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Research In-Progress

Haptic Models Protocol with AI: Transforming Learning and Surgery

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Introduction: Traditional surgical education relies primarily on observation and supervised practice, which often leads to a steep learning curve, variability in skill acquisition, and potential risks to patient safety. The limited accessibility of high-fidelity simulators further restricts opportunities for standardized training. To address these challenges, we propose a hybrid system that integrates haptic feedback, mixed reality (MR), and artificial intelligence to enhance surgical suturing training.

Methods: The system consists of an ergonomically designed wristband—modeled in CAD and fabricated via 3D printing—equipped with actuators and inertial sensors capable of delivering real-time vibrotactile feedback whenever deviations in knot tension, hand trajectory, or procedural sequence are detected. This is complemented by a physical suturing pad, which provides essential tactile resistance, and an MR environment developed in Unity/Unreal Engine, where learners visualize corrective cues, compare their performance against expert benchmarks, and better understand procedural errors. Beyond the technological development, the project includes a pilot validation study with medical students and residents, randomized into conventional versus hybrid training groups. Performance outcomes will include error rate, knot precision, execution time, and efficiency of the learning curve. Pre- and post-training evaluations will assess improvement, and structured surveys using Likert scales, along with usability interviews, will capture qualitative feedback regarding user experience and perceived utility.

Preliminary Results: Preliminary prototyping suggests that the system is both feasible and intuitive, with initial users reporting improved awareness of mistakes and greater confidence in skill transfer to clinical contexts.

Next Steps: The upcoming validation study will determine its effectiveness compared with traditional methods. Ultimately, this innovation bridges virtual simulation and physical practice, offering a scalable, safe, and accessible tool to accelerate technical proficiency, reduce variability across learners, and strengthen surgical education with the broader goal of improving patient safety and outcomes.