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Using Smartphone-Based Virtual Reality to Explore Internal Anatomy of 3D Heart Models

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1 Background

The recent and rapid developments of immersive, interactive 3D environments have been critical in advancing interfaces for entertainment, design, and education. For cardiovascular research, our laboratory and others have been able to use such software tools for the construction of heart models from DICOM files. These models can then be printed in hard or soft plastic from a 3D printer. In general, such models are considered useful for surgical planning and education; these modalities are being applied as critical tools in the field of cardiovascular research.

Recently, the development of virtual reality (VR) has introduced a new modality for exploring 3D virtual structures with high resolution, high flexibility, and fast turn-around times. Until recently, the adoption of these technologies has been hindered by the high costs of VR goggles and the complexities in their setup. New developments in phone software and hardware, however, have alleviated some of these difficulties by allowing smartphone screens, graphics units, and gyroscopes to provide the necessary technologies for VR. In this way, phones can be placed inside a headset holder and used freely, without being connected to the computer.

Here we explore the utility of using this VR setup in the context of internal heart anatomy visualization.

2 Methods

Hearts were first received from an organ procurement agency called LifeSource. They were subsequently perfusion-fixed to elicit and end-diastolic shape and then scanned using MRI or CT. From generated DICOM datasets, 3D models were constructed using a software package called MIMICS (Materialise, Belgium). These whole-heart tissue models were then exported to a stereo-lithography (STL) file format and later converted to an object file.

The creation of a virtual environment for cardiac imaging was setup by taking advantage of recent developments in Google's Cardboard and Daydream projects. First the Unity video game engine was installed along with the Google Daydream VR plugin. Within Unity, a new scene was created, allowing for a heart model object file asset to be imported. At this point the first person perspective can be placed in any chamber of the heart. For our demo shown here, we decided on the left ventricle near the mitral valve and left ventricular outflow tract.

Outputting Unity's environment to an external device required installation and configuration of Android software development kits and application programming interfaces. First Android was installed with the proper packages for Android API version 7.0 (Nougat). The Java developer kit version 8.0 needed to be installed as well as it is a dependency of Android. Once these were available to Unity, it could be configured to build and run under this operating system.

A Nexus 6p running Android 7.1 was used for testing. After activating its developer mode and allowing USB debugging, the scene from Unity could be built and run on the device. This produces a stereoscopic view where the scene is duplicated on two halves of the device. In order to view the scene, the phone was placed in a headset with built in lenses to show the correct half of the phone to the respective eye. In our case we used a Utopia 360 headset, but other headsets like Google Cardboard follow the same design specification and could just as easily be used.

Fig 1: VR Headset Setup

Once the setup is completed and the user is wearing the headset, the phone's gyroscope will sense head motions and react as if the person was located within the heart chamber of choice.

Using 360-degree panoramic picture/video functionalities of Unity, static internal shots can be easily uploaded to an online server and viewed within the browser. Without the overhead of rendering the 3D model, time to VR is faster and more convenient at the cost of user interaction. A demo of these views can be found at our Atlas of Human Cardiac Anatomy.
(http://www.vhlab.umn.edu/atlas/vr/)

3 Results

For our demo, we placed the user in the left ventricle of a fully modeled human heart.

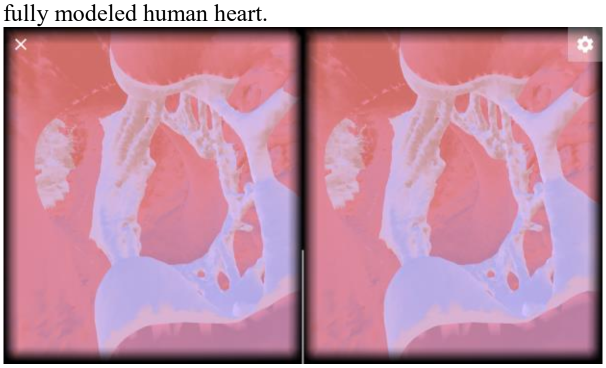

Fig 2: VR view of mitral valve

In figure 2, the mitral valve can be seen on the right of the screen while the left ventricular outflow tract, along with the aortic valve, can be seen at the left of the image. Large papillary muscles can also be seen extending from the top and bottom of the screen. The valve structures are presented in an off-white color, while the myocardial tissue is depicted as a light red.

The apex of the heart (figure 3) can be seen if the user turns their head around. Trabeculations can be clearly visualized in this view. Any pixilation of the muscle is a result of DICOM to model conversion and not of the VR setup itself.

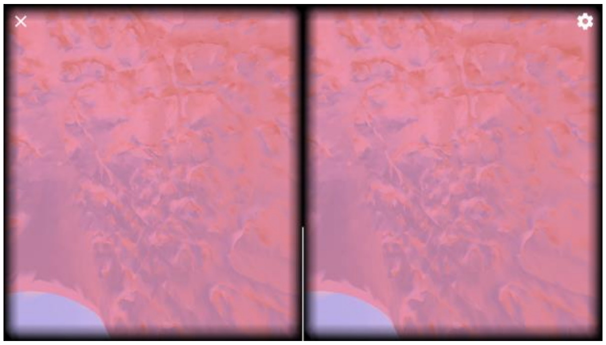

Fig 3: Apex view

4 Interpretation

An advantage of the mobile approach for VR is that the cost of material and time for development cycle is relatively cheap. In this way, exploration of 3D anatomical structures can be easily distributed to anyone with a capable mobile phone and compatible VR headset. Unfortunately, there are some technical difficulties. Running a VR scene is GPU intensive, drains mobile phone battery, and requires a framerate which can cause flickering. These problems are less severe, or remediated entirely, with high end VR headsets like the Oculus Rift or HTC Vive. However, a powerful computer is required to operate these VR headsets. Our workaround for this was to implement 3D static panorama shots which are not affected by the rendering overhead, providing clearer pictures on less capable phones. This is at the cost of user interaction with the model. In any case, advances in technology will continue to make VR experiences more convincing, even for smartphones.

Given the ease of distribution for a smartphone based VR system, we believe this setup is very well suited for education. High schools, colleges, and medical schools would all be possible markets for a product like this that can offer an immersive educational experience. Since most people in these consumer groups already own a smart phone capable for VR, teachers would only need to purchase a headset to give their students an interactive VR anatomy tutorial of the heart.

Surgical guidance is another possible application. For example, patient DICOM files can be modeled and viewed on a computer monitor, therefore these same models could be viewed with VR. This offers a much more compelling modality, to have 360 degree views from inside internal structures. Surgeons would be able to explore and focus on specific anatomy in a more immersive modality prior to performing the procedure.

Virtual prototyping of medical devices is a field of rapid growth, with complex VR systems being developed by multiple centers (including the Medical Device Center at the University of Minnesota). The VR approach described here allows for additional applications complementing the more sophisticated approach for medical device prototype simulation. Even with the system we describe, medical devices could be virtually implanted into heart models utilizing advanced VR technologies. This in turn would offer a new way to envision the implantation of a device and how the device would interact with the heart post implant.

In conclusion, mobile VR of internal heart or other anatomies may offer a unique and cheaper modality to enhance anatomic learning. Because of the ongoing advances in VR technologies and their reasonable costs, this approach could become an excellent educational tool that could be readily utilized for academic education, medical device design, and surgical planning.

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