Detection of volume data of aortic tissues based on three dimensional domain growing

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Abstract: In general, three dimensional computed tomography (CT) is used in diagnosis of a patient suffering from aneurysm. This medical imaging technique can clearly show the region of blood flow by using contrast agent. Cardiovascular surgeons construct three dimensional volume model based on patient CT data in order to make a surgical plan before surgery. Effective information to diagnosis patient's condition is contained in the computed tomography image, however it does not produce sufficient information for surgical planning. There is a lack of information about aneurysm tissue, so that it makes it difficult to derive a safe surgical plan. In order to overcome this problem, a diagnosis support system is highly required by the co-author cardiac surgeons. In this paper, we built an algorithm to automatically generate a volume model from patient's CT images. This paper presents our image processing methods to extract volume data from patient's CT data, and some volume rendering results are shown in this paper.

Keywords: *Virtual reality, Image processing, Computer aided system, and Surgical planning.*

1. Introduction

For a patient suffering from aneurysm, cardiovascular surgeons displace the diseased artery with artificial vessel according to a surgical plan made by the patient thoracic CT image. Aneurysm often occurs at distant arch aorta part, and then the operation becomes difficult because surgeons have to perform coronary surgery against the arteries connecting to the brachial region and brain by using a heart lung machine before the operation. Important thing of this surgery is to arrive at the aneurysm and ensure the surgical field with a small invasion. And then cardiac surgeons carefully make a surgical plan that determines how to approach to the diseased part and how to replace the diseased artery with artificial vessel by dereferencing to the three dimensional reconstructed model composed of patient CT image.

Computed tomography, especially the one taken by using contrast agent, is commonly used in a diagnosis of patient's aorta condition, where an image is drawn with gray scale as shown in Fig. 1. White areas show bone and vessel. The reason why the vessel region is shown with white color is that the contrast agent flow in vessel and it is reflected on CT image. Meanwhile, contrast agent does not sink in tissue of aorta. As a result, the outer wall cannot be detected clearly from CT image as well as inner region of aneurysm. In aneurysm, thrombus prevents inflow of blood so it is not also shown in CT image. Due to the mentioned reasons, CT image for diagnosis is hard to make surgeons know the statement of aneurysm before patient thoracic incision in operation room. Additionally, because of them, it sometimes happens that the surgical plan is forced to be changed during operation. In the case of the mentioned scene, skilled surgeon breaks through but the operation time and patient physical load are increased.

Against the current situation of cardiovascular field, the co-authors of cardiac surgeon highly require a diagnosis support system for patient's aneurysm that enables the surgeons to see the accurate figure of aneurysm from any view point. In this paper we have built an algorithm that can automatically extract inner region of vessel and reconstruct it as three dimensional model on a computer display. Additionally, we try to extract not only inner region but also outer wall, aorta tissue. This algorithm and some volume rendering results are drawn in the following sections.

Fig. 1 Original computed tomography image

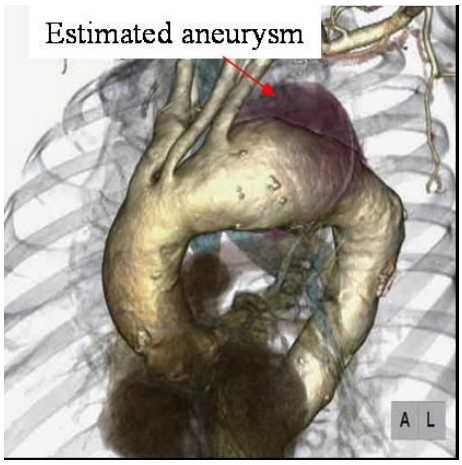

Fig. 2 Estimated aneurysm

2. Current situation

Fig. 2 shows the images generated by the combination of masking images. Masking is a filtering method, where three dimensional organ we'd like to obtain from patient image can be take out by varied the settings of threshold. This figure is composed of the following masking organ, bronchus, bone, and coronary veins. Surgeons use this composed image to estimate the statement of aneurysm before surgery. This masking procedures are manually performed by radiation technicians. In the field of radiology, to make it rapid and accurate to perform the mentioned processes is one of the problem to be solved.

