Medical Imaging VR: Can Immersive 3D Aid in Diagnosis?

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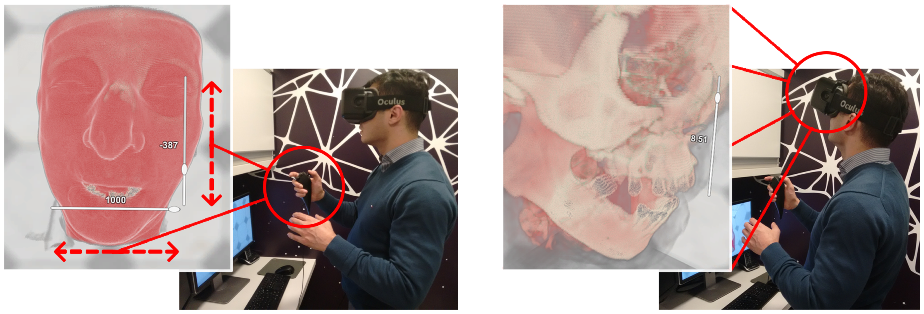

Figure 1: *A user interacting with a 3D dataset through our VR interface. On the left, he changes the contrast for soft tissues using a handheld analog joystick. On the right, he highlights the bonny structures and focuses on a specific region with natural head rotations.*

Abstract

In the radiology diagnosis process, medical images are most often visualized slice by slice on 2D screens or printed. At the same time, the visualization based on 3D volumetric rendering of the data is considered useful and has increased its field of application. In this work we present a user study with medical specialists to assess the diagnostic effectiveness of VR usage in fracture identification over 3D volumetric reconstructions. We then performed user experiments to validate the approach in the medical practice. In addition, we assessed the subjects perception of the 3D reconstruction quality and ease of interaction. Among other results, we have found a very high level of effectiveness of the VR interface in identifying superficial fractures on head CTs.

Keywords: Virtual Reality, Healthcare, Diagnostic imaging, 3D images, Radiology, Oculus Rift

Concepts: •**Applied computing** → *Health care information systems;* •**Computing methodologies** → *Virtual reality;*

1 Introduction

In diagnosis, while 3D image acquisition is ubiquitous (e.g. CT and MRI), the outgoing images are still most often visualized slice by slice on 2D screens or printed out for posterior analysis. This occurs because 2D slices show both internal and external structures in one image. Spatial information, however, is lost. While volume visualization is capable of solving this problem, it faces the difficulty that more internally located structures may be occluded by structures near the surface [Hänel et al. 2014]. In some specific cases only (e.g. planning surgeries, complex fractures and virtual colonoscopy), a visualization based on 3D volumetric rendering of the data is considered useful and is currently applied [Randall et al. 2015; Mirhosseini et al. 2014]. Even in these cases, the volume is exhibited and manipulated with mouse and keyboard by the specialist as an interactive projection on conventional 2D screens.

Given this context, we report, in the present work, a user study to assess VR usage in the diagnostic procedure of fracture identification. Our premise is that VR technology allows for accurate diagnosis with high efficiency. Moreover, we evaluated the diagnostic effectiveness and quality of 3D volumetric reconstructions made for current VR devices.

2 Methods

We selected two specific exams for our analysis. The exams have been searched in the partner clinic's database with the strings: *comminuted fractures*, *bone fracture* and *polytrauma*. Head CT studies appeared as a convenient choice as they are common in routine examination of trauma situations. Moreover, they are suitable for analysis by any radiologist, regardless of specialty.

Fifteen radiologists and one medical physicist participated voluntarily in the study (thirteen males and three females). The subjects have subspecialties in radiology. The 33.3% are members of the neuroradiology team, followed by 26.7% of specialists in abdominal radiology, 26.7% in musculoskeletal, 6.7% in thoracic and (6.7%) other in specialties. This study was the first experience with virtual reality for 81.3% of participants.

The main user task in our experiment is to find fractures in a reconstructed 3D volume in a virtual environment by applying transformations (such as zoom and rotation) and windowing adjustment. No additional clinical information or viewing in 2D plans were

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available. Furthermore, no cutting planes were allowed in this version of the interface.

