# Virtual Reality System for Invasive Therapy

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## ABSTRACT

In invasive therapies such as invasive ventilation and deep brain stimulation, doctors face the challenge of planning, performing, and learning complex surgical procedures. VR systems were built to help doctors plan surgeries. However, the previous VR designs focused on navigation and visualization but not risk estimation. In this paper, we introduced a novel VR system for invasive treatment. Our approach supports 1) 3D navigation of anatomical models by a bi-manual miniature-world design; 2) simulation of probe trajectory and calculation of the corresponding risks; 3) visualization of different layers; 4) visualization of cross-sectional cutting by a plane. These functions allow doctors to easily manipulate the anatomical model and plan probe trajectory based on the estimation of risks.

**Index Terms:** I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality;

## 1 INTRODUCTION

Invasive therapies play an important role in the treatment of diseases like COVID-19 (invasive ventilation [5]), Dystonia, Parkinson (deep brain stimulation [9]). Invasive therapies usually involve implanting a probe or a tube into the patient, and this process accompanies the risk of hurting patients' body structures and bleeding [1].

Recently, virtual reality has been applied to minimize the risks in invasive therapies by planning and simulating surgeries, like 3D navigation of anatomical models, video-assisted cardiothoracic surgery, and clinical training. However, these works focused on the navigation and visualization of anatomical models but not estimating the risks caused by implanting probes. Therefore, we identified a need to build a VR system to support doctors to plan the probe trajectory by the corresponding risk estimation.

In this work, we designed and developed a VR system for invasive therapy planning. It includes functions like 3D navigation, visualization of different layers, slicing views, simulation of probe trajectories and calculation of the corresponding risks. This system would be beneficial for doctors to plan invasive therapies. For example, a doctor could calculate the number of blood vessels being hurt on specific probe trajectories and find the optimal trajectory that is safe and close to the destination before the real surgery.

## 2 RELATED WORK & GAP

VR systems were built to support doctors in surgeries. The first kind of VR design support doctors navigates the anatomical model. Hanson and Yu built a VR system which used hand-based or foot-pedal input devices to enable targeting and selection [3]. To address the need for hands-free control, Grinshpoon et al. [2] came up with the head-tracking and voice-based 3D user interface for vascular interventions by using Microsoft HoloLens to produce 3D models. Rapetti et al. [6] presented a virtual reality surgical navigation system for performing targeted prostate biopsies, without the need of the uncomfortable trans-rectal ultrasound (TRUS).

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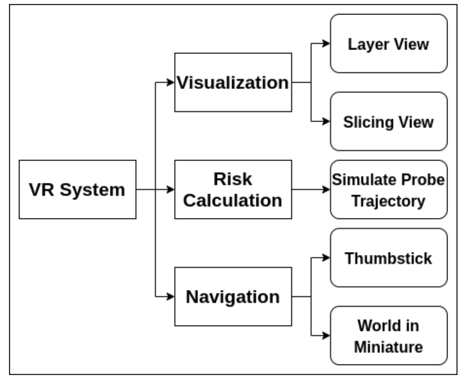


Figure 1: An overview of the virtual reality system for invasive therapy.

The second kind of VR design provides doctors with different views of the anatomical model. Jalaliniya et al. [4] developed a gesture-based interaction system which enabled users viewing medical images by hand or foot gesture input. Reddivari et al. [8] and Dam et al. [7] designed VR systems which provided different 3D images to display tumours in several meaningful ways.

However, these VR systems did not provide the direct risk estimations on probe trajectories. As the anatomical model was often large and complicated, doctors might not be able to estimate the risk of specific probe trajectories even when they were provided with different views. Thus we identified a need to build a VR system which could give users such risk data.

## 3 DATA COLLECTION

We collected the data of a brain model from the Medical Devices Centre of [blinded]. All researchers have completed the HIPAA training. Considering the size of the original model we got, to save computing power, we downgraded the number of vertices in meshes from over 50000 to 10000. After successfully downgrading these meshes, the Oculus Quest result was smooth, and the time it took for compiling was also reasonable and fast.

## 4 SYSTEM DESIGN

We arranged meetings with researchers from the medical device centre. From the discussions, we agreed on the opportunity to explore virtual reality in invasive therapy planning. We identified the following design requirements for the VR system:

**1) Probe Trajectories Simulation and Risk Calculation**. We used a ray to simulate the probe then found the structures it hurt.
**2) Navigation**. Our system would help the user identify where he currently is and where he wants to teleport.
**3) Layer View**, for doctors who want to focus on specific structures.
**4) Slicing View**. The doctor would be able to slice the model.
Figure 1 is the overview of the VR system.

## 5 SOFTWARE IMPLEMENTATION

We implemented the system on the Oculus Quest platform by Babylon JS, Webxr. The system allows users to view the model on an HMD and input by two hand controllers.

### 5.1 Simulation of Probe Trajectory and Risk Calculation

After the user presses the right trigger, the right controller will cast a ray (probe trajectory), and the risk information will appear on top of the left controller. Here the ACPoint (pink sphere) is the point to reach under the optimal situation. NearPoint (blue sphere) is the point closest to the ACPoint on the ray. For example, Figure 2 shows that the direction of the ray is (0, 0, 1); the position of ACPoint is (1, -19, 29); the position of NearPoint is (0.5, 1.5, 29); the distance between ACPoint and NearPoint is 20.51; the ray intersects with vasculature 1 time, with Thalamus_R 1 time, with Thalamus_L 1 time, with brain 2 times.

