Real-time transverse process delineation in tracked ultrasound for scoliosis measurement

Csaba Pinter, Bryan Travers, Zachary Baum, Tamas Ungi, Andras Lasso, Ben Church and Gabor Fichtinger

Laboratory for Percutaneous Surgery, Queen's University, Kingston, ON, Canada

PURPOSE: Ultrasound (US) is a safe, radiation-free imaging modality for visualizing the spine and measuring scoliosis. Poor bone visibility in US, however, poses a major challenge in measurement of spinal curvature. We propose an algorithm and its implementation for real-time automatic delineation of the posterior surface patches.

METHODS: The algorithm operates in the image space, so scan-lines are first converted to a linear image. Pre-processing follows to prepare the image for bone detection using thresholding, Gaussian smoothing, edge detection, island removal, and morphological opening. Potential transverse processes are then marked based on the presence of a shadow; bones cast shadows in US images, so the area on their far side becomes darker (*i.e.* of lower intensity). A subsequent filtering step ensures viable position and size for the detected patches. Further shadow analysis follows, which looks for sufficient non-shadow areas to both sides of the potential bony areas. Finally, the image is converted back to its original geometry, which is an essential step in case of curvilinear probes. The algorithm was developed as part of the PLUS toolkit [1]. All image processing and analysis parameters used can be changed in the PLUS configuration file.

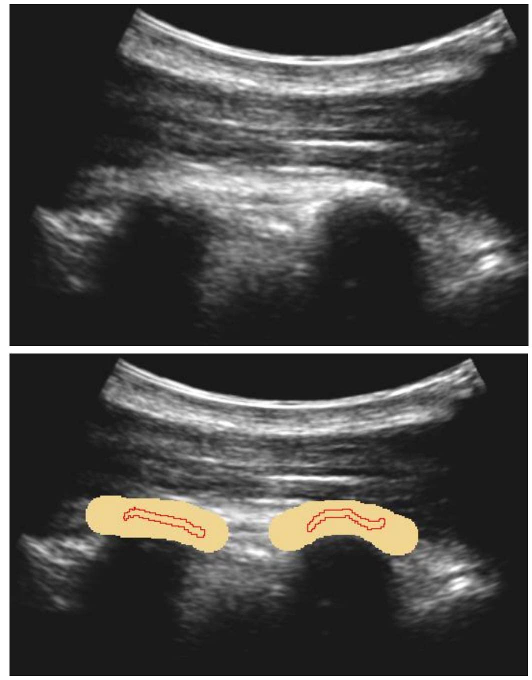

Fig. 1. Top: Frame produced by a SonixTouch US machine (Analogic Corp., Peabody, MA, USA) using an Ultrasonix C5-2 probe. Bottom: Output (red) compared to ground truth with added tolerance margin

Utilizing the pose data from a 3D trakSTAR (NDI, Waterloo, ON, Canada) electromagnetic tracker also acquired with the scan, a 3D volume is then reconstructed from the output. By matching the reconstruction to a spine model using deformable registration, a qualitatively accurate patient-specific spine visualization can be achieved, allowing for accurate measurement of the curvature.

RESULTS: An expert provided manual segmentation of the posterior surface of the transverse processes in four US sweeps in two steps: ground truth regions that definitely contained bone, and tolerance margins encompassing possible accepted regions as well. Accuracy was evaluated by comparing the output to the two marked regions (Fig. 1). The mean of the average Hausdorff distance between tolerance margin and output was 5.13mm, with mean false positive ratio of 0.19%. Same metrics for the ground truth segmentation was 3.02mm and 1.22%, respectively. Each frame took on average 0.016s to process, yielding 62 frames per second. Future plans include enhancing the edge detection step and thorough evaluation of the method against CT data.

Fig. 2. Left: Reconstructed output bone patches. Right: Registered to spine model.

CONCLUSION: An algorithm has been presented for automatic detection of transverse processes in tracked US images. The result can be reconstructed in 3D and matched to a spine model by deformable registration. Both detection and reconstruction happen real-time, allowing the sonographer to improve results by returning to inadequately processed regions. The proposed method aims to facilitate quantitative spine curvature measurement under ultrasound modality.

REFERENCES: [1] Lasso, A., Heffter, T., Rankin, A., Pinter, C., Ungi, T., & Fichtinger, G. (2014). PLUS: open-source toolkit for ultrasound-guided intervention systems. *IEEE Transactions on Biomedical Engineering*, *61*(10), 2527-2537.