An immersive virtual reality environment for diagnostic imaging

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Abstract. Advancements in and adoption of consumer virtual reality are currently being propelled by numerous upcoming devices such as the Oculus Rift. Although applications are currently growing around the entertainment field, widespread adoption of virtual reality devices opens up the potential for other applications that may have been unfeasible with past implementations of virtual reality. A virtual reality environment may provide an equal or larger viewing volume than what is provided with the use of multiple conventional displays while remaining comparatively cheaper and more portable. A virtual reality application for the viewing of multiple image slices was designed using: the Oculus Rift head-mounted display, Unity, 3D Slicer, and a gamepad controller. A web server acquires data from volumes loaded within 3D Slicer and forwards it to a Unity application that proceeds to render a scene for the Oculus Rift head-mounted display. Users may interact with the images adjusting windowing and leveling using the handheld gamepad controller. Multiple images could also be brought closer to the user for detailed inspection. Application usage was demonstrated with the simultaneous visualization of concurrent slices of a serial CT scan of a patient with a lung nodule. The tasks of identifying the lesion and determining the malignancy status by monitoring the growth of the lesion over time were performed successfully. Also demonstrated was the studying of multiple-sclerosis lesion evolution by visualization of a large time-series MRI dataset. A virtual reality environment for the purpose of aiding diagnostic radiology has been created and demonstrated with potential use cases.

1 Introduction

Virtual reality has long been explored as a technology for creating immersive environments conducive to exploring data. Virtual reality systems have been implemented in the past with what is widely considered the first virtrual reality head-mounted display (HMD) being created in 1968 [1]. Since then, various virtual reality systems have been developed and demonstrated for a wide variety of applications including medical imaging and minimally invasive surgery [2].

Consumer-oriented VR devices have been available since the 1990s with little commercial success. Multiple technologies are crucial for satisfactory VR experiences including display resolution, tracking systems, interfaces, latency, and graphics rendering. Additional important factors for a successful consumer-oriented device are cost, convenience, and software support. Widespread consumer adoption has been limited due to deficiencies in all or some of these areas. More recently, however, there is a resurging interest in affordable, consumer virtual reality systems. Notable technologies important to VR have manifested in modern smartphone development. Portable and relatively cheap high-resolution displays and motion sensors have led to the development of new VR devices such as the Oculus Rift, introduced by Oculus VR (Irvine, CA) in late 2012 acquired by Facebook, inc. for $2 billion USD in 2014. Following Oculus VR, other companies such as Sony, Microsoft, Samsung, and HTC have either announced or released their own virtual reality headsets as seen in Fig. 1. Although current applications for these new consumer-oriented VR HMDs are centered around the entertainment field, specifically the video game industry, potential widespread adoption of VR devices makes practical applications that beforehand would have required specialized and potentially expensive hardware.

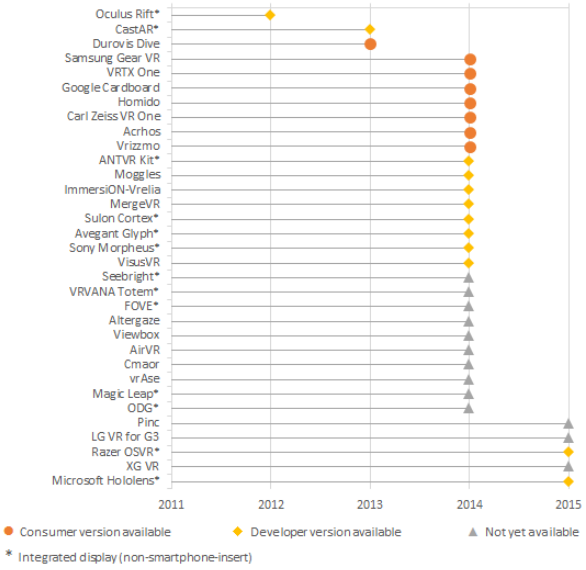

Fig. 1. Approximate initial announcement dates of virtual and augmented reality devices.