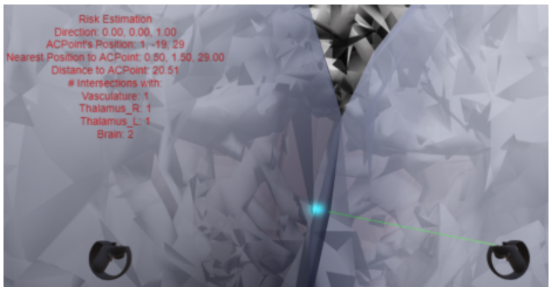


Figure 2: Risk information about the ray (probe trajectory).

### 5.2 3D Navigation

To enable the user to navigate the model, we first designed a simple approach where the user could move forward in the direction of the ray from the right controller by pushing up the right thumbstick or do the opposite by pushing down the right thumbstick. However, after we implemented the thumbstick approach, we found that the model is too complicated — it is possible that the user does not know where they are and where they would like to go when they are in the virtual world.

Then we used a bi-manual world in miniature design (WIM) to enable the user to move in the large model quickly. The WIM would be attached to the left controller. It also includes a headset, whose edge is rendered with green light, to represent the user's current location in the large world. The user could select the headset by pressing the right controller's squeeze button and move the headset to change his/her position in the large world quickly.

### 5.3 Layer View

We designed a button panel that would only appear if the user switches to the visualization mode (the user could change Risk/WIM/Layer View mode by pressing the left squeeze button). The button panel will be attached to the left controller. The user could select and deselect the button by pressing the right trigger to cast a ray to that button; then the corresponding mesh will disappear (the button with white text) or appear (the button with green text).

### 5.4 Slicing View

Considering in real life, instead of separating the layers from a whole as we have done in the Layer View section, doctors may want to view the cross-sectional model, showing where the probe may damage the structures. Thus, we offered a choice to let doctors see the model in a slicing view. By using the squeeze button in the right controller, a plane will be generated. Holding this plane as the blade, users can slice the model with any direction they would like to. A cross-sectional view will be generated and attached to the left controller, see figure 3, 4.

## 6 Conclusion Limitation

In this project, we built a VR system that could support doctors planning invasive surgeries by navigating and visualizing the anatomical model, and calculating the simulated probe trajectories' risks. We hope this work could help doctors plan the tube's trajectory in invasive ventilation during the treatment of the COVID-19.

A limitation of this project is that there are probes of different lengths to meet different needs during surgery in real life. However, we only have a ray to simulate the probe with a fixed size. It would be beneficial to offer different probes and instruments, such as a slide box to enable the doctor to change the ray's length.

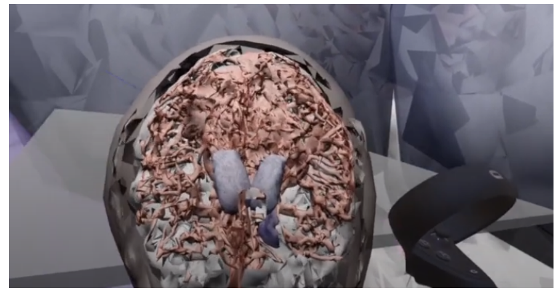

Figure 3: Using a plane attached to the right controller to cut the miniature world on the left controller to get a slice.

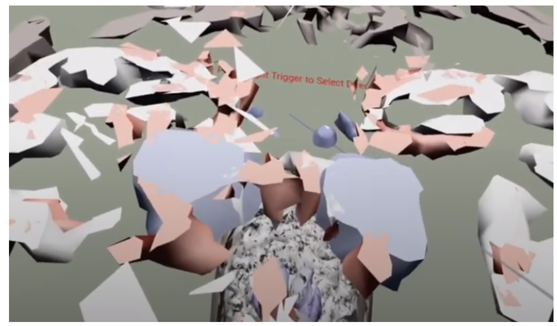

Figure 4: Slicing view of the model will be attached to the left controller.

## References

[1] Z. J. Elliot and S. C. E. and. An overview of mechanical ventilation in the intensive care unit. *Nursing Standard*.

[2] A. Grinshpoon, S. Sadri, G. J. Loeb, C. Elvezio, and S. K. Feiner. Hands-free interaction for augmented reality in vascular interventions. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces*.

[3] M. S. Hasan and H. Yu. Innovative developments in hci and future trends. In *2015 21st International Conference on Automation and Computing (ICAC)*, pp. 1–6, 2015. doi: 10.1109/IConAC.2015.7313959

[4] S. Jalaliniya, J. Smith, M. Sousa, L. Büthe, and T. Pederson. Touch-less interaction with medical images using hand foot gestures. pp. 1265–1274, 09 2013. doi: 10.1145/2494091.2497332

[5] P. Mehta and J. C. Porter. Therapeutic blockade of granulocyte macrophage colony-stimulating factor in covid-19-associated hyper-inflammation: challenges and opportunities. *The Lancet Respiratory Medicine*, 8(8):822 – 830, 2020.

[6] L. Rapetti, S. Crivellaro, E. De Momi, G. Ferrigno, C. Niederberger, and C. Luciano. Virtual reality navigation system for prostate biopsy. Association for Computing Machinery, 2017.

[7] S. Reddivari, J. Smith, and J. Pabalate. Vrvisu: A tool for virtual reality based visualization of medical data. In *2017 IEEE/ACM International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE)*, 2017.

[8] A. van Dam, A. S. Forsberg, D. H. Laidlaw, J. J. LaViola, and R. M. Simpson. Immersive vr for scientific visualization: a progress report. *IEEE Computer Graphics and Applications*, 20(6):26–52, 2000.

[9] C. A. Wingrave, Y. Haciahmetoglu, and D. A. Bowman. Overcoming world in miniature limitations by a scaled and scrolling wim. In *3D User Interfaces (3DUI'06)*, pp. 11–16, 2006.