Towards More Effective VR-Based Presentations of Real-World Assets: Showcasing Mobile MRI to Medical Practitioners and Technicians

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Abstract

The main aim of this research is to examine the benefits of using VR to present mobile MRI. Even though such devices were specifically designed for mobility, it is still often unfeasible to transport them across long distances. Hence, new methods are required that help familiarize potential patients and medical personnel with the advantages and shortcomings of mobile MRI. To do this, we developed a system that transports the user to the VR environment populated with the real-scale MRI model.

Index Terms: Applied computing—Life and medical sciences—Consumer health—; Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality

1 Introduction

Over the past decades, medical imaging has become one of the most prolific aids in patients' diagnoses. One of the most widely adopted imaging techniques is *magnetic resonance imaging* (MRI) [4]. MRI scanners come in various forms, including stationary or mobile devices mounted on a truck trailer. As they ensure the same quality of diagnostic results as classic, stationary devices, the mobile MRIs are presently considered a real alternative and supplement to currently used non-portable imaging equipment [4]. Mobile MRI can also be rented when a medical facility does not have an imagining apparatus [4].

However, even in the case of mobile MRI, the ability to transport such devices over long distances can prove to be difficult and resource-consuming. Their logistics will depend on time, type and means of transport, weight and costs. Moreover, the transit causes a temporal inability to use the device for medical diagnosis and increases the risk of damaging the MRI.

Despite these difficulties and costs, the manufacturers and renters of mobile MRI devices want to be able to explore new markets and familiarize medical practitioners with the possibilities of new MRI scanners and other medical apparatuses.

A promising approach to this is offered by VR technology which is already widely adopted in health informatics [3]. Unlike other multimedia technologies, VR allows the user to be completely "immersed" in a digitally generated three-dimensional space by evoking a "sense of presence" [7] in the user. Consequently, we utilize this characteristic and simultaneously explore the benefits and limitations of using VR to present medical devices to a broader audience in a cost-effective manner.

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To achieve that, we prepared a real-life size model of a mobile MRI truck trailer, which we used to populate an interactive VR environment (see Fig. 1) that a user could freely explore by means of walking [10]. In that context, we decided to use a standalone head-mounted display (HMD) [9, 11] rather than other potential realizations of a VR environment such as CAVE [2] not to diminish the portability gains offered by a wireless HMD.

2 System Architecture

2.1 Apparatus

To develop our VR system, we used *Unity*[1] game engine that is widely used by the VR community [9, 11]. To facilitate the VR environment, we decided to employ the *Vive Focus 3*[2] HMD due to the range of capabilities offered by this particular standalone headset. This includes the high display resolution (2448 x 2448 pixels per eye), up to 120°FoV, built-in hand-tracking and the possibility of pairing the Focus goggles with the wrist trackers. The headset also offers an option of streaming the user's view through *Miracast*.

We used Vive wrist trackers to map and track in real time the exact position of a chair with wheels in the real world with which the users can interact within the VR environment. Thus blending virtual and real worlds to provide a more immersive experience.

2.2 System Components

Thanks to the utilization of object trackers, i.e. Vive wrist trackers, our VR environment is a blend of real and virtual elements consisting of five distinct components. These elements are:

(1) **User**: in an interactive VR-based presentation (see Fig. 1), we often consider the user as an integral part of the visualization [9, 11]. This is even more persistent in our case as we want to give the user a "sense of presence" [7] within the modeled asset, here, the indoors of a real-life mobile MRI truck.

(2) **VR headset**: the VR goggles should map the real-world position of the user and selected components of the presentation onto the position within the 3D model of a mobile MRI truck. Furthermore, to provide a more immersive experience as well as increase the user's feeling of presence, the headset should support hand-tracking capabilities [1].

(3) **Mobile MRI model**: the exact 3D replica of the mobile MRI interior adjusted to provide a feasible trade-off between the level of detail and visualization smoothness (see Fig. 1). It should be prepared on a real-world scale, pending the size of a space intended for moving the user in the real world. Moreover, the MRI model should incorporate interactive elements (e.g. a movable chair or door) to engage the user [7].

