SlicerVR for image-guided therapy planning in immersive virtual reality

Csaba Pinter[1], Andras Lasso[1], Mark Asselin[1], Jean-Christophe Fillion-Robin[2], Jean-Baptiste Vimort[2], Ken Martin[2], Gabor Fichtinger[1]

[1] Laboratory for Percutaneous Surgery, Queen's University, Kingston, Canada

[2] Kitware Incorporated, Carrboro, North Carolina, USA
csaba.pinter@queensu.ca, gabor@cs.queensu.ca

INTRODUCTION

Virtual reality (VR) allows experiencing 3D-rendered scenes in a fully immersive virtual environment that has proved to be useful in variety of medical applications. There is, however, a lack of free open source software to enable immersive virtual reality experience during image-guided therapy planning. 3D Slicer [1] is a widely-used free open source medical data visualization platform, on which image-guided therapy applications can be created with minimal development overhead [2].

In an early prototype, we demonstrated the concept of VR-based image-guided therapy planning in 3D Slicer that showed improvement in the efficiency and ease of scene navigation compared to conventional display and mouse based navigation [3]. In this paper, we report the development of a comprehensive open source platform SlicerVR (www.SlicerVR.org) that provides immersive virtual reality exploration and navigation during image-guided therapy planning while taking advantage of the full functionality of 3D Slicer. Significant novelties since the early prototype include enhanced controller interactions, multiple collaborative features and more extensive support for a variety of VR hardware devices.

MATERIALS AND METHODS

System Design: SlicerVR is designed as an extension module in 3D Slicer that connects to the VR hardware seamlessly with the 3D Slicer features (Fig 1).
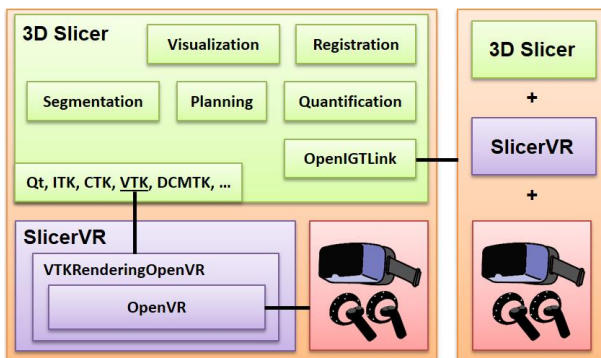

Fig. 1 SlicerVR architecture overview. Left side shows a detailed SlicerVR system with 3D Slicer and the VR hardware. The right side is a similar system connecting to the other via OpenIGTLink.

SlicerVR is designed to provide one-button integration: any scene visualized in 3D Slicer is seamlessly passed to be viewed in the VR headset and manipulated using the VR controllers. No programming or setup from the user is required. Upon installing SlicerVR as a regular 3D Slicer extension, the user connects the headset, populates the 3D Slicer scene, and then launches VR rendering by a single button press. By using the same rendering scene, SlicerVR simultaneously manipulates the immersive virtual scene and the conventional monitor-mouse based therapy planning scene. Thus, unlike conventional "virtual exploration" environments, all changes and manipulations made in the virtual scene are automatically propagated back to the therapy plan.

Controller Interaction Features: Users can choose to perform visualization tasks with moving their head (look around or into objects), using the controllers (fly, rotate, magnify, etc.), or using the mouse to set a desired view then propagate camera to VR with a button press. SlicerVR allows for prolonged convenient stay in the virtual environment by automatically harmonizing rendering parameters with user motions and actions (*i.e.* progressive rendering), thereby preventing motion sickness. Manipulating objects, such as moving and rotating using the controllers intuitively, is also possible. Moving 2D slice views is achieved by attaching "handle" objects to the slices via the volume reslice and transform functions of 3D Slicer. Surgical tools can be simulated by showing arbitrary tool models in place of the controllers. In addition, any function in the 3D Slicer ecosystem can be made accessible in the virtual environment via simplified VR-accessible user interface widgets, including therapy planning tasks, such as registration or changing therapy parameters.

Collaborative Features: Multiple users can share and manipulate the same scene. The state of the 3D Slicer instance of each VR user is synchronized via an OpenIGTLink [4] connection. Headsets and controllers of the other users can be broadcasted and displayed as well. This scene sharing enables the creation of novel cooperative experiences, such as collaborative planning or telemedicine. In a 1 to N scenario, where multiple trainees observe an instructor explaining anatomy or an intervention, the trainees can watch the VR scene from arbitrary distance, angle and magnification.

Hardware Support: We accommodate a wide range of users by supporting a variety of popular VR hardware through using the OpenVR software development kit providing hardware abstraction. SlicerVR supports all OpenVR-compatible headsets, such as the HTC Vive, all Windows Mixed Reality headsets (by Acer, Lenovo, HP, etc.), and Oculus Rift.

