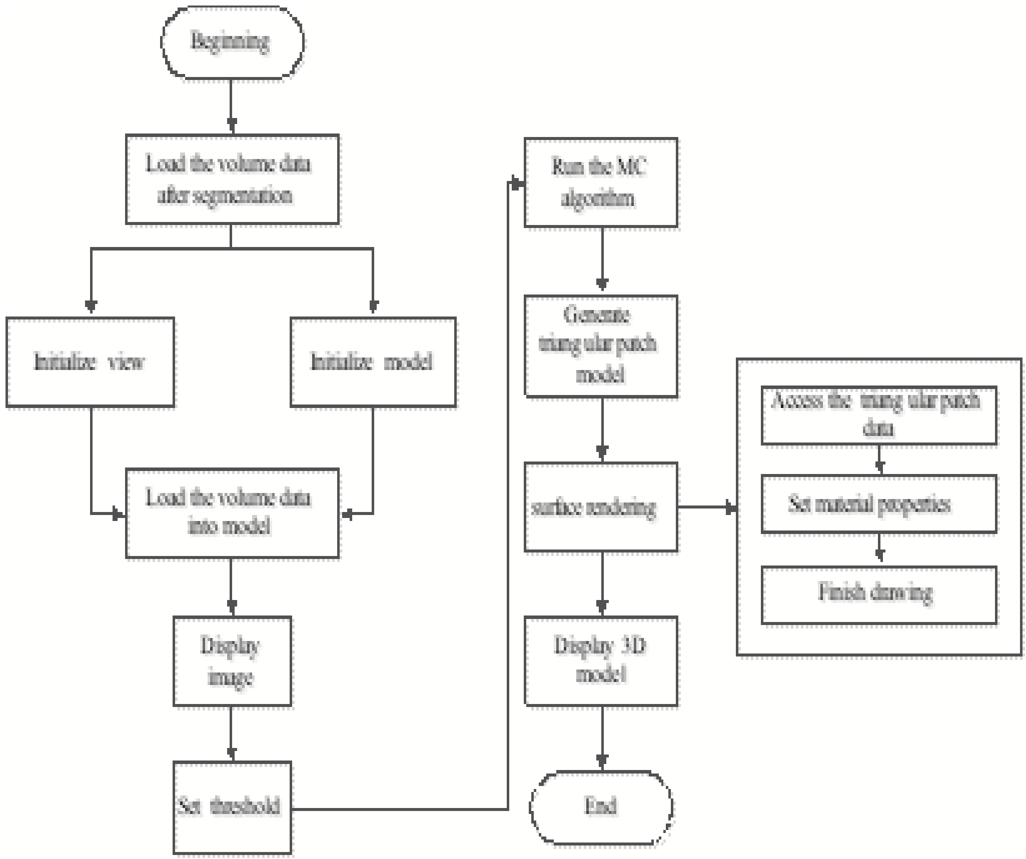


Fig. (1). D reconstruction program flow chart.

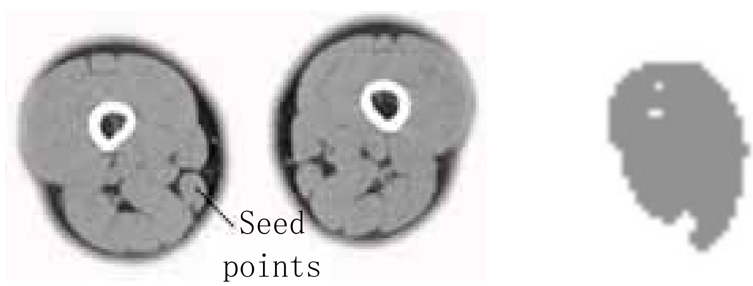


Fig. (2). Muscle segmentation result (dv=cv=30).

weight is 65kg, who is in good condition and has no history of hip fracture or muscle damage, etc. The axial continuous tomography is utilized in this paper. A total of 700 tomographic images are selected. The space between the images is 1.0 mm. Every image is a lattice of 512×512 pixels. In addition, Visual C++ is used in geometric modeling program, which is run in the Windows PC platform.

Extracted program results include the results of the study under different parameters of the same seed points using the region growing segmentation algorithm, the results of the study under same parameters of the different seed points using the region growing segmentation algorithm, the results of the femur segmentation using respectively the region growing segmentation algorithm and the interactive segmentation and the results of the semitendinosus segmentation using respectively the region growing segmentation algorithm and the interactive segmentation.

(1) The points selected in gracilis in source image are regarded as seed points. Meanwhile, parameters dv and cv are 30. The segmentation result can be obtained by making use of the region growing method as shown in Fig. (**2**).

