2D/3D Registration of Ultrasound and Fluoroscopy: is image preprocessing useful?

Motivation: In prostate brachytherapy, transrectal ultrasound (TRUS) is used to visualize the anatomy, while implanted seeds can be seen in C-arm fluoroscopy. Intra-operative dosimetry optimization requires reconstruction of the implanted seeds from multiple C-arm fluoroscopy images, which in turn requires estimation of the C-arm poses. We propose to estimate the relative pose of C-arm images by the registration of the 2D fluoroscopy images to the 3D TRUS volume, and by doing so we estimate the poses of C-arm images in a coordinate system fixed to the prostate. This paper investigates whether pre-processing the TRUS images increases registration performance.

Methodology: We implemented 7 different filters for the TRUS volume to investigate whether image pre-processing is a requirement. The baseline for comparison is no filtering (US-0). US-1 is a noise reduction filter based on two successive thresholdings. US-2 is a phase congruency filter. The beam profile filter (US-3) accounts for the finite thickness of the ultrasound beam and the focusing in the elevational and lateral directions. In US-4, we combine parallel noise reduction, phase congruency and beam profile filters in a Bayesian model. In US-5 noise reduction is followed by phase congruency. In US-6, noise reduction is followed by beam profile filtering. Finally, in US-7 we cascade noise reduction, phase congruency, and beam profile filtering. ***Experiments and Results:*** A commercial phantom was implanted with seeds and imaged with TRUS and CT. Ground-truth registration was established between the two modalities by fiducials. Synthetic ground-truth fluoro images were created from the CT volume and registered to the 3D TRUS using normalized correlation metric. The US-0 baseline provided best results for pose estimation: the average rotation and translation errors were $1.1 \pm 1.2°$ and 1.1 ± 0.6 mm. The US-6 filter followed with average rotation and translation errors of $3.1 \pm 3.9°$ and 3.2 ± 3.4 mm. In human patient data, the measured registration error compared to the manually selected seed locations by the clinician was 2.86 ± 1.26 mm when not filtering TRUS. ***Conclusion:*** Fully automated image-based C-arm pose estimation was demonstrated in prostate brachytherapy where accuracy and robustness was excellent on phantom and adequate in human patient data. We conclude that pre-processing of the TRUS images did not yield significant improvement in the process.