Development of a Consumer-level Haptic Epidural Simulator

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Abstract

Performing an epidural is one of the most demanding skills for an anesthetist to learn. It is a complex task of 3D visualization, tactile sensitivity, and fine motor skills [1]. Virtual haptic simulators have potential to become a cost-effective way to improve new anesthesiologists’ expertise, increasing patient safety and procedure success rates. Thus, we present Unity Simulator for Epidural Insertion Training (USEIT), a haptic-enabled system which aims to facilitate further study into epidural training. USEIT implements a novel model for emulating soft tissue forces and offers fluid resistance feedback. The system uses off-the-shelf materials and 3D printed parts, putting it in a uniquely cost-effective position for an epidural simulator.

The Epidual Procedure

In this procedure, a needle must be precisely guided between vertebrae into the epidural space with little visual feedback. The large volume of sessions required to achieve competence [2] can be difficult to achieve in a given training period, highlighting the potential for digital simulators to enrich training.

- Frequently—but not exclusively—performed for pain relief during childbirth
- Complications include failure to block pain, debilitating Post-Dural Puncture Headache or nerve damage [3,4]

The USEIT System

The USEIT System simulates the Unity3D game engine as its main development platform to bridge an Arduino-based electronic setup, and the Chai3D haptics library, into one application.

Haptic Simulation

- User manipulates position and orientation of a real needle
- Models forces of needle interacting with patient
- Rigid lumbar spine vertebrae
- Penetrable soft tissues utilize a unique “mobile nonlinear spring” model (pictured right)
- Resists movement perpendicular to the needle axis when inside the skin

Plunger Resistance

- Arduino-controlled fluid-valve system facilitates commonly used Loss-of-Resistance technique for needle positioning
- User may attach a water/saline filled syringe to feel resistance to flow
- The resistance experienced by the user varies by the medium the needle tip is in

Development Tools

- Unity3D Engine
- Arduino and associated libraries
- Chai3D Haptics Library
- C, C++, C
- Autodesk Fusion 360
- Prusa i3 MK3 3D Printer

System limitations

- Limited depth perception (non-stereoscopic view)
- Haptic device constraints limit force and impulse, inconsistent at different angles and positions, and does not offer torque feedback
- Requires 3D models, thus difficult to reconfigure for different body shapes

Conclusion

Despite potential advantages, existing digital epidural simulators have not reached the required state to play a large role in modern training. USEIT has progressed well over its 3-month research and development period, and can be improved with upgrades such as mixed reality integration, patient movement, immersive audio, and enhanced configurability. In the future, this project aims to improve our understanding of haptic simulation and skill acquisition through studies, working to meet the training needs of tomorrow’s anesthetists.

References


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