Virtual reality displays offer a large field of view as demonstrated in Fig. 2 that can only be obtained traditionally when using multiple conventional flat displays or a singular large display. Large displays have been shown to act as a benefit in regards to tasks such as those involving visual scanning and in regards to both 3D and 2D data

[3][4][5]. Head-tracking also allows a user to look around an environment in a manner more natural and intuitive when compared to scrolling on traditional displays while also intuitively allowing for scalable increases in the amount of usable screen space available.

Although past implementations of virtual reality systems have achieved success in creating displays with a large field of view and even head-tracking, such systems often required a significant investment in cost and space. Such systems included the CAVE, which consisted of multiple projectors directed to different walls of a room; and the ImmersaDesk [6], a 170x127 cm display featuring stereoscopic, head-tracked images. HMDs are now overcoming limitations in weight, accuracy, and cost that have previously precluded their practical use. The current developer model of the Oculus Rift HMD weighs under 1 lb. and the consumer model is also set to retail in the $200 USD to $400 USD price range.

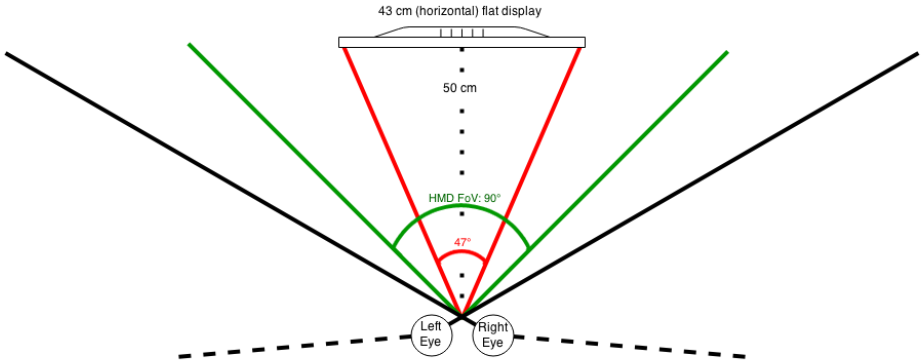

Fig. 2. Field of view offered by a HMD compared with a single traditional 43 cm wide display at a viewing distance of 50 cm

Diagnostic radiology cases exist where a potentially large amount of data are required to be viewed as is the case with longitudinal and time-series studies. Possible examples include the evaluation of lung lesions and studying of multiple-sclerosis lesion evolution.

Due to the potentially poor accuracy of lung biopsies [7], differential diagnosis of lesions is typically performed by monitoring the size of lung lesions over time. In some cases, as many as 7 to 8 scans taken over a two year period are necessary to determine the growth of the lung lesion or the solid component within the lesion. Therefore it is imperative to simultaneously view multiple CT scans to determine the malignancy status by visually detecting a change in size or nature of the solid component of the lesion.

Monitoring of disease activity in multiple sclerosis is typically accomplished using MRI imaging of lesions that form on the brains of patients [8]. Resulting MRI time-series studies may span the course of months generating enough image data that it is beneficial to simultaneously view multiple MRI volumes at once in order to track disease progression.

The design of a standard radiology reading room aids the comparison aspect of such tasks through the use of multiple conventional flat displays, however, the usage of multiple traditional displays may be prohibitive to portability and cost. The use of a virtual reality HMD may allow for diagnostic radiology tasks to be completed in a virtual reading room accessible to those without access to a standard reading room as may be the case in rural areas or otherwise outside of a hospital setting. We present one application of a virtual reality system as a potential solution for relatively cheap and portable intuitive simultaneous visualization of multiple volumes.

2 Methods

A virtual reality application for the viewing of multiple image volume slices was designed using the Oculus Rift Development Kit 2 (DK2) stereoscopic head-mounted display. The DK2 features a resolution of 960x1080 pixels per eye with head-tracking accomplished with a gyroscope, accelerometer, and magnetometer. Positional tracking is also achieved using a near infrared camera (Fig. 3). Of particular interest is the usage of a low persistence display that serves to reduce motion blur resulting in more visually stable scenes and allowing for improved readability of images. Such readability is of significant importance for tasks requiring a user to analyze subtle changes between multiple images.

