Virtual Reality for Studying Cardiovascular Anatomy by Assembling Elements

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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 assemble moldable elements of the human anatomy. It also 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 and their manipulation.

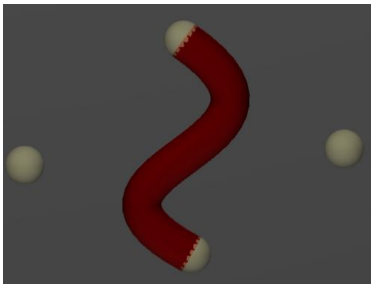
Concept and Components

This work presents a teaching tool prototype based on the idea of learning anatomy by building it yourself. The users can interact with a variety of anatomical parts around the heart so that they can connect them and build the core section of the circulatory system. Initially, focusing on the vessels around the cardiac system, different components have been modeled and included (with great emphasis on the aorta). As a starting point, the application includes static anatomical structures that serve as a visual reference to the user so he can start assembling the rest of the pieces. After each attempt, the application assesses whether the action is correct, and informs the user accordingly.

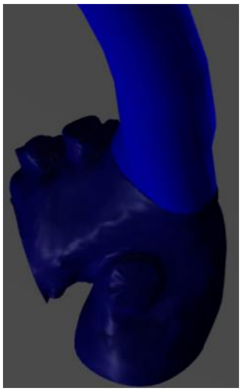
Vessel Meshing

Our application generates a specific mesh for each vessel and allows the manual deformation of these pieces via restricted dynamic meshing achieving realistic shapes.

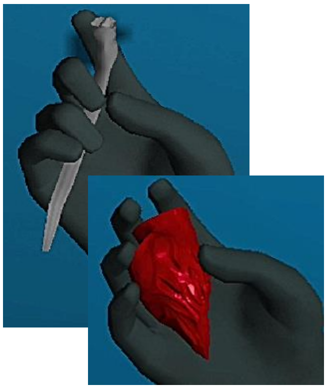
Using a 3D cubic Bézier curve, the system generates the points that describe the form of a vessel. A variable number of sampling points are used depending on the size or the shape of the vessel. With these, each cross section is roughly tessellated (16 vertices) forming a cylindrical surface. The cross-sectional accuracy increases on points near the beginning of a branch. These vertices are moved to create the circular form of a bifurcation. This algorithm has been implemented so that it is not computationally intensive, so it can recalculate the mesh in real-time, as the curve is deformed. Finally, as the triangle network is isomorphic, it only needs to be computed at start-up.



Deformed vessel by moving the control points



Connection between the right atrium and the superior vena cava



Grabbing different objects

Hand manipulation and assembly

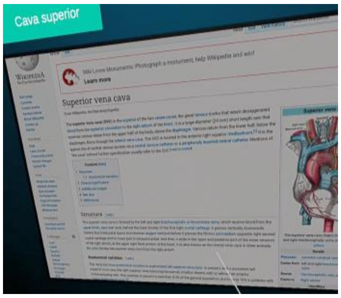
A realistic and natural behavior is essential for this type of application. For this reason, we use a hand model that adapts to the object that is being grabbed. This is possible thanks to a series of colliders able to detect when the hand is touching an object. When users stop grabbing them, the systems checks if a connection was made.

The connections between objects with static meshes are simple, they can be attached to a specific anchor, relative to the parent object. In contrast, the mesh of a vessel changes when a connection is made. If the connection is made with a static component or a bifurcation, the end of the vessel adapts its shape to the vertices that describe the union. On the other hand, when two parts of the aorta are connected, an additional control point near the joint point of the vessel is added, turning the Bézier curve into a spline which avoids sharp connections.

User Information

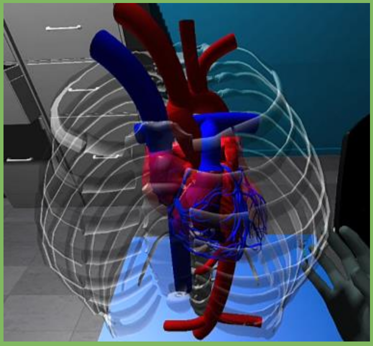
The application allows the user to access basic information of the parts of the body. In order to display it, we include interactive hypertext content within the scene. In addition, contextual anatomical information is complemented by feedback of the user's actions. According to the work of Vosinakis et al ([VK18]), using an appropriate technique can significantly improve the user's score.

Avoiding eye-catching effects as they were deemed too distracting, 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.



Information panel

Notification of successful union



References

[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)