Virtual Reality Multiplayer Interaction and Medical Patient Handoff Training and Assessment

Christopher Lewis, Daniel Enriquez, Lucas Calabrese, Yifan Zhang
Computer Science and Engineering
University of Nevada, Reno
Reno, NV, USA
christopher_le1@nevada.unr.edu, denriquez@nevada.unr.edu, lcalabrese2018@gmail.com, yfzhang@nevada.unr.edu

Steven J. Anbro, Ramona A. Houmanfar
Behavior Analysis Program
University of Nevada, Reno
Reno, NV, USA
stevenanbro@nevada.unr.edu, ramonah@unr.edu

Laura H. Crosswell
Reynolds School of Journalism
University of Nevada, Reno
Reno, NV, USA
lcrosswell@unr.edu

Michelle J. Rebaleati, Luka A. Starmer
@Reality
University of Nevada, Reno
Reno, NV, USA
mrebaleati@unr.edu, lstarmer@unr.edu

Frederick C. Harris, Jr.
Computer Science and Engineering
University of Nevada, Reno
Reno, NV, USA
Fred.Harris@cse.unr.edu

***Abstract*—Virtual worlds have the potential to mirror many aspects of real life. Immersive virtual worlds constructed through the use of Virtual Reality (VR) are useful in simulating the technology, equipment, and practices of many different fields. In the medical field, VR can be heavily relied upon to circumvent a wide variety of tools, human resources, and other objects that may be limited or difficult to procure at any given time. As a result, the goal of this research was to develop a low-stakes virtual environment (VE) in which medical students could practice developing skills necessary to their profession. As such, this environment needed to mirror, as closely as possible, an environment the medical students would see frequently during their practice. The result of this work is an application for use in patient handoffs, a situation where patient care is transferred from one medical professional to another. In order to achieve this, this work created a multiplayer VR environment with an immersive virtual world simulating standardized patient rooms and standard mediums of communication and interaction between users. While doing so, a framework was developed as the need for VR multiplayer, VR with voice communication, and a VR interaction system was seen to be needed for future VR multiplayer applications. This framework can be used to construct more applications for communication fueled environments, like the patient handoff.**

***Index Terms*—Virtual Reality, Multiplayer, Framework, Software, Simulation, Eye Tracking, Photogrammetry**

I. Introduction

The medical field, and those who work in it, can be considered the backbone of a modern society. This is evident in normal life, but overly obvious in a global pandemic. A task often taking place in any hospital around the world is the patient handoff. The patient handoff is the transfer of patient care from one medical professional to another. Patient handoffs happen at a very high frequency, often occurring multiple times per patient, per day. It is estimated that the most serious adverse events in hospitals are caused by communication failures, mainly to do with patient handoff errors [1]. These errors can cause very large problems to both patients and medical professionals. Through virtual reality, this work introduces a tool to streamline and standardize patient handoff training, a step forward in addressing these errors.

VR is rising in popularity throughout the world in many different sectors. Major sectors innovating with virtual reality are the education and medical sectors. In fact, there has been major growth in the use and innovation of VR for training medical professionals and for healthcare in general. VR provides these sectors, and many other sectors, with engaging and immersive educational scenarios that help reinforce taught behaviors in a kinesthetic way. These kinesthetic learning methods help to engage the user, which cements the lesson into their memories by providing multiple learning styles for the user to learn from [2].

II. Background and Related Work

Patient handoffs happen very regularly across any hospital, making the handoff one of the most pivotal and important actions medical personnel should learn to do effectively. Yet, handoffs have the potential to cause a large amount of harm due to their somewhat regular missteps and miscommunications [3]. This highlights the need for greater care and plentiful innovation in the education and training of medical professionals, particularly in the skill of patient handoff. The SBAR is an effective innovation in the communication and standardization of handoffs. It has been shown that the SBAR has had an incredibly positive impact in the areas it affects [4].

With the improvement in the structure of the handoff that SBAR creates, innovations have also taken place around the education or implementation of handoffs. One such innovation is with the user study this application was built for [5].

