Training and evaluation of lumbar punctures in a VR-environment using a 6DOF haptic device

Matthias Färber [a,1], Erik Hoeborn [a,c] David Dalek [a] Friedhelm Hummel [b]
Christian Gerloff [b] Christian A. Bohn [c] and Heinz Handels [a]

[a] *Dep. of Medical Informatics, University Medical Center Hamburg-Eppendorf*
[b] *Dep. of Neurology, University Medical Center Hamburg-Eppendorf*
[c] *Computer-Graphics & Virtual Reality, University of Applied Sciences Wedel*
Hamburg, Germany

Abstract. A virtual reality system for the training of the lumbar puncture intervention is presented. We use a haptic device with six degrees of freedom (6DOF) to feedback forces that resist needle insertion and rotation. An improved haptic volume rendering approach is used to calculate the forces and an evaluation component has been developed to rate the success of virtual lumbar punctures to trace the training process of the user and to give feedback about failures.

Keywords. Procedure simulation, Surgical Simulation, Visualization, Virtual Reality, Haptic feedback, Lumbar puncture

1. Background

Lumbar punctures are performed by inserting a needle into the spinal chord to inject medicaments or to extract liquor. Experienced physicians obtain information about the needle position from the different haptic behavior of structures like skin, fat or ligaments that are pierced during the needle insertion. Usually, the lumbar puncture is trained directly on the patient. The motivation for the development of a virtual reality training system for lumbar punctures is that with such a system experience can be gained cheaply without risking the patient's health and the trainee can get new insights into the human anatomy. Recently our lumbar puncture simulator [2], which, unlike other simulators [3,5,1], uses a 6DOF haptic device and a haptic volume rendering technique, has been extended by an evaluation component and new assistance visualization techniques to become a VR-training system.

[1]Corresponding Author: Institute of Medical Informatics, Martinistrasse 25, 20246 Hamburg, Germany; E-mail: m.faerber@uke.uni-hamburg.de

2. Tools and Methods

Our training system presents a virtual scene that consists of a user-steered virtual needle and a virtual body generated from segmented CT data. The simulation is split up into a haptic, a visual and a scoring component. The haptic component renders the forces that affect the needle during the insertion. A force feedback device with six degrees of freedom (Sensable Phantom Premium 1.5) is used for the haptic I/O. Different force components are considered: Resisting force, surface friction and viscosity of medical structures are simulated based on a proxy-based haptic volume rendering approach [4] that has been extended to combine structure information extracted from original CT data with segmented label data [2]. This way the haptic rendering of small unsegmented structures is enabled and extends the haptic impression calculated from the skin, bone, muscle or fat label data. Furthermore the realistic behaviour of the needle is improved by restricting rotation and transversal motion of the needle inside the body using the torque motors of the 6DOF haptic device.

The visual component (Fig. 1) is build up of a 3D view with optional stereo view showing the puncture scene and assistance visualizations that enable insight into the human anatomy by showing 2D slices of the virtual body or 3D visualizations with transparent organs or special perspectives like a needle cam. The evaluation component has been developed to rate the success of the needle insertion and give feedback to the user. For this purpose the movement of the needle is recorded during the insertion. This user-path is compared to an optimal path defined by experienced physicians. Furthermore the piercing of structures at risk like bones or nerves and the puncture time is evaluated. An overall score is calculated to compare the success of different users.

3. Results

Several users with varying medical experience tested the simulation of lumbar puncture (Fig. 2). The users were able to identify different tissues like muscles, fat, skin and bone

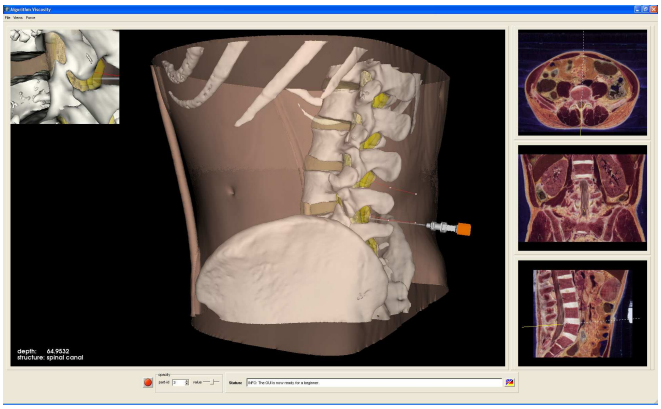

Figure 1. Graphical user interface of the lumbar puncture trainer showing a (slightly rotated) 3D visualization of the virtual scene enhanced by a detailed needle cam view (upper left corner). Furthermore orthogonal slices of the RGB data are shown on the right-hand side.

Figure 2. Trainee using the virtual lumbar punctur trainer using stereographic visualization with shutter glasses.

by means of viscosity, resisting force and friction. The synchronization of force feedback and miscellaneous visualization techniques provided a realistic impression of the anatomy. The trainees were motivated by the evaluation system to get the 'high score' for the best lumbar puncture.

4. Discussion

The use of virtual reality techniques opens up new perspectives to support and improve the lumbar puncture training in medical education. The training method offers a new way to understand human anatomy and to gain experiences in using a puncture needle. The evaluation scoring system offers a good way to give feedback to the trainees and to motivate them. The training system is prepared to work with arbitrary patient data. Currently the Visible Human and Visible Korean Human datasets have been used to generate the training data. Other datasets are being prepared to be used in our training system.

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