Towards Next Generation Neurosurgical Microscope: A VR Assisted Prototype System

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ABSTRACT

We aim to develop a Virtual Reality assisted neurosurgical microscope system that displays medical information from multiple resources even with a single display. For this ultimate purpose, we developed a prototype system. We conducted a small user study to discuss both hardware and software issues to be improved.

1 INTRODUCTION

Modern neurosurgery began by Cushing [1]. Since then, neurosurgeons have explored new devices for accessing pre- and intra-operative information to make surgery safer and more efficient. For example, Kurze introduced microscope and L'Espinasse and Walker independently started using endoscope in neurosurgery [2]. Recent development of such devices realizes 4K and 3D visualization [3]. According to the evolution of those devices, operating rooms have introduced computer monitors. Active development in display industry has realized high-resolution, high-frequency, and large-size display. Even 3D stereoscopic displays are available.

We should note a significant drawback of them that operation rooms tend to be occupied by those devices. In most of operating rooms, they use a monitor for each data resource and the monitors are generally larger for their visibility. This drawback poses a dilemma for neurosurgeons that they welcome more devices to realize safer and more efficient surgery but those devices occupy the operating rooms and therefore constrain their workflow.

The history of Virtual Reality origins early 1960s [4, 5]. The display devices used in the past decades are larger and hence limit its usage environment. The display industry has made effort to make VR devices smaller, higher-quality, and more inexpensive. Oculus Rift by Oculus impacted the community and even ordinal people by its great balance of quality and cost. Since then, the industry has actively developed and even wireless models are available as of 2019 [6]. In the history of Virtual Reality and Augmented Reality, researchers have proposed dozens of thousands of medical applications [7]. The applications contain pre-operative planning, intra-operative visualization, and even medical education. Now is the time to seriously consider its applicability and possibility. This situation is similar to smartphones opened door of ubiquitous computing and Kinect of human computer interaction for ordinal non-tech people.

Our ultimate goal is to solve the dilemma in neurosurgery. Our idea is to use Head Mounted Display (HMD) as a unique but powerful personalized monitor. Each surgeon and even nurse accesses all necessary information including intra-operative 3D microscope view even in real-time without any time delay. Furthermore, each staff can customize and control the view on his/her own HMD with their desired format by non-contact way. This design must change the current ad-hoc operating rooms. For this purpose, we develop a prototype of neurosurgical microscope and its visualization system. We conduct a user study to evaluate the prototype and discuss key issues to be satisfied in both hardware and software views.

2 OUR PROTOTYPE SYSTEM

This section describes our prototype system of neurosurgical microscope system. Our key idea is to introduce Head Mounted Display (HMD) as customizable monitor. Via an HMD, a surgeon can see pre-operative medical images as well as live video stream of intra-operative ones. Since recent HMDs enable to see data in 2D and 3D, the surgeon can refer to different data even with a single monitor. Consequently, ORs are released from the curse of massive monitors while the surgeons can change image sources as necessary. The other idea is to use a stereo-camera as microscope. The video stream captured by the stereo-camera is recordable and can be displayed on a 3D display.

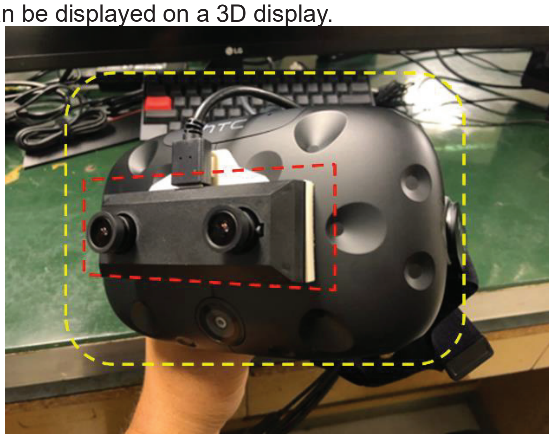


Fig. 1 Hardware setup of our prototype system. Yellow and red dotted lines enclose the HMD and the stereo-camera respectively.