The medical VR interface used in our experiment runs on multiple possible devices. It can be used with a smartphone adapted as an HMD using Google Cardboard or other off-the-shelf or 3D printed mobile HMDs. Alternatively, it can run on a desktop environment attached to an Oculus Rift and a clicker. Both platforms allow rotations, translations and windowing (i.e. to select the density corresponding to bone or soft tissue) in the reconstructed volume. A simple switch action, such as a click on a joystick or a trigger on the HMD, allow navigating through the visualization options. For this experiment, we chose to use the Oculus Rift DK2 attached to a desktop computer.

3 Results and Discussion

The first exam has 7 correct answers and 2 false, as illustrated in Fig. 2. Regarding the correct options, the lateral right orbit wall and right orbit floor were correctly interpreted by 7 radiologists (87.5%). The right zygomatic arch by 5 radiologists (62.5%), the nasal bones 4 (50%) and maxillary sinus walls 3 (37.5%). The left orbit floor and Le Fort type I had a single vote each. The answers to the two false alternatives are also shown in the chart of Fig. 2. No subject marked the left zygomatic arch (100% hit).Mandible (jawbone) ramus had one wrong vote made by only participant that is a medical physicist, who is not expected to succeed in identifying fractures.

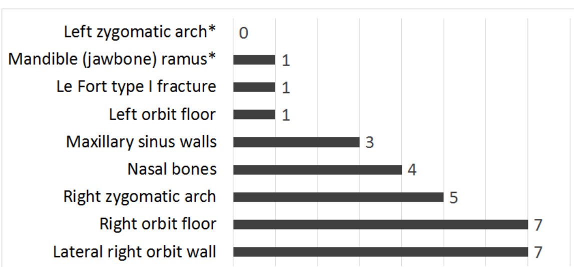

Figure 2: *Diagnostic effectiveness for dataset a. Possible fractures are in the y-axis. The x-axis shows the number of users that have marked each possible option. The ∗ indicates that the respective bar represents a non-existent fracture (false option).*

Fig. 3 shows the answers about the second exam with six correct alternatives and two false ones. Depressed right anterior maxillary sinus wall was interpreted by all radiologists (100% hit). Then, the right zygomatic arch and depressed right anterior frontal sinus wall received 7 votes each (87.5% hit). The posterior maxillary sinus wall, which is an internal structure scored only two votes (25%) and other 2 correct fractures in internal structures have no vote. This was expected, as the ethmoidal cells, posterior frontal sinus wall and posterior maxillary sinus wall are head internal structures, hardly seen without making cuts in the 3D volume or viewing on 2D slices. Similarly to the first exam, the dataset b scored only one vote in one of the false alternatives, applied to bone nasal left, and none in the other. The exam presents facial polytrauma affecting nearby structures. This seem to have taken a participant to precipitate (rather a memory effect than perception). The lateral left orbit wall had no marking, as expected.

The general usability average was 4.0625 points (max = 5, min = 2, stdev = 1.44). This assessment reflects the simplicity of our interface to focus on a region (zoom + head rotations) and to set parameters of interest (window). Concerning the quality of the reconstructed image volume, we rely on the subjective analysis of radiologists and medical physicists, who are very demanding in terms of image attributes. In both studies their answers present a general average of 2.85 (max = 5, min = 2, stdev = 1.1474).

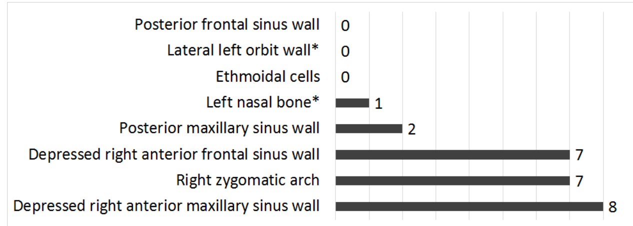

Figure 3: *Diagnostic effectiveness for dataset b. Possible fractures are in the y-axis. The x-axis shows the number of users that have marked each possible option. The ∗ indicates that the respective bar represents a non-existent fracture (false option).*

4 Conclusion and Future Work

In this paper we presented a user study with medical specialists to assess diagnostic effectiveness of VR usage in fracture identification. We performed experiments to validate the proposed approaches with sixteen expert professionals in image diagnostic procedures. The results showed high effectiveness in identifying superficial fractures for two different volume exams. We believe that VR provides referring physicians with a more complete and intuitive interface to analyze the results of imaging exams. An excellent opportunity for a future work is to design an experiment to assess if it is possible to increase the physicians' understanding and correlation between the imaging findings and clinical examination.

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