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The study and implementation of liver volume measuring method based on 3-dimensional reconstruction technology

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ABSTRACT

In this paper, a novel liver volume measuring method using 3D reconstruction technology is put forward, it can measure the 3D liver model directly. The 3D liver model which is constructed by Marching Cube algorithm is composed of a number of triangle meshes, and the normal vectors of different directions of all triangle meshes must be modified, then the meshes are traversed and projected onto a projection plane of 3D spatial coordinates one by one. Then, a lot of pentahedrons can be built and the volumes of all pentahedrons are calculated, the final volume of 3D liver model is the algebraic sum of all pentahedron volumes. Compared with the volume integral method which is a traditional volume measurement method in medicine, experimental results show that the proposed method is optimally approximate to the liver volume, and it cannot be affected by the internal of scan image.

1. Introduction

With the development of computer technology and computer graphics, 3D reconstruction technology of medical image has been carried out widely [1,2].

In China, there are a number of people have to confront with the risk of liver diseases [3], it is important for doctor to get more accurate volume data of liver, which are necessary to diagnose and treat liver diseases. Liver volume measurement can be used for quantitative assessment the size of liver and monitoring liver function, on the other hand, it is also of a great significance for liver transplantation, liver tumor surgery, predicting liver function reserve and so on. So, how to get more accurate liver volume data has a direct impact on the diagnosis and treatment of liver diseases [4,5].

The shape of liver tissue is irregular, but the size of liver volume can be estimated by using some corresponding formulas [6,7]. For some liver patients, there may be some lesions or tumors in their liver, then volume estimation of liver may be difficult. In medicine, a series of liver images are segmented from a continuous sequence of abdominal medical images and the area of liver region can be calculated by counting the number of pixels in liver regions, then the volume of liver is achieved by volume integral method [8–10].

In addition, stereology method [11] is always used to calculate the area of object region approximately and get the volume of tissues and organs using volume integral method. In paper [11], a piece of abdominal image is divided into a lot of rectangular grids, the area of the liver region is achieved by counting the number of grids which are contained in liver region. The above two volume measurement methods are based on different area calculation methods, but the core idea of the two methods is volume integral method. But, for volume integral method, there are still some disadvantages at present. It is rather time-consuming to calculate the area of object region of all images; the result of volume measurement can be affected by the interval of scan images. Most of all, the repeatability, reproducibility and the visualization effect are not satisfactory [12,13]. At present, there are few methods which can measure the volume of 3D model directly, in paper [14], Quasi-Monte Carlo method [15] is put forward, which is based on a kind of probabilistic model, the method can be applied to volume estimation of solid engineering model. But its elapsed time overhead and accuracy can be affected by the number of points which are known as low discrepancy sequences points. In medicine, direct volume measurement method for 3D reconstruction model not only improves the accuracy of liver volume measurement, but also the external shape of liver also has more advantages for doctor to analyze and treat liver diseases.

In order to improve the accuracy of liver volume measurement, a method based on projection is put forward to measure the volume of 3D liver model directly. In order to implement the method, a

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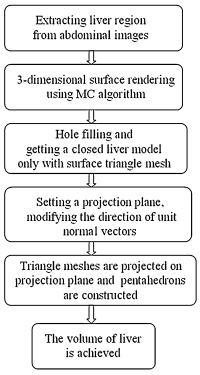

Fig. 1. The main steps of the proposed method.

projection plane is set in 3D spatial coordinates. The triangle meshes of the 3D liver model are traversed and projected onto the projection plane one by one. Then, a pentahedron can be constructed by a triangle mesh on the surface of 3D model and a projected triangle on the projection plane. All of the pentahedrons are classified into two categories according to the direction of normal vector of every triangle mesh, then the volume of the 3D reconstruction liver model is the algebraic sum of all pentahedron volumes. Fig. 1 shows the main steps of the proposed method.

2. Construct 3D liver model

Different from other engineering research fields, in medicine, volume measurement is aimed at tissues and organs of living body. So, to measure the volume of tissues and organs of living body is more difficult than in vitro object, because the 3D tissues and organs model of living body which is only with surface triangle meshes cannot be reconstructed using 3D laser scanning technology directly. In general, there is a lot of information in medical image (such as CT, MRI, PET), if these images are used to reconstruct 3D model directly, interior structure of the 3D model may be particularly complex. But, in the paper, the proposed method is aimed at the volume measurement of a closed surface mesh model, so how to make use of the medical image to get a closed 3D surface mesh liver model is the key to implement the novel method of this paper.

In order to get a closed 3D surface mesh liver model, a series of abdominal CT images are segmented one by one. It is generally known that an effective segmentation method can improve the accuracy of volume measurement. According to the paper [16], the step of liver segmentation method is as follows and Fig. 2 is a piece of abdominal CT image:

(1) The first step is image simplification, it is regarded as preprocessing. The scope of liver region is identified firstly and the non-liver region is eliminated so as to reduce the search area and computational effort. The intensity distribution of liver region and adjacent muscle are investigated and analyzed, then a segmentation method based on multi-threshold is proposed to separate tissues or organs from the liver and its adjacent region.
(2) The multiscale morphological filter is applied to detect the search range of initial liver contour. In this process, erosion and dilation operations are very important. Then, the region labeling algorithm is used for marking out the largest labeled liver region, which is still coarse liver region. And the coarse liver region is divided using modified K-means algorithm, then it is easier to achieve the initial liver region. But, there are still some regions around liver region which are caused by the first morphological filtering, so the second morphological filtering is reused to reverse these regions.
(3) The third step is to get liver contour. A contour-based segmentation algorithm is proposed, because the segmentation method is a labeling-based search algorithm, so it can refine the initial liver boundary. At last, a clearer liver contour image is achieved.

In this paper, the volume measurement is aimed at 3D reconstruction liver model which is only with surface mesh, so the segmented liver image is carried on binary processing, as shown in Fig. 3.

The segmented liver images are used for surface rendering using Marching Cube algorithm (MC) [17], and then a 3D liver model only with surface mesh is achieved. The advantages of MC algorithm are that the detail information of a reconstruction model can be stored, such as the unit normal vector of every triangle mesh, 3D coordinate of space points. The disadvantage of MC algorithm is that there may be some holes on the surface of 3D reconstruction liver model, so the holes must be repaired to get a closed 3D model. According to the paper [18], the main process of the hole filling is as follows:

(1) Several boundary vertices around a hole are applied to initialize the range of the hole;
(2) The angle θ who is between two adjacent boundary edges e_i and e_{i+1} can be calculated;
(3) According to the three rules shown in Fig. 4, the hole is repaired by creating new triangles;
(4) Update the information of the 3D model.

The above steps are repeated until the region of the hole is repaired by new triangles. The 3D reconstruction liver model is shown as Figs. 5 and 6 is the surface mesh model of liver. The interval of the liver scan images is 2 mm.

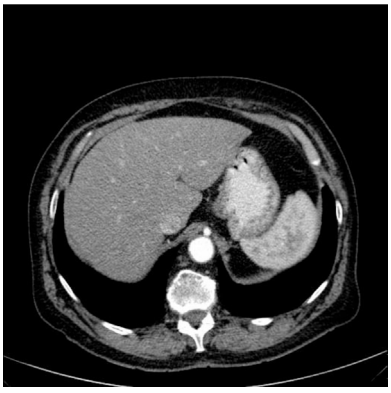

Fig. 2. The abdominal CT image.

Fig. 3. The binary liver image.