# A SYSTEMATIC USER INTERFACE FOR MODELING MAJOR ARTERIES USING A COMBINED PARAMETRIC AND IMAGE-BASED METHOD

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## ABSTRACT
A comprehensive modeling and analysis system for the computational fluid mechanics application to clinical cardiovascular medicine is developed. Large arteries including the aorta were modeled using a combination of differential geometrical method and an over-set grids method. Sophisticated graphical user interface was developed to build computational models based on clinical medical images. Delicate branch shape could be reproduced in the model by adjusting it with the images. Some preliminary computational results showed the potential of the proposed method.

## INTRODUCTION
It is conventionally considered in the modeling of arteries and the heart that parametric and realistic methods are substantially different approaches. In the former, some characteristic configuration of the vascular system is modeled using simple and elementary geometrical modeling. In the latter, direct segmentation, registration, and vectorization of complex anatomical structures from medical images are carried out. In the former, though contributions of various factors in the geometrical variations to the blood flow can be studied, some extents of oversimplification are thought to be unavoidable. On the other hand, in the latter, enormous work is necessary to depict the details of the complex geometrical factors of the real artery, which, in turn, sometimes conceal the essential cause and its outcome. These problems should be solved before we try to apply the computational method to the daily clinical practice.

## PARAMETRIC AND REALISTIC MODELING OF THE LARGE ARTERIES
We therefore proposed the so-called differential geometrical method of modeling arterial trees as a method that combines these two directions of modeling methods. In our method, vascular trees are represented using their centerlines and their normal planes defined by a combination of normal and binormal vectors. Each branch is modeled separately and connected using an overset (or a chimera) mesh technique when fluid mechanical computations are made. To evaluate the devised method, we constructed an aortic arch model for CFD simulations that incorporates both non-planarity and the major branches, based on a set of MR images.

Our basic idea is that the branching structure of the aortic arch can be crudely simplified as a main pipe, i.e., the aortic arch, with three (or more, as necessary) major branches connected to it. Using the differential geometry modeling method devised and applied in our previous study, the aortic trunk and the three branches were individually constructed based on their centerlines using 3-D reconstructed MR images. There were regions in each model in which the corresponding computational grids overlapped, where we combined the element models to form a single computational domain of the arch with its branches. To model each vessel geometrically, we devised an interactive clinical interface for MR images. Fig. 1 shows an MR image, and the CFD model constructed on it within a graphical user interface window. Details of the branch point are shown in Fig.2. By magnifying the image and the model at the same time, a user can adjust the finer details of the branch wall. The overlapped grids can also be detected and controlled by an inspection in the interface window. Fig.3 shows the method to correct the acute angle of the branch junction wall by controlling the aortic wall as well as the branch artery wall semi—automatically.

## PRELIMINARY ANALYSIS
To use the overset grid method, the velocity vectors and pressure for each grid in the overlapping regions must be interpolated and transferred from one region to the other at every computational step. The transferred data were always regarded as part of the boundary conditions in the recipient region. The CFD computations used a commercial program, SCRYU version 1.4 (Software Cradle, Osaka, Japan). The 3-D unsteady Navier-Stokes equations for the incompressible flow were solved. The solution was advanced in time using a finite volume method of discretization. The boundary conditions were a steady uniform velocity perpendicular to the cross section at the aortic inlet, no-slip at the wall, zero pressure and zero velocity gradient at all the outlets. The Reynolds number defined using

the diameter and the inflow velocity was 1600. Figure 4 shows the wall shear stress distribution in which a specific concentration of the high shear stress area on the aortic wall occurs because of the curvature and the torsion of the main trunk of the aorta.

## CONCLUDING REMARKS

This study demonstrated that the combined method of differential geometrical modeling based on the vascular centerline, with overset meshing for the branches, is a powerful means of conducting a CFD analysis of the blood flow in the aortic arch. Current work is in progress to construct a more realistic CFD model using the database of medical images.


