Virtual Reality for Studying Cardiovascular Anatomy by Assembling Elements

J.J. Reyes-Cabrera[1], J.M. Santana-Núñez[1], A. Trujillo-Pino[1], M. Maynar[2] and M.A. Rodriguez-Florido[2]

[1]Imaging Technology Center (CTIM), University of Las Palmas de Gran Canaria, Spain
[2]Chair of Medical Technology (CTM), University of Las Palmas de Gran Canaria, Spain

Abstract

Virtual reality (VR) is a very powerful tool for educational programs. In this work, we present a VR prototype for educational purposes in the subject of human anatomy. Our application suggests the users (i.e. a medical student) to assemble moldable elements of the human anatomy (in particular, a part of the circulatory system) and tests their performance in this task by checking the correct anatomical connection between the provided pieces. In this proposal, we show a brief description of the elements in the system, with a special focus on the dynamic modeling of the vessels. The manipulation of these vessels and their connections for VR users was the focus of this prototype. Ultimately, this document introduces our proposal for a holistic VR educational environment oriented to the teaching of human anatomy.

CCS Concepts
• ***Applied computing*** → ***Interactive learning environments;*** • ***Human-centered computing*** → ***Visualization;***

1. Introduction

In recent years, several studies have been carried on the use of VR in medical education. For example, Falah et al ([FCK*14]) have developed a real-time 3D representation of the heart in an interactive VR environment that provides self-directed learning and assessment tools.

In this project, we present a teaching tool prototype based on the idea of learning anatomy by building it yourself. We use the Oculus Quest 2 HMD to allow the users to interact with a variety of anatomical parts around the heart (aorta, ventricles, vertebrae...) so that they can connect them and build a part of the circulatory system. The application assesses whether an action is correct or not, and can inform the user accordingly. All this work is supported by the Chair of Medical Technology at the ULPGC which has contributed with its medical expertise.

2. Main components

Initially, focusing on the vessels around the cardiac system, different components have been modeled and included to represent these regions (with great emphasis on the aorta). The reason for adding more human parts is that the user can find an interaction between the vessels and these objects or use them as a visual reference. The interactable objects, which were deemed of interest of the medical experts, are:

- Ribs and vertebrae.
- Heart: Ventricles, atria and valves.
- Vessels: Aorta, superior vena cava, inferior vena cava and pulmonary artery. Also, the aorta is separated in 4 parts (ascending aorta, aortic arch, descending thoracic aorta, descending abdominal aorta) and is connected to different branches.

3. Vessel meshing

The 3D object that represents a vessel is the most complex one, since each vessel can be bent. Our application generates a specific mesh for each one, and uses different techniques to get a shape as realistic as possible, that can be dynamically deformed. Using a cubic Bézier curve, the system generates all these vessels and controls how they bend.

In this stage of the process, the form of the mesh is computed using the Bézier control points. We use a different amount of points depending on the size or the shape of the vessel. With these points, we generate a group of sixteen vertices around each of them and form a cylindrical surface. This amount increases if that point is near the beginning of a branch. Moving these vertices to the direction of the previous and next points of the curve, the circular form of a bifurcation is created. This algorithm has been implemented so that it is not computationally intensive, in order to be recalculated in real-time. Additionally, we only compute this process when the control points are moved.

Once the vertices have been computed, the next step is to triangulate the mesh. In this process, the application creates all the triangles that represent the shape. This is only calculated when the dynamic mesh is created. In figure 1 there is an example.