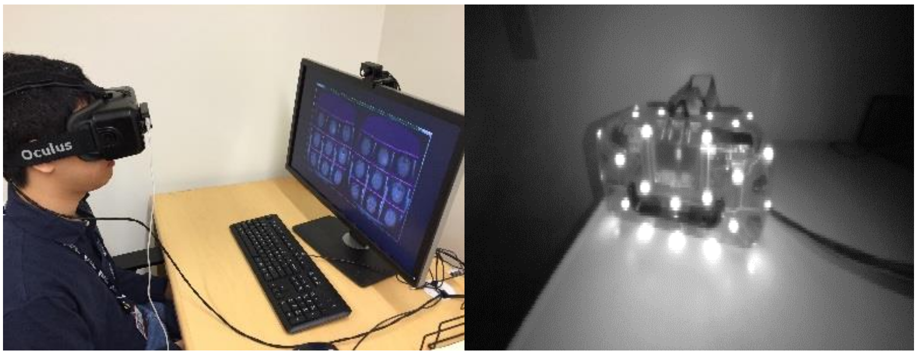

Fig. 3. (Left) The Oculus Rift Development Kit 2 with positional tracking camera (Right) Markers tracked by infrared positional tracking camera

The virtual reality application makes use of volumes loaded within 3D Slicer, a free and open-source software package used for a variety of medical applications [9]. 3D Slicer features a number of state-of-the-art image registration algorithms and supports numerous common data formats. A web server module for 3D Slicer was created and used to forward volume slice image data to the virtual reality application. The virtual reality application itself was created using the Unity game engine. A Unity scene containing slice windows loaded from 3D Slicer was rendered to the Oculus Rift HMD. The architecture is laid out in Fig. 4.

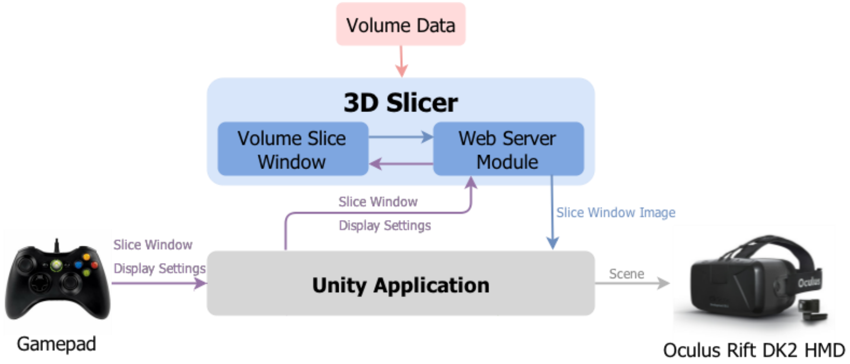

Fig. 4. Overview of virtual reality application architecture

Users are able to interact with image slice windows displayed in the scene. Slice windows are selected for interaction by the sightline of the user. Using a gamepad controller, users can adjust the windowing, leveling, and slice offsets. Slice windows can be individually selected by the controller to be moved closer to the user for detailed inspection. As seen in Fig. 5, multiple slice windows may be selected and arrayed around the user to create a wide display intended for the comparison of longitudinal series. The user may also use the controller to virtually walk around the scene away from the default position.

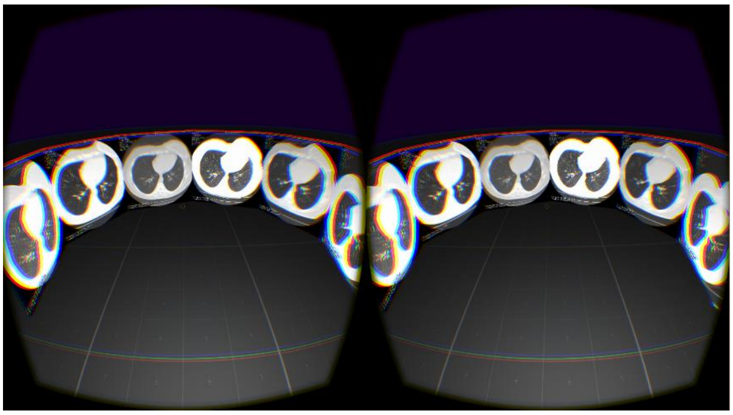

Fig. 5. Slice windows can be arrayed around the user

3 Results

The virtual reality diagnostic radiology application is capable of displaying, as a slice window, any volume that can be loaded in 3D Slicer. Depicted in Fig. 6 and the accompanying video is the simultaneous visualization of 6 CT volumes of a 61 year old patient obtained over a 2 year period.

