The Hand Guide: A Virtual Reality Application for Surgical Training

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Abstract. *Surgical practices in controlled and mistake-safe environments are traditionally limited by the tutor's time availability and by the usage of consumable materials to simulate surgeries in patients. In this context, we developed the "Hand Guide", a virtual reality application that allows expert surgeons to record their hand movements during a simulated surgical procedure and offer it to a surgical student to try to replicate it. The application provides real-time feedback and also a final score at the end of the recorded procedure. Validation with a specialist revealed that the application may be used to teach theoretical content to students with no surgical background and to demonstrate new techniques to experienced surgeons.*

1. Introduction

Virtual reality (VR) and augmented reality (AR) techniques are being developed and evaluated by researchers to allow surgical students to study and practice procedures in a low-risk environment to obtain the required knowledge and experience to operate on patients without putting them at risk [Nagayo et al. 2021, Nagayo et al. 2022, Nair et al. 2021, Munawar et al. 2024].

Traditional training requires the availability of resources that may be consumable, expensive, or hard to obtain, such as animal [Nair et al. 2021], cadaveric, or synthetic models [Nair et al. 2021, Munawar et al. 2024]. A tutor professional is also necessary for this training methodology for providing information about the correctitude of the performed procedure by the students, limiting the self-training [Nagayo et al. 2021, Nagayo et al. 2022].

In this paper, we present the Hand Guide, a VR application developed for the Meta Quest 3 (`meta.com/quest/products/quest-3/`). The application aims to improve surgical training by allowing the recording of surgeons' hand movements and making the record available to students to replay via a 3D "ghost hand". We hypothesize that the usage of hand tracking from Head-Mounted Displays (HMDs) along with the procedure recording function and automatically provided feedback may improve the training process of surgical students by helping them to improve their hand movement precision.

2. Resources and Materials

To evaluate our thesis, we developed the "Hand Guide". The Hand Guide is a VR application developed for the Meta Quest 3 (`meta.com/quest/products/quest-3/`) with two key functionalities: record and replay the movements from one of the user's hands during simulated procedures. The application also provides automatic feedback to users during the replay of procedures.

The application was developed in the Unity Engine (`unity.com`) using the "XR Interaction Toolkit" (`docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@2.3`) and "XR Hands" (`docs.unity3d.com/Packages/com.unity.xr.hands@1.1`) packages to allow the development of the application for VR with the hand-tracking feature. The XR Hands package provides access to 26 key points from each user's hands during runtime, allowing the display of the user's hands in the virtual environment

3. Application

The application environment resembles an operating room with a virtual patient that may be used as a reference for the simulated procedures. Users can choose which functionality to execute by interacting with a floating user interface (UI). In the UI, previously recorded procedures are shown as buttons in a scrollable list.

In the application, users can select which hand they want to record before starting a recording. When the recording function is activated, the application will store the position and rotation of each key point from the user's selected hand in each frame. After the user stops the recording, the recording data is stored in the device in a JSON file.

When the user selects one of the recorded procedures to replay, a "ghost hand" will appear. For each frame, the position and rotation values from the recorded hand key points in the respective frame are assigned to the corresponding key point values of the ghost hand. As a result, the ghost hand will perform the same movements as the user's hand from the selected recording.

Using the application, professional surgeons could record a simulated surgical procedure and pass the recording data to surgical students. The students could replay the procedure to try to replicate the hand movements of the surgeons. The applications provide real-time feedback by painting in red the vertices from the ghost hand related to the key points in a wrong position, that is, key points from the user's hand 2 cm away from the same key point in the ghost hand. Key points in a correct position have their name on the list and related vertices colored green as shown in Figure 1. After the procedure finishes, a final score is displayed to the user indicating how aligned their hand was with the ghost hand during the procedure replay.

The final score is calculated by obtaining the percentage of key points in the correct position for all the frames of the procedure and realizing the mean of it. During the score calculation, the first and last 40 frames are not considered in procedures with more than 130 frames to reduce the influence of the user pressing the buttons to start and stop the recording.

