SIMUMED: MIXED REALITY DISSECTION AND SURGERY SIMULATOR FOR ETHICAL MEDICAL EDUCATION

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Introduction:

1. Medical and surgical education has traditionally relied on cadavers, animal specimens, and physical mannequins to provide hands-on learning experiences. While these methods offer realistic exposure to human anatomy and procedural techniques, they present several challenges such as limited availability, ethical concerns, high maintenance costs, and limited opportunities for repeated practice. In addition, cultural sensitivities and the growing need for humane alternatives have further highlighted the limitations of conventional training approaches. With advancements in immersive technologies, particularly Mixed Reality (MR), there is a growing shift toward more flexible, accessible, and ethically responsible methods of medical education.
2. SimuMed is a Mixed Reality–based surgical simulation platform designed to overcome these challenges by providing a virtual environment for practicing dissection and suturing. The system replicates key surgical interactions using detailed 3D anatomical models, real-time tool–tissue responses, and visual feedback such as tissue deformation and controlled bleeding. It is designed to operate on standard computer systems, making it affordable and easily deployable in academic environments. By enabling repeated practice, self-paced learning, and performance evaluation, SimuMed helps bridge the gap between theoretical knowledge and practical surgical skills, while promoting a safe and ethical learning experience.

Objectives:

1. To provide a virtual environment for surgical skill development
2. To enable realistic tool and tissue interaction
3. To support repeated practice and mistake correction
4. To offer an affordable and scalable solution
5. To integrate suturing with interactive thread behaviour
6. To include performance evaluation and feedback

Methodology:

1. The development of SimuMed follows a systematic and modular approach to create a realistic and interactive surgical training environment. The process begins with the design and preparation of 3D anatomical models representing human tissue layers. These models are structured in a way that allows step-by-step interaction, enabling users to perform procedures such as dissection and suturing in a controlled virtual space.
2. The system captures user inputs through standard interaction devices and translates them into real-time actions within the simulation. When a surgical tool is selected, the system detects its interaction with the anatomical model through collision detection mechanisms. Based on the movement and direction of the tool, the system calculates incision paths, depth, and deformation of tissues. Visual feedback such as separation of layers and bleeding indicators is generated dynamically to reflect the effect of user actions.
3. For suturing, the methodology involves tracking the movement of the needle and simulating thread behaviour using constraint-based logic. The system ensures proper entry and exit points on tissue edges and dynamically adjusts thread tension to bring wound edges closer. Multiple stitches can be placed, and their alignment is evaluated to ensure realistic wound closure.
4. In parallel, a performance evaluation mechanism continuously records user actions, including precision of cuts, consistency of sutures, and overall procedural flow. At the end of the simulation, these parameters are analysed to generate feedback and scores, helping users identify areas of improvement.
5. Overall, the methodology integrates anatomical modelling, real-time interaction, visual simulation, and performance assessment into a single workflow, enabling an effective and repeatable learning experience for surgical training.

Result and Conclusion:

1. The implementation and evaluation of SimuMed demonstrate that the system provides a realistic, stable, and interactive environment for basic surgical skill training. The dissection module produced accurate tissue deformation with clear and continuous incision paths, even under rapid tool movement. Similarly, the suturing module enabled precise needle insertion, realistic thread behaviour, and effective wound closure with proper alignment and tension. The system maintained smooth performance throughout extended usage, with no noticeable lag or instability. The inclusion of visual feedback such as bleeding indicators enhanced realism and helped users understand the impact of their actions. Additionally, the performance evaluation module successfully tracked user activities and generated meaningful feedback, with observed improvement in user scores over repeated attempts, indicating progressive learning.
2. Overall, SimuMed effectively achieves its goal of providing an ethical, accessible, and cost-effective alternative to traditional surgical training methods. By integrating interactive simulation, visual feedback, and performance assessment, the system bridges the gap between theoretical knowledge and practical skill development. It

enables repeated practice, supports self-paced learning, and encourages continuous improvement in a safe environment. Thus, SimuMed represents a significant step toward modernizing medical education and offers strong potential for future expansion with more advanced features and training modules.

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Future Scope:

The future scope of this project includes:

1. Integration of advanced physiological simulations such as detailed vital signs, organ response, and real-time complications for enhanced realism.
2. Addition of multiple surgical procedures and anatomical models to expand the platform beyond basic dissection and suturing.
3. Incorporation of AI-based guidance and personalized feedback to assist learners in improving accuracy and decision-making skills.