

The steps about the three Dimensional Modeling of Bioprosthesis

Heart Valves Based on CT Images

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Abstract: In this paper, we use the reverse modeling softwares to complete the reconstruction of the aortic valve based on the modeling principle of the human heart valve. By using the cardiac CT scanning to get the Dicom format data and then using the three-dimension software Mimics to do the segmentation, edit, smooth processing to get the more realistic, the more precise structural heart valve model and peripheral blood in STL format surface model appearance. Then we mix up the two models in Geomagic Studio for further optimization. Finally we can get the model of blood and heart valves[1,2]. After importing the model into ANSYS Workbench for further treatment, we can get the model of the blood and the arterial wall preparing for the next finite element analysis about the leaflets and the arterial wall[3,4].

1. Introduction

Medical imaging is a subject that uses the methods of medical imaging for medical services. It is not only used for non-invasive examination of medical diagnosis and anatomical structure of human body, but also used in computer simulation and operation simulation in the analysis of engineering field[5,6]. As you know, the structure of the human heart valve is special, and the surface of the valve is changed obviously. So, it is difficult to establish the accurate model of the valve model which is consistent with the real heart valve. While the rapid development of medical imaging technology and computer technology in recent years has made the image information in the accurate extraction of medical imaging equipment to complete scanning of the anatomy, finding the precise shape required for organ a significant progress. All in all, medical imaging is an important symbol of the rapid development of medical imaging technology, and it is also the only way to the development of computer simulation of human organs.

2.steps

2.1 Image Acquisition .The data acquisition of the subject is a 30-year-old healthy male without heart disease, cardiac and thoracic trauma. We use the CT scanning imaging device(Model:GE MEDICAL SYSTEMS/Discovery CT750 HD, Working Voltage: 120KV, Working Current: 102.60mAs, Exposure Time: 228s) to scan then we get the human heart (CT) data, image width: 512mm, height: 512mm, pixel: 0.488, slice thickness: 0.625mm, and the scanning number is 209. Finally, we move

the the Dicom image which can clearly show both the sagittal sectional and the continuous cross-sectional images about the aortic valve (Fig. 2-1) to the mobile hard disk by the workstation ,as the modeling data of the blood and aortic valve.



Fig. 2-1 The Aortic valve on CT image

2.2 Image import. Use Mimics to import the file into the computer, and then select the heart image data that we want to use in this modeling. The Mimics can automatically extract a series of individual image information. After the picture imported, it will displayed with three views as shown in (Figure 2-2): the right view scanned along the direction of the exit is called axial view (xy-view), the upper left corner of the view scanned along the direction of Z axis is called a coronal view (xz-view), the lower left corner of the view scanned along the direction of X axis is called the sagittal view (yz-view).

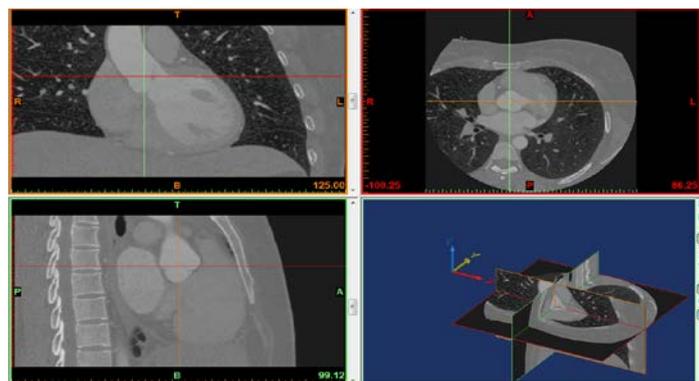


Fig. 2-2 Images after imported

2.3 Model generation. Five steps are contained in these parts: threshold analysis; image editing; regional growth; Calculation; Optimization of the three dimensional model and redivision of the mesh. And it will be introduced one by one.

The threshold is used as a image segmentation tool. And when the minimum value is 300, it can meet the requirements of the aortic valve being selected in this paper. After pointing the "apply" button, a green mask will be generated at the right interface bar.

Doing the image editing, you should clear the part not related to the picture and fill the holes which will have a great impact on the finite element analysis.

Regional growth: In the above step, the selected green areas are scattered, and the distance from the target area is too large, so it is necessary to separate the non-connected structure in the green area, and drop the pixels which are not clear. Click the regional growth button or press Ctrl + R, then the dialog box will be popped up.

Calculation: The options used to calculate the 3D model is the right "Calculate" tool for modeling. If you want to select multiple masks, you should hold down the CTRL key and select another mask.

About the Optimization of the three dimensional model and redivision of the mesh, there are 3 steps.

1) Select the "remech" tool on the right toolbar to Redivide the mesh of the 3D model so that it can be better used in the finite element analysis.

2) After the completion of the optimization of the aortic surface, we get a smooth artery and the model will be exported and saved as STL format file. In order to get the heart valve model, We need to shell part of the artery, by using the graphics design tool.

3) In order to get the model of the valve leaf, we use the shear command  under the surface treatment tool of Finish. Cutting along the upper part of the carotid sinus and in (Figure2-3) direction, we can get the(Figure 2-4) model save it as STL format.