A. Medical Training Simulators

Innovations in medical training can have wide reaching impacts for the overall medical community. One such innovation is within the use of haptics for medical training simulators. Coles, Meglan, and John in [6] cover the use of haptics for training in simulators through various scenarios, such as: palpation, needle insertion, laparoscopy, endoscopy, and arthoscopy. Overall, the authors found that surgical simulations incorporating haptic feedback provides a richer training experience, compared to the simulations that don't.

VR based medical training simulators have also come to fruition. One such medical training simulator is for periodontal training [7]. The authors put haptic feedback into a VR simulator to allow the user to fully experience working on teeth. This is ultimately a safer approach since it doesn't involve a patient or real teeth. The authors also found, through various studies and expert interviews, that their work provided a realism that could serve as a, "useful instruction tool with high teaching potential" [7].

B. VR in Medicine

VR is seeing more prevalent use in the medical industry as an alternative for training applications for surgeries. New technologies, such as the simulations made by ArthroSim [8] and ORamaVR [9], are some of the most innovative VR surgical simulators.

ArthroSim [8] is a VR knee and shoulder arthroscopy simulator. ArthroSim uses a dedicated machine for high precision surgery training. It uses a dual-monitor display that reflects the training simulator task and data, as well as the simulated imagery of a camera used for these surgeries. This machine focuses on precision due to its dedicated machinery and its use of haptic feedback in training. AnthroSim also focuses on realism, where the precise use of haptic feedback would be similar to physically performing surgery on a person. The simulated images of the camera also use accurate anatomy to reflect where the user is currently working. This technology provides a much safer and efficient solution to training surgeons, opposed to letting surgeons learn on mannequins or on patients.

OramaVR [9] is a general purpose VR medical training simulator with multiplayer capabilities. One of the largest benefits of using this system is its reliance on mass-produced VR head mounted displays (HMD). Not only are these HMDs much cheaper than a dedicated machine, but they can generally be used interchangeably with other varieties of HMDs. This allows the application to be used by a large variety of users and to be flexible for new technology and innovations within VR technology.

C. Multiplayer VR Simulators

Multiplayer VR is a relatively new technology. Although some applications, mostly video games, use multiplayer VR as a form of entertainment, not much research has been done surrounding it and its intrinsic problems. One such intrinsic problem with VR that has been studied is room-scale multiplayer VR. Sra in [10] addresses the use of a Galvanic Vestibular Stimulation system to allow the user to avoid collisions with their environment while not breaking the user's immersion. This technology looks incredibly promising for the future of VR for commercial use, as not every person has a large room to navigate in.

Multiplayer VR can also have very interesting and useful applications. One such application is in the world of construction. Du, Shi, Mei, Quarles, and Yan in [11] detail the use of multiplayer VR for building walkthroughs. A building walkthrough is a tour of a building, often before it is built, through the use of simulations, models, and CGI images. Building walkthroughs using multiplayer VR allowed this project's stakeholders to view a 3D virtual model of a building that they otherwise couldn't experience aside from inside a less interactive medium. It is also important to note that this application also allowed the users to verbally interact with each other. Due to the immersive nature of VR applications, the users of this program would also be able to experience the building in the exact same scale as their avatars, causing a more robust and informative walkthrough.

III. Implementation

A. Process of Execution

As described in Figure 1, before the program is started two participants were briefed separately as to the current condition of a unique simulated patient. Each participant wrote down any information they chose about the patient to help convey the information needed during the patient handoff. Each of these files are given to the operators of the program to be uploaded into the program.

Once the participants have been properly worn the HMD, the simulation will start. Both participants are then put into the VR world together. They each start in the same room as seen in Figure 2. This room allows the participants to choose their avatar and appearance freely. Once either participant is ready, they can point and press their remotes at a sign that will teleport them into the standardized patient room as seen in Figure 3.

