A Haptic-based Ultrasound Examination/Training System

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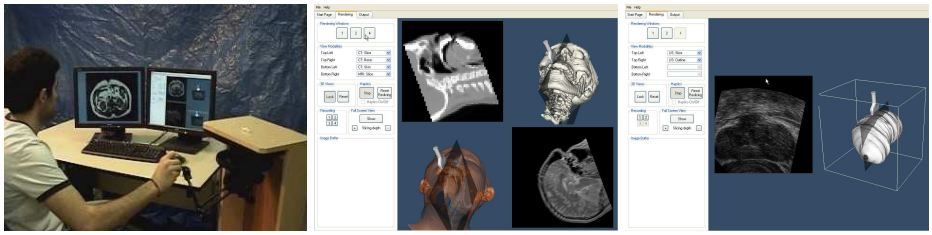
Abstract. We present a novel haptic-based simulator for training radiology residents and sonographers. The system consists of a force feedback haptic device that interacts in real-time with registered 3D multi-modality data sets of a subject anatomy, rendered and sliced simultaneously. The proposed system allows to develop radiology expertise with minimum practice on live patients, or in places or at times when radiology devices or patients with rare cases may not be available. The haptic interface guarantees position correspondence between the operator's hand and a virtual probe. Thus the simulated procedure emulates actual examinations condition in clinic. Preliminary human factor studies have demonstrated satisfactory performance of the system.

1 Introduction

Simulation of medical procedures is one of the interesting applications of virtual reality and has attracted significant amount of attention in the last decade. Several medical simulators, such as surgical [1], or diagnostic [2] systems, have been proposed. For the first time, we propose to integrate the haptic technology with realistic simultaneous visualization of multi-modality image data for training radiology residents. The system allows for medical image training sessions to be conducted at any time and on a variety of cases, while the performance of the trainee can be easily evaluated by an expert (Figure 1(a)). The setup consists of a graphical user interface (GUI) to visualize and interact with the graphical model of the examined tissue, as well as displaying the corresponding 2D multi-modality reslices of pre-registered data sets. The haptics is implemented using a PHANToM Premium 1.5 haptic device.



(a) (b) (c)

Fig. 1. (a) The proposed setup; real-time MRI/US examination of abdomen, (b) Real-time MRI/CT examination of Visible Human data set, (c) Prostate US examination.

2 Design and Implementation

The software is developed in VC++ in a fully object-oriented structure. The GUI is designed with Qt (Trolltech Inc.), providing the capability of rendering up to four volume sets simultaneously. Image processing and visualization are implemented using VTK and ITK libraries. A virtual probe controlled by the user's hand motion slices through volume sets along the plane of a virtual ultrasound(US) beam. The GUI displays the 2D reslice as an image on the virtual US beam plane using texture mapping in real-time. Pre-registered volume sets of different modalities provide the possibility to visualize an arbitrary cross-section of the anatomy with different modalities (Figures 1(b), 1(c)). The system also allows to visualize the reslicing in full screen in a separate monitor for better viewing.

The heart of the proposed system is the interaction between the GUI and the haptic interface. The haptic force guarantees a one-to-one mapping between the operator's hand motion and the location of the virtual probe on the skin. While the static data sets seem to be sufficient for basic radiology training, deformable volume sets would more realistically simulate an interaction with a patient. Currently, finite-element based deformation of volume sets under operator's hand force is being developed. The hand force is estimated through the identification of the PHANToM dynamic parameters [3].

3 Validation

The current implementation includes four data sets: MRI and CT data of head available from Visible Human database, as well as three US data sets of neck, abdomen (US/MRI), and prostate captured from volunteers. Preliminary human factor studies with volunteers have demonstrated satisfactory performance of the system in terms of haptic feedback, system ergonomics, image clarity, and the usefulness of GUI. Further studies by medical students and radiology experts at local hospital are underway.

4 Discussion

We have demonstrated a powerful, yet simple US examination/training system for radiology residents and technicians. Our pilot human factor studies have demonstrated the significant potential for scientific and commercial applications. The system is portable, inexpensive and is able to demonstrate US reslicing together with other registered imaging modalities simultaneously. Further development will include the incorporation of finite-element models to provide a more realistic visualization and haptic force feedback to the operator.

References

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