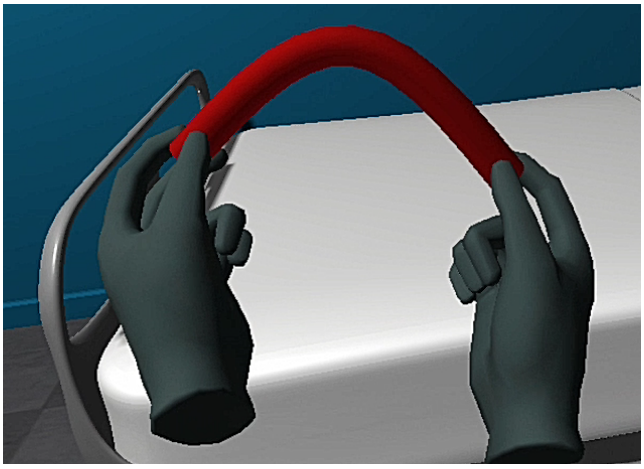

Figure 1: *Users can handle and bent the vessels*

4. Grabbing and Connections

In the opinion of the particular experts, a realistic and natural behavior is essential for this type of application. For this reason, we use a hand model that adapts to the object that is being grabbing. This is possible thanks to a series of colliders able to detect when the hand is touching an object. In addition, the controllers allow interaction with the elements of the scene with 6 degrees of freedom (DOF), including translations and rotations. Using that, every object on the scene can be inspected and, when users stop grabbing them, the systems checks if a connection was made.

The connections for objects with static meshes are simple, they can be attached to a specific anchor, relative to a parent object (i.e. the position of the pulmonary valve depends on the position of the right ventricle). In contrast with those, the mesh of a vessel changes when a connection is made. We consider two types:

- Connection with a static component or a bifurcation: In this case, the end of the vessel adapts its shape to the vertices that describe the connection.
- Connection between two parts of the aorta: To represent a smooth transition between vessels, an additional control point near the joint point of the vessel is added. This spline will avoid sharp connections.

5. User information

At this moment, the application allows the user to access basic information of the parts of the body. To get it, we display hypertext content inside the scene, with which they can interact. On the other hand, information from the objects is not the only important aspect, getting good feedback of their action is also necessary.

Choosing the correct way of prompting this feedback is very important. According to the work of Vosinakis et al ([VK18]), using some techniques can improve the user's score. In our case, we avoided eye-catching effects as they were deemed too distracting. For this reason, we use a panel that displays related information (i.e. if the object is near or the connection was made). This content appears behind the connected object to avoid disturbing the user.

6. Results

The system built by connecting all the anatomical parts of the scene is in the figure 2. To achieve this state, the user must move all the elements to learn their correct position. This process is intended to be simple and intuitive, so that most users can interact naturally with our application.

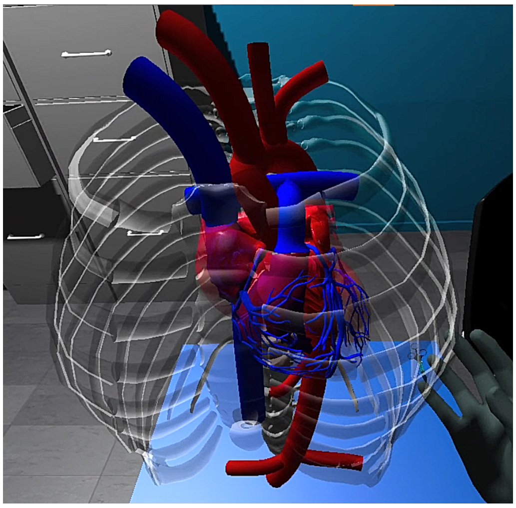

Figure 2: *Complete system built*

7. Conclusions and future ideas

In this work, a VR application to interact and learn the structure of part of the circulatory system has been developed, focusing on the main vessels around the heart.

The inclusion of further parts of the human body and other anatomical systems will be considered in the future. Additionally, despite our team has focused on the interactions and the management of the different 3D anatomical models, providing more contextual anatomical information is being considered. Lastly, our project will improve in future user experience tests with field experts. Their feedback will help validating the current state of the project and providing new ideas.

References

[FCK*14] Falah J., Charissis V., Khan S., Chan W., Alfalah S. F., Harrison D. K.: Development and evaluation of virtual reality medical training system for anatomy education. In *Science and Information Conference* (2014), Springer, pp. 369–383. 1

[VK18] Vosinakis S., Koutsabasis P.: Evaluation of visual feedback techniques for virtual grasping with bare hands using leap motion and oculus rift. *Virtual Reality 22* (03 2018). doi:10.1007/s10055-017-0313-4. 2