When both participants had teleported to the standardized patient room, they could start the patient handoff for each patient. Each participant had the notes they made about the patient displayed on their left hands in the form of a clipboard. This was done so that they could glance at it and help themselves complete their patient handoff using the written information, like in a physical working environment.

Finally, when both participants completed their patient handoffs, the simulation ended and they took off their HMDs.

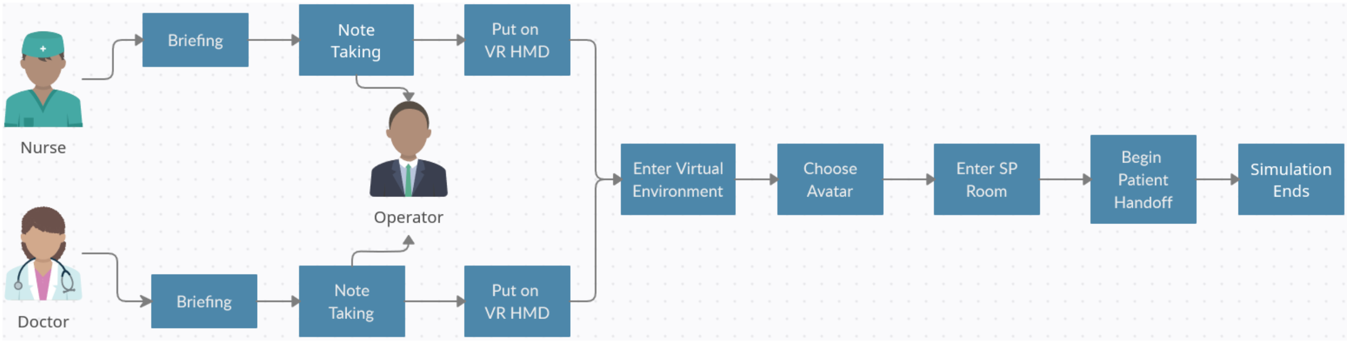

Fig. 1. The execution order of the application in use during the user study.

Fig. 2. A participant configuring their avatar in the starting room.

Fig. 3. The standardized patient room put into VR via photogrammetry.

B. Eye Tracking

For this work the Vive Pro Eye was used for eye tracking through the interface of HTC's SRanipal SDK [12]. The observer and the recording could observe timestamps and location data of when and where the user was looking throughout the application. This data could be used to determine where in their handoff the users were engaging with the other user, looking at the patient as seen in Figure 4, or getting distracted by the environment.

Fig. 4. The standardized patient room put from the perspective of the observer with eye tracking visible.

C. Recording

To monitor user experience in this application, this work recorded the movements, communications, and interactions using RockVR video capture [13]. This video capturing is recording the exact screen that the observer views, including eye tracking lines, and audio from both participants. The physical room during the user study [5] was also being recorded using an in-room camera that connected to an overseer station as seen in Figure 5. Lastly, some participants were recorded in a more close-up manner, as seen in Figure 6.

IV. Room Creation

The VR patient room was a very accurate approximation of a standardized patient room. This room was created to have the participants in an immersive space that is, very likely, familiar to them. To generate this room, this project needed to do three tasks accurately. First, the appearance of the room needed to emulate a standard patient room. Second, the room had to feel approximately the same size as it would in real life. Third, the appearance of the objects, the equipment and the dummy needed to appear as similar to real life as possible, with training equipment mirroring standard tools that are used in medical practice. Both the first and second tasks were done using a technique called photogrammetry, while the last task needed to be done, largely, manually.

Fig. 5. The overseer station used in the user study.

Fig. 6. A participant engaged in the user study with an operator in the background.

A. Photogrammetry

Photogrammetry, broadly, is the technique of finding the correct size of virtual objects that correlates with the size and spacing of the physical objects they are associated with. The entire room, and the full body mannequin, are both generated using photogrammetry for 3D modeling. These models were exceedingly large in terms of the storage space they required on the computers. These models were so large, in fact, that Unity [14] struggled to render them. Thus, we had to lower the polygon count of the objects. To do this, every wall was replaced with larger flat polygons, rather than a large amount of small polygons. Other parts of the room were then cleaned to remove gaps and other wrong textures, all while replacing these features with larger polygons that would take up less rendering time. This removes some of the finer resolution of this technique, but ultimately doesn't change the appearance of the room to any significant degree.