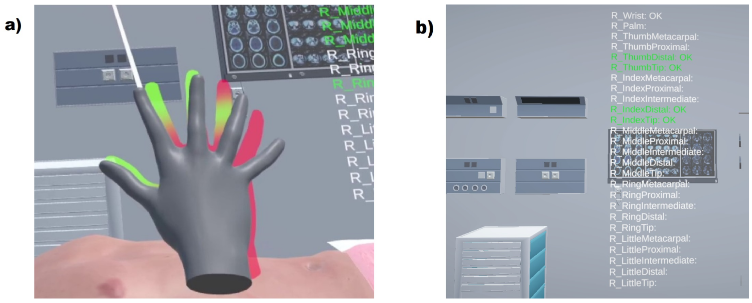

Figure 1. The visual (a) and textual (b) feedback provided by the application. Key points on a correct position have their name and vertices colored in green.

4. Evaluation

To validate the proposed application, we conducted a demonstration and testing session with an experienced cardiologist from a teaching hospital. The cardiologist was not involved in the research and development of the application until the moment of validation.

The purpose of the application and the research hypothesis were presented to the cardiologist along with a video showcasing the application's features. The video also demonstrated how users could interact with the application and how the feedback was provided to the user.

Finally, the application was given for the surgeon to test it and instructions based on a previously established script were provided. The surgeon was amazed with the virtual environment even though he had previously used an HMD. The cardiologist interacted correctly with the UI buttons even though sometimes more than one click was necessary to activate the buttons.

To better demonstrate the replay feature, a procedure simulating an incision was previously recorded and made available in the application. Despite that, when the surgeon started the procedure replay, he had difficulty interacting with the ghost hand when the previously recorded procedure was replayed. Our thought is that it was due to the pre-recorded procedure having a short duration, not allowing the surgeon sufficient time to perceive and respond to the ghost hand.

When asked to record a simulated surgical procedure in the virtual patient, the surgeon affirmed that it would not be possible due to the absence of tactile feedback on the application. According to him, tactile feedback is fundamental for the training of surgeons due to differences in tissue resistance and consistency between organs that the surgeons need to feel and know. He stated that without tactile feedback, it would not be possible to train a surgeon.

However, the surgeon affirmed that it would be possible to perform surgical training using the application if the tactile feedback could be provided by some means, like from a glove that could vibrate. The surgeon also affirmed that the application, in its current state, would be useful for teaching theoretical subjects to students or to demonstrate new techniques to skilled surgeons since it allows the user to observe the execution of a surgical procedure.

At the end of the test, we asked two subjective questions. The first question was whether he would use the technology. He stated yes, but to teach theory and not surgical practice. The second question was if he could imagine the application in the future of medicine. He said that could imagine each student in a classroom using a VR headset to study surgery.

It's worth mentioning that at no point did the cardiologist claim to have felt dizzy or any other symptoms resulting from motion sickness during the application test.

5. Conclusion

In this paper, we presented the "Hand Guide", a virtual reality application with the aim of improving the training of new surgeons. The application was validated and tested by an experienced cardiologist who affirmed that, despite not being its intended use, the application may be capable of teaching theoretical knowledge to students with no knowledge of surgery or teaching a new technique to experienced surgeons.

Future works for improving the application include adding a technology to provide tactile feedback to users to allow practical surgical training using the application. Including the tracking of real instruments in the application would also benefit the user's learning process. After adding these features, a test experiment with surgical students should be conducted to collect subjective and objective feedback from them about the effectiveness of the application.

Acknowledgment

We thank André "Fox" Figueiredo for making the operating room assets available for us and Dr. Fabio Granja for evaluating the application and for his candid feedback. We also thank the Sketchfab user "edouard77" for the "Patient" model available under the CC-BY in (`sketchfab.com/3d-models/patient-00b483f284a542899b94e99831f1ad1c`).

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