In order to support doctor's diagnosis with patient medical image, lots of techniques for medical image processing are developed and reported. Kitasaka [1] proposed an extraction method for bronchus from patient 3DCT image. They applied region growing to inner volume of bronchus of CT image and sterically reconstructed the extracted volume data on a computer display. Qi Zhang [2] presented a real-time beating heart model by using high performance graphical board, where patient thoracic multidetector CT image are sterically-constructed and continuously switched in order to show a beating motion. Do-Yeon[3] used 3D region growing to extract carotid artery for automatic generation of navigation path. According to earlier studies, region growing is one of effective methods to extract artery. Then, we have adopted this method to recognize the region of aneurysm and extract its volume data from patient 3DCT image.

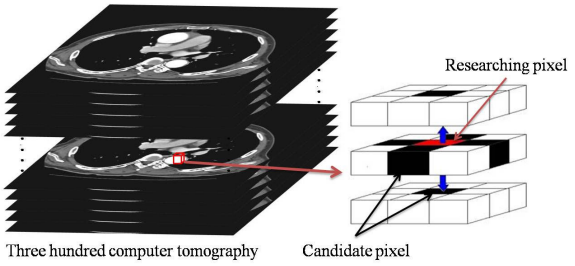

Fig. 3 Schematic diagram of region growing method

3. Method

3.1 Pre-processing

A total number 788 of computed tomography images from patient's thoracic part had been taken. And, consecutive images of 300 image data including the main artery are chosen from the original data set.

As mentioned above, region growing method is an effective extraction method against three dimensional medical images. This method explores the pixel which indicates a part of the target organ by using conditional equations such as threshold and other significant data. In this study, region growing algorithm searches around six pixels as shown in Fig. 3 under the condition of threshold. Depending on the value of threshold, the number of volume data extracted by region growing changes. In this study, we firstly applied region growing in the centre pixel of vessel of the lowest CT image. Selecting the start point for region growing is only one procedure we have to do manually to use our system.

Fig. 4 shows the image taken as the result of region growing, where a white region is region passed the threshold. The higher the threshold increases, the lower the number of volume data passed. Therefore, the setting of threshold has an impact on post-processed image and computation time. We experimentally decide threshold to clearly detect the cross section of vessel.

OpenGL Volumizer that is high level graphics library for volume rendering API is employed in this study. Fig. 5 shows a result of volume rendering taken by applying region growing to the original CT image,