RESULTS

Some of the image-guided therapy planning scenarios enabled by SlicerVR include the following.

Pedicle screw placement planning. The scene contains volume rendering of the spine CT or surface rendering of segmented vertebrae (set to be static), and a number of screws (set to be movable). The user naturally picks up and places the screws in the optimal position, which can be verified by "looking into" the anatomy along the screw (see Fig. 2).
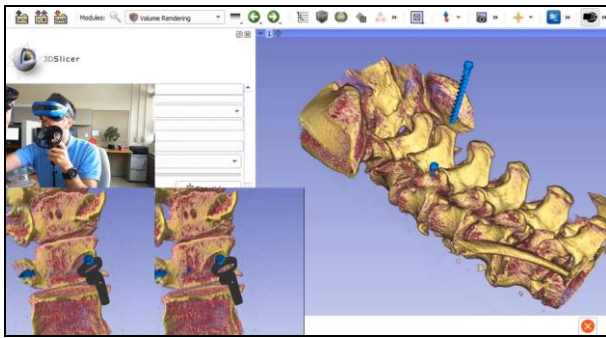

Fig. 2 Using SlicerVR for pedicle screw insertion planning. The background shows 3D Slicer with a single 3D view displaying the spine CT in volume rendering and the screws. The bottom left shows the VR mirror – what the user sees with each eye. The middle left shows the user with the headset and controllers, placing the current screw. Introduction video: https://youtu.be/F_UBoE4FaoY

Visualization of cardiac tomographic and echo images: Cinematic image series in standard DICOM 3DE format can be viewed in motion, allowing for full immersive visualization of the beating heart.

Ultrasound-guided needle insertion training: These skills are difficult to acquire due to simultaneous manipulation of the ultrasound device and needle. VR helps in training by improving hand-eye coordination and spatial awareness. The trainees can re-watch their insertions in VR to better understand the spatial relationships involved.

Fig. 3 Remote VR collaboration for brain surgery planning using real-time tractography. Top left: Participants local (blue headset) and remote (black headset). Bottom left: VR mirror image (local). Top right: 3D view of the SlicerVR instance (local). Bottom right: coronal slice in the position of the tractography seed (local). Introduction video: https://youtu.be/rG9ST6xv6vg

Brachytherapy catheter identification: Paths of brachytherapy catheters are challenging to follow due to their diverging and often crisscrossing pattern. VR enables better visualization of the catheters through stereoscopic vision and intuitive navigation (*i.e.* head movements), thus affording faster and more reliable identification of the catheters.

Collaborative surgery planning: Brain tumour surgery planning can be performed in remote VR collaboration using SlicerVR (see Fig. 3). The MRI image is shown in volume rendering with diffusion tractography calculated real-time with the tip of a needle used as seed point that can be moved using the VR controllers by either participant. The head and hands of each participant can be seen in the scene as virtual avatars.

DISCUSSION

Ongoing work includes the development of in-VR user interfaces. This will allow displaying arbitrary user interface widgets available in 3D Slicer or built specifically for VR. A laser pointer originating from the controller will interact with the panel similarly to conventional mouse interactions. This framework will make possible advanced use cases such as segmentation, which is crucial in planning (*e.g.* defining the target) or can be used in training (*e.g.* anatomy education or annotations).

An increasing number of VR hardware (such as HTC Vive Pro) are equipped with video cameras. By showing the real-time stereo camera image in the background, VR turns into augmented reality, which opens the way for a wide range of novel applications of SlicerVR in interventional navigation. For example, by using real position-tracked surgical tools instead of VR controllers we can render highly realistic and sophisticated image-guided therapy planning and training scenarios.

The SlicerVR extension is freely available for download in the 3D Slicer extension manager for versions 4.10 and later. To date, SlicerVR (www.SlicerVR.org) has been downloaded over 1,000 times.

REFERENCES

[1] Fedorov, A., Beichel, R., Kalpathy-Cramer, J., Finet, J., … Kikinis, R. (2012). 3D Slicer as an image computing platform for the Quantitative Imaging Network. Magnetic Resonance Imaging, 30(9), 1323–1341.

[2] Ungi, T., Lasso, A., Fichtinger, G. Open-source platforms for navigated image-guided interventions. Medical Image Analysis, 2016 Oct;33:181-186.

[3] Choueib, S., Pinter, C., Lasso, A., … & Fichtinger, G. (2019, March). Evaluation of 3D slicer as a medical virtual reality visualization platform. In Medical Imaging 2019: Image-Guided Procedures, Robotic Interventions, and Modeling (Vol. 10951, p. 1095113). International Society for Optics and Photonics.

[4] Tokuda, J., Fischer, G. S., Papademetris, X., Yaniv, Z., Ibanez, L., ... & Kapur, T. (2009). OpenIGTLink: an open network protocol for image-guided therapy environment. The International Journal of Medical Robotics and Computer Assisted Surgery, 5(4), 423-434.