Force-Feedback-Enhanced Navigation for Interactive Visualization of Coronary Vessels

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Figure 1: Different input devices supported by the exploration system: Logitech's WingMan Cordless Rumblepad (left), Primax' Raptor 3D joystick (center), and Microsoft's SideWinder force-feedback steering wheel with race car pedals (right).

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 results from studies designed to identify basic causes for this common disease is. To find out more about the true reason for CHD, virtual models can be employed 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 suited ways to prevent coronary heart diseases. To investigate a given model, appropriate navigation methods are required, including suitable input devices. For the visualization, graphics cards originally designed for gaming applications are used; so, it is a just natural transition to adapt gaming input devices to a visualization system for controlling of the navigation. These devices are usually well designed with respect to ergonomics and durability, yielding more degrees of freedom in steering than two-dimensional input devices, such as desktop mice. This poster describes a visualization system that provides the user with advanced control devices for navigation enabling interactive exploration of the model. Force-feedback and sound effects provide additional cues.

Force-Feedback-Enhanced Navigation

Virtual biomedical models can help to better understand how diseases affect the function of organs and parts 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). Exploring such a model and visually inspecting certain regions of interest is usually limited by restrictions of traditional input devices, such as keyboard and mouse, often resulting in a non-intuitive and difficult to use visualization system. To improve navigation, one could use expensive input devices, such as pinch gloves [3], which are commonly used in virtual environments. Newer approaches [2] use a *finger sleeve*, for instance, combining a regular six degree-of-freedom (6DOF) tracker with two buttons attached to the index finger. Both approaches rely on costly tracking devices that are usually not installed on common desktop computers. To create a natural environment for artists in a CAVE®, Keefe et al. [1] employ painting devices, such as paint-brushes, as tracked input devices. Zhai [5] compares different 6DOF input devices, some of which are derived from 2D devices, such as a mouse, and analyzes their performance when used by different test persons. He showed that there is no optimal input device so far that fits all the needs of the user while using the different systems. In a similar tube-shaped environment than the one presented in this poster, Wan et al. [4] derive an optimal path for an automatic flight through a colon based on a distance field approach to avoid collision with the colon walls.

In this work, a visualization system for cardiovascular trees has been developed, which enables the exploration of a detailed geometric 3D model of the cardiovascular tree within a scalable virtual environment in real time. To improve control and navigation, different standard gaming devices were utilized for changing the view position, enabling the user to zoom, pan, and rotate, as well as navigating through the interior of the model. The advantage of these gaming devices is their low cost (usually under $150), wide availability, universal applicability, good support through DirectInput, easy calibration, ergonomical design, high robustness, and flexibility through a number of programmable analog and digital axes and ergonomically placed buttons.

In the visualization system, 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. Using an input device similar to the Logitech© WingMan® Cordless Rumblepad™, which is shown in figure 1, can greatly improve the usability and ease of navigation due to its two built in joystick devices. Such a four-axial input device then

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enables the user to zoom, rotate, and pan the object all at the same which would not be possible with typical desktop input devices, such as keyboard and mouse.

The interior of the cardiovascular tree as depicted in figure 2 can be inspected during a dynamic virtual fly-through simulation, which provides a view comparable to a traditional endoscopic examination. This interactive, free fly-through provides detailed information about the interior of the cardiovascular structure, for example bifurcation angles and diameters of vessels. The user has complete manual control over the position and orientation of the camera and/or the viewpoint, while the vascular tree always stays fixed. The user is free to roam the current vessel tree as shown in figure 3. Thereby, the system provides an experience similar to steering a submarine.

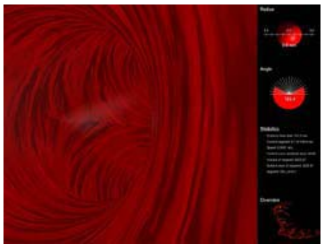

Figure 2: Interior view of a cardiovascular tree (left circumflex [LCX] coronary artery).

The goal is to design a system that is easy to use and allows for an effective exploration of the 3D model. Therefore, a 2D input device, such as a desktop mouse, obviously has its restrictions due to its limitation to just two axes allowing for a 2DOF navigation. Gaming input devices usually offer more than two-axial controls resulting in a better and often more intuitive navigation. As an example, the Logitech WingMan Rumblepad has two analog joysticks built in. Using one of these joysticks for moving the viewpoint up and down or left and right, while the second one moves the camera back and forth or rotates it, enables the user to easily navigate through the vascular structure and to obtain an arbitrary viewing position. This allows for a detailed investigation of any region of interest. Similarly, other input devices, such as the Primax® Raptor 3D joystick or the Microsoft® SideWinder Force-feedback steering wheel shown in figure 1 can be used as input devices for this system. The lack of a sufficient number of axes in the latter device can be compensated by emulating an axis with two buttons for up or down movement, respectively.

Figure 3: A user in front of the visualization system using Microsoft's SideWinder Force-feedback wheel.

The system utilizes Microsoft DirectX®, thus being able to support virtually any kind of gaming input device for which drivers are available. A general interface based on DirectInput, where buttons and axes provided by the gaming device can be mapped arbitrarily to the controls of the system, allows for a setup tailored to the requirements of the user. During the navigation through the vascular tree, collision detection with the vessel walls ensures that the camera cannot leave the structure.

Additional haptic and auditory cues enhance the navigation. Force-feedback features of the input device are used to signal the collision. In this case, a force is induced on the gaming device proportional to the speed and angle of the collision between camera and vessel wall. The harder the camera hits the vessel wall the stronger the repelling force will be. Sound effects using DirectSound accompany this signal to provide additional cues.

Besides allowing for a more intuitive navigation and steering in a virtual environment, gaming input devices have another advantage: they are usually ergonomically well designed, often with a compact casing. In case of the Rumblepad, for instance, this results in a flexible low-cost 3D virtual environment, which enables efficient and intuitive 3D navigation. Due to the compact size and the cordless connection of this gaming device, the user can freely move in front of the display screen. Its buttons ergonomically located in the back can be easily reached and used without changing or shifting the position of the hand and allow for untethered control of the system without having to use keyboard or mouse at all.

Overall, this work presents a visualization system for vascular structures that is easy to use due to the utilization of intuitive gaming devices for navigation through the structure as well as control of the external view, including zooming, panning, and rotating. Choosing ergonomically well designed devices equipped with several buttons and axes results in a system that no longer depends on traditional input devices, such as keyboard and mouse, at an increased rate of usability.

Since different input devices are suitable for different application areas, user studies will be conducted as part of the future work. It is already obvious that gaming devices, which are tailored to racing simulations, such as the steering wheel, have its limitations in this type of application. Regular joysticks, such as the Raptor 3D, and gamepads, such as the Rumblepad, seem to be much more appropriate and give a far more natural and intuitive navigation than standard input devices, such as keyboard and mouse.

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