[1] https://unity.com/
[2] https://www.vive.com/uk/product/vive-focus3/overview/

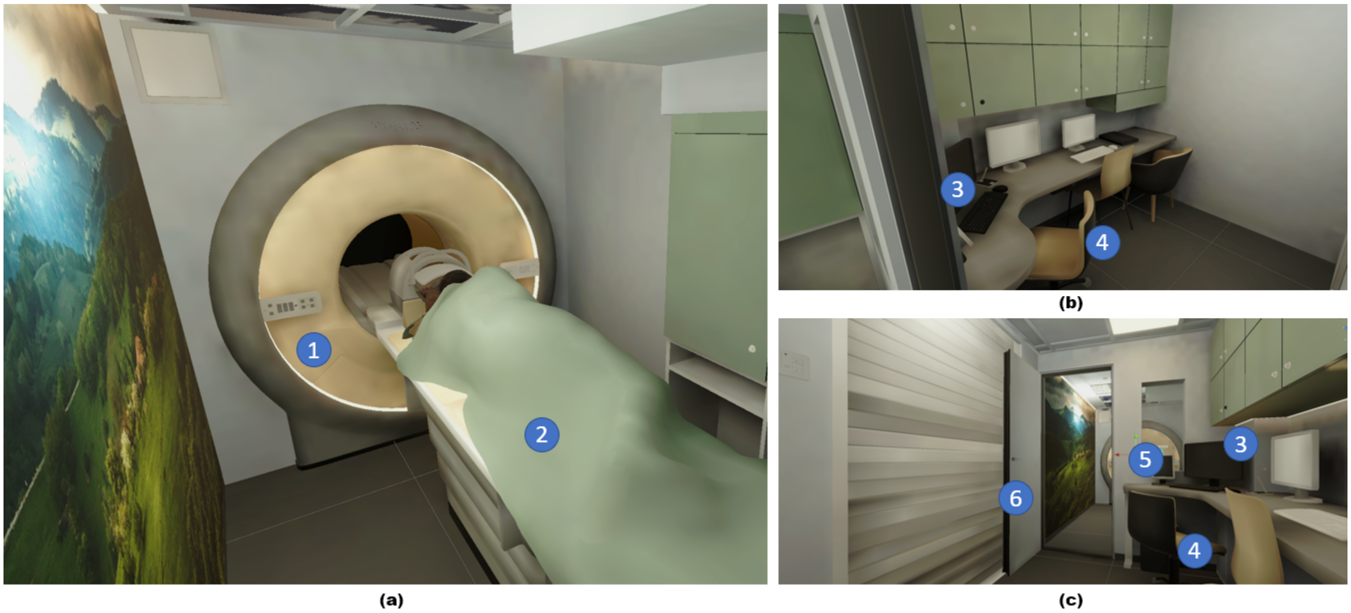


Figure 1: The indoors of a mobile MRI truck as seen by the VR headset wearer: (a1) the MRI device, (a2) the avatar of a patient undergoing an MRI scanning procedure, (b3), (c3) a monitor which will show MRI scan results, (b4), (c4) an avatar of a movable physical chair, (c5) button for starting MRI scan which will cause the doors (c6) to close, sliding of the avatar into the MRI device, and scan to start.

(4) **External monitor**: a screen on which the user's view is streamed in real-time. The monitor provides a reference point to a person responsible for safeguarding the user and a lure for other potential presentation viewers.

(5) **Physical railings**: A passive presentation element is used to determine and limit the user's movement trajectory, which also protects against a collision with objects in the physical space.

The relationships between the above five elements can be further analyzed by examining signals exchanged between them [9, 11].

In that context, the **user** exchanges signals with the rest of the VR system in a number of ways. First, by using hand-tracking functionality, the user transmits signals to the **VR headset** with the movement and position of hands [11]. In response, the **VR headset** simultaneously provides feedback by displaying virtual hands. Moreover, the **user** interacts with the **MRI model**, whilst all the user's view is unidirectionally streamed onto the **external screen**. Moreover, the **user** can also come in physical contact with the **physical railings**.

3 Interface Verification and Usability

As our system is yet to undergo evaluation with users during the upcoming Arab Health 2023 conference, we verify the usability of the system using a heuristic approach [6]. In this case, we utilized Nielsen's usability guidelines [5,6] as they are a tool often employed in immersive interface research [9]. Furthermore, we identified the potential improvement of our interface presented next to the individual heuristic analysis.

i **Visibility of system status:** the system shows its status to the user thanks to a number of interface features, i.e., through the (1) hand models showing the actual movement, position and hand gestures made by the user (see Fig. 2(a1)), (2) bouncing arrows together with textual labels denoting interactive elements of the VR environment (see Fig. 2(b5)(b6)), (3) displaying the results of the hand scan on the screen in the virtual control room (see Fig. 2(b3)(c3)), (4) a recorded sound of a working MRI device played during the hand palm scan, and (5) movable visualization components: the position of physical chair mapped onto chair's 3D model position in VR (see Fig. 2(b4)), and the opening or closing of the door between the control and MRI scanner room (see Fig. 2(b6)).