B. Room Objects

A few of the room objects were not available to have photogrammetry done to them. This includes the computer monitor, the cart of medical equipment, and the IV bag and trolley. All of these room objects were instead created using computer-generated imagery (CGI). Each of these elements had to be placed and sized directly emulating the room's photogrammetry. This created a small amount of scaling issues, as the objects couldn't be exactly the correct scale as we had no real life object to compare to the virtual room. All room objects can be seen in Figure 7.

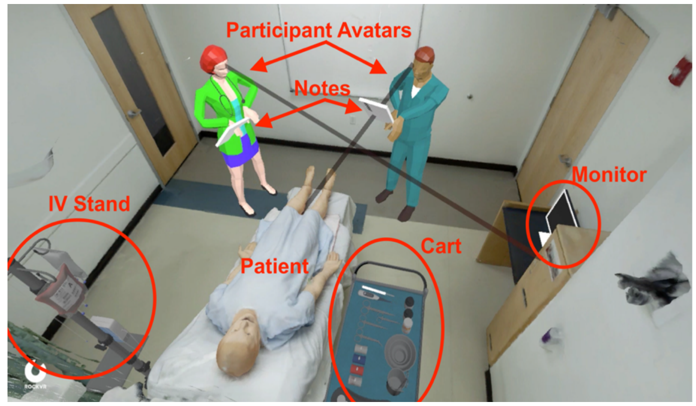

Fig. 7. The room objects that were made using CGI and the patient mannequin.

V. INTERACTION

A. Avatars

The participants had the ability to change the avatar of their own personal character. This allows them to change their own virtual appearance to their liking to either fit their role or fit their own personal character. The participant can change to either wear a medical smock or to wear scrubs to fit their role of a doctor or a nurse. These outfits had a variety of different options associated with them as seen in Figure 2. They could also change their skin color, gender, and hair color accordingly to whatever they deemed fit.

B. Voice and Audio

The participants are required to communicate verbally to each other in order to perform the patient handoff. This includes both producing audio and receiving audio throughout the application. This was accomplished using the built-in microphone and speakers found in the HMD. As a result, this application included the ability to communicate with one another via voice chat. Due to this voice chat integration, both participants can execute the patient handoff in almost exactly the same ways they would in the real world.

C. Clipboard

Each of the participants were briefed before entering the virtual world on a particular scenario of a patient's current status. Each of the participants were then instructed to write down everything they wished to convey during the patient handoff. Theses notes were then transferred into the application and displayed on a clipboard in their left hand to emulate a typical medical setting. These notes were only available to be seen by the person who wrote them.

VI. Framework

A. Interactables

In many instances of multiplayer VR, some form of visible interaction can occur between objects and/or users that all users should be able to see. In this framework, interactable objects in the shape of spheres were made that could be picked up and thrown that the other player would be able to see move and interact with the environment. If a player were to pick up the object by moving to the object, putting their controller into the object, then pressing the trigger, the object would then mirror the movements of their controller. Upon release of the trigger, the object would be thrown in the direction and speed that mimics the direction and speed of the controller.

These types of interactions require data transfers to be broadcast between all of the users involved in that instance of VR. This is to ensure the concurrency and accuracy of these interactions on all user instances. To accomplish this in the multiplayer framework, a client to server system was implemented. A client to server system has a server that communicates between the players and gets the inputs necessary for program functions such as movement and interaction updates and it shares it to all users in that instance of VR. The server also stores important information such as synchronized objects and the active scene. As a result of this server model, if a user were to grab an object, the object would exist on the server's independent storage of the object. This means that if the user were to move the object, the user needs to communicate with the server that they have grabbed the object and have moved it. The server would then broadcast to the user holding the object and all other users that the object is being moved. This handshake is very slow, and the movement of the object would appear choppy and inaccurate. However, to counteract this problem, our framework has the ownership of the object swap from the server to the player in contact with the object. This means the server is no longer keeping track of the object, but is getting frequent updates by the user holding the object as to the position, rotation, and velocity of the object. This means that there would be no latency in moving the object for the user holding the object. When the interactable is then released by the user, the server takes control of it again, causing the updates to only be broadcast from the server and thus lowering latency between the users.