Fig. 5. Displaying CT lung volumes

Subtle changes in the lesions prevented an early diagnosis of the malignancy study. Subsequent to the last scan, the patient underwent wedge rejection surgery and the lesion was determined to be malignant. As seen in Fig. 6, the user selects multiple slice windows in order to make a more detailed visual evaluation. The simultaneous visualization of multiple lesion CT images by the virtual reality application could assist in the detection of subtle changes in the structure of the solid component of the lesion, thereby confirming the malignant status at an earlier stage.

The tasks of identification and classification of the lesion were found to be accomplishable albeit with display resolution as a potentially limiting factor especially for cases with small and easily missed important details. Improvements to the display are expected with future iterations of the Oculus Rift and similar devices. Shown in Fig. 7, almost a total range of 180 degrees of lateral head movement were recorded as a user made comparisons between all 6 CT images.

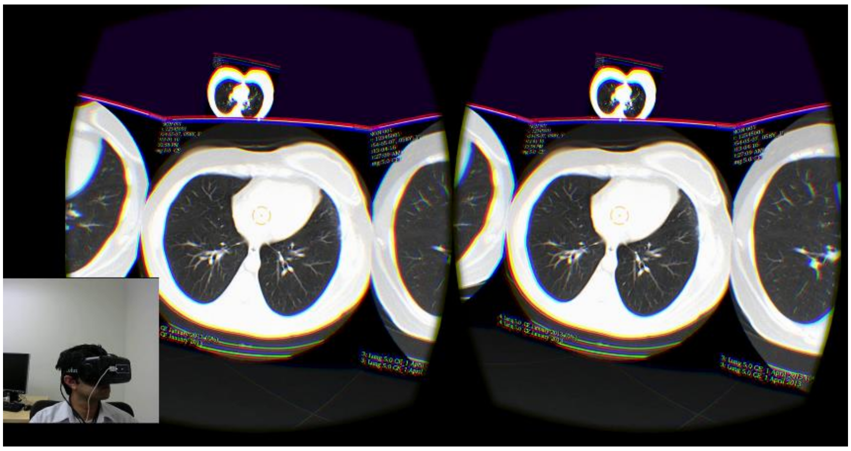

Fig. 6. Identification and classification of lung lesions

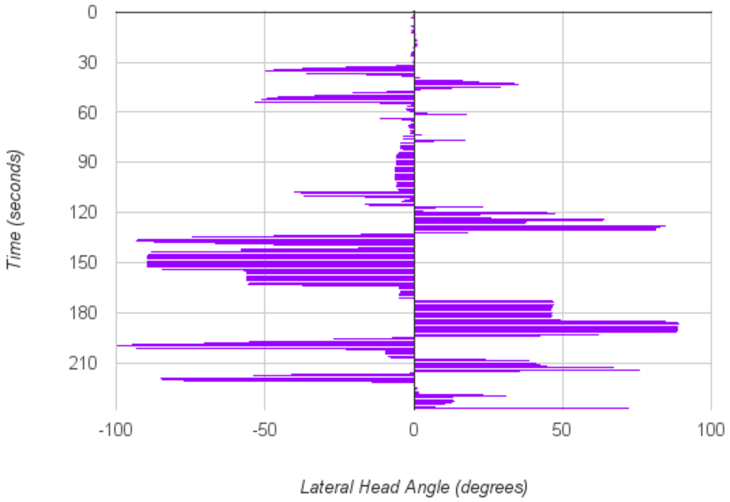

Fig. 7. Lateral head motion where facing directly forwards is represented by 0°

Also shown in Fig. 8 is usage of the prototype for displaying a temporal MRI series consisting of 21 MRI volumes for a multiple sclerosis patient. The windows fill a large portion of the field of view of a user and lesion changes are visible across the dataset allowing for quick overall comparisons and evaluation of lesion evolution to be made. As with the previous case, multiple images were selected whenever detailed comparisons were needed.

