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K. Bühler, L. Linsen, and N. W. John (Editors)

A Haptics-enabled Simulator for Transperineal Ultrasound-Guided Biopsy

Panagiotis D. Ritsos[1], Marc R. Edwards[2], Iqbal S. Shergill[3] and Nigel W. John[1]

[1]University of Chester, UK
[2]Bangor University, UK
[3]Wrexham Maelor Hopsital, UK

Abstract

We present the development of a transperineal prostate biopsy, with high fidelity haptic feedback. We describe our current prototype, which is using physical props and a Geomagic Touch. In addition, we discuss a method for collecting in vitro axial needle forces, for programming haptic feedback, along with implemented an forthcoming features such as a display of 2D ultrasonic images for targeting, biopsy needle bending, prostate bleeding and calcification. Our ultimate goal is to provide an affordable high-fidelity simulation by integrating contemporary off-the-shelf technology components.

Categories and Subject Descriptors (according to ACM CCS): J.3 [Life and Medical Sciences]: Medical information systems—I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1. Introduction

Prostate cancer remains one of the most common causes of cancer for males, throughout the world. Treatment is usually preceded by a screening process, involving blood sampling for prostate specific antigen, or prostate biopsies at hospital. The most common biopsy method is a transrectal prostate biopsy. However, transperineal ultrasound guided biopsies have grown in popularity and are generally preferred in Europe [THH*06]. During the procedure, which is performed under general anaesthesia, an ultrasound probe is inserted into the back passage and the prostate is scanned. A grid (template) with holes every 5mm is placed against the perineum. A biopsy needle is inserted through each hole, allowing sampling of the prostate gland every 5mm.

Current training methods include the use of biopsy phantoms, and cadavers. A biopsy phantom is an expensive block of composite materials shaped to represent the prostate gland, which wears out with usage over time and represents a generic gland with no possible variations in shape etc. Cadavers on the other hand are not easily accessible and exhibit tissue behaviours unlike those of a living person.

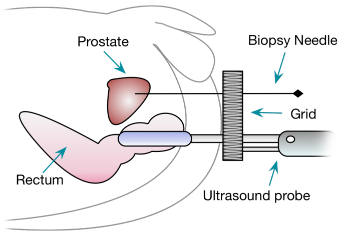
Nonetheless, health care professionals can use high-fidelity virtual training simulation (VTS) so that necessary procedures may be practised and refreshed before operating on a real person. VTSs do not wear out and can be programmed for simulating alternative scenarios. Moreover, advantages of relying on such controlled learning environments includes; zero patient risk, development of psychomotor skills for the medical tools and the opportunity to experience challenging ‘what if’ scenarios.

2. Background and Motivation

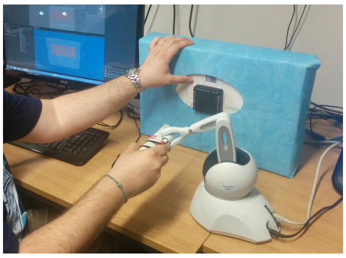
Currently very few training simulators address transperineal prostate biopsies, and those that have been developed [SCV*09, CCS*11, XWS*98, ZBZ*01] do not represent common procedural features such as tissue deformation as the needle is injected, needle bending or prostate bleeding. The VTSs also do not utilise the guidance grid used for the procedure but represent it virtually and simplified such as a grid of twelve holes. The benefit of using the actual grid would add to the VTS realism and familiarise the user with the prostate biopsy resolution available during the procedure.

3. Our Prototype

In this poster we describe our current VTS prototype, which is using physical props for the patient’s body, a guidance grid such as those attached against the perineum



(a) Transpernineal prostate biopsy



(b) Early haptic-enabled VTS

(c) Ultrasound mock-up

Figure 1: During a transperineal prostate biopsy, the needle is injected through the grid, which is placed against the perineum, into the prostate and a sample is selected (a). Our prototype uses physical props for the body with a grid attached, a Geomagic Touch and a G-Coder Simball 4D (b). The main guiding visualization for the process is the ultrasound display mock-up (b).

in real biopsies and two haptic interfaces for the biopsy needle and ultrasound probe. Our VTS is build on Unity3D and comprises of three main modules: i) the biopsy needle-simulator which uses the haptic plug-in by Poyade et al. [PKP14] and a Geomagic Touch (formerly the Sensable Omni), ii) the ultrasound-guidance system which is built around a G-Coder Simball 4D joystick and a custom C++ wrapper, to enable real-time communication of the device's driver with Unity and iii) a web-cam tracking needle insertions through the grid. The haptic devices are placed in the arrangement shown in Figure 1b. The Touch is placed on 90° rotated to the left and at a distance of 12cm from the body prop, in order to have a larger frontal operating volume for the prostate needle attachment. A real biopsy needle is attached to the Touch's stylus. Through this arrangement the body prop, grid and needle are registered with the virtual scene, comprising of objects corresponding to the patients body and organs, the ultrasound probe and the biopsy needle.

As the user inserts the needle through the grid, the haptic behaviour of each virtual organ encountered by the virtual needle counterpart, is applied through the Touch. The haptic profile of each virtual object is determined by means of *in vitro* measurements, following the procedure described in [EJaCS14]. The result of this method is a force profile of the needle showing peaks at the perineal membrane, prostate, and firing of the needle.

Current development is focused on the ultrasound module. To increase the fidelity of the ultrasound display, alternative voxel and point-cloud representations are being evaluated, in terms of rendering-performance. In addition, the ultrasound display interfaces with a web-cam, attached to the back of the body mock-up, and uses computer-vision to track the needle insertions through the grid. This information is then overlaid on the ultrasound by means of a graphical grid, for guidance.

4. Conclusions & Future Work

In this poster we present work-in-progress on our ultrasound-guided prostate biopsy VTS. Feedback from our medical collaborators, on the usability of the current prototype has been very positive. Current development is focused on increasing the fidelity of the ultrasound, followed by the incorporation of visualizations depicting the biopsy needle bending. Future incarnation of the system will be using the buttons on the Touch to simulate the needle sampling, allowing initiation of prostate bleeding visualization, thus increasing simulation fidelity.

5. Acknowledgements

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