(2) The points selected in gracilis in source image are regarded as seed points. Meanwhile, parameters dv and cv are 90. The segmentation result can be obtained by making use of the region growing method as shown in Fig. (**3**).

(3) The points selected in semitendinosus in source image are regarded as seed points. Meanwhile, parameters dv and cv are 30. The segmentation result can be obtained by making use of the region growing method as shown in Fig. (**4**).

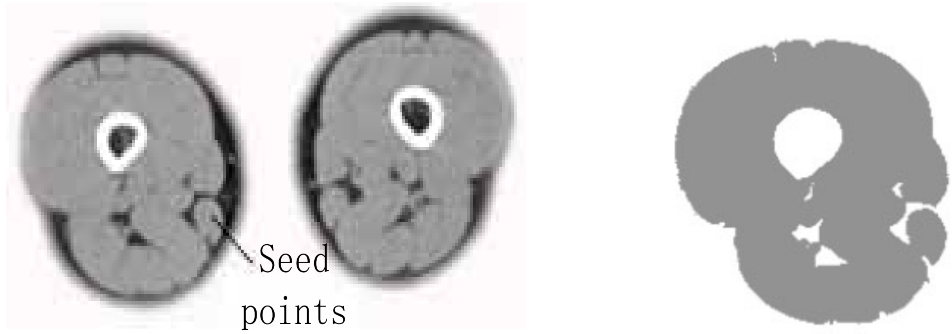


Fig. (3). Muscle segmentation result (dv=cv=90).

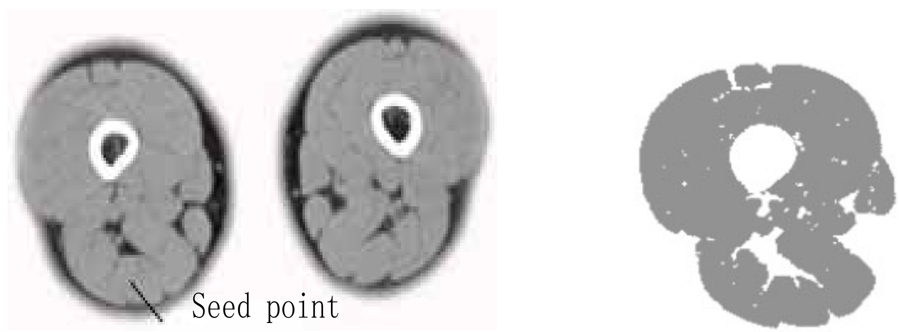


Fig. (4). Muscle segmentation result (dv=cv=30).

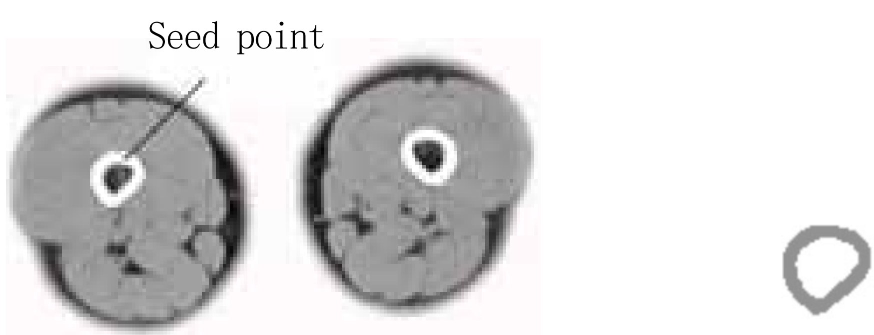


Fig. (5) Femur segmentation result.

(4) A point selected in femur is regarded as seed point. Due to the larger gray value of bone, therefore, parameters dv is 300 and cv is 900. The segmentation result is shown in Fig. (**5**).

The segmentation result indicates that the points selected in gracilis muscle in source image are regarded as seed points. Meanwhile, parameters dv and cv are 30. The whole gracilis muscle biopsy can be obtained using the region growing algorithm. However, to the same seed points, when parameters dv and cv are 90, due to the larger parameters, the region growing method can be employed to obtain multiple muscles connected. If parameters dv and cv are 30, under the constant parameters, users can select a point in the semitendinosus whose boundaries are fuzzy as seed point to segment. The segment result is multiple muscles including semitendinosus. As can be seen from the segmentation result of muscle and bone, the region growing algorithm has high requirement in the control of parameters and the selection of seed points. In addition, to tissues whose boundaries are fuzzy, excess parts are easy to be extracted except the segmentation object, that is, excessive segmentation.

