Creating 3D models from Radiologic Images for Virtual Reality Medical Education Modules

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Abstract

Virtual Reality (VR) is a powerful tool that has increasingly being used by medical field in recent years. It has been mainly used surgical training in particular laparoscopic procedures. VR can be used for the teaching of anatomy. The aim of the study is to show application of transforming 2D radiologic images into 3D model by using thresholding and segmentation and import into VR interface at an affordable cost. Four anatomy modules are created with inputs to control the rotational and translational movement of 3D models in the virtual space. These movements allow users to explore 3D models by using head tilt and gaze input. 3D models of the Circle of Willis, Vertebral Aneurysm, Spine, and Skull are rendered in the user's field of view at runtime. VR is constructed to have many potentials uses in radiology education. Visualization of 3D anatomic structures in a virtual environment give another tool for teaching to students and patients about anatomy of the body. Four anatomy modules described here demonstrate example user interaction patterns best suited for viewing contexts. Instead viewing stacked 2D images or 3D models confined to desktop applications, virtual reality increases user interactivity of education. An intuitive understanding of anatomic structures in 3D space enhances the learning experience for medical students, residents, and patients we are treating.

Introduction

Virtual Reality (VR) technology has made a major impact in multiple industries since its introduction including entertainment, automotive and military. VR immerses the user in an environment with audio and visual feedback to create a tangible experience. VR is gaining recognition in medicine for its potential to enhance education, patient care and aid in healthcare decision-making.

VR technology has been adopted in surgery residency programs to train residents in laparoscopic surgery technique [1]. A valuable skill set in successful laparoscopic surgery includes altered tactile feedback, translation of two-dimensional video image from a three-dimensional working area and resultant hand-eye coordination, and the fulcrum effect [2, 3, 4].

For healthcare decision-making, surgeons are also using VR for making preoperative decision. In a study conducted in Spain, computed tomography (CT) was utilized to make 3D models to confirm anatomical compatibility with recipients.[4] There is currently a randomized controlled study to assess if preoperative VR planning improves a surgeon's efficiency in operation. (NCT03334344).

For patient care, VR is demonstrating efficacy in stroke rehabilitation and upper limb recovery [5]. VR has been able to use treat alcohol dependence by immersing the patient in an environment, designed to alter brain metabolism and decrease alcohol craving [6]. Another use is reducing surgical patient's stress level by introducing VR modules preoperatively to describe the surgical operation from preoperative stage to postoperative stage [7].

VR has been successful in multiple areas; however, there are potential applications to other fields to improve healthcare. In order to do that, we need to equip the tools need for healthcare worker to harness the power of VR. The purpose of the paper is to introduce affordable method of developing VR modules with use segmentation of radiologic image and making of 3-D models and implementation into virtual-reality software.

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How to process and construct VR anatomical modules?

The process of constructing these VR modules was 3 steps: transforming the Digital Imaging and Communications in Medicine (DICOM) images into a 3D model, adapting and revising the 3D model, and uploading the model into virtual reality space. First, DICOM images of various CT or MR scans were downloaded from one open repository, such as National Institute of Health (NIH) Cancer Imaging Archive and Osirix (Pixemo Inc.), and were uploaded into an imaging processing software. Softwares used were 3D Slicer (The Slicer Community) and Osirix for this process. The next step made use of a volume rendering module to select for specific organs using thresholds in Hounsfield units within DICOM image. The selected organ is then reconstructed into a 3D model with its 3D rendering module.

Once the 3D model has been made, it can be uploaded into a computer aided design (CAD) program for editing. The two CAD programs used were Blender (Blender Foundation) and MeshMixer (Autodesk). Meshmixer provides the capability to remove extraneous structures from the model, while Blender provided the benefit of smoothing out the rough textures of the model to yield a clean user-friendly model. The model then can be able to upload into virtual reality space either creating your own with software such as Unity or public space such as SketchFab (Sketch Fab).

Four anatomy models were created and were uploaded into a virtual reality space. The models were: Circle of Willis, Lungs, Large Colon, and Skull (Fig. 1). These VR modules have the capabilities of transitional movement, moving the module along an axis, and rotational movement, these maneuvers are managed by action such as head-tilt in the VR headset. Anatomical structures within the virtual environment were annotated with a title and description. For example, the numbered the major vessels that are part of the Circle of Willis, Lungs and Colon (Fig. 1).