2.1 Hardware setup

We build a prototype system with ordinal devices. Figure 1 shows the hardware setup of our prototype. A stereo-camera (enclosed by red dot line) and an HMD (enclosed by yellow dot line) are connected to a PC. The stereo-camera is used as microscope while the HMD is used as a monitor. The live video stream captured by the stereo-camera is sent to the PC. We store pre-operative medical images in the PC and therefore the system can display the video stream and the pre-operative medical images alternately.

We adopt an OvrVision Pro camera as stereo-camera and an HTC Vive as HDM. Their spec is as follows:

- OvrVision Pro
  - Resolution (FPS): 2560x720 px at 60 Hz
  - Latency: 60 msec
  - Angle of view: 120 deg. (H) and 105 deg. (V)
  - Weight: 80 g
- HTC Vive
  - Resolution: 2160x1200px at 90 Hz
  - Angle of view: 110 deg.
  - Weight: 555 g

The camera and HMD are connected to a laptop PC with a GPU, Nvidia GeForce GTX 1060.

2.2 Software architecture

We develop a simple visualization software to confirm the concept of our prototype. Specifically, we use Unity to enable all data and images on HTC Vive. The software has three modes, each of which displays data from different source. The surgeon changes the visualization modes if necessary. In our prototype, keyboard is used to change the modes.

MODE 1 displays the live video stream captured by the stereo-camera and the surgeon can see his/her surgical field in 3D. *MODE 2* displays pre-operative 3D data such as CT volume or planning. Same as *MODE 1*, the surgeon can see the data in 3D. *MODE 3* displays many kinds of clinical data such as vital information and medical images. The surgeon selects his/her target of information by using mouse (a nurse may control the mouse in OR).

3 RESULTS

We conducted a user study with a neurosurgeon. We first calibrated the camera and HMD. The neurosurgeon wore the HMD and tried tying a surgeon's knot to evaluate the quality of 3D visualization as shown in Fig. 2.

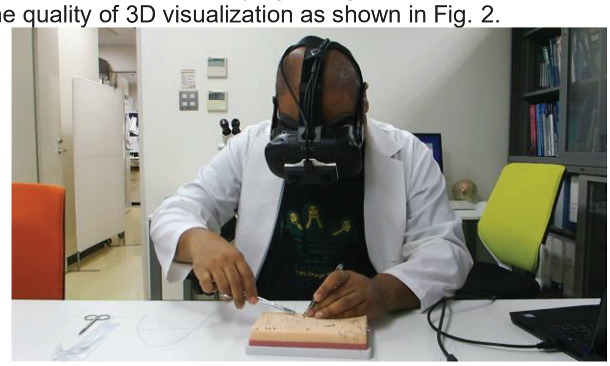


Fig. 2 The experimental environment.

Figure 3 shows screenshots of the system for each visualization mode. Let us enumerate feedback from the neurosurgeon. Tying is done in smaller area than one required for normal neurosurgery. Therefore, the surgeon needs less focus control and field-of-view. The feedback is as follows:

- The surgeon perceived stereoscopic view in *MODE 1* as 3D and the perception was enough for tying.
- The latency of the HMD and the fixed focus of the stereo-camera did not affect tying.
- The narrower field-of-view was enough for tying.
- The camera parameters such as white balance and brightness are fixed during the experiment
- The surgeon would like to access multiple resources at same time.

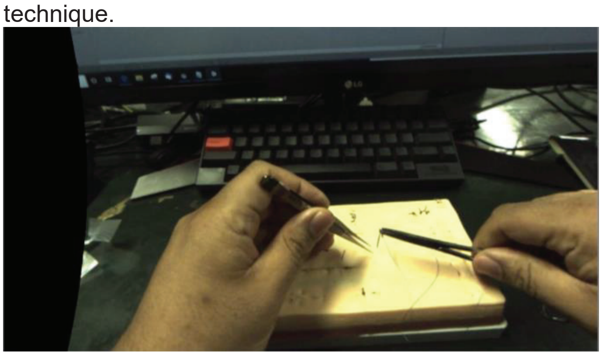
4 DISCUSSION

This section gives discussion on hardware and software issues on the feedback from the surgeon.