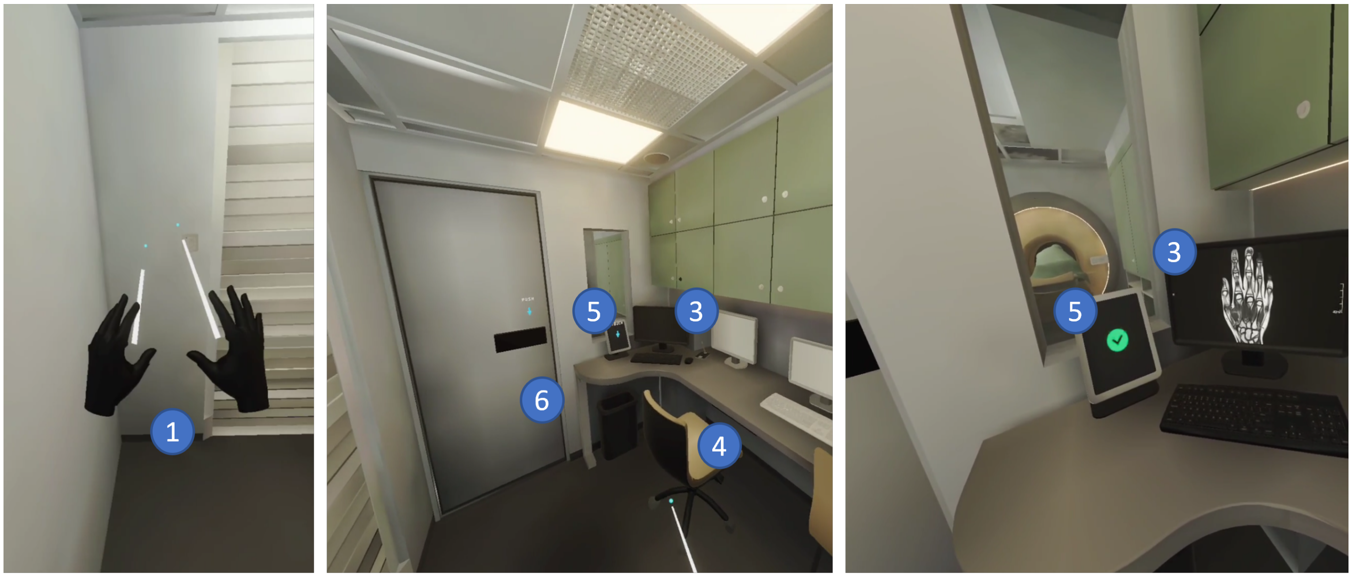
ii **Match between system and the real world:** the system mimics the real-world mobile MRI environment to a great extent. We achieved this effect by a combination of the hand-tracking and gesture recognition (see Fig. 2(a)) as our main interaction method and by populating the VR environment with a near-perfect representation of the mobile MRI interior (see Fig. 1 and Fig. 2). The user can explore the virtual space in exactly the same manner as in the real world by simply walking within the VR environment. Moreover, during the mock hand scan (see Fig. 2(c)), the system plays a recording[3] of an actual MRI examination. In addition, the user is able to sit on a physical chair mapped onto the position of the 3D chair model in the virtual control room (see Fig. 1(b4)(c4) and Fig. 2(b4)).

iii **User control and freedom:** the user can freely explore the mobile MRI interior, i.e. move around in the VR virtual space while walking in the non-virtual world as the user's position is mapped in real-time onto the coordinates in the virtual world.

Suggested changes: allowing to redo the mock hand scan as often as the user wants.

iv **Consistency and standards:** all interactive elements of the VR visualization are marked in the same way, i.e. with the bouncing arrows with textual labels (see Fig. 2(b5)(b6)). Since we used a realistic life-size model of the mobile MRI interior (see Fig. 1 and Fig. 2) and the interaction with the system occurs by recognizing the user's natural hand gestures (see Fig. 2(a1)) (e.g. pushing the door between the control and

[3] Bernie Borkent, Recordings of an MRI scanner of the UMC Utrecht `https://freesound.org/people/borQue`, used under CC BY 3.0



(a) (b) (c)

Figure 2: All the interactive elements of our system are confided in the mobile MRI control room. The doors and the tablet are marked with bouncing arrows and textual labels. The 3D chair model denotes the position of a physical chair in the real world, tagged with the wrist tracker.

MRI scanner space), the consistency with the exploration of physical MRI is maintained to a high degree.

Suggested changes: allowing the user to push the door from both sides rather than pulling it from the other side.

v **Error prevention:** the view shown to the user wearing the VR headset will be simultaneously streamed to an external screen to enable monitoring of the user's behavior and detect potential errors.