Discussion

In this article, the groundwork for constructing VR modules was made. The four anatomy modules described demonstrate user interaction patterns best suited for viewing educational
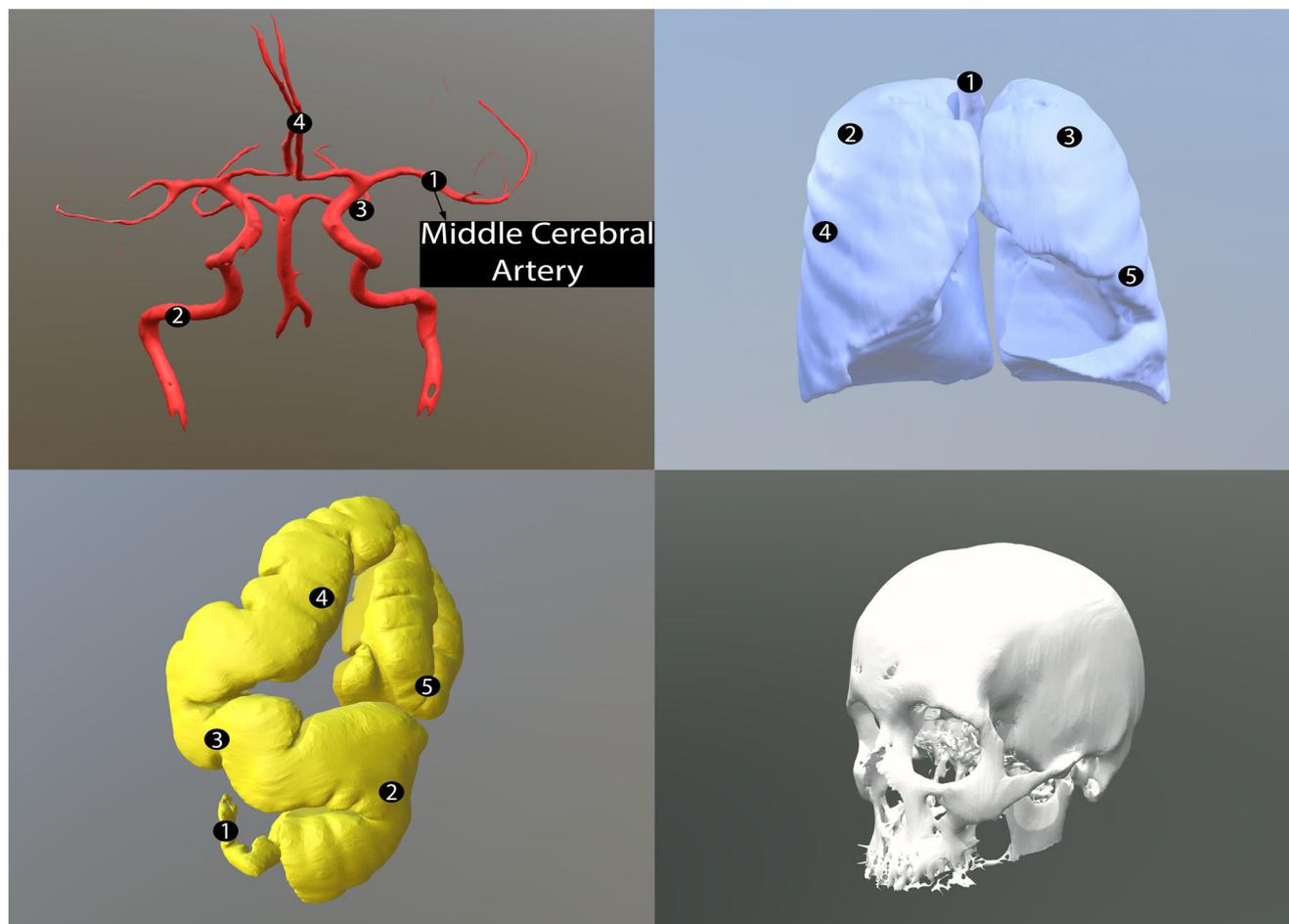
Fig. 1 Virtual Reality Module of Circle of Willis, Lungs, Large Colon, Skull

contexts, anatomical structures. This process gives the user a streamline approach to develop VR modules. Osirix repository had high-quality images of multiple organs; however, there was a limited selection of images and a high cost to get access to these images as well. There are multiple DICOM repositories which are open access, easy to use, and high number of images to choose as well, such as NIH Cancer Imaging Archive and Federal Interagency Traumatic Brain Injury Research. Another aspect about the process is that all the softwares were free to use, which gives the user one less barrier to reach when making these VR modules. Additionally, these software programs have instructional guides that enable the user to operate software at its fullest capabilities. Be that as it may, developing VR models currently requires the use of multiple software applications at the same time, which can be difficult for the user to learn. However, one solution would be the use of higher functioning software such Autodesk AutoCAD or Solidworks. Even though the software programs are harder to master, these higher functioning software applications give the user more capabilities to edit their 3D models. Lastly, model implementation in the VR space gives the user an understanding of the anatomical structure and provide different viewpoints that user might not be able to physically access. Animation of these models in the VR module would be the next great step in this process and give the user insight into how the anatomy functions. Overall, this process is an easy skill to learn, even for those who do not have a background working with this technology, to create immersive education experiences.

Currently, DICOM data constructs a 3D structure through the processing of hundreds of stacked 2D images. The application of virtual reality can render these 3D structures into an interactive environment which accurately depicts anatomic spatial relationships that offers the potential to enhance radiologic and anatomic education. For example, a retrospective analysis of second year medical student evaluations regarding a course that implemented the combined teaching of radiology and anatomy, demonstrated that nearly all students (90%) agreed that the integration of anatomy and radiology made the understanding of anatomy easier, enhanced their motivation to learn and their interest in the subjects [8]. Furthermore, it has been demonstrated that anatomy education with 3D models and VR are just as effective as anatomy education with traditional methods (i.e. textbooks and cadaveric dissection) when compared using post-instructional assessment performance [9, 10]. This supports the notion that one can convert use VR 3D models to use as an adjunct to traditional teaching methods. However, the benefit of VR would be its accessibility on smartphones and the ability to access a resource with accurate anatomic spatial relationships from anywhere.

VR can be used as a technology platform for head-mounted stereoscopic displays to create 3D immersive environments. Additionally, we illustrate an affordable method of developing VR modules with user interface design interactions, such as gaze-controlled directional motion inside the virtual environment, which created an immersive exploration of 3D models. VR can merge the discipline radiology and anatomy for a better learning experience. The ability to create these interactive environments opens the door for more possibilities and equips users with additional tools for medical education optimization.

Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

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