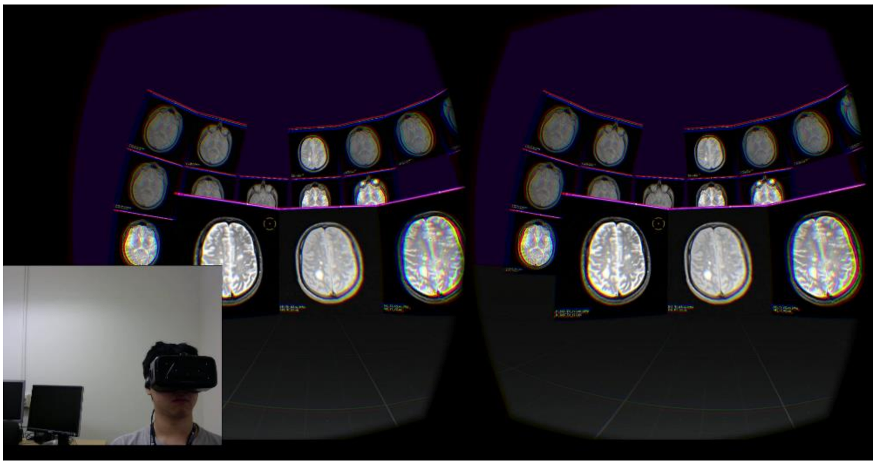

Fig. 8. A large amount of temporal MS data displayed in virtual reality

4 Conclusion

A virtual reality environment created using a consumer-level virtual reality head-mounted display for the purpose of aiding diagnostic radiology has potential use cases that warrant further research to be followed by usability testing. The impetus provided by widespread consumer-level virtual reality devices expands usage of applications that have previously only been practically available to a limited user base and we are continuing to explore potential new visualization techniques and remote collaboration tools while evaluating their clinical utility.

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References

1. Sutherland I.E.. "A head-mounted three dimensional display", Proceedings of AFIPS 1968, pp. 757-764.
2. Pieper S., McKenna M., Chen D., McDowall I., "Computer animation for minimally invasive surgery: computer system requirements and preferred implementations", Proc. of SPIE 2177 Stereoscopic Displays and Virtual Reality Systems, pp. 401-408 (1994).
3. Ni T., Bowman D.A., Chen J., "Increased display size and resolution improve task performance in Information-Rich Virtual Environments", Proc. of Graphics Interface 2006, pp. 139-146.
4. Ball R., North C., "Effects of tiled high-resolution display on basic visualization and navigation tasks", CHI 2005 Extended Abstracts on Human Factors in Computing Systems, pp. 1196-1199.
5. Tyndiuk F., Lespinet-Najib V., Thomas G., Schlick C., "Impact of large displays on virtual reality task performance", Proceedings of AFRIGRAPH 2004, pp. 61-65.
6. Czernuszenko M., Pape D., Sandin D., DeFanti T., Dawe G.L., Brown M.D., The ImmersaDesk and Infinity Wall projection-based virtual reality displays. SIGGRAPH Comput. Graph. 1997; 31(2):46-49.
7. Kothary N., Lock L., Sze D.y., Hofmann L.V., Computed tomography-guided percutaneous needle biopsy of pulmonary nodules: impact of nodule size on diagnostic accuracy. Clin Lung Cancer. 2009; 10(5):360-3.
8. Rovira A., Auger C., Alonso J., Magnetic Resonance Monitoring of Lesion Evolution in Multiple Sclerosis. Ther Adv Neurol Disord. 2013; 6(5):298-310.
9. Fedorov A., Beichel R., Kalpathy-Cramer J., Finet J., Fillion-Robin J-C., Pujol S., Bauer C., Jennings D., Fennessy F., Sonka M., Buatti J., Aylward S.R., Miller J.V., Pieper S., Kikinis R. 3D Slicer as an Image Computing Platform for the Quantitative Imaging Network. Magn Reson Imaging, 2012. 30(9):1323-41.