Suggested changes: allowing to redo the mock hand scan as many times as the user wants.

vi **Recognition rather than recall:** as we populated the VR environment with a very realistic model of the mobile MRI interior (see Fig. 1 and Fig. 2) and used close-to-natural interaction techniques based on hand tracking and gesture recognition (see Fig. 2(a1)), the user is not forced to learn and memorize new ways of visualization exploration.

vii **Flexibility and efficiency of use:** our VR application is intended for both professional medical personnel (e.g. doctors and radiology technicians) and patients who are not familiar with mobile MRI scanner technology. We achieve this effect mainly thanks to the use of a realistic mobile MRI interior model (see Fig. 1 and Fig. 2) and close-to-natural interaction techniques (see Fig. 2(a1)).

Suggested changes: allowing to redo the mock hand scan as many times as the user wants.

viii **Aesthetic and minimalist design:** we prepared the interface in an aesthetic and clear manner. Moreover, we marked all its interactive elements with textually labeled bouncing arrows. (see Fig. 2(b5)(b6))

ix **Help users recognize, diagnose, and recover from errors:** We will stream the VR user's view onto an external screen to supervise the user's behavior and help us detect potential issues. Thanks to such an approach, the user can seek the help of the presentation supervisor while being immersed in the VR environment.

Suggested changes: allowing to redo the mock hand scan as often as the user wants.

x **Help and documentation:** we designed the system to familiarize patients and medical staff with mobile MRI equipment and its usage. For both these groups of users, it is crucial to provide natural interaction techniques such as the use of natural hand gestures (see Fig. 2(a1)), allowing them to explore the MRI by walking, supporting mixed-reality interaction via, for instance, the possibility of identifying and sitting on a physical chair from within the VR environment (see Fig. 2(b4)). Thanks to these features and the population of VR environment with a realistic real-life size mobile MRI interior 3D model (see Fig. 1 and Fig. 2), the system does not require additional documentation. In addition, as we are streaming the user's view on the external screen, it is possible to obtain immediate assistance from the person supervising the VR presentation.

4 Discussion and Conclusions

In this abstract, we present how a VR environment could be used to develop a cost-effective yet engaging presentation of medical equipment. As a basis of our system, we used a one-to-one replica of a mobile MRI truck trailer. Moreover, we have implemented a range of interaction techniques. This includes hand-tracking and gesture recognition [11] (see Fig. 2(a1)) as well as the usage of external trackers to provide a truly immersive experience for our users [1] (see Fig. 2(b4)).

We verified the usability of our system with the help of the well-established Nielsen's heuristics [5, 6]. Thanks to this approach, we have confirmed the applicability of our system for its main purpose, i.e., familiarization of potential patients and medical personnel with the advantages and shortcomings of mobile MRI systems. This exercise has also helped us to identify and include two potential improvements to our interface, mainly the ability to redo the mock hand MRI scan and the way in which the user should operate the doors connecting the virtual control room with the MRI scanner space.

Consequently, we designed, built and refined a prototype of a VR environment populated with a close-to-real replica of a mobile MRI device capable of familiarizing medical practitioners with the possibilities of new MRI scanners and other medical apparatuses.

5 Future Work and Evaluation

In the near future, we plan to test our system in a non-laboratory, real-life setting with a number of users. In this study, which utilizes a mixed-methods approach, we will track, collect and analyze qualitative and quantitative data concerning the participants' behavioral patterns [11] in an interactive and non-interactive VR environment. We will recruit the testers from volunteers working within the medical sector taking part in the *Arab Health 2023* exhibition in Dubai. This will allow us to further rectify our design by selecting and implementing the most appropriate methods of interaction for medical technology showcasing.

To capture the data, we plan to use functionalities offered by the *Ultimate Replay 2.0*[4] package. This Unity asset allows for capturing of a user's actions while immersed in VR that can be later on replayed from a chosen perspective, i.e. camera orientation and position. We will also capture the rotation and position data related to a user's hands and head movements.

Moreover, we will capture further qualitative data through questionnaires administered before and after participating in the experiment. Here, we will ask the volunteers to fill in the *Simulation Sickness Questionnaire* (SSQ) [8] before and after using the VR headset in order to establish a baseline before the study and track the occurrence of simulation sickness symptoms after using our VR system. Next, to assess the "feel of presence" experienced by participants [7], we will ask to fill in the *Igroup Presence Questionnaire*[5] (IPQ). Both of these questionnaires are often used in user studies involving an immersive interface [10, 11].

Consequently, the results of planned user studies will allow us to ascertain whether our VR system, coupled with currently existing high-end commercial headsets, will provide a feasible alternative to *in situ* presentation of medical assets.

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