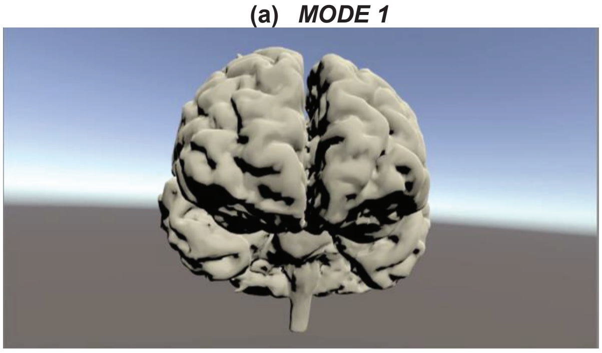
4.1 Hardware issues

For both HMD and stereo-camera, higher-resolution equivalent to or better than naked eyes are required. Also, both devices are better to be wireless so that surgeons can move freely in OR and be less constrained by wires.

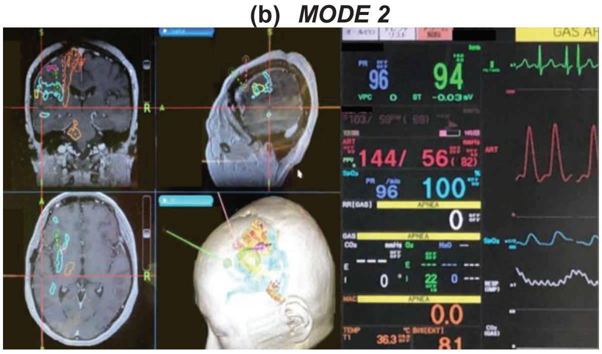
To realize wireless higher-resolution HMD and stereo-camera, we need higher quality image compression, higher-speed data transmission, less latency display technique.



(a) ***MODE 1***



(b) ***MODE 2***



(c) ***MODE 3***

Fig. 3 Screenshots of the system.

4.2 Software issues

The software components have a lot of issues to be improved. Regarding data accessibility, the software must provide both one in window and multiple data in window modes as Virtual Desktop [8] so that surgeons can select each of them depending on the situation and their preference. Another issue is about depth/3D perception. Depth perception is an important factor in both Virtual and Augmented Reality [9-11]. In general, HMDs are more suitable for depth perception than ordinal flat monitors, however we must design the software carefully because the perception directly affects surgeon's performance.

User interaction must be also improved. In our prototype, the software is fully controlled by using mouse and keyboard, which may bother the surgeons. Since HMDs are personalized monitor, it is favored that each staff can interact by oneself. In this sense, we need to integrate better HCI technique such as voice- and gesture-based control [12, 13] so that each staff can control even when his/her eyes and hands are occupied by their activity.

Entire software design including user experience and interaction must be considered. As mentioned in several studies, we must make an effort on designing user experience to realize actual real-world applications [14-16]. Experts in general have a lot of tasks in their work and thus have less time to learn new systems, software, and hardware. To avoid wasting their time, sophisticated user experience must be required.

Last but not least, it is better to have functionality to record all information. Such information is used for autonomous logging and further education. There is a significant gap between medical education and actual medicine. Virtual and Augmented Reality applications have potential to fill the cap by utilizing important surgical information in the applications [17].

5 CONCLUSIONS

In this paper, we developed a prototype of HMD based stereo-camera viewer in both hardware and software sense toward next generation neurosurgical microscope. Through the user study, we confirmed that the prototype is on the right way and that there still remains certain rooms to be improved. The authors hope this paper builds a bridge among neurosurgeons, camera and display researchers, and industry.

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