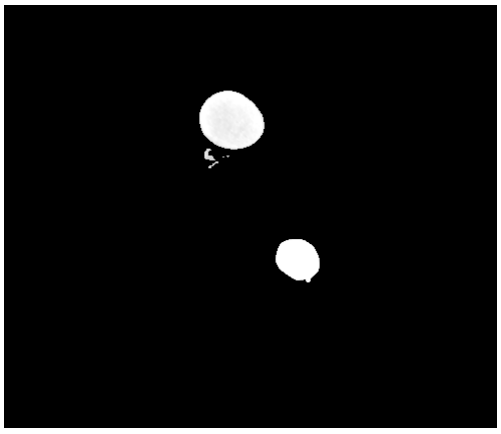

Fig. 4 Result of region growing method

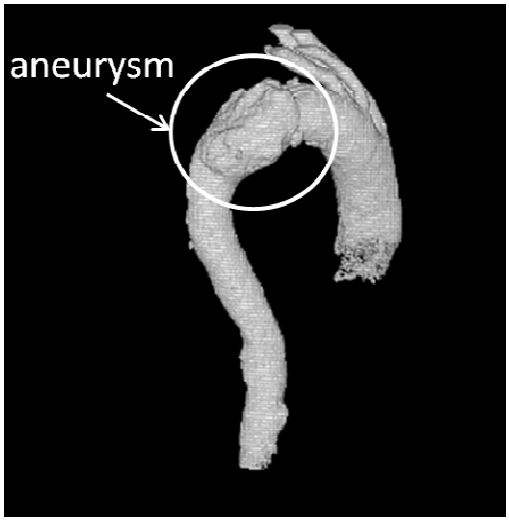

Fig. 5 Result of volume rendering for CT image data

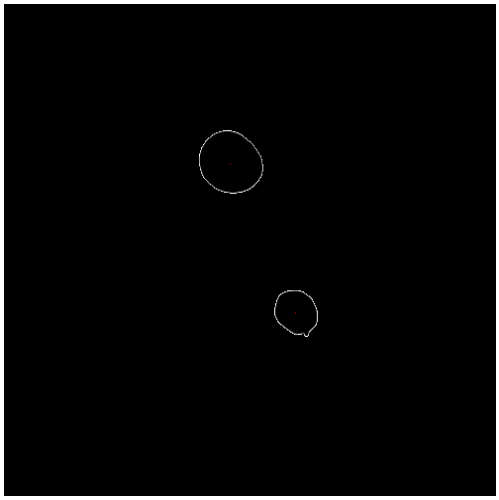

Fig. 6 Result of detect edge

where we can distinguish a part of aneurysm around arch part, and other vessels derived from heart are also remained in the result.

3.2 Extraction aortic outer wall

To render inner region of aorta as three dimensional model is succeeded, but not only aneurysm but also outer wall tissue of aorta is not visualized. The reason why this result, region growing we applied had extracted only high contrast pixels by judging with the threshold. This means that conventional use of region growing is not able to completely detect the region of aorta and aneurysm.

So, we try to apply the following processes to overcome the mentioned problems. First, labelling process excludes the regions in respect to little arteries from figure 3, after this labelling process the cross sections of the arch aorta are clearly shown. Second, Laplacian filtering, described in equation (1), is applied to detect the edge line of aortic cross section. Fig. 6 shows the result of edging process.

$$\nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2} \qquad (1)$$

Fig. 7 shows a cross section of vessel. The blue line shows the edge of inner wall and the red line is the edge of outer wall that we have to automatically detect from patient's CT image. We use region growing again, here it judges the pixel along with the edge of the inner section as shown in Fig. 6. The condition of this application of region growing, a threshold and the distance between the center of cross section and the pixel that is subjected to be processed. In Fig. 7, a radius of inner wall is shown as r(θ), and a radius of outer wall is shown with R(θ).*P*(*x*, *y*) is a value of brightness of the coordinate point that is subjected to be processed by region growing. The square of inner region is easily derived by accumulating total number of white color pixels. It is shown as S. If the pixel has a brightness higher than the threshold and its distance from the center point of inner section is less than r(θ) + R(θ), then this pixel is judged as a part of tissue of vessel and/or aneurysm, where R(θ) is derived with equation (3).

$$r(\theta) = \sqrt{\frac{S}{\pi}} \qquad (2)$$

$$R(\theta) = \text{const} \times r(\theta) \qquad (3)$$

After implementations the mentioned processes, the cross sectional images including a part of outside wall issue as shown in Fig. 8.

