VR Medical Simulator Proposal

Molly Bruggeman
molly@email.com
Fort Collins, Colorado

Raghma Elmagbari
raghma@email.com
Fort Collins, Colorado

Rachel Xie
rachel@email.com
Fort Collins, Colorado

Sean O'Leary
sean@email.com
Fort Collins, Colorado

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1 Introduction

The VR Medical Simulator is a project focused on using virtual reality (VR) to help people learn medical skills in a hands-on way. Right now, medical students mostly rely on books, lectures, and real-life practice, which can be hard to get enough of. This simulator would let them practice in a virtual space, giving them a safe way to improve their skills without needing actual patients or expensive equipment. The goal is to make learning more interactive and help students develop better hand-eye coordination for medical procedures. With realistic visuals, touch-based feedback, and adaptive challenges, this project could make medical training more accessible and engaging for students at all levels. From an HCI perspective, this project would explore how people interact with technology in situations that require high levels of precision and control. Designing a simulator that feels realistic would require intuitive controls, responsive feedback, and immersive visuals, all of which are critical elements in creating an effective learning tool. By improving the way humans interact with computers for training purposes, this project could pave the way for even more advanced educational tools in medicine and other technical fields. VR has the potential to enhance medical training by making learning more interactive, immersive, and hands-on. A VR simulator would allow for unlimited, risk-free practice, helping students build muscle memory, improve hand-eye coordination, and gain confidence before working with actual patients. Key benefits include repetitive practice, realistic emergency simulations, and instant feedback. Students could refine procedures like suturing or IV insertion without needing physical materials, while also training for high-pressure situations such as cardiac arrest. Performance tracking would provide immediate corrections, improving skill development and retention. By offering a more accessible, engaging, and effective learning experience, VR could revolutionize medical education and become a standard tool for training future healthcare professionals.

2 Previous Work

In "Virtual Reality and the Transformation of Medical Education," Jack Pottle (2019) discusses how VR is revolutionizing medical training by offering immersive, cost-effective, and standardized clinical simulations. The paper highlights VR's potential to provide on-demand, repeatable training scenarios that enhance learning outcomes and facilitate inter professional education across various medical disciplines. Kyaw(2019) conducted a systematic review and meta-analysis, revealing that VR-based training leads to improved cognitive skills, higher knowledge retention, and better procedural accuracy compared to traditional teaching methods. Their findings suggest that VR can enhance learning outcomes by allowing

students to repeatedly practice complex medical procedures in a risk-free environment. Similarly, Pottle (2019) highlighted how VR enables cost-effective and standardized training, ensuring that students receive consistent exposure to clinical scenarios. The study also emphasized the importance of VR in surgical training, where hands-on experience is often limited. Additionally, Samadbeik(2018) analyzed VR applications in medical training and found that 74Current research on VR in medical training has demonstrated its effectiveness in enhancing learning outcomes, procedural accuracy, and dexterity, but several gaps remain. One key limitation is the lack of real-time adaptability in training simulations. Many existing VR applications offer static experiences that do not adjust to the learner's progress or skill level, potentially limiting individualized learning. Our project aims to explore the integration of AI-driven adaptive learning, where the simulator could dynamically adjust the difficulty of tasks based on user performance, providing a more personalized training experience. Another significant gap is the limited incorporation of realistic haptic feedback. Many current systems do not replicate the physical sensations of medical procedures, which are critical for skill development. Our concept considers implementing advanced haptic feedback technology to create a more tactile and realistic experience, allowing users to feel resistance, pressure, and texture variations during procedures. Additionally, collaborative learning in VR remains underexplored. Most existing simulations are designed for individual users, missing the opportunity to train medical students in teamwork and communication—essential components of real-world healthcare. Our project envisions a multi-user VR environment where students can practice together, simulating team-based clinical scenarios to improve coordination and decision-making.

3 Project Description

The VR medical simulator is designed to provide accessible immersive training for medical students to develop essential medical procedural skills. We hope to enhance hands-on learning by providing a platform for students to practice medical techniques in a risk-free, virtual setting that students are able to access from their own homes, without needing excess materials. By leveraging VR technology, users will be able to perform medical procedures while receiving feedback in real-time when an instructor is not present. With real-time assessment and adaptive difficulty levels, this simulation will provide students time to practice hand-eye coordination, quick decision making, and procedural accuracy. This project is deeply rooted in HCI principles. We plan to design an intuitive and engaging interface for learning medical skills. The most notable principles that will be integrated in this project are haptic, visual, and audio feedback, an adaptive learning system, intuitive interface design, and immersive learning. By focusing on these principles, our simulator will provide an interactive, engaging, and effective learning experience for students. We would like to differ from existing research using AI-driven adaptive learning, haptic feedback, and collaborative learning in a VR-environment.AI-driven personalization: existing simulators provide static training environments. We would like our system to dynamically adapt based on user progress by analyzing real-time performance of the student. The simulator will adjust the difficulty level, introduce more complex cases, or suggest areas for improvement. Haptic feedback: We plan to measure procedural accuracy, task completion time, and error rates. The instant feedback will help students correct their mistakes immediately. Collaboration: Students will be able to collaborate with classmates regardless of their physical location. This allows for more freedom in the time and location that students choose to practice.

4 Prototype Visualization

The VR simulator will allow for a hands-on experiential learning process where the person can practice critical medical procedures like suturing, laparoscopic, and venipunctures with low stakes in hopes of

translating the skill to a more important and serious setting. This simulation will include a semi realistic interface using a headset and motion controllers for the precision tracking, an interactive environment that will replicate a medical training lab. We will include prep tables with different tools so that medical students can become familiar with them, a dynamic scenario-based learning with real-time feedback and guided tutorials, and AI-driven adaptability making so that it will adjust the complexity of the tasks based on the user's skill advancement.

5 Experiment Design

To gauge the effectiveness of our VR simulator, we will conduct an experiment study with medical students or nursing students at CSU taking part. The study will assess improvements in operational accuracy, dexterity, and learning retention. The participants will be divided into two groups: one using the VR simulator and the other using traditional training methods. The independent variable is the training method (VR-based vs. traditional), and the dependent variables are procedural performance scores, task completion times, and user engagement levels. Data collection will be focused on task completion times, rate of errors, and participant-reported confidence and engagement levels via surveys. The chosen participants will range from new medical students to experts, making sure to perform an accurate and broad assessment. Performance metrics and qualitative feedback will be analyzed to determine how VR-based learning compares to traditional methods.

6 Technology

At this time, the technology that we will use to perform and test this experiment will be a Meta Quest 2 or 3 running our custom simulator from a host machine. Any additional technology that we feel is necessary to conduct the experiment will be added as we determine the need for it.

7 Deliverables

By the end of the semester and the conclusion of our experiment we would like to deliver a VR medical simulator for assistance with learning and dexterity. This simulation we would like to have a smooth and consistent user interface that will allow testers to navigate and practice complex procedures with various medical tools. We would also like this experiment to deliver realistic visuals, touch-based feedback, and adaptive challenges that can provide additional engaging practice for medical students of all levels. We would also like to gather data on the effectiveness of a VR medical simulator to determine if there is any particular part about the design we implement that can be improved for usability, learnability, increases in dexterity, and confidence in the practicing participant.

8 Conclusion

The VR Medical Simulator aims to change medical training by offering an interactive, immersive, and adaptable educational setting. Our project aims to improve medical students' dexterity and decision-making skills in a safe, controlled environment by combining HCI principles with advanced VR technology. Future work could include expanding the simulator to support interactive multi-user training, incorporating AI-driven customization, and integrating biometric feedback to improve learning outcomes.

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