## ACKNOWLEDGEMENT

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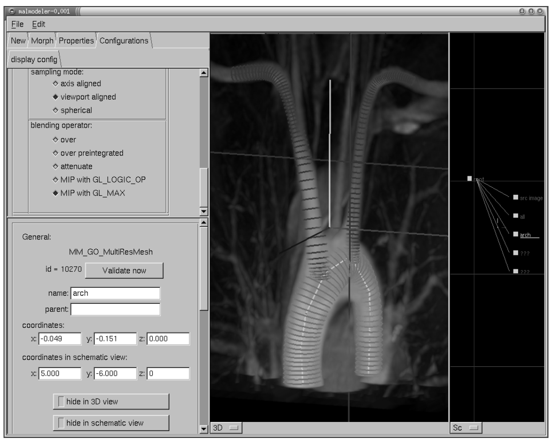

**Fig. 1 A graphical user interface screen showing the 3D reconstructed MRI image of the thoracic part of the aorta and its major branches. A set of computational grids are also shown by overlapping on the image.**

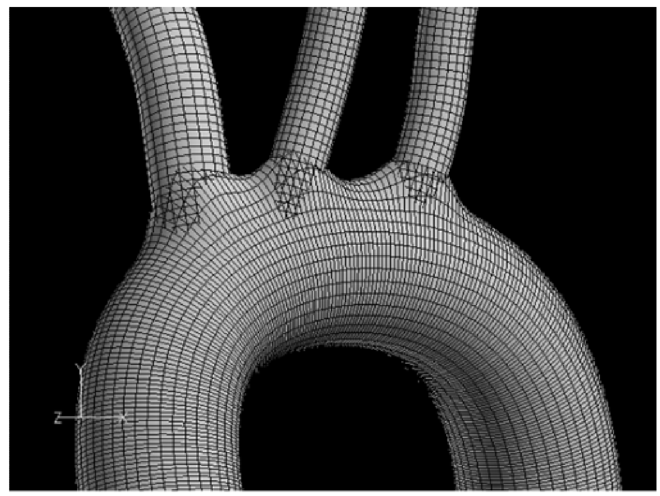

**Fig. 3 A result of semiautomatic smoothing for the branch junction wall. The aortic wall as well as the branch wall are adjusted to make the junction smooth.**

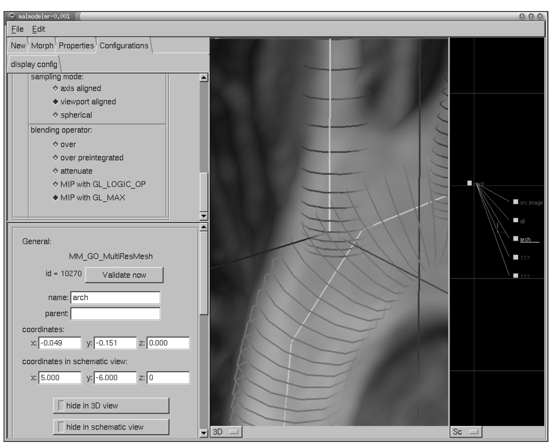

**Fig. 2 A close up of the branch wall around the brachiocephalic artery and the aortic arch.**

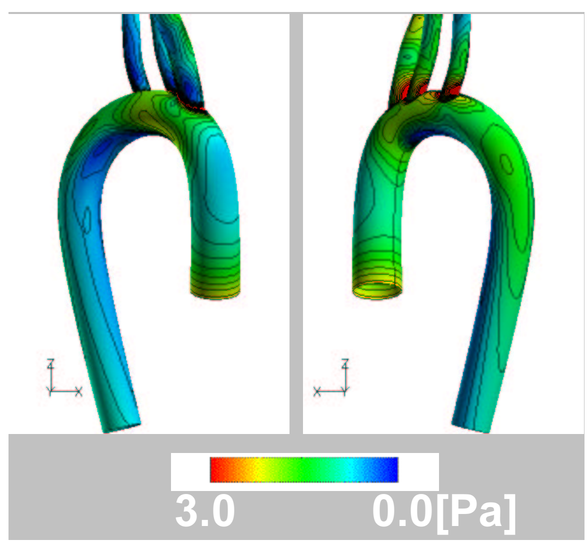


**Fig. 4 A preliminary result of the wall shear stress distribution computed by using the present method of modeling.**