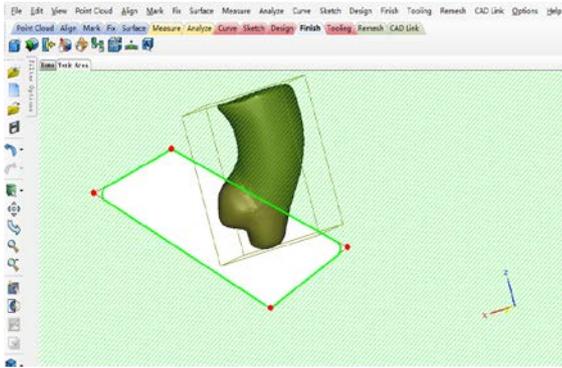


Fig. 2-3 The shear sketch map

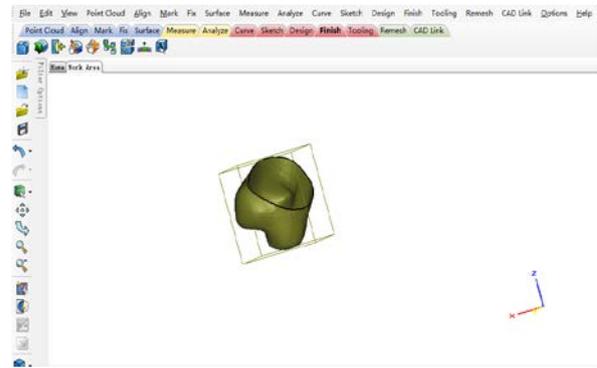


Fig. 2-4The shear completed graph

Importing the cut leaflet model into the Mimics, using the simulation tools  to divide them into valve1, valve2 and valve3 in ,then save them as STL format.

Then import the optimized model of the aortic blood body to the Mimics, and construct a section of the artery at the lower part of the valve. In the region growing step by using multi layer editing commands in accordance with the above steps to edit, the same final 3D model is generated, and use the Boolean operations to get a complete blood model.

Finally, Select "tools in the smooth interface above the Toolbar" (smooth mask) , and do the triangle processing ,mesh refinement and optimizing on the new blood model. After that, we can get the optimized blood model, and save the output model as STL format.

2.4 Model optimization.Because the surface of the heart valve model is complex and changeable and the curvature of each leaflets is large, it is difficult to meet the requirements that needed in the finite element analysis . In this paper, We will use the reverse engineering software Geomagic Studio to Further optimize the model.

There are three steps: Firstly the point cloud stag: Removing the irrelevant and noise points, optimizing the number of points cloud, packaging should be done; Next is the Polygon stage:it contains Polygon repair, removal of excess parts, quantity adjustment, smooth processing, detection and correction ;The final is the surface stage: it includes the outline construction, the patches construction, the grid construction and fitting surface .

2.5 Imported to workbench .Open the finite element software Workbench, then get into the Design Modeler interface, select the external geometric model, and import the saved blood valve model, later you will get the aortic wall model and valve model shown in (figure 2-5).

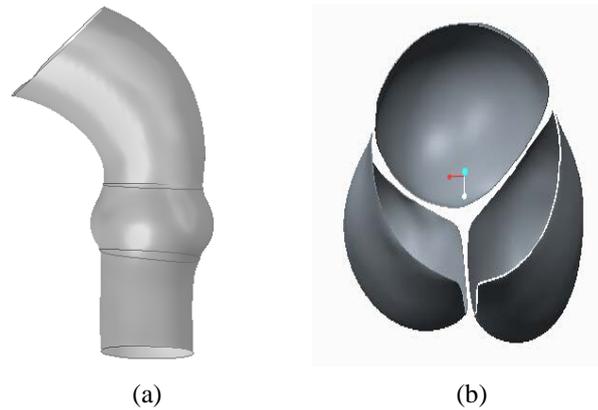


Fig. 2-5 The aortic wall (a) and heart valve (b) model

Summary

With the improvement of the science and technology, medical imaging is developing rapidly. It not only serves the medical field, but also provides a reliable data for the generation of 3D model. In this paper, all the data is acquired from the CT scanner and directly imported to the 3D generation software Mimics. The whole modeling process is: Firstly, we use the CT scanning equipment to get the data of the heart valve saved in Dicom format; Then, by using the Mimics software to import the image into the computer to do the segmentation, editing, multi layer editing, hot extraction and region growing operations, we can get the aortic segments above the valve ,and using the remech tools to smooth, to do the triangle processing ,to optimize, to use the shell command and shear command, we will generate the model; Later, we use the Mimics to cut apart the model of the three valve leaflets by the order of linear cutting, to derive STL format model of valve leaves .Finally, we should import the model stored in STL format into Geomagic software for processing, to get the final output of the valve and blood entity mode. After leading the valve and blood model into ANSYS Workbench for treatment, the model of the valve and the arterial wall will be obtained.

References

- [1] Schoen F J, Levy R J. Calcification of tissue heart valve substitutes: progress toward understanding and prevention [J]. *Annals of Thoracic Surgery*, 2005, 79(3):1072-1080.
- [2] Philippe P, Dumesnil J G. Prosthetic heart valves:selection of the optimal prosthesis andlong-term management[J]. *Circulation*, 2009, 119(7):1034-1048.
- [3] W. Vongpatanasin, L.D. Hillis, R.A. Lange. *New Engl J Med* 1996; 335: 12-14.
- [4] D.Y. Li, L.M. Li, Y.H. Peng.*AdvSciLett* 2011; 4: 30-37.
- [5] J. Turina, B. Jamnicki, R. Hug, M.I. Turina.*Circulation* 1999; 100: 75-84.
- [6] Qian Ruojun, Dong Shilin , Yuan Xingfei. *Advances in research on fluid structure interaction theory. Spatial structures* 2008; 134; 45-57.