(5) The sources of medical data are same to the region growing module, that is, users utilize the interactive segmentation algorithm to conduct the segmentation on muscle and bone. The segmentation result of semitendinosus is shown in Fig. (**6**). The segmentation result of femur is shown in Fig. (**7**).

Fig. (6). Muscle segmentation result.

Fig. (7). Femur segmentation result.

Fig. (8). Comparison of real sartorius muscle and geometry model.

As can be seen in the segmentation result (5), users can take advantage of the interactive segmentation to segment any interested tissues and organs. However, the method will take a large amount of time on operating. Furthermore, it has high requirement on operator. Therefore, to the tissues whose boundaries are clear and the gray level difference is larger such as femur can be immediately segmented with the region growing method. Comparatively, to the muscle tissues whose boundaries are fuzzy such as semitendinosus, the interactive segmentation can be taken into consider. On the other hand, users can firstly employ the interactive segmentation to obtain generally the interested parts. Afterwards, the tissues whose gray difference is few are separated. And then, users can employ the region growing method to obtain preferably the desired results. Not only avoids the excessive segmentation resulting from the region growing, but also provides the efficiency of the segmentation.

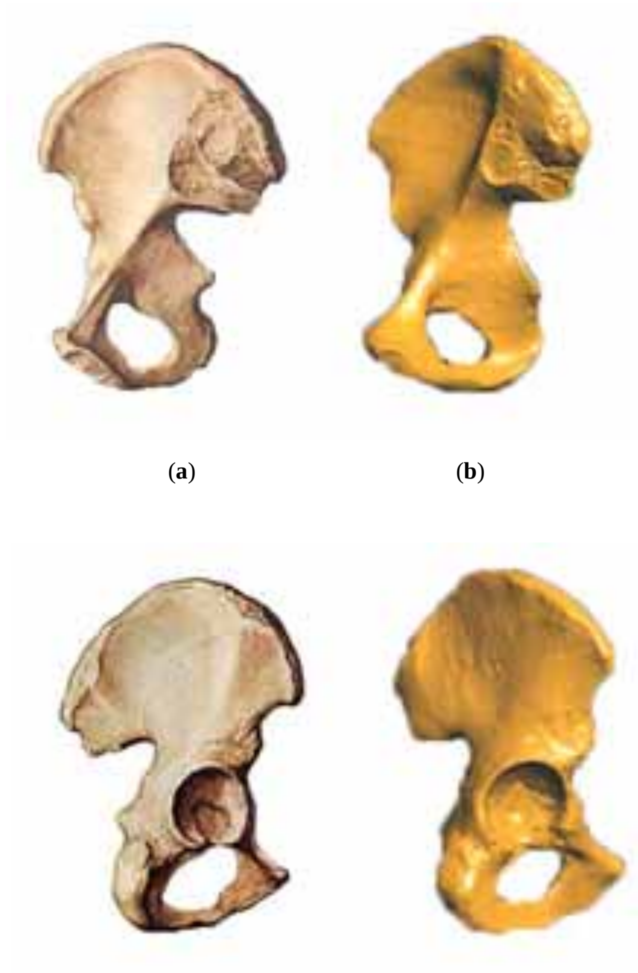
4. DISCUSSION

Owing to employing the computer to mimic the 3D reconstruction model which is unnatural image, therefore, users have to set and adjust the relevant parameters as needed. As a result, it is difficult to quantitatively assess the results of reconstruction. At present, to assess the quality of 3D reconstruction is mainly subjective. On the basis of the experience in anatomy or comparison with real human organs, users compare key feature points of 3D model to judge the merits of reconstruction results. The comparison between 3D model reconstructed by our software and structure of real muscle and bone is shown in the following.

The comparison of sartorius muscle is shown in Fig. (**8**). On the left is the real structure of the human sartorius. On the right is the geometry model of sartorius muscle based on this software.

The comparison of the hipbone is seen in Fig. (**9**). Figure (a) is the front structure of real hipbone. (c) is the back of real hipbone. (b) and (d) are the front and back model of the established hipbone based on this software.

As can be seen from Fig. (**8**) and Fig. (**9**), the 3D geometry model attained based on this software inosculates basically with the physiological structure of real muscle and bone and can show up the detail characteristics of



(**a**) (**b**)

(**c**) (**d**)

Fig. (9). Comparison of real hip and geometry model.

corresponding muscle and bone. In future studies, the generation of volume model and the implementation of program will be taken into consider so as to integrate with the meshing module and the finite element analysis of biomechanics module that research group designed.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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