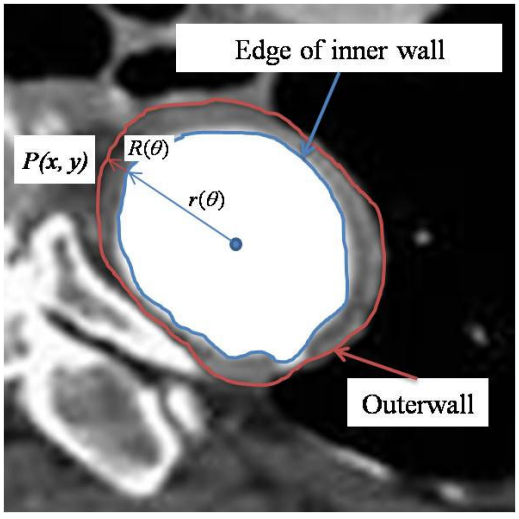

Fig. 7 Scheme of a cross section of vessel

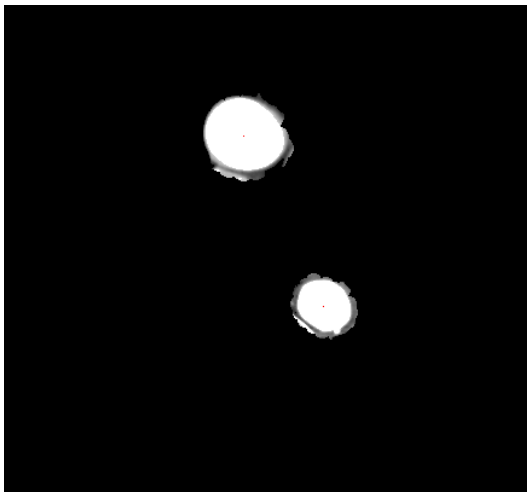

Fig. 8 Result of the second region growing method along to the edge

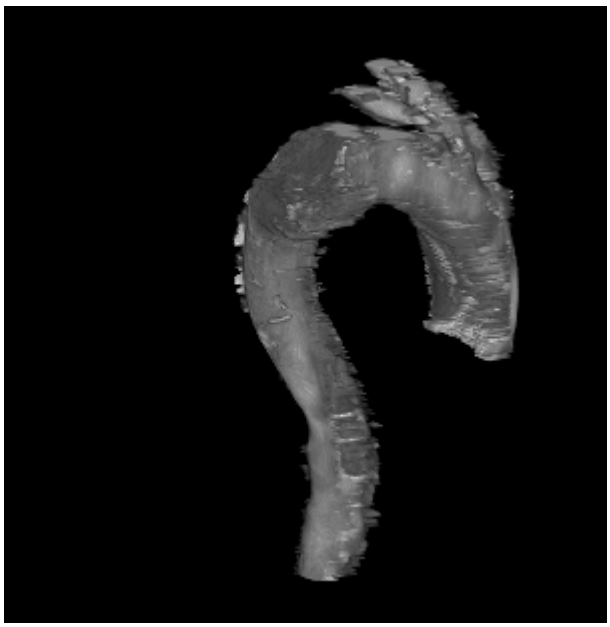

Fig. 9 Volume rendering result executed against the second region growing method

Fig. 9 shows a volume rendering result through OpenGL Volumizer, where approximately 1480000 volume data constructs this volume model. The inner model shown in Fig. 5 is composed of approximately 900000 volume data. The increased volume data is for the volume data of outside tissue of aorta. However, there is a lack of outside of aneurysm at arch part, and we can find this volume model is not smoothly composed. Because of them, the conditions of region growing were not enough to detect accurately the tissue of aorta.

4. Discussion

Due to difficulty to let computer recognize the tissue of aorta, cardiovascular surgeons cannot accurately know the shape of aneurysm of patient. So, the surgeons expect the development of diagnosis support system for patient aneurysm before surgery.

In order to recognize the region of aortic tissue from patient's thoracic CT data, a method of region growing is applied two times. First use succeeded to detect the inner region of aorta that reflected with high contrast. And after edge processing against inner region of aorta, second region growing is applied along with the edge. However, this method extracted a part of the outer tissue of aorta.

In order to extract all pixels of outer tissue, we have to firstly detect the edge of outer tissue of vessel and aneurysm based on the skill of doctor's interpretation of radiogram. Recently some report applies Fuzzy inference to image processing. By optimizing Fuzzy set, membership function and so on, some reports have succeeded to extract the edge of object from image such as fruits, vegetables, and signal plates. Application of Fuzzy inference has possibility to complete our purpose [5]. If the edge of outer wall and/or the region of aneurysm can be detected, region growing has possibilities to extract the most of pixels of aneurysm.

References

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