An assistant for improved ultrasound-guided regional anaesthesia of the femoral nerve

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Introduction

The use of regional anaesthesia (RA) is increasing due to the benefits over general anaesthesia (GA) such as reduced morbidity and mortality, reduced postoperative pain, earlier mobility, shorter hospital stay, and lower costs. Despite these clinical benefits, RA remains less popular than GA. One reason for this is that GA is far more successful and reliable than RA. Ultrasound has been employed to increase the success rate of RA. However, ultrasound-guided RA can be a challenging technique, especially for inexperienced physicians and in difficult cases. Good theoretical, practical and non-cognitive skills are needed in order to achieve confidence in performing RA and to keep complications to a minimum. Studies indicate that RA education focusing on illustrations and text alone is not sufficient.

The RASimAs project (Regional Anesthesia Simulator and Assistant) is a European research project which aims at providing a simulator to improve the training of doctors performing RA, as well as an assistant to lessen the cognitive burden and help performing RA procedures. The assistant will guide the user to 1) find a good probe placement and view of the target injection sites, 2) inject needle and 3) inject local anaesthetics. In step 1, segmentation of the structures of interest and registration of the 3D model will be used to guide the user to the target area. Visual cues will be given to the user indicating which direction the probe should be moved to reach the target area. After the target area has been located, the assistant will guide the needle insertion by visualizing the needle in both the ultrasound image and the 3D scene. In the final step, the user injects local anaesthetic which will be displayed in the annotated ultrasound images. Although the assistant is applicable for different ultrasound-guided RA applications, the focus in this project has been on the femoral nerve (see figures 1 and 2).

Methods

The ultrasound system consists of an Analogic Sonix MDP scanner with a linear probe and electromagnetic tracking (SoniGPS) of both probe and needle. The images are streamed to the assistant using the Plus toolkit and the OpenIGTLink protocol. So far, automatic vessel segmentation and registration methods have been developed for the assistant. The vessel is detected and tracked automatically in real-time using an elliptical vessel model, a Kalman filter and a graphic processing unit (GPU). A mesh model of the surrounding anatomy was created from a CT dataset. Registration of this model is achieved by first placing the ultrasound image frames at the target site. After this initialization, each ultrasound image frame is registered to the artery model using the detected centerpoints from the vessel tracking. If any bone is detected in the images, it is used to register the model in the head-feet direction. The segmentation and registration methods must be able to process the images in real-time to be useful for the femoral nerve block assistant. This is achieved by implementing the assistant with the FAST framework which uses GPUs and OpenCL for processing and visualization. Figure 3 shows a diagram of the different parts of the assistant.

Results

A total of 12 ultrasound image sequences from 3 subjects were collected. The number of images per sequence ranged from 110 to 524. For each sequence, the vessel was manually segmented in 4 randomly selected frames. The vessel detection initialized the tracking successfully in all 12 sequences. On average, the tracking was successfully initialized after the vessel detection was run on 84 frames. Assuming 25 frames per second, the tracking is initialized in about 3.4 seconds.

Conclusion & future work

The presented methods are able to automatically and accurately track the femoral artery in ultrasound images and use this to register a model of the surrounding anatomy in real-time. This will be part of an assistant for ultrasound-guided regional anaesthesia of the femoral nerve. Currently, we are working on segmentation of the femoral nerve, fascia lata and fascia iliaca (see Figure 6), needle insertion guidance and enhancement of the local anaesthetic after insertion. In 2016, the assistant will be clinically tested and evaluated at three different sites.

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