# The Vasculature of the Heart: An Interactive Guided Tour

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## Abstract

Coronary heart disease (CHD) is the number one killer in the United States. Although it is well known that CHD mainly occurs due to blocked arteries, there are contradictory studies about what the basic cause for this disease is. To find out more about the true reason for CHD, virtual models can help to better understand the way the heart functions. With such a model, scientists and surgeons are able to analyze the effects of different treatment options, and ultimately find more appropriate ways to prevent coronary heart diseases. To aid in this endeavor, a geometric model of the vascular system of the heart has been developed, which considers vessels of different sizes, including even the very complex capillary level of the arteries.

To effectively explore and interpret a cardiovascular tree, the dataset needs to be displayed both from a global point of view (overview map) and from an interior point of view (fly-through mode). Different views of the same tree provide a variety of geometrical and structural information. Being able to switch between an external and an internal view of the vascular structure or being able to observe both views simultaneously enables the user to efficiently accomplish a variety of data exploration tasks including locating a feature by navigating to a particular region of interest and taking measurements of the data. The exterior view of the tree allows for a global examination and measurement of individual features, such as distances, while an interactive, guided or free fly-through provides detailed information about the interior of the cardiovascular structure, for example bifurcation angles and diameters of vessels.

The implemented system offers both an exterior and an interior view of the data. In the exterior view, the camera and viewpoint stay fixed, while the complete object moves in front of the user. Individual segments can be picked, highlighted, and labels showing quantitative information about a segment can be attached. Analysis and measuring tools allow for precise determination of, for instance, distances between different vessel segments, the length of such segments, and angles at bifurcation points. In addition, by means of visual inspection, efficient validation of the simulated vascular tree helps to quickly identify areas of interest and potential problem zones.

A dynamic fly-through simulation of the vascular tree allows the inspection of the interior anatomy in real time. The data can either be explored in manual mode or in a guided interactive mode governed by a smooth traversal of the tree, traveling along the center line of the vessels. At each bifurcation either a pre-defined path is chosen or the path can be picked interactively. Modes can be switched at any time. In the currently implemented system, various manual navigation modes are available during the fly-through. The user has complete manual control over the position and orientation of the camera and/or the viewpoint, while the object stays fixed, thereby providing an experience similar to steering a submarine, with the additional benefit of automated collision avoidance.

Traditional desktop environments usually utilize only keyboard and 2D mouse for interaction. For steering in a 3D scene, a 2D input device obviously has its limitations. To overcome the restrictions of these traditional input devices with limited degrees of freedom, an additional cordless USB input device for navigational control is added to the desktop. As a result, the system provides a flexible low-cost 3D virtual environment, which enables efficient and intuitive 3D navigation. In the current implementation, the Logitech© WingMan® Cordless Rumblepad™ was chosen as the main 3D interaction device, because it provides two analog joysticks that emulate six-degrees-of-freedom input.

The software is scalable to various virtual environments (VEs). Such a VE facilitates the simulation of computer-aided diagnoses similar to those obtained in real-world surgery environments. In the future, we plan to evaluate different navigation modes and input devices for a comparison with traditional real-world endoscopic navigation. In addition, we are going to investigate in a user study if other features of this type of input device, such as the rumble capability of the gamepad, can be used to enhance the user experience when a collision with a vessel wall occurs.

Figure 1: A cardiovascular tree with measuring tool (left) and a user interactively flying through the vasculature (right).

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