It is important to note that while the user study only allowed two users into the VE at any given time, this framework allows for many users to collaborate. The varying factors for precisely how many users are: the number of assets used in the game, the internet speed of the users and server, the power of the user's computer (largely GPU based), and the number of assets set up for networking/interaction.

B. Voice

Voice communications across users are synchronized to the other player. This means that if one player speaks the other player is able to hear the audio. In this work, the medium of voice communication was done through Photon PUN Voice chat [15], with the microphones being connected to the HMD as well as the audio from the other person coming through the speakers of the HMD. Voices were also being played and recorded on the observer's computer.

VII. Conclusions

VR is seeing more implementation in training and education than ever before, particularly inside the field of medicine. With medicine being one of the most important parts of civilization, it is critical to improve the training of common sources of error and miscommunications, like the patient handoff. The work presented is an application where the standardization of patient handoff training could be effective in achieving reduced errors and reduced miscommunication.

This work demonstrated a framework for user communication and user interaction in multiuser VR environments. It also created an application specific to typical medical environments and training in a particular medical scenario. This application was tailored to a standardized patient room and attempted to mirror common interactions and points of communication for evaluation of communication such as voice recording, video recording, and eye tracking. As a result of this application, a framework was developed to streamline the process of these multiplayer interactions that could allow for future development for VR multiplayer interaction applications.

VIII. Future Work

A. VR Cross-compatibility

As a result of this application being made to be compatible with the HTC Vive Pro Eye's eye tracking software [16], the application doesn't work with other HMDs. This means that the program is not compatible with other popular VR hardware, such as: Oculus Rift/Quest [17], Vive Wave [18], mobile VR, etc. A future iteration on this work could allow for the inclusion of different mediums of VR. The removal of a hardware requirement would allow accessibility to people who own a different VR headset. This would, however, disable eye tracking for the HMDs that couldn't support it.

B. Avatar Eyeball Movement

As a result of eye tracking being a prominent feature of this application, it could be beneficial to share the eye movement of the other participant. A situation in which this could be useful is to experiment with the level of eye contact occurring in the hand off. Eye contact is crucial for flawless communication to occur, so allowing other participants to see what another participant is looking at could be very impactful.

C. Avatar Lip Tracking

For communication to occur smoothly in VR, increased immersion is very important. The more immersion the participants experience, the more seriously they would take the simulation, which would cause communication to become more accurate. If a participant is able to see another participant's mouth moving, it might increase the immersion of that participant. An example of technology that could be used is to implement Vive's facial tracking technology and synchronize facial expressions to the other player over the network [19].

D. Object Interaction

In medical environments, it could be useful to have the medical equipment synchronized to other players. This would allow a user to show an application of specific equipment on an object to other users, how to use a stethoscope for example. It would also be more realistic to see objects, that other people are using, move and interact similar to the real world. This may improve the immersion of the users which may improve the effectiveness of the training.

E. Notepad Improvements

The virtual notepad that is being held by the participant may see some utility to share notes if these notes were synchronized across different users. This means that it may be useful for participants to share their notes/objectives to the other users. Allowing the user to dynamically create their own notes is also an important consideration, as creating your own notes is an important function for effective communication. Current note taking technology in VR is limited, as it is difficult to precisely write things down without a physical pen-shaped object to write with. This is an issue with the precision and maneuverability of the standard VR controllers. It is also difficult to type in VR due to the fact that the user is generally standing up or moving around the environment. Standard controllers have issues with precision and speed for typing in VR on a virtual keyboard.

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