Interactive Cardiovascular Editor Using Echocardiographic Images

*M. Nakao[1], Y. Masuda[2], R. Haraguchi[3], K. Kurosaki[3], K. Kagisaki[3], I. Shiraishi[3], K. Nakazawa[3] and K. Minato[2]

[1]Graduate School of Informatics, Kyoto University
[2]Graduate School of Information Science, Nara Institute of Science and Technology
[3]National Cerebral and Cardiovascular Center

Abstract

We propose a three-dimensional cardiovascular modeling system where medical doctors can interactively construct patient-specific cardiovascular models based on neonatal echocardiographic images, and share the complex topology and the shape information. For the construction of cardiovascular models with a variety of congenital heart diseases, we propose a set of algorithms and interface that enable editing of the topology and shape of the three-dimensional models. The cardiovascular models generated from some patient data confirmed that the developed technique is capable of constructing cardiovascular disease models in a tolerable timeframe.

Keywords: Interactive editing, vascular model, echocardiogram

1 Introduction

In this study, we present a cardiovascular modeling system not only using echocardiogram images but with the simple interaction to the model by the user. Since echocardiogram images do not include complete information of the anatomical structures, conventional segmentation-based approaches have difficulty in representing detailed structures of the vessels. We utilize a deformable template to interpolate anatomical features common to sparsely selected images, and introduce topology-editing interface to easily create a cardiovascular model.

2 Cardiovascular Model and Editing Algorithms

With surface mesh models, mesh subdivisions and collision detection is needed to edit the shape and the topology. Also, the radius of the vessels is not easy to handle. We define a cardiovascular centerline for a skeleton S_i comprising nodes and edges. For the construction of cardiovascular models with a variety of congenital heart diseases, we propose algorithms and interface that enable editing of the topology and shape of the three-dimensional models. In order to facilitate interactivity, the centerline and radius of the vessels are used to edit the surface of the heart vessels. This forms a skeleton where the centerlines of blood vessel serve as the nodes and edges, while the radius of the blood vessel is given as an attribute value to each node. Parent-child relationships are given to each skeleton. They are expressed as the directed acyclic graph (DAG), where the skeletons are viewed as graph nodes and the connecting points are graph edges. (Fig. 1) For the details of our algorithms and interface, see [1].

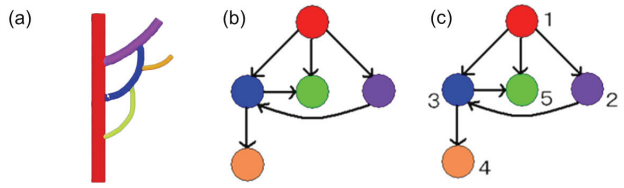

Fig. 1 Topological sort of the skeletons for topology-based editing.

The 21st International Conference on Artificial Reality and Telexistence
November 28-30, 2011, Osaka, Japan
ISSN: 1345-1278

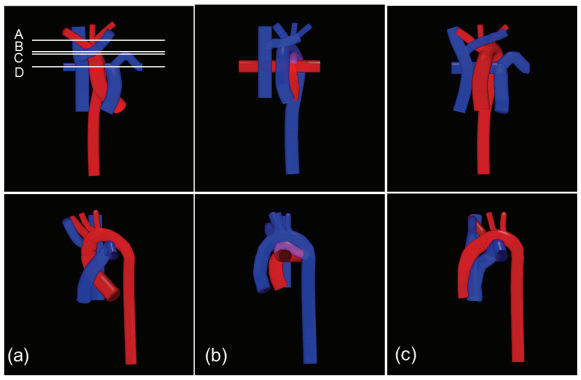

Fig. 2 Cardiovascular modeling results from a template model.

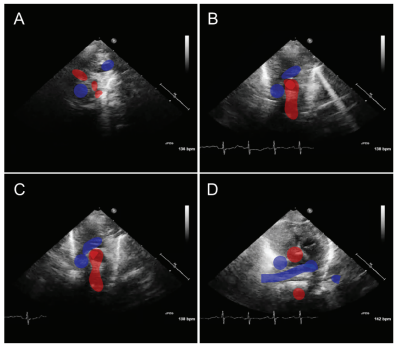

Fig. 3 Editing interface for manipulating cross sections of the model.

3 Results and Conclusion

Fig. 2 shows the interactive editing results from a normal cardiovascular template model. It took approximately 5-7 minutes to complete each model. The aorta and pulmonary artery form a helical shape in the normal heart and the modeling results confirmed that this feature could be expressed. Fig. 3 displays echocardiogram images and cross sections of the cardiovascular model on the four planes A, B, C and D depicted in Fig 2a. We note the cross sections include the branch and small vessel structures that cannot be extracted from the echocardiogram images. The user only indicates the correct 2D position of the vessels based on the information clearly revealed on the reference echocardiogram images. However, our system can generate 3D cardiovascular models that satisfy user's knowledge from the partial or incomplete anatomical information given on the arbitrarily selected 2D planes. Our approach can support representation of the patient-specific heart vessels for better understanding in preoperative planning and tele-diagnosis.

Reference

[1] M. Nakao, K. Maeda, R. Haraguchi *et al*, "Cardiovascular Vessel Modeling of Congenital Heart Disease Based on Neonatal Echocardiographic Images", IEEE Trans. on Information Technology in Biomedicine, 2012. (in press)