Virtual Exploration of a Cardiovascular System

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Virtual biomedical models can help to better understand how diseases affect the function of parts and organs of the human body. By thoroughly exploring such a model, scientists and surgeons are able to analyze the effects of different treatment options, and ultimately find more appropriate ways to prevent diseases. Specifically a virtual model of the vascular system of the heart can aid in finding out more about the way the heart functions, and might give insights in what causes conditions such as coronary heart disease (CHD), which still is the number one killer in the United States. We have developed a system which allows the exploration of a detailed geometric 3D model of the cardiovascular tree in a scalable virtual environment in real time.

The implemented system offers both an exterior and an interior view of the data. The exterior view of the cardiovascular tree allows for a global examination and measurement of global distances. The camera and viewpoint stay fixed, while the vascular tree moves in front of the user. Individual segments can be picked or highlighted. Labels attached to selected segments show quantitative information about the data. 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.

The interior of the cardiovascular tree can be inspected during a dynamic virtual fly-through simulation, which provides a view comparable to a traditional endoscopic examination. This 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 camera and viewpoint travel along the center lines of the vessels during the guided exploration, thereby enabling a smooth traversal of the tree. At each bifurcation either a pre-defined path is chosen or the path can be picked interactively. At any time, the navigation mode can be switched to manual. Here, the user has complete manual control over the position and orientation of the camera and/or the viewpoint, while the vascular tree stays fixed. The user is free to roam the current vessel segment. Thereby, the system provides an experience similar to steering a submarine.

The dataset can be displayed both from a global point of view (overview map) and from an interior point of view (fly-through mode), thus enabling effective exploration and interpretation of the cardiovascular tree. 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.

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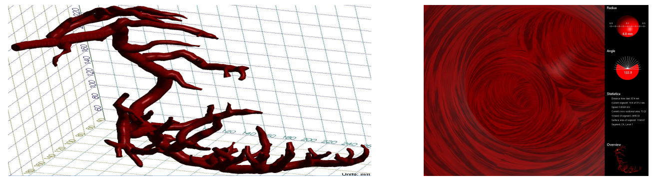

Figure 1: Exterior and interior view of a cardiovascular tree (left circumflex [LCX] coronary artery).

Figure 2: The Logitech© WingMan® Cordless Rumblepad™ in a desktop environment.

Since we want to effectively explore the 3D model, a 2D input device, such as a desktop mouse, obviously has its limitations. An additional cordless USB input device supplements our system and provides unrestricted navigational control in 